EXPERIMENTAL INVESTIGATION OF ALUMINIUM ALLOY ENGINE CYLINDER BLOCK IN TWO WHEELERS

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Submitted by

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|| *Shri Amba-Renuka Namaha* ||

Dedicated to my Beloved Parents, Family…..

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"Automobiles have always been part of my life and I am sure they always will be. What is it about them that moves me? The sound of a great engine, the unity and uniqueness of an automobile's engineering and coachwork, the history of the company and the bikes and cars and of course, the sheer beauty of the thing."

Attempts are never accomplished alone; there are constantly a few steady hands. This proposition is a careful aftereffect of direction of such individuals around me who have presented to me all through the way. Along these lines, I want to express gratitude towards them just for their nearness in my life throughout the work. I am to a great degree lucky to be required in a research work of this kind. It has advanced my life, giving me a chance to work in the territory of "Internal Combustion Engines". This work upgraded my reasoning capacities and understanding ability. After the finish of my work, I encountered a sentiment self-delight.

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The present research work was completed in three stages, first the manufacturing and finishing of the cylinder block, second the assembly of the engine and third testing. I want to mention here the help from a number of persons who had helped me a lot during all these stages.

The market survey regarding the present scenario in the use of material for the cylinder blocks was conducted to collect the data of engines from various manufacturers. The following persons shared their valuable time with me to build a strong foundation to initiate the research work, were Mr. Muralidhar Urane, M/S Badshah 'BAJAJ', Ichalkaranji; Mr. Sambhaji Patil, M/S DSK 'HYOSUNG', Kolhapur; Mr. Jagdish Powar, M/S Popular 'HERO', Ichalkaranji; Mr. Rohan Bijjargi, M/S Kaizan 'HONDA', Ichalkaranji; Mr. Manju Itagi, Belgaum 'KAWASAKI', Belgaum and Belgaum 'KTM', Belgaum; Mr. Sheetal Patil, M/S Sheetal

Motors 'MAHINDRA 2 WHEELERS', Ichalkaranji; Mr. Nitin Kolekar, M/S Motor India, 'ROYAL ENFIELD', Kolhapur; Mr. Satish Hiralage, M/S Trio 'SUZUKI', Ichalkaranji; Mr. Raju Borgave, M/S Borgave 'TVS', Ichalkaranji; Mr. Avinash Nikam, M/S Nikam 'YAMAHA', Ichalkaranji; Mr. Tammubhai, M/S Perfect Motors 'VESPA', Sangli.

The patterns were prepared by M/s A.P. INDUSTRIES, MIDC, Shiroli, Kolhapur. Tthe Castings were produced by Mr. Shrinivas Nilajikar of 'PURVA METALS', G.M. Industrial Estate, Miraj-Kupwad block. Further it was machined to get a finished and ready-to-fit block by M/s GANAPATI ENTERPRISES, Shivaji Udyamnagar, Kolhapur; Mr. Harshavardhan Patil of 'CST TOOL MFG. INDUSTRY', MIDC, Shiroli, Kolhapur followed by Mr. J. V. Pawar of 'MACHINE TOOL WORKS', Shivaji Udyamnagar, Kolhapur. I whole heartedly thank M/s INDRANI/MAHAXAMI HEAT TREATERS, Mahalaxmi Industrial Estate, A/P Nagaon, Kolhapur for helping to heat treat the newly developed cylinder block as per the requirements.

CFD analysis is also playing important role in all these steps of manufacturing the block. So many persons helped me by taking a lot of efforts in modeling and analysis of the cylinder block. They are Mr. Nikhil, Mr. Akash, Mr. Pravin, Mr. Amit from M/s AXIS DESIGN SERVICES, Gokul Shirgaon MIDC, Kolhapur working in the field of 2D/3D inspection, CMM & tooling. Post treatment consists of analysis of the model to get the actual results. Mr. Pratik Patil of M/s SHRIVED SOLUTIONS PRIVATE LTD., Ichalkaranji was the person who had supported me to get the satisfactory results by careful analysis of the model.

After getting the finished block which was ready-to-fit on engine, it was necessary to mount it on the engine. So, lot of spare parts were supplied by the following persons in re-construction of the engine and restoration of the test vehicle. In this phase, the persons helped me were Mr. Vinayak, Mr. Prakash, Mr. Dagadu, Mr. Omkar from M/s S. M. PATEL (Spare part dealer) from Ichalkaranji; Mr. Vinayak from M/s AUTO ANTARIKSHA (Authorised 'Hero' Spare Part counter), Shahupuri, Kolhapur; Mr. Harish Gaikwad, Mrs. Jagtap, Mrs. Sontakke, the spare part staff of M/s POPULAR AUTOMOBILES (HERO), Yadrav, Ichalkaranji; Mr. Patil, Mr. Gajanan, Mr. Sandip and Mr. Vishal of M/s MANISHA AUTOMOBILES (HERO), Jaysingpur.

There was a very important role of two wheeler mechanics in fitting of newly developed block and assembly of the engine. So many aspects were discussed from time to time with them during the research work. Following persons helped me a lot by giving their precious advice.

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It was very essential to check the engine with Cast Iron and Aluminium Alloy engine cylinder blocks for ‘Pollution Under Control’ from the view point of different gases in exhaust like CO, HC, CO_2, O_2 and NO_x. Mr. P.Y. Patil of M/s PANKAJ MOTORS, Sangli availed the facility to check the engine by using the latest technology to get accurate results. I am really thankful for this co-operation extended by him.

Finally, the engine with existing Cast Iron cylinder block and newly developed block was tested by developing the experimental set-up. Mr. Shree Mane of M/s SCIENTIFIC INDIAN, MIDC, Miraj-Kupwad helped me a lot in developing the engine set-up and testing also.

I express my genuine thanks and appreciation to my folks, family, instructors, companions and all other people who have been a steady wellspring of motivation and support for me through one way or the other from the very adolescence and who remained by me at all, at all periods of my life. Finally, I say thanks to **Almighty God** for giving me a chance to work in such a domain with such great and educated individuals around.

MR. APPASAHEB D. PATIL

ABSTRACT

Always it is expected that every engine should return good mileage in Automotive Sector which will result in the fuel economy in operating them. This will challenge automakers to find ways to decrease vehicle weight and frictional loss between power train components. One approach to increasing an automobile's fuel economy by reducing engine weight and friction loss simultaneously is to remove the cast iron cylinder blocks and replace them with a lighter, more thermally efficient material. The aim of this research work was to find possible alternative to cast iron engine cylinder block, replaced by Aluminium alloy engine cylinder block. The work was carried out for the engine cylinder block according to the following steps:

Preparing the patterns, mould and pouring for the engine cylinder block, CFD analysis: Initially the patterns were prepared by scanning the old block and then the casting was obtained which was of Aluminium Alloy. For this, help of CFD was also taken to bring the new block in existence and to check the thermal performance.

Machining and finishing of engine cylinder block casting: The casting was produced by using the sand cast method which required the machining and finishing. This was done in the second stage to get a finished cylinder block ready to fit on engine.

Experimental setup and calculations: Then the experimental setup was developed and observations were recorded for the engine by using both the cylinder blocks which was a Laboratory/indoor testing of the engine to verify and compare the performance.

Field testing (ON ROAD) was done by using the Test Bike which was fitted with the engine with old Cast Iron and newly developed Aluminium Alloy cylinder block.

Comparison of the results: The results of the experimentation were compared and discussed in the next section. Finally the conclusions were drawn from the analysis of the results. An effort has been made to search the possible solution for weight reduction of the engine cylinder block of two wheeler engine to achieve better fuel economy by changing the material from Cast Iron to Aluminium Alloy. The present work is quite successful and this technology can be implemented on commercial basis in existing engines as well as new engines.

Keywords: Air cooled, spark ignition engine, cast iron, aluminium alloy, engine cylinder block, engine performance, engine emissions, mileage, and fuel economy.

LIST OF FIGURES

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LIST OF SYMBOLS

Symbols	Title	Units
P_a	Atmospheric Pressure under test condition	N/m^2
T_a	Atmospheric temperature	K
ρ_a	Mass Density of air under test conditions	kg/m^3
ρ_w	Mass Density of water under test conditions	kg/m^3
h_a	Pressure difference across orifice, cm of H_2O	cm of H_2O
Cd	Coefficient of discharge of Orifice	----
d_o	Diameter of Orifice	m
m_a	Mass flow rate of air	kg/s
m_f	Mass flow rate of fuel	kg/s
m_w	Mass flow rate of cooling water	kg/s
m_{eg}	Mass flow rate of exhaust gas	kg/s
Cp_g	Specific heat of the exhaust gas	KJ/kg.K
Cp_w	Specific heat of the exhaust gas	KJ/kg.K
N	Engine Speed	rpm
η_m	Mechanical efficiency of engine	%
η_{bth}	Brake thermal efficiency of engine	%
R	Gas Constant	J/kg.K
CV	Calorific value of fuel	KJ/kg
T_{wi} [T_1]	Temperature of water entering the calorimeter	^0C
T_{wo} [T_2]	Temperature of water coming out of the calorimeter	^0C
T_{gi} [T_3]	Temperature of exhaust gas entering the calorimeter	^0C
T_{go} [T_4]	Temperature of exhaust gas coming out of the calorimeter,	^0C
BSFC	Brake specific fuel consumption	kg/KW.s
HF	Heat supplied by the fuel	KW
HBP	Heat equivalent to BP	KW
(W-S)	Net load on dynamometer	kg
T	Torque on dynamometer	N.m
R_b	Mean radius of brake drum	m
BP	Brake power	KW
BP_1	Actual Brake power	KW
IP	Indicated power	KW

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Chapter 1

INTRODUCTION

1.1 General Introduction

Always it is expected that every engine should return good mileage in Automotive Sector which will result in the fuel economy in operating them. This will challenge automakers to find ways to decrease vehicle weight and frictional loss between power train components. One way to reducing engine fuel consumption is to decrease engine weight and friction loss with the weight of the engine is to use a lighter, more thermally efficient material. The aim of this work is to search possible alternative to the use of cast iron engine blocks and liners by using Aluminium alloy cylinder blocks.

1.2 Objectives of the Project

The objectives of this research work to search possible alternative for replacing the cast iron engine blocks and liners that are typically used in today's modern bikes and passenger cars in conjunction with an Aluminium alloy engine block. Objectives are given below.

1 To develop Aluminium alloy engine cylinder block for the selected model of the motorcycle,

2 To test the engine separately by fitting both the cylinder blocks,

3 To compare the results of the experimentation with each other; Cast Iron block as the base for present work.

1.3 Limitations of current cylinder block design

Automakers have to move from cast iron cylinder block/cast iron sleeve to Aluminium alloy cylinder blocks in order to reduce the engine weight only in some exceptions like Yamaha in their famous model R15 v1.0 and v2.0 versions. Replacing Cast Iron with Aluminium alloy for engine cylinder blocks results into almost 45 % reduction in weight for petrol engines.**[01]** Historically, then the remedy on this is to go for the use of sleeve of Cast Iron in the cylinder. The cylinder bores were fitted with the Cast Iron sleeve. These were cheaper, durable, and manufactured with ease, which are the key criteria for mass produced automobiles. Now, in India due to hike in Gasoline prices, the automakers are searching the new ways like two or three spark plugs, fuel injection by using different sensors, exhaust tech technology resurrecting old solutions to increasing automobile Gasoline fuel economy and to follow pollution norms laid by Government of India.

Moving away from Cast Iron sleeves gives the automakers an opportunity to solve some of the secondary issues with using cast iron sleeves on aluminium alloy cylinder block bores. Cast Iron liners are a cheaper alternative at the moment but with some limitations like weight, size, different thermal conductivities, different thermal expansions and they are reusable.

The deformation can be observed in case of the liners as coefficient of thermal expansion of Cast Iron and Aluminium Alloy was different.

1.4 Cylinder block requirements

Internal combustion engine cylinder blocks should fulfil different functional requirements. In the cylinder, the burning of the fuel produces quick and continuous changes in pressure along with the temperature, shear loads with formation of Gases. Circumferential and longitudinal tensile stresses are induced due to higher combustion pressure. The working requirements are block should last the total life of the automobile, covering moving parts and fluids inside, easy to service and maintain and withstand combustion pressures. The material of the block bore surface should have high resistance to wear and should be capable of withstanding higher pressures inside the combustion chamber during working. The porosity allowed should be less than one percent and the size of pore should be upto 500 microns for the surfaces subjected to sliding. **[02]**

Resistance to corrosion, high strength, resistance to wear, modulus of elasticity, scuffing resistance etc. are the desired properties of the cylinder block material to meet the functional requirements. Sufficient hardness to resist the wearing of the piston as it slides up and down on the cylinder wall is also playing important role in working.

Cylinder block surface also have high wear and scuffing resistance, are also very important properties. Wear is the erosion or displacement of block material from its original position on a solid surface. **[03]** The phenomenon in which the movement of surface elements to form the scratches and local welds is called as scuffing. **[04]** When the lubrication conditions deteriorate, wear and scuffing occurs. An increased oil and fuel consumption and increasing emissions are the results of deformation of the liner. The Aluminium alloys used for cylinder blocks demand strictly controlled characteristics and mechanical properties to meet the functional requirements mentioned above in order to perform as expected in modern automobiles.

1.5 Characteristics required for cylinder block material

[01] High strength

[02] Low density,

[03] High modulus of Elasticity,

[04] Low thermal expansion,

[05] High wear resistance

[06] Good machinability

[07] High scuffing resistance

[08] Good ability to cast

[09] High corrosion resistance

[10] Good vibration dampening

[11] High thermal conductivity

[12] Ability to withstand high temperature of combustion of fuel

1.6 Methodology

The present project is concerned with the experimental study of use of all Aluminium alloy air cooled engine cylinder blocks in two wheeler engines using all Cast Iron cylinder blocks and Cast Iron liners. Information on the topic will be gathered using online engineering databases and articles from relevant technical publications. This information will serve as the basis in satisfactory completion of the project work with expected results. After conducting survey of some major automakers like Hero Moto Corp (Hero-Honda), Bajaj Auto, TVS, Royal Enfield, etc., it was understood that all of them still they are using the Cast Iron cylinder blocks/liners. Hence, it was decided to conduct the study of use of Aluminium alloy engine cylinders in two wheelers which has a tremendous scope in this field.

1.7 History of the Two Wheelers

The automobile industry covers a span of more than two centuries. The earliest recorded automobile was built in 1668 by Ferdinanel Verbiest a Beloiun. Gasoline car was developed by Kari Fried Rich Benz in 1885. Trucks, motorcycles and other types of vehicles were also invented at that time.

The two-wheelers historical development consists of the 1885 "Gettibe Diameter", the first motorcycle. It travelled at the rate of 19 kmph. British started the Production of Motorcycle in 1889, West Germany was the biggest manufacturer of motorcycles, manufactured 1000 motorcycles in 1894. Presently, Japan is biggest manufacturer of modern motorcycles.

Internal combustion engine was first employed on a two wheeler vehicle by the German Engineer GOTTLIEB DAIMLER in 1885. His motor ‘36 cycle’ had a single cylinder, aircooled, four stroke engine, the earliest motorcycle to be commercially produced was made by Hildebrand and wolf muller of munich in 1894. Its 760 cc single cylinder water-cooled engine propelled it up to 39 kmph (24 mph). The motorcycles during the beginning were not used by people. Starting of the engine was pushing the vehicle. The Speed mechanism was the same, again low powered power plants were there so pedals were also provided to propel the motorcycles. Belt drives were slipping, no any springing. Then since 1907, starters by kick pedals, Clutches, Gearboxes, Chain drive and Springs were introduced slowly, converting the motorbikes into an economic form of transport. Still there was need of pedals to help the engine of the moped or a motorcycle with power plants of capacity less than 50 cc.

Auto-Ped, a version of the child's platform scooter was introduced in the USA in 1915, and by 1919 was being made in Europe. But it was not very successful. The motor scooter reappeared after the 2nd world war as a feature of Italy's industrial revival. The Piaggio Company's Vespa ("Wasp" in Italian) based on the war time scooters used by airborne troops, set off a worldwide boom in motor scooters that tested until the advent of cheap light weight motorcycle in the 1960's.

1.8 ‘Hero Motocorp’ (Earlier Hero-Honda) Company Profile

Munjal brothers were the architects of ‘Hero’ who was the manufacturer of bicycles. Finally complete bicycle was presented by them in 1956. Then ‘Honda Motors’ Company of Japan and the ‘Hero’ Group that established ‘Hero Honda’ Motors Ltd. These things were started by founder Mr. Dayanand Munjal (1912-1968).Other three of the confounders Mr. Satyanand Munjal, Mr. Brijmohan Lal and Mr. O.P. Munjal took operations of the Hero Group. Third generation of the family and workers started work at Ludhiana, in Punjab. Some of India's finest workers were also engaged in Hero Honda Motors Ltd., was so successful. ‘Hero’, started the journey of motorcycles since almost four decades ago. Now it is multi-national company with number of products are manufactured by them. It is the largest manufacture of 100 cc motorcycles in India and world. Collaboration with international organization of technology excellence, constant research to adopt to the emerging, to meet the specific requirements of the markets and belief in the psychology of industrial interdependence have made, Hero Honda Motors Ltd. The group's human approach is manifest in aspects of commercial production. The group has the privilege of manufacturing in environments friendly range of products. Concern for environment extends to social and cultural obligations too. The group has always endeavoured the remain in the national mainstream and its contribution in the field of technology, economic growth and employment is duly recognized. Its contribution to the field of education and public health are much significant. A charitable trust has also been setup, in the area of social and educational development. The name of the foundation working towards that is Raman Kant Foundation. Hero Honda Motors Ltd., in incorporating the worlds existing technology to meet the Indian consumers demand, by collaborating with internationally removed companies. The success of Hero Honda Motors Cycles do not remain confirmed to the Indian shares. Finding enthusiastic buyers across the world. It becomes the largest exported vehicle from India. A joint venture with Showa Manufacturing Company Japan, for the Production of front forks and shock absorbers for two wheelers. The group also ventured into a technical consultancy agreement with STAYR PUCH of Austria for the manufacturing 65 cc Porsche-design mini-motor cycle. The group also acquires the services of foreign consultants and experts for identifications and development of business opportunities and assistance in technical up gradation.

1.9 Importance of selecting two wheeler engine

When there was thought of researcher to work on this topic, such technology was already incorporated in four wheelers multi-cylinder engines like Honda Amaze known as ‘All Aluminium engine’. There were some problems like quantum of manufacturing multi-cylinder engine cylinder block, etc. at personal level which was beyond the capacity as the block was big. Hence, researcher after knowing this, conducted market survey of two wheelers given in chapter 4 and found that only twelve two wheelers of higher displacements with such type of cylinder block in out of total one hundred fourteen total two wheelers. But, this technology was not incorporated in small displacement bikes or scooters manufactured in India. As in India, small displacement bikes or scooters (100 to 125 CC) are used everywhere and with very big population. There was wide scope to save fuel by adopting this technology to reduce weight or to improve power to weight ratio and to get better fuel economy. There was another consideration of use of this engine in number of models sold by the Company ‘Hero Motocorp’ formerly known as ‘Hero Honda’. As the same engines are used in their bikes right from the beginning, still they are in use. So, two wheeler engine of ‘Splendor’ was selected for this purpose. The same block is compatible with all models without any modification.

This is elaborated in section 2.3 i.e. knowledge gap. The reason to select this engine is that Hero Honda/Hero Motocorp had used this engine in 16 to 17 models which are largest selling among all automakers in two wheeler sector in India due to reasons like light weight, better looks, low maintenance and good mileages.

1.10 Chapter summery

In the present chapter, a description of current engine cylinder block design is given in the form of current technology, its limitations and requirements of block material. The methodology which is to be used in the present research work is also given. As ‘Hero Motocorp’ is largest two wheeler selling manufacturer and their ‘Splendor Plus’ model is selected for the current research work, this chapter ends with importance of selecting two wheeler engine.

1.11 Outline of the Thesis

The remaining chapters are arranged as per the following table:

Chapter 2	**Literature review**	The literature which is collected from different sources is reviewed which will form the base for the current research work. The literature for Engine Materials, Manufacturing Sciences & Metallurgy, Heat Transfer, CFD and Engine Testing is collected and presented in this chapter.
Chapter 3	**Testing procedures and Instrumentation**	Generally forced cooling method is employed in actual applications on air cooled engines for the enclosed engines like in scooters whereas the engine cylinders of motorcycles are directly exposed to the surrounding and cooling of such engines takes place by natural convection when the bike will be on stand and by forced convection when the bike will be in motion, discussed in this chapter.
Chapter 4	**Market Survey**	The market survey required to identify actual need of the present technology was essential. That was conducted by identifying various major manufacturers and the details are given in the present chapter. Results are discussed in the later part of the chapter. Chapter ends with the point 'further steps in completion of the Research Work'.
Chapter 5	**Engine cylinder manufacturing and CFD analysis**	Entire manufacturing process and steps involved are described in this chapter right from beginning till the actual fitment of piston in the block. Chapter ends with CFD analysis of Cast Iron & Aluminium Alloy engine cylinder blocks.
Chapter 6	**Experimental details**	The experimental set-up to conduct the experimentation is discussed in this chapter. This chapter also explains the experimentation of the present research work. All the observations required to evaluate the performance parameters for both the cylinder blocks, indoor and outdoor test readings recorded are presented in tabular form. The later part of the chapter consists of the results of the experimentation along with sample calculation.
Chapter 7	**The Results and discussion**	The experimentation results from present research work are given in this chapter. It also gives the discussions related to the results of the experimental work.
Chapter 8	**Conclusions and recommendations for further research**	Conclusions from the results of the research work are presented in this chapter along with recommendations for further research work.

Chapter 2

LITERATURE REVIEW

2.1 Introduction

The literatures relevant to the problem undertaken were collected after going through the different sources and presented in summarized form in this topic.

2.2 Literature

The literatures collected were divided into four parts like general literature, literature helping for the material selection, relevant to heat transfer from air cooled cylinders and engine testing in the form of Indian Standards. The literature is reviewed in the present section and discussed below.

2.2.1 General Literature

In today's automobile market manufacturers using hypereutectic Al-Si alloys include Honda, Mercedes, Audi, VW, Porsche, BMW, Volvo and Jaguar. ALBOND®, Alusil®, DiASil, Lokasil®, Silitec®, Mercosil, are all trade names or trademarks for Al-Si which is hypereutectic for cylinder bore wear surfaces. Each case of the engines using the hypereutectic material are typically low volume, larger engines with six or more cylinders. One of the leading manufacturers of hypereutectic Al-Si cylinder blocks is KS Aluminum-Technologie AG (KS ATAG), a Kolbenschmidt Pierburg AG company. KS ATAG has been producing hypereutectic Al-Si alloys for last ten years. Successful formulations are low-pressure die cast engine cylinder blocks made from hypereutectic alloy AlSi17Cu4Mg and Alusil®. Alusil® is Al-Si alloy. KS ATAG produces cylinder blocks out of Alusil® with a low-pressure die cast process. The cylinder block's primary silicon particles are formed during solidification as small, hard grains, on the surface of the cylinder bores.**[05]** The silicon has sufficiently porous surface enough to retain oil, and is good surface from view point of bearing. Alusil® is used in the majority passenger automobiles with larger, eight cylinders or more, engines in Europe. Currently Audi, Volkswagen, BMW and Porsche all use Alusil® for one or more of their production car cylinder blocks. Development of hypereutectic Al-Si for the US market could come from KS ATAG importing their technology or selling the rights to use their proprietary materials.

Another manufacturer with recent success with Aluminium-Silicon alloy as a material for cylinder block is Mercury Marine. Mercury Marine created a castable Aluminium-Silicon alloy without copper, Mercosil for internal combustion engine cylinder blocks. Along with primary silicon particles dispersed in the parent Aluminium matrix, Mercosil has solid lubricant particles held in the cylinder wall to further enhance the wear resistance of the material. Through testing Mercury Marine has shown that the copper-free hypereutectic Al-Si alloy Mercosil is superior to A390 hypereutectic Aluminium alloy in that Mercosil has uniform distribution of silicon and the castings produced are sound with ease in production. **[06]**

There is only one automaker in India and it is YAMAHA **[07]** in two wheeler sector. In their famous model R15 v1.0 and 2.0, this technique is implemented. This is a 4 stroke, 150 cc, liquid cooled, fuel injected power plant which is made up of Aluminium alloy which is known as DiASil cylinder. These cylinders are 'All Aluminium' cylinders has almost twenty percent Silicon with the help which harder surfaces can be created as a substitute for cast iron sleeves. Hence, the cylinder block will totally be of Aluminium having better heat transfer and light in weight as Aluminium alloy's thermal conductivity is three times greater than Cast Iron.

As far as multi cylinder engines are concerned, Mahindra and Maruti Suzuki India Limited are the car manufacturers and the same technology is utilized by them in multi cylinder engines. The 1.5 litre three cylinders Diesel Engine is developed by Mahindra for their newly launched 'XYLO' which is all Aluminium, double overhead Camshaft, Common Rail, Twin Camshaft, Twin turbo charger.

Maruti Suzuki India Limited being the Countries leading car manufacturer developed the K-Series which is a common power plant for Alto K-10, A-Star, Estilo and new Wagon-R. This engine is also All-Aluminium engine which is light in weight, hence offers best in class fuel efficiency.

The design, production, repair and reconditioning of Aluminium alloy cylinder blocks is given along with the machining procedures for Aluminium alloy cylinder bores is reviewed in the service manual of KOLBENSCHMIDT, PIERBURG AND TRW. **[08]**

A. Rabiei, et al. studied microstructure, deformation of the ferrous coatings which are thermally coated. The emphasis has been on coatings made by the high velocity oxyfuel (HVOF) process, especially the role of Al alloy additives. The oxide phase present in the material and preferred pathways for local cracking and separation have been determined. A major finding of the study was that in both HVOF and PTWA (plasma transfer wire arc) coatings, thin amorphous oxide layers exist between a–Fe splats. Because of its thinness and uniformity, it has been proposed that the inter-splat oxide is formed by solid state oxidation.

Implementing approaches that inhibit such oxidation would substantially enhance the durability of the coating. **[09]**

Fabio Grosselle et al. analysed the mechanical properties alongwith microstructure of a HPDC four cylinder inline cylinder block. A HPDC 4-cylinders-inline cylinder block was exhaustively analysed and mechanical properties were correlated to microstructural features. Mechanical properties are affected by microstructure. The best values of UTS and elongation to fracture are obtained for low secondary dendrite arm spacing (SDAS) values and small and more compact eutectic Si particles. **[10]**

Advanced casting techniques for lighter automobile components were discussed by Alan A. Luo, Anil K. Sachdev and Bob R. Powell at General Motors Global research and development centre, Warren, MI, USA. This paper provides an overview of alloy and process developments in aluminium and magnesium castings for lightweight automotive applications. Thin wall and hollow casting components were being produced by low pressure die casting processes for structural applications. The paper emphasized on simulation tools developed to predict the interfacial interactions of the dissimilar components and the structural integrity of the overcast systems and their validation in the casting trials. **[11]**

R.R. Navthar and P.A. Narwade found that engine weight can be reduced by selecting the proper material for cylinder block and cylinder head by using LM-13, an alloy of Aluminium. This results into high strength of cylinder with minimum weight. The main objective of design is to reduce weight to power ratio & will result in producing high specific power. The authors have proposed preliminary design cylinder & cylinder head of a horizontally opposed SI engine, which develops 120 BHP and possess the maximum rotational speed of 6000rpm. For the requirement of weight reduction the material selected for design of cylinder and cylinder head was Aluminum alloy LM-13. The cylinder bore coating using NIKASIL coating was done to improve strength of cylinder with minimum weight.**[12]**

'Manufacturing Feasibility of All-Aluminum Automotive Engines via Application of High Silicon Aluminum Alloy' is verified, discussed by Mercury Marine, Dr. Raymond Donahue and Philip A. Fabiyi from Daubert Chemical Company. This paper presents the new advancements to the old hypereutectic aluminum-silicon technology for linerless parent bore aluminum blocks. The technology was centred on the use of a copper-free hypereutectic aluminum-silicon alloy parent bore material and a piston coating that has particles of a solid lubricant embedded in the plated coating. **[13]**

The functional requirements of the engine block, manufacturing techniques and the mechanical properties of the alloys are studied by Hieu Nguyen in his paper entitled "Manufacturing Processes and Engineering Materials Used in Automotive Engine Blocks". AMC-SC1 magnesium alloy will be able to increase fuel efficiency and power-to-weight ratios of automotive engines while decreasing emission levels. In this paper, the functional requirements of the engine block, the processes used to manufacture the part, and the mechanical properties of the alloys were discussed. **[14]**

Aluminium Alloy and Casting Process Optimization was studied by M.O. of Otte ; F. J. Feikus; L. Heuslerof VAW Aluminium AG, Bonn, Germany for Engine Block Application. In this paper, firstly, the beneficial effects of the application of local cooling with metal chills on the microstructurel and mechanical properties of sand castings is described. Secondly, a newly developed alloy of the type AlSi7MgCuNiFe is presented and characterised in terms of tensile tests at room and elevated temperatures, fatigue tests as well as creep tests. The achieved properties measured in samples from prototype engine castings are compared with the mechanical characteristics of existing alloys for engine block applications. **[15]**

'Mechanical properties of a recovered Al-Mg-Sc ALLOY' are studied by REZA ROUMINA and submitted in the form of Ph. D. thesis submitted to THE UNIVERSITY OF BRITISH COLUMBIA (Vancouver). In this study the effect of recovery on the yield strength and work hardening of a model Al-Mg-Sc alloy in the presence of Al3Sc precipitates was investigated. Recovered microstructures containing Al3Sc precipitates were obtained through a series of thermo-mechanical treatments including pre-aging, cold rolling and annealing. **[16]**

A patent was filed by Salvador Valtierra-Gallardo, Jose Talamantes-silva, Andres Ferando Rodriguez-Jasso, Jose Alejandro Gonzalez-villarreal entitled "Wear resistant Aluminium Alloy for casting Engine blocks with linerless cylinders". The developed alloy has very good machining characteristics giving a significantly improved surface finish in the cylinder bores while manufacturing cost is reduced in about 40% as compared with using current commercial alloys of the prior art requiring iron liners.**[17]**

Teramoto S., Sakakibara Y., Nakashima K., Yoshida M. et al. published a paper on "Thermal Characterization of Air-Cooled Aluminum Die-Cast Cylinder Blocks with Various Cast Iron and Aluminum Liners," in SAE journal in which the advantages of Aluminium cylinder blocks are discussed by the authors. This study attempts to maximize heat transfer while minimizing cylinder weight, by comparing four liners: (1) a cast iron liner with higher projections on its periphery, (2) a cast iron liner with lower projections, (3) a cast iron liner with lower projections, and aluminum-silicon coated on its periphery by thermal spraying, and (4) a high-silicon aluminum alloy liner with aluminum-silicon coated by thermal spraying. **[18]**

A paper on “Improving Cylinder Cooling Using Tapered Fins and Baffle Plates between Fins in Air-Cooled Engines” was published by Teramoto S., Nakashima K., Ishihara S., Murakami Y., et al. in Society of Automotive Engineers Journal which highlights the significance of parameters like cross section and baffle plates This is an attempt to maximize the performance of air-cooled engines (such as motorbike engines and small stationary engines) by increasing cylinder cooling and by maintaining uniform temperature around the cylinder circumference. **[19]**

"Optimum Fin Layout of Air-Cooled Engine Cylinder in Air Stream" was studied and presented by Murakami Y., Yoshida M., Nakashima K., Ishihara S. et al. in SAE Journal. It is important for an air-cooled engine to utilize fins with effective engine cooling and uniform temperature in the cylinder circumference. In order to permit the development of design data, an experimental cylinder was developed having variable fin pitch and number of fin capability. This experimental cylinder was tested in a wind tunnel. **[20]**

Polunin V., et al. published an article on "A Wear-Resistant Coating for Aluminium-Silicon Alloys Using Micro arc Oxidation and an Application to an Aluminium Cylinder Block" in SAE Journal. **[21]**

“Improved Aluminium Alloy for Engine Applications” was published by Henkel G Smith D., and Legge R. in SAE Journal which gives the new improved Aluminium alloy for the cylinder blocks of the engines. **[22]**

Dos Santos Filho D., prepared a technical report in the form of a paper on “An Approach of the Engine Cylinder Block Material,” published in SAE journal. The review study reveals the requirements from the view point of selection of material for multicylinder engines with main aim to reduce cost with improvement in mileages. **[23]**

Troxler P., et al. published a technical article on "Experimental Investigation into the Temperature and Heat Transfer Distribution around Air-Cooled Cylinders " in SAE Journal which describes the distribution of temperature in air cooled cylinders. This paper describes an experimental investigation into the surface heat transfer coefficient of finned metal cylinders in a free air stream. Ten cylinders were tested with four different fin pitches and five different fin lengths. **[24]**

2.2.2 Literature related to material selection

S. Das has studied different properties of Aluminium Alloy composites in his paper and presented conclusion based on the same as these alloys are offering higher wear resistance, corrosion resistance, etc. properties and mentioned that the composite components have the potential to replace the existing components and these components could be exploited commercially. **[26]**

'Motor Service Manual for technical personnel' gives the guidelines to the machining techniques and tools required to bore the Aluminium Alloy castings after casting. **[27]**

The brochure of A. hadleigh Castings (Aluminium Technology) gives all the details like composition, properties, heat treatments, applications of LM25, an Aluminium Casting Alloy. **[28]**

The Aluminium Automotive Manual also discusses the composition, properties, heat treatments, etc. in their brochure. **[29]**

BS:1490:1988 gives the details of Aluminium Alloys and Approximate Equivalents of all countries like UK, India, France, Germany, Italy, USA ASTM & SAE, Japan. **[30]**

Cast and Alloys, An ISO 9001:2000 Company gives the properties and recommended end use of LM series of Aluminium Alloys **[31]**

Jonathan A. Lee reviewed the Cast Aluminium alloy for high temperature applications like piston, blocks etc. engine components. **[32]**

2.2.3 Literature related to Heat Transfer from air cooled cylinders

Dissipation of heat in engine cylinders by using air cooling are reviewed by Benjamin Pinkel at Langley Memorial Aeronautical laboratory. Some semi-empirical equations are given by them which are very useful in study of heat transfer from hot combustion gases to cylinder and from cylinder to the atmospheric media air. Simple equations for the average head and barrel temperatures ass functions of the important engine and cooling variables are obtained from these expressions. These involve a few empirical constants, which are obtained from engine test in the form of numerical values. **[33]**

G.F. Berry and C.S. Wang has developed a heat transfer model who are from Energy and Environmental Systems Division to calculate the heat transfer from combustion gases through the cylinder wall to the coolant in an internal combustion engine. The treatment of convective heat transfer accounts for the physical problems of rotating and impinging axial flow inside the engine cylinder. The radiative heat transfer includes gas radiation (CO_2, H_2O and CO) and soot particle radiation. **[34]**

The effects of spark timing and load on the in-cylinder heat transfer of a SI engine were studied by A.Sanli et al. by using experimental engine test. They found that heat transfer properties of engine which they have tested is mainly related to the load. The aim of this study was to examine numerically the effects of spark timing and load parameters on the in-cylinder heat transfer of a SI engine by using experimental engine test data. **[35]**

The relationship of average fin surface heat transfer coefficient in terms of wind velocity is obtained by Pulkit Agarwal et al. They have been studied the effect of ambient temperature on overcooling and low thermal efficiency. It was observed that when the ambient temperature reduces to a very low value, it results in overcooling and poor efficiency of the engine. **[36]**

Amit V. Paratwar et al. carried out studies based on dissipation of heat as well as analyzed the flow of cooling jacket of six cylinder turbo after-cooled medium duty diesel engine and then investigated the factors affecting cooling performance by using CFD analysis and validated with results obtained by conducting the trials. **[37]**

Amit Kumar, Gupta et al. studied the design of circular fins on the cylinder of single cylinder, four stroke Spark Ignition Engine. The main objective of design was to provide the maximum cooling will result in producing high efficiency. Considerable specific data of the engine cylinder was compression ratio, bore, stroke, maximum torque, volume of the cylinder, etc. **[38]**

Christopher Depcik et al. discussed a heat release simulation to understand the thermodynamic fundamentals. This paper illustrates the use of engine modelling through the development and use of a single zone, premixed charge, spark ignition engine heat release simulation. **[39]**

Herman H. Ellerbroce et al. had successfully tried to investigate the determination and correlated the experimental surface heat transfer coefficients of finned cylinder with different air stream cooling arrangements. The test was conducted at the Langley Memorial Aeronautical Laboratory. **[40]**

A computer simulation was developed by Mohand Said Lounici et al. Experimental measurements were carried out for comparison and validation of the results. Researchers investigated the effect of choice of heat transfer correlation and burned zone heat transfer area calculation method and provide an optimized choice for a more efficient two-zone thermodynamic model, in case of natural gas SI engines. **[41]**

The experimentation by Oleg Spitsov gives the comparison of numerical data with experimental results has showed a small deviation in obtained heat flux values throughout the cycle and different behavior of heat flux curve after Top Dead Center. Specific aspects of heat transfer in the combustion chamber of compression ignited reciprocating internal combustion engines and possibility to directly measure the heat flux by means of Gradient Heat Flux Sensors. **[42]**

2.2.4 Literature related to CFD analysis of air cooled cylinders

Stefania Falfaria et al. in their paper entitled "Definition of a CFD Methodology to Evaluate the Cylinder Temperature Distribution in Two-Stroke Air Cooled Engines", a 3D-CFD simulation methodology is designed to perform a detailed evaluation of two stroke air-cooled engines. Authors present a 3D-CFD simulation methodology designed to perform a detailed evaluation of two stroke air-cooled engines. The methodology was applied on two different engines equipping handheld brush-cutter machines. The optimization of the air-cooling system of such a machine is a very challenging task because the machine design must be very compact forcing all the engine parts to remain quite close each other. [**46]**

Mishra A.K., Nawal S. and Thundil Karuppa Raj R. in their experimental investigation, CFD was used on finned metal cylinder. The heat release from the cylinder which is calculated numerically is validated with the experimental results. They have tried to study the effect of fin parameters on fin array performance which includes variation in pitch and fin material. In addition, this paper considers the effect of air flow velocity on different fin pitch by using CFD technique. An effort is made to study the effect of fin parameters on fin array performance which includes variation in pitch and fin material. In addition, the current paper considers the effect of air flow velocity on different fin pitch. With the help of the available numerical results, the design of internal combustion engine cooling fins can be altered for better efficiency. **[47]**

An attempt was made by Mayur Shrikhande, et al. to simulate the engine heat transfer using CFD analysis. GAMBIT was used for modelling and FLUENT for simulation. An expression of average fin surface heat transfer coefficient in terms of wind velocity was obtained. It was observed that when the ambient temperature reduces to a very low value, it results in overcooling and poor efficiency of the engine. [**48]**

A methodology is developed for the analysis of diesel engine in-cylinder processes and combustion by C.S. Sharma, T.N.C. Anand and R.V. Ravikrishna. Beginning from CAD data of the engine geometry, the methodology involves use of a commercial code AVL FIRE for simulation of suction stroke, and an open-source code KIVA-3V for simulation of the closed-valve part of the diesel cycle. For this, an algorithm is first developed to map a generalised three-dimensional Computational Fluid Dynamics (CFD) solution from an unstructured mesh in AVL FIRE to a structured mesh in KIVA-3V to provide initial conditions for the closed-valve simulations. **[49]**

B.N. Niroop Kumar Gowd and Ramatulasi have been studied the thermal properties by changing the geometry, material and thickness of cylinder fins. Parametric models of cylinder with fins have been developed to predict the transient thermal behavior. The models are created by varying the geometry, rectangular, circular and curved fins. Present thickness of the fin is 3mm, it is reduced to 2.5mm. **[50]**

Ashishkumar N. Parmar, Prof. Arvind S.Sorathiya et al. have studied the past researches to enhance heat transfer by fins by changing cylinder block fin climate condition, fin geometry, and material. In Indian motorcycles, Air-cooling is used due to reduced weight and simple in construction of engine cylinder block. As the air-cooled engine builds heat, the cooling fins allow the wind and air to move the heat away from the engine. Low rate of heat transfer through cooling fins is the main problem in this type of cooling. **[51]**

CFD analysis was used by Hardik S. Rajput and Vivek B. Patel in which they simulated the heat transfer of the engine block. The heat transfer rate was evaluated by changing the fin geometry using CFD as a tool. Motorcycle engine releases heat to the atmosphere through the mode of forced convection heat transfer. To solve this, fins are provided on the outer part of the cylinder. The heat transfer rate is defined depending on the velocity of vehicle, fin geometry and the ambient temperature. Increasing the temperature difference between the object and the environment, increasing the convection heat transfer coefficient, or increasing the surface area of the object increases the heat transfer. **[52]**

P.T. Nitnaware, Prachi S. Giri, optimized the design of air cooled engine fins using CFD. This study is an attempt to understand the effects of the number of fins, fin pitch, relative air velocity and ambient temperature on cooling of a two wheeler engine using commercially available CFD codes. Varying trends are tabulated and determined and the values which give optimized fin surface from thermo-structural aspect at a given heat flux are determined. **[53]**

CFD technique was used by Amit Ranjan & D.S. Das to study the heat transfer from motorcycle engine cylinder. Various fin geometries and speed condition were the variable for this study. An effort is made to study the effect of wind velocities and fin geometries on heat transfer rate and simulation of the heat transfer using CFD. **[54]**

2.2.5 Literature related to Engine Testing

Abhishek Chakraborty, Shivam sharma found the experimental performance results for various sizes of main jet that gives better result under various load and gear operating condition during the test on engine. The author have used single cylinder two stroke experimental way. A driver controls the engine speed by increasing or reducing the amount of fuel with the help of accelerator pedal. The experimental results show that which size of main jet gives better result under various load and gear operating condition. **[55]**

Siddharth Shukla, Pranav Ravi used various blends of L.P.G and Biogas and conducted the tests on 4-stroke, single cylinder, air cooled SI engine. The experimental results were analyzed for the selection of better blend of L.P.G and Biogas suitable for SI engine for better performance with reduced pollution.**[56]**

R. Bhaskar Reddy, B. Siddeswararao found that with honne oil- diesel blend the performance of the engine is better compared with diesel. The break thermal efficiency and mechanical efficiencies were found to be maximum at 200 bar injection pressure with both honne oil- diesel blend, compared with 180 bar and 220 bar. The brake specific fuel consumption was to be minimum at 220bar compared with 180 bar and 200 bar. Hydro carbon emissions of honne oil-diesel operation were less than the diesel fuel mode at all fuel injection pressures.**[57]**

Blessen Sam Edison, Christy Binu obtained the engine performance characteristics and emissions experimentally and various graphs were plotted to study the effects of these factors at four engine loads for hybrid fuel engine. The results obtained showed that the engine with addition of hydrogen had an efficiency of 21.3%. The combined effect of water injection decreased the former efficiency by 4.3%. The net efficiency of the entire setup including hydrogen and water injection was 17%. **[58]**

One attempt by Amit Ashokrao Gulalkari, Vijay G. Gore, Aniket P. Pathre, Manoj J. Watane is to design, fabrication and fine assembling of each and every component, analysis of mileage, future scope etc. of complete assembled mileage testing unit. This project was undertaken with an objective to test the average of vehicle in showrooms and service centers. The machine was fabricated and assembled according to design, with flexible features and under tested running the vehicle on the road using 50 ml fuel. **[59]**

Swarup Kumar Nayaka, Bhabani Prasanna Pattanaika has studied the Performance and Emission Characteristics of a Diesel Engine Fuelled with Mahua Biodiesel Using Additive. The present paper provides a strong platform to continue further investigation on using biodiesel fuel in a diesel engine with variety of fuel additives under varying engine operating parameters. **[60]**

Sulaiman, M. Y., Ayob, M. Ra and Meran, I. analyzed the characteristics of single cylinder SI ICE fueled by LPG. In particular, torque and engine speed were examined with using the universal dynamometer in WOT condition under stable condition. In addition the fuel consumption has been measured to identify which fuel is more practical for SI ICE. SI engine fueled by LPG has slightly decreased on power output up to 4 % compared to ULP. However, engine fueled by LPG reduce on specific fuel consumption (SFC) to 28.38 %. In addition, LPG engine have low energy price than ULP engine with difference up to 47.40 %. **[61]**

The study by Yuh-Yih Wu, Bo-Chiuan Chen and Anh-Trung Tran describes and proposes a lean-burn system for reducing pollutant emissions and improving motorcycle engine performance. This study describes and proposes a lean-burn system for reducing pollutant emissions and improving motorcycle engine performance. The lean-burn system, called semi-direct injection (SDI), is comprised of high-swirl charge, injection during intake-valve opening, and liquefied petroleum gas (LPG) injection. A conventional motorcycle engine with port fuel injection (PFI) and spark ignition (SI) was retrofitted by designing a new intake port with a controllable plate to enhance the swirl of intake flow. **[62]**

In the work by E. Ramjee and K. Vijaya Kumar Reddy, Compressed Natural Gas (CNG) has been introduced as an alternative fuel to overcome the above problems. The emission characteristics of HC and CO are better for CNG compared to petrol and experimental investigations have been carried out pertaining to the engine performance and exhaust emissions of a single cylinder 4-stroke air cooled type Bajaj-Kawasaki engine.**[63]**

Avinash Kumar Agarwal, Atul Dhar discussed the performance, emission and combustion characteristics of this biodiesel and its 20% blend and compared with mineral diesel in a direct injection (DI) engine. Detailed combustion characterisation revealed that combustion starts earlier for biodiesel fuelled engine at all operating conditions but start of combustion was slightly delayed for 20% blend of biodiesel in comparison with mineral diesel. Combustion duration for biodiesel blends was shorter than mineral diesel. **[64]**

Sandeep M. Joshi et al. studied the effects of various blends on engine torque, specific fuel consumption and emissions. They were experimentally evaluated and it was found that among the four blends tested, E20 produced the best thermal and mechanical efficiency of 34% and 92.77%, respectively. The CO and HC emissions were found to be 4.22% and 780 ppm, respectively. **[65]**

2.3 The knowledge gap in the earlier investigation

As far as the earlier investigation is concerned no much research is done in the field of material science to use the nonferrous material in construction of engine cylinder blocks for two wheelers of smaller displacement. Therefore, it was decided to undertake this project. This technology is implemented by many carmakers in India. But, no try in two wheeler segment. So, there is wide scope to use Aluminium Alloy engine cylinder blocks instead of Cast Iron engine cylinder blocks which will improve the power to weight ratio and return better fuel efficiency.

From the information given in the section discussed above, it can be concluded that, there is a large potentiality to study the feasibility of such type of non ferrous metals as the cylinder block materials; hence the present investigation has been carried out accordingly.

2.4 Chapter summery

In the present chapter, the literature which was collected from different sources was reviewed which will form the base for the current research work. The sources include the research papers from journals, conferences and websites. Work has been done by different researchers worldwide in different fields like Engine Materials, Manufacturing Sciences & Metallurgy, Heat Transfer, Engine Testing and CFD analysis of engine components. The relevant literature was selected and presented in this chapter.

Chapter 3

TESTING PROCEDURES AND INSTRUMENTATION

3.1 Introduction

The engines are designed and developed with the aim of improvement in the performance. In order to achieve this aim, R and D section has to compare the performance of the engine under development with other engines. For this testing of engine and collecting the data of different parameters is made. The project undertaken as a part of research work is to investigate the Aluminium Alloy Engine Cylinder Block in Two Wheelers tested by conducting the experimentation. The testing procedures in the present investigation are discussed in this chapter.

3.2 Dissipation of heat from cylindrical surfaces

The heat which is required to be dissipated by cylinder at full load is 36 J/w.min to 55.0 J/w.min. In addition, the lubricating oil dissipated heat in the oil cooler ranges from 23.57 to 28.28 J/w.min and a total of 47.13 to 58.91 J/W.min is extracted from the cylinder. Assuming a mean cooling surface temperature of 218 ^{0}C, an air temperature of 7 ^{0}C and a surface coefficient h=20 W/m^2.K gives for necessary minimum cooling area.

A= {1500/ [(450-70) X 20]} = 0.20 Sqft/hp = 2.49 X 10 m^2/w ………. (3.1)

With a lower 'h' resulting from lower velocities or with a greater heat to dissipate, the necessary area may go up to 4.35 X 10^{-5} m^2/w.

Proper cowling of a radial engine gives more effective cooling with a decreased head resistance. Engines with inline and vee cylinders require a special hood with baffles to direct the air stream over all cylinders.

The computations of the heat 'Q' dissipated by a cylinder with fins are much simplified by the use of an equation of a structure similar to the general equation namely,

$Q = A_0 . \grave{U} . (t_3 - t_4)$ ………. (3.2)

Where,

A_0 = the outside surface area of the cylinder, Sq.m.

$\grave{U}$ = special heat transfer coefficient, J/m^2.sec.K

t_3 = the average surface temperature, K

t_4 = the cooling air temperature, K

The expression for this special heat transfer coefficient is:

$\mathring{U}=\{(h_2/(s+b)\}X\{2/a[1+(w/2.r_0)\tan h\ [a(w+0.5b)]+S_0\}$ ………. (3.3)

Where,

S, b, r_0 and w, in the above figure in 'm',

S_0 = the spacing of tapered fins on the cylinder surface, m

h_2 = the film coefficient, $J/m^2.sec.K$

a = a factor, where a= square root of $(2.h_2/k.b)$

k = the conductivity from table of properties of metals, $J/sec.m^{-1}.K^{-1}$

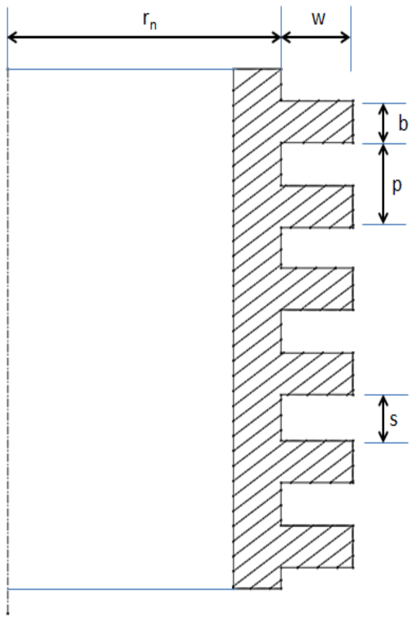


Figure 3.1, Fin Dimensions

3.3 Geometrical parameters affecting the heat transfer:

[01] Fin thickness (b)

From the figure 3.25, for a given space's' does not have an appreciable effect upon the heat dissipation.

[02] Fin spacing (S)

The distance between two fins is called as fin spacing. There is interference of the boundary layers formed at adjacent fins creates problem for the air flow and film coefficient

‘h_2’ decreases. It increases until a point where the adjacent fins do not interfere any more. This happens in case of closely spaced fins.

[03] Fin Width (W)

Tests with fins of different width ‘w’ have shown that for the width as used in practice, 12.0 to 38.0 mm, ‘h_2’ can be assumed to be independent of ‘w’.

3.4 Guidelines for design of fins

The inner surfaces of the cylinder wall must be shaped and finished so as to absorb a minimum amount of heat and the outer surfaces so as to dissipate this heat most readily. A polished metal surface absorbs less heat than a rough surface. Therefore the inner surface even though it is not in contact with the piston must be highly polished and in order to machine the inside of the cylinder head, the overhead valve construction is most frequently used. A polished surface has an additional advantage in that carbon formed from burned lubricating oil does not adhere so tightly to the walls and is more readily blown out with the exhaust.

The overhead valve arrangement also gives the minimum combustion space surface which decreases the heat given up by the gases. Quick exhausting of the incandescent products of combustion is also important along with quick opening large size exhaust valves must be used.

The hottest parts of a cylinder head are the exhaust valve and port and particular attention must be given to their cooling. Contrary to expectation the rear side of a cylinder loses at least as much heat to the air that streams around it as the front side directly impinged on by the air.

In radial engines the exhaust valves should be located on the right side of the cylinder looking upon the forward end of the engine along the path of the air thrown back by the propeller.

The following features help to keep down the temperature of the exhaust valve: a heavy head to allow rapid travel of heat from the center to the seat, a wide seat to reject the heat, a large stem and a heavy valve guide extending fairly close to the head.

3.5 Heat transfer theory of air cooling in engines

In engines, excessive heat is produced due to combustion of fuel. Due to this excessive heating, there is possibility of some adverse effects on the parts which are in contact of this heat. So, it is essential to remove this excessive heat from the overheated parts. For this purpose, an effective cooling system is introduced. The cooling effect can be achieved by using either air or water depending upon the type of cooling system used.

As the present research work is concerned about the natural and forced/combined cooling, some important points about the heat transfer from heated parts of engine are given in this section.

3.5.1 Temperature of gases in cylinder of an I.C. Engine

During combustion of the fuel in chamber, the gases are formed. The temperature of these gases in cylinder varies widely in the course of a working cycle from 320 to 2400 K and depends upon the type of engine, load, speed and thermal condition of the engine, its tuning, etc.

The temperature of gases 'T_g' for the compression and expansion strokes (between the moments of inlet valve closing and exhaust valve opening, when the weight of the charge remains almost constant) can be calculated by the characteristic equation :

$T_{gx} = (P_x . V_x) / (W.R_g)$ ……… (3.4)

Where,

P_x , V_x = pressure and volume of gas in the cylinder at 'x' of the indicator diagram.

W = Weight of the charge in the cylinder during the compression stroke

$W = W_a = (P_a . V_a) / (R.T_a)$ ………. (3.5)

i.e. the weight of the charge at the beginning of the compression stroke during the expansion stroke.

$W = W_{cp} = (W_a + b_c)$ ………. (3.6)

Where, W_{cp} is the weight of the combustion products and 'b_c' is the fuel injected per cycle. The mean cycle gas temperature 'T_{gm}' in a carburetor engine cylinder is higher than in that of a Diesel Engine. The temperature 'T_{gm}' rises with an increase of the load and the compression ratio.

The measurement of momentary gas temperature in an engine cylinder entails great difficulties since measurements involve the use of special thermocouples with a low thermal inertia and a high resistance to heat. Therefore, the temperature of the working gases in a cylinder is seldom measured experimentally and is calculated from the above formula.

3.5.2 Temperature of the cylinder walls of an I.C. Engine

The equation for the mean temperature of a cylinder wall Δt_w (liner, head and piston) washed by gases at inner side and by a cooling medium (water, oil and air) at the outer side of the cylinder is obtained as follows.

The amount of heat transferred per cycle from the gases to a unit area inside the cylinder wall can be found from formula,

$Q_{cycle} = Q_{wg} = (\alpha_{gm}(T_{gm}-T_{wgm})T_0)$ KJ/m^2.cycle ………. (3.7)

Assuming that this amount of heat is completely rejected to cooling medium, the heat transferred to this medium can be written as :

$Q_{cycle} = (K_1(T_{wgm}-T_{cool})T_0)$ KJ/m^2.cycle ………. (3.8)

Where, 'T_{cool}' is the temperature of the cooling medium washing the wall; 'K_1' is the heat transfer coefficient from the cylinder internal surface to the cooling medium through the cylinder wall. The heat transfer coefficient can be calculated as follows:

$K_1 = \{1/[(\delta/\lambda)+(1/\alpha_{cool})]\}$ KJ/m^2.hr.^{0}C ……….. (3.9)

Where, δ = thickness of the cylinder wall in meters

λ = coefficient of heat conductivity of the wall

α_{cool}= heat transfer coefficient from the wall to the cooling medium

$\alpha_{gm}(T_{gm}-T_{wgm}) = K_1(T_{wgm}-T_{cool})$ ………. (3.10)

Formula for calculating the average temperature of cylinder wall on the inner side is,

$T_{wgm} = \{[(\alpha_{gm}.\ T_{gm}) + (K_1.\ T_{cool})] / (\alpha_{gm}+ K_1)\}$ K ………. (3.11)

The temperature of the cylinder wall on the cooled side ($T_{w.cool.m}$) can be found using the following expression for the mean specific thermal load of a cylinder wall during a cycle,

$Q_m = [Q_{cycle}/T_0] = \lambda\{(T_{wgm}- T_{w.cool.m})/ \delta\}$ KJ/m^2.hr ………. (3.12)

Hence, $T_{w.cool.m} = T_{wgm} - Q_m.(\delta/\lambda)$ ………. (3.13)

And $\Delta t_w = (T_{wgm}- T_{w.cool.m}) = Q_m . (\delta/\lambda)$ ………. (3.14)

3.5.3 Forms of heat transfer in an engine

In the complicated process of heat transfer from one body to another three forms of transfer are distinguished viz. heat conduction, convection and radiation.

All the three forms of heat transfer are encountered in an engine cylinder. Heat is dissipated from the working gases to the walls of the cylinder by radiation and physical contact and thorough the cylinder walls by conduction.

From the outer surfaces of the cylinder liner and the cylinder head heat is transferred to the cooling water and from the outer surface of the piston crown to the cooling oil by physical contact whereas in the case of air cooling of these parts by contact and radiation.

Heat transfer in the engine exhaust pipe is of the same nature as in an engine cylinder from the gases to the walls by radiation and contact through the pipe wall by conducting from the wall to the water by contact and in the water by forced convection. In oil coolers and circulating water cooling systems heat is transferred by forced convection contact and conduction from the outer walls of the cooler to the air by contact and radiation.

3.5.4 Forced cooling of an engine

The mean temperature of the gases in a cylinder during a working cycle under full load varies from 500 to 800 ^{0}C. At such a temperature of the gases natural rejection of the heat from the cylinders would not sufficient or dependable engine performance, since in this case the lubricating oil would burn up quickly, the clearances between the friction parts would be taken up, these parts would wear down rapidly and even burning of the piston crowns and valve heads would occur. Thus, to maintain the permissible temperature of the piston crown, their forced cooling had to be introduced. The heat produced by friction of the piston is transferred through the cylinder liner to the cooling water, the heat originated by friction in the bearings is carried away by the lubricating oil which runs down into the crankcase and is then cooled in the oil cooler. The heat transferred by the gases to the exhaust pipe walls is carried away by the cooling water. Such a forced system of cooling the engine enables a relatively low temperature of its working parts to be maintained.

3.5.5 Blowers for air cooling [44]

The blowers generally used to provide the blast of air required for cooling engine cylinders are of the Sirocco type. Such a blower consists of two parts, the casing, whose peripheral surface is of spiral shape and the impeller. The latter is a revolving wheel with numerous curved blades or vanes near its circumference, between the outer portion of a disc provided with a hub, and an annular ring of the same outside diameter as the disc and a radial depth equal to the width of the vanes. When the impeller is being revolved, the vanes cause the air between them to revolve with the disc and the centrifugal force on the air causes it to flow outward into a volute or scroll surrounding the runner. The air enters through the open side of the casing. The volume of air delivered by such a blower varies directly as the speed, but the power absorbed by it varies as the cube of the speed. The Franklin automobile engine, which as stated, developed 87 hp at 3100 rpm, carried a 15-in. blower on the forward end of its crankshaft. At 3000 rpm this blower delivered 3920 cu ft of air per min and absorbed 4.20 hp. Air, of course, must be delivered at a sufficient rate so that under the most adverse conditions none of the operating parts of the engine will reach excessive temperatures. What this rate must be depends on details of design and also on the conditions of operation. However, a fair idea of the amount of air required for cooling purposes can be gained from the assumptions that when the engine is operating under full load the air must carry off heat at the rate of about 50 Btu per bhp per min. As air at normal atmospheric pressure and temperature weighs 0.0762 lb and has a specific heat at constant pressure of 0.241, the rate of air flow required to absorb this heat with a temperature rise of 75 F is,

{50 / [75 X 0.0762 X 0.241]}=36.3 cu ft per bhp per min ………. (3.15)

As the air delivery varies in direct proportion to the engine speed while the brake horse power does not vary as rapidly as the speed, the cooling system is put to its most severe test when the engine is operated continuously the speed of maximum torque. For the highest specific output from an air-cooled engine the blower, the ducts, and the cylinder cowling all must be designed for the easiest possible flow. The cooling air is heated to a considerably higher temperature than in a water cooled engine and since the amount of heat to be dissipated per bhp is substantially the same, not nearly as much air needs to be moved. This, of course, has a favorable effect on the fan horse power required.

3.5.6 Heat transfer coefficients

The amount of heat rejected per hour by the gases to the cylinder walls to the cylinder head and piston crown by contact and radiation can be expressed as follows:

$Q_g = Q_r + Q_c = \{[\alpha_r(T_g - T_w) + \alpha_c(T_g - T_w)]A\}$ KJ/hr ………. (3.16)

$Q_g = \{\alpha_g(T_g - T_w).A\}$ KJ/hr ………. (3.17)

Where,

$\alpha_g = \alpha_c + \alpha_r$ = Total heat transfer coefficient from the gases in combustion chamber to the walls by contact and radiation

α_r = Heat transfer Coefficient by radiation

αc = Heat transfer Coefficient by contact

T_g and T_w = Temperature of the gases and of the wall washed by the gases.

On the basis of experiments with a single cylinder air injection Diesel (Nb=50 hp at n=250 rpm) a well know Soviet Scientist, Professor N.R. Briling **[45]** established the following relation between total coefficient 'α_g' and the pressure 'P_g' working gas temperature 'T_g' and mean piston speed of a Diesel engine.

$\alpha_g = (\alpha_c + \alpha_r) = \{0.362[\{(T_g^4/100) - (T_w^4/100)\} / (T_g - T_w)] + 0.99.$Cube root of $(P_g^2.T_g)$.

(1+1.45+0.185 cm)} Kcal/m^2.hr.^{0}C ………. (3.18)

Where (1.45+0.185 cm) is a correlation sum of terms taking into account the increase of heat transfer by contact due to turbulence in the cylinder caused by the atomizing air and injected fuel (1.45) and by movement of engine piston (0.185 cm).

The first term in above formula expresses the coefficient 'α_r' and the second one the coefficient 'α_c'.

According to the experiments and calculations **[45]**, the amount of heat transferred by radiation is considerable less than that transferred by contact and is equal in Diesels to,

$Q_r = 0.176\ (Q_r + Q_c)$ ………. (3.19)

i.e. 17.6 per cent of total Q_g

$Q_c = 0.824\ (Q_r + Q_c)$ ………. (3.20)

i.e. 82.4 per cent of the total Q_g

Therefore, for Diesel engines, it is general practice to consider 'α_g' to be approximately equal to 'α_c'.

3.5.7 Basic principles involved in design of fins

[01] Cooling fins must be placed as close as possible to the critical sources of heat input, including especially exhaust valve sears, exhaust ports, spaces between ports and valves, spark plug bosses and exhaust port bridges of two cycle engines.

[02] No portion of the cylinder head or barrel down as far as the position of the piston rings at bottom center should be unfinned.

[03] Fins should be oriented in the direction of air flow.

[04] Fins should be as deep and as closely spaced as possible considering the material and manufacturing process used. The large air cooled aircraft engines used Aluminium fins on their cylinder heat as deep as 2.5 inch (60mm) and spaced as close as 0.20 inch (5mm) with a thickness of 0.10 inch (2.5mm). However, such finning had to be machined and would be justified only for engines of very high specific output.

[05] For engines of over 127 mm bore, high conductivity fins applied to the cylinder barrels may be necessary. These usually consist either of a finned cast Aluminium jacket or sheet Aluminium rings pressed or rolled on the barrel.

[06] Air flow should be directed at right angles to the cylinder axis with the exhaust side "upwind".

In the past various types of applied finning have been used on cylinder heads. Air flow parallel to the cylinder axis has also been used. Experience has shown these methods to be inferior to finning integral with the cylinder head and to flow in the radial direction.

3.6 Testing procedures in the present investigation

3.6.1 General testing of the engine

First of all it was necessary to calculate the maximum load to be applied to the engine dynamometer accordingly it was calculated. Checked the petrol level in the fuel tank, water supply to the calorimeter and engine oil level. Ensured that the engine is running on no load condition. After starting, initially the engine was kept in running condition for some time.

The loads were applied gradually by using loading arrangement and the engine was run at constant speed. Ensured the water is supplied to the brake drum and the calorimeter too. The engine was loaded in steps.

Then for each load, the observations from both the spring balances, time required for circulation of particular quantity of water supplied to the calorimeter, time required for consumption of particular quantity of fuel, manometer reading, water inlet and outlet temperatures, exhaust gas inlet and outlet temperature from calorimeter, etc. Finally after noting all the observations, unloaded the engine by removing the load gradually. Finally the engine was stopped.

3.6.2 Exhaust emission testing of the engine

The engine was started as per the steps given above. The NETEL make exhaust emission tester was used for this purpose which was from an authorised PUC testing centre. After starting the machine, intake pipe was inserted in the exhaust muffler of the engine under consideration with both the engine cylinder blocks Cast Iron and Aluminium Alloy separately. The observations for different loads were obtained in the form of prints from this machine. The parameters were CO, HC, CO_2, O_2 and NO_x measured in percentage while Hydro Carbons were measured in terms of PPM.

3.6.3 Hardness testing

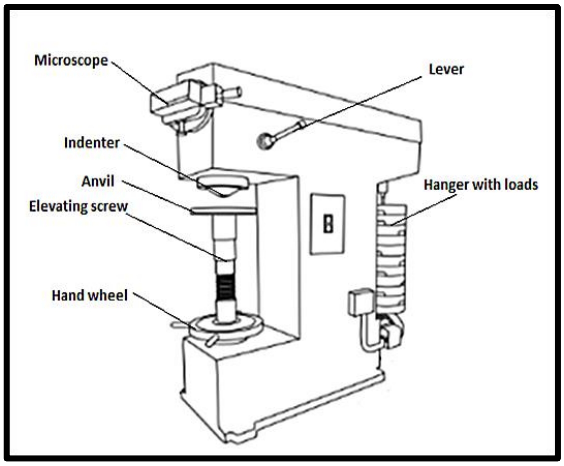


Figure 3.2, Brinell hardness tester

Brinell hardness test method is used to determine Brinell hardness commonly used to test materials that have a structure that is too coarse or that have a surface that is too rough to be tested using another test method e.g. casting and forgings. Brinell testing often use a very high test load 3000 kgf and a 10 mm diameter indenter so that the resulting indentation averages out most surface and sub-surface inconsistencies.

The Brinell method applies a predetermined test load (F) to a carbide ball of fixed diameter (D) which is held for a predetermined time period and then removed. The resulting impression is measured with a specially designed Brinell microscope or optical system across at least two diameters usually at right angles to each other and these results are averaged (d). Although the calculation below can be used to generate the Brinell number, most often a chart is then used to convert the averaged diameter measurement to a Brinell hardness number.

Common test forces range from 500 kgf often used for non-ferrous materials to 3000 kgf usually used for steels and cast iron. There are other Brinell scales with load as low as 1 kgf and 1 mm diameter indenters but these are infrequently used.

Brinell hardness number is given by equation,

$$HB=[(2.F)/(\Pi.D\{D-(D-d)^{1/2}\}]$$

Where,
D=Ball diameter
D=impression diameter
F=Load
HB= Brinell Number

Typically the greatest source of error in Brinnel testing is the measurement of the indentation. Due to disparities in operators making the measurements, the results will vary even under perfect conditions. Less than perfect conditions can cause the variation to increase greatly. Frequently the test surface is prepared with a grinder to remove surface conditions.

3.6.4 3D Scanning

Figure 3.3, 3D scanning of the object

The required steps to get an optimal scan output are generally common to every scan procedure. It is a non-contact, non-destructive technology that digitally captures the shape of physical objects using a line of laser light. 3D laser scanning is way to capture a physical objects exact size and shape into the computer world as a digital 3D representation.

3D laser scanners measure fine details and capture free form shapes to quickly generate highly accurate point clouds. 3D scanning is ideally suited to the measurement and inspection of contoured surfaces and complex geometries which require massive amounts of data for their accurate description and where doing this is impractical with the use of traditional measurement methods or a touch probe.

An object that is to be scanned is placed on the bed of the digitizer. Specialized software drives the laser probe above the surface of the object. The laser probe projects a line of laser light onto the surface while 2 sensor cameras continuously record the changing distance and shape of the laser line in three dimensions (XYZ) as it sweeps along the object.

The shape of the object appears as millions of points called a “Point cloud” on the computer monitor as the laser moves around capturing the entire surface shape of the object. The process is very fast, gathering up to 7, 50,000 points per second and very precise (to ±0.0005”).

After the huge point cloud data files are created, they are registered and merged into one three-dimensional representation of the object and post-processed with various software packages suitable for a specific application.

3.7 Chapter summery

The hot gases of combustion are the products of combustion of fuels. These gases give the heat to the walls of engine cylinder. So, this excessive heat is dissipated to the atmosphere with the help of an effective cooling system. This heat is transferred by different forms like conduction, convection and radiation thorough the fins which are provided on cylinder block as well as cylinder head. Generally, forced cooling method is employed for enclosed engines like in scooters whereas the engine cylinders of motorcycles are directly exposed to the surrounding and cooling of such engines takes place by natural convection when the bike will be on stand and by forced convection when the bike will be in motion. The cooling phenomenon are discussed in this chapter.

Chapter 4

MARKET SURVEY

4.1 Introduction

As it was decided to undertake the research work of "Experimental investigation of Aluminium Alloy engine cylinder block in two wheelers", it was necessary to conduct a thorough market survey in order to know the present scenario of the cylinder blocks used in different models of different auto makers as far as the scope of the present research work is concerned. Hence, researcher has visited different show rooms and their service centres. Accordingly, by consulting with the incharges of different service centres, the data regarding different models manufactured & available for sale, their displacements and type of engine cylinder blocks was collected and presented in tabular form. It was helpful to fulfill the scope of the present work. In all, twelve manufactures were identified and by confirming material and construction of the block of the dismantled engines, data was collected and given in section 4.2.

4.2 Market Survey conducted to identify the types of engine cylinders: Present Scenario [25]

The market survey was conducted by visiting the authorized service centers in and around Kolhapur City. The results are given below.

Figure 4.1, Photography of the motorcycle selected for the research work "*Splendor+*"

4.2.1 BAJAJ AUTO LIMITED: (www.bajajauto.com)

Table 4.1, BAJAJ AUTO LIMITED

Sr. No.	Model	Engine Capacity (CC)	C.I. Engine Block	C.I. Sleeve With Aluminium Fins	All Aluminium Engine Cylinder
1	CT 100B/100/ALLOY	99.27	√	----	----
2	PLATINA 100 /ES	102.00	----	√	----
3	DISCOVER 125	124.60	----	√	----
4	DISCOVER 150 S/F	144.80	----	√	----
5	V15	149.50	----	√	----
6	PULSOR LS135 DTS-i	134.66	----	√	----
7	PULSOR 150 DTS-i	149.01	----	√	----
8	PULSOR 180 DTS-i	176.80	----	√	----
9	PULSOR 220 DTS-i	219.90	----	√	----
10	PULSOR NS 200	199.50	----	√	----
11	PULSOR AS 150	149.50	----	√	----
12	PULSOR AS 200	199.50	----	√	----
13	PULSOR RS 200	199.50	----	√	----
14	PULSOR RS 200 ABS	199.50	----	√	----
15	AVENGER 150	149.01	----	√	----
16	AVENGER 220	219.90	----	√	----
17	AVENGER220 CRUISE	219.90	----	√	----

√ - Indicates the type of Engine cylinder to which the corresponding model belongs.

In the two wheelers manufactured by **BAJAJ AUTO LIMITED**, only one motorcycle engine belongs to Cast Iron engine cylinder whereas remaining sixteen models has engine blocks with Cast Iron Sleeve. There is no any engine which has All Aluminium Engine Cylinder Block.

4.2.2 DSK HYOSUNG: (www.dskhyosung.com)

Table 4.2, DSK HYOSUNG

Sr. No.	Model	Engine Capacity (CC)	C.I. Engine Block	C.I. Sleeve With Aluminium Fins	All Aluminium Engine Cylinder
1	GT 250R	249.00	----	√	----
2	GT 650R	647.00	----	√	----
3	GV250 AQUILA	249.00	----	√	----
4	GV650 AQUILA PRO	647.00	----	√	----
5	ST7	678.20	----	√	----

√ - Indicates the type of Engine cylinder to which the corresponding model belongs.

There are five heavy motorcycles in production of DSK HYOSUNG. They are GT250R, GT650R, GV250 AQUILA, GV650 AQUILA PRO and ST7. In the two wheelers manufactured by **DSK HYOSUNG**, a Korea based manufacturer, all motorcycle's engines belongs to Cast Iron Sleeve type. There is no any engine which has Cast Iron Engine Block or even All Aluminium Engine Cylinder Block.

4.2.3 HERO MOTOCORP: (www.heromotocorp.com)

Table 4.3, HERO MOTOCORP

Sr. No.	Model	Engine Capacity (CC)	C.I. Engine Block	C.I. Sleeve With Aluminium Fins	All Aluminium Engine Cylinder
1	HF DAWN/DELUXE/ECO	97.20	√	----	----
2	SPLENDOR+/PRO/CLASSIC/i Smart	97.20	√	----	----
3	PASSION PRO/ES/X PRO	97.20	√	----	----
4	SUPER SPLENDOR	124.70	----	√	----
5	GLAMOUR NORMAL/FI	124.70	----	√	----
6	IGNITER	124.70	----	√	----
7	ACHIEVER	149.01	----	√	----
8	HUNK (F/R DISC)	149.20	----	√	----
9	XTREME/SPORTS 149.2 CC	149.20	----	√	----
10	PLEASURE	102.00	√	----	----
11	MAESTRO EDGE LX/VX	110.90	√	----	----
12	DUET	110.90	√	----	----

√ - Indicates the type of Engine cylinder to which the corresponding model belongs.

HERO MOTOCORP (FORMER HERO HONDA) is the largest manufacturer of two wheelers in India and in world too. They are exporting their bikes to the some Asian, African and American countries like Bangladesh, Nepal, Srilanka, Africa, Columbia, Peru, Equador, some countries from Central America, Keniya, Mozambik, Burkinia, countries from West Africa, Ethiopia in North Africa, Brazil, Nigeria, Ghana, Liberia, Guinea, Madagaskar etc. There is future planning to sale the bike among 50 countries by the end of 2020. Their famous largest selling Splendor range two wheelers are still using old design Cast Iron engine blocks except super splendor. All scooter engines belongs to the same category. But the bikes from premium sector like igniter, hunk, achiever, xtreme, impulse are using the Cast Iron sleeve engine cylinders. As the Sale is at top and the bikes are exported to the countries mentioned above, there is wide scope for the improvement in the cylinder block design of the engines of hero vehicles.

4.2.4 HONDA 2 WHEELERS INDIA :(www.honda2wheelersindia.com)

Table 4.4, HONDA 2 WHEELERS INDIA

Sr. No.	Model	Engine Capacity (CC)	C.I. Engine Block	C.I. Sleeve With Aluminium Fins	All Aluminium Engine Cylinder
1	NAVI	109.00	√	----	----
2	CD110 DREAM	109.20	√	----	----
3	DREAM NEO	109.20	√	----	----
4	DREAM YUGA	109.20	√	----	----
5	LIVO	109.20	√	----	----
6	CB SHINE/SP/CBS	124.70	----	√	----
7	CB UNICORN	149.10	----	√	----
8	CBUNICORN 160/CBS	162.70	----	√	----
9	CBHORNET160 R/CBS	162.70	----	√	----
10	CBR150R	149.40	----	√	----
11	CBR250R/ABS	249.60	----	√	----
12	ACTIVA-i	109.00	√	----	----
13	ACTIVA-3G	109.00	√	----	----
14	ACTIVA125/DELUXE	125.00	√	----	----
15	DIO	109.00	√	----	----
16	AVIATOR/DISC	109.00	√	----	----

√ - Indicates the type of Engine cylinder to which the corresponding model belongs.

In the two wheelers manufactured by **HONDA**, a Japan based manufacturer, all motorcycle’s engines in 125 CC to 250 CC capacity belongs to Cast Iron Sleeve. There is no any engine which has All Aluminium Engine Cylinder Block. All Scooters and motorcycles in range 110 CC capacity are fitted with Cast Iron cylinder blocks engines.

4.2.5 KAWASAKI-INDIA : (www.kawasakji-india.com)

Table 4.5, KAWASAKI-INDIA

Sr. No .	Model	Engine Capacity (CC)	C.I. Engine Block	C.I. Sleeve With Aluminium Fins	All Aluminium Engine Cylinder
1	Z250	249.00	----	----	√
2	NINJA 300	296.00	----	----	√

√ - Indicates the type of Engine cylinder to which the corresponding model belongs.

In the two wheelers manufactured by **KAWASAKI**, a Japan based manufacturer, all motorcycle's engines belongs to All Aluminium Engine Cylinder. There is no any engine here which has Cast Iron Engine Block or even C.I. sleeve with Aluminium fins.

4.2.6 KTM-INDIA : (www.ktm.com/in)

Table 4.6, KTM-INDIA

Sr. No.	Model	Engine Capacity (CC)	C.I. Engine Block	C.I. Sleeve With Aluminium Fins	All Aluminium Engine Cylinder
1	200 DUKE	199.50	----	----	√
2	390 DUKE	373.20	----	----	√
3	RC200	199.50	----	----	√
4	RC390	373.20	----	----	√

√ - Indicates the type of Engine cylinder to which the corresponding model belongs.

In the two wheelers manufactured by **KTM**, a Austria based manufacturer, all motorcycle's engines belongs to All Aluminium Engine Cylinder. There is no any engine here which has Cast Iron Engine Block or even C.I. sleeve with Aluminium fins.

4.2.7 MAHINDRA 2 WHEELERS: (www.mahindra2wheelers.com)

Table 4.7, MAHINDRA 2 WHEELERS

Sr. No.	Model	Engine Capacity (CC)	C.I. Engine Block	C.I. Sleeve With Aluminium Fins	All Aluminium Engine Cylinder
1	CENTURO ROCKSTAR	106.70	√	----	----
2	CENTURO DISC BRAKE	106.70	√	----	----
3	GUSTO DX	109.60	----	√	----
4	GUSTO VX	109.60	----	√	----
5	GUSTO 125 DX	124.60	----	√	----
6	GUSTO 125 VX	124.60	----	√	----
7	RODEO UZO	124.60	√	----	----

√ - Indicates the type of Engine cylinder to which the corresponding model belongs.

In the two wheelers manufactured by **MAHINDRA 2 WHEELERS** (former Kinetic India Limited), India based manufacturer, all motorcycle’s engines belongs to Cast Iron Sleeve. There is no any engine which has All Aluminium Engine Cylinder Block. All Scooter engines are fitted with Cast Iron Sleeve engines except Rodeo Uzo.

4.2.8 ROYAL ENFIELD: (www.royalenfield.com)

Table 4.8, ROYAL ENFIELD

Sr. No.	Model (All With Unit Construction Engine) [UCE]	Engine Capacity (CC)	C.I. Engine Block	C.I. Sleeve With Aluminium Fins	All Aluminium Engine Cylinder
1	BULLET 350	346.00	----	√	----
2	BULLET ELECTRA	346.00	----	√	----
3	BULLET 500	499.00	----	√	----
4	CLASSIC 350	346.00	----	√	----
5	CLASSIC 500	499.00	----	√	----
6	CLASSIC DESERT STORM	499.00	----	√	----
7	CLASSIC CHROME	499.00	----	√	----
8	THUNDERBIRD 350	346.00	----	√	----
9	THUNDERBIRD 500	499.00	----	√	----
10	HIMALAYAN	411.00	----	√	----
11	CONTINENTAL GT	535.00	----	√	----

√ - Indicates the type of Engine cylinder to which the corresponding model belongs.

ROYAL ENFIELD is a United Kingdom (UK) based manufacturer started the production in India in collaboration with Eicher Motors Limited in Tamilnadu. In the two wheelers manufactured by this bike maker, all the engines are of ‘Unit Construction Engine’ i.e. recently developed by them and known as ‘UCE’. All of them are using the Cast Iron sleeve as the cylinder along with Aluminium alloy fins as a part of the cooling system. Engine capacities are ranging from 350 to 535 CC, the heaviest engines and bikes too as far as Indian scenario is concerned.

4.2.9 SUZUKI-INDIA: (www.suzukimotorcycle.co.in)

Table 4.9, SUZUKI-INDIA

Sr. No.	Model	Engine Capacity (CC)	C.I. Engine Block	C.I. Sleeve With Aluminium Fins	All Aluminium Engine Cylinder
1	HAYATE EP	113.00	----	√	----
2	SLINGSHOT PLUS	124.00	----	√	----
3	GS150R	149.60	----	√	----
4	GIXXER/SF/FI MOTOGP	155.00	----	√	----
5	LET'S	112.80	----	√	----
6	SWISH 125	124.00	----	√	----
7	ACCESS 125	124.00	----	√	----

√ - Indicates the type of Engine cylinder to which the corresponding model belongs.

As far as the products of **SUZUKI INDIA** are concerned, there are in all four motorcycles and three scooters. The two wheelers manufactured by Suzuki, a Japan based manufacturer, all motorcycles and scooter engines belongs to Cast Iron Sleeve type. There is no any engine here which has Cast Iron Engine Block or even All Aluminium Engine Cylinder Block.

4.2.10 TVS MOTORS LIMITED: (www.tvsmotor.co.in)

Table 4.10, TVS MOTORS LIMITED

Sr. No.	Model	Engine Capacity (CC)	C.I. Engine Block	C.I. Sleeve With Aluminium Fins	All Aluminium Engine Cylinder
1	SPORT	99.70	√	----	----
2	STAR CITY+	109.70	√	----	----
3	VICTOR (DISC)	109.70	----	√	----
4	PHOENIX (DISC)	124.50	----	√	----
5	APACHE RTR160	159.70	----	√	----
6	APACHE RTR180/ABS	177.40	----	√	----
7	APACHERTR200 4V CARB	197.70	----	√	----
8	APACHE RTR200 4V FI	197.70	----	√	----
9	SCOOTY PEP+	87.80	√	----	----
10	SCOOTY ZEST 110	109.70	----	√	----
11	WEGO	109.70	----	√	----
12	JUPITOR/ZX	109.70	----	√	----
13	SUZUKI FIERO	149.60	----	√	----

√ - Indicates the type of Engine cylinder to which the corresponding model belongs.

In the two wheelers manufactured by **TVS MOTORS LIMITED**, a India based manufacturer in collaboration in earlier years with Suzuki, for some motorcycles like Fiero, India's first four stroke motorcycle got many awards like 'Motorcycle of the year 2000', was launched with C.I. sleeve design engine cylinder while in the present models except sport, Star City and Scooty Pep +, the same design is continued by this manufacturer. There is no any engine here which has All Aluminium Engine Cylinder Block.

4.2.11 YAMAHA-MOTOR INDIA: (www.yamaha-motor-india.com)

Table 4.11, YAMAHA-MOTOR INDIA

Sr. No.	Model	Engine Capacity (CC)	C.I. Engine Block	C.I. Sleeve With Aluminium Fins	All Aluminium Engine Cylinder
1	CRUX	105.60	√	----	----
2	SALUTO RX	110.00	----	√	----
3	SALUTO125/DISC	125.00	----	√	----
4	SZ RR 2.0	149.00	----	√	----
5	FZ-16	153.00	----	√	----
6	FZ-S	153.00	----	√	----
7	FZ-16 2.0 FI	149.00	----	√	----
8	FZ-S 2.0 FI	149.00	----	√	----
9	FAZER	153.00	----	√	----
10	FAZER 2.0 FI	149.00	----	√	----
11	YZF-R15 S	149.80	----	----	√
12	YZF-R15 2.0	149.80	----	----	√
13	RAY Z/DISC	113.00	√	----	----
14	RAY ZR/DISC	113.00	√	----	----
15	CYGNUS ALPHA	113.00	√	----	----
16	FASCINO	113.00	√	----	----

√ - Indicates the type of Engine cylinder to which the corresponding model belongs.

In the two wheelers manufactured by **YAMAHA-MOTOR-INDIA**, a Japan based manufacturer, only one motorcycle and all scooter engines belongs to Cast Iron Sleeve. There are nine models in which engine cylinders are fitted with Cast Iron sleeve. Only the manufacturer who has implemented the All Aluminium Engine Cylinder Technology in their famous models YZF-R15 S and YZF-R15 version 2.0.

4.2.12 VESPA-INDIA: (www.vespaindia.com)

Table 4.12, VESPA-INDIA

Sr. No.	Model	Engine Capacity (CC)	C.I. Engine Block	C.I. Sleeve With Aluminium Fins	All Aluminium Engine Cylinder
1	VXL 125	125.00	----	----	√
2	SXL 125	125.00	----	----	√
3	VXL 150	150.00	----	----	√
4	SXL 150	150.00	----	----	√

√ - Indicates the type of Engine cylinder to which the corresponding model belongs.

VESPA, Italian manufacturer, manufacturing only scooters all Scooter engines belongs to Cast Iron Sleeve. There is no any engine here which has Cast Iron Engine Block or even All Aluminium Engine Cylinder Block.

4.3 Results and Discussion from the Market Survey

From the Market Survey data given above in section 4.2, the results can be summarized as below.

Table 4.13, Results from the Market Survey

Sr. No.	Manufacturer	Total Models	CI Blocks	CI Sleeve	All Aluminium Cylinder
01	Bajaj Auto Limited	17	01	16	----
02	DSK Hyosung	05	----	05	----
03	Hero Moto Corp	12	06	06	----
04	Honda	16	10	06	----
05	Kawasaki	02	----	----	02
06	KTM	04	----	----	04
07	Mahindra 2 wheelers	07	03	04	----
08	Royal Enfield	11	----	11	----
09	Suzuki	07	----	07	----
10	TVS	13	03	10	----
11	Yamaha	16	05	09	02
12	Vespa	04	----	----	04
	Total	114	28	74	12
	% age	100	24.56	64.91	10.50

Out of total 114 models under consideration launched in India, 24.56 % models belongs to total Cast Iron cylinder block technology whereas 64.91 % belongs to Cast Iron sleeve technology and only 10.50 % are in favor of All Aluminium blocks.

1 From the above study, it is clear that still 24.56 % models are using Cast Iron engine blocks at present, 64.91 % are using the blocks with Cast Iron sleeve technology while only 10.50 % are using all Aluminium cylinder blocks. It seems that sleeve technology is very widely used as far as present scenario is concerned. One thing to mention over here is that remaining 10.50 % models which are working by using Aluminium cylinder blocks are coming under premium segment (Higher CC & liquid cooled). So this technology can be introduced in small capacity (<100 CC) engines. Hence, there is wide scope to adopt new technology to replace CI block and sleeve technology.

2 As a part of the present research work, the largest selling model in India and manufactured by largest manufacturer of two wheelers in the world, ***'splendor+'*** was selected which is using Cast Iron Engine Block.

3 For the model which was selected, the old block of Cast Iron was obtained and by using solid modelling technique, the patterns were prepared. From the patterns, the Aluminium alloy casting was prepared and machined afterwards. So that it was ready to fit on the engine body. The steps required for manufacturing of the new block are given in chapter 5 of this thesis. The composition of the Aluminium alloy (LM25) is as per given in the table.

4 The experimental set-up required to conduct the test was also developed and given in detail in the chapter 5 of this report.

4.4 Further steps in completion of the Research Work

4.4.1 Preparation of mould and pouring,

4.4.2 Machining and finishing of Casting,

4.4.3 Development of the experimental setup,

4.4.4 Laboratory (Indoor) Testing of the engine with C.I. block,

4.4.5 Laboratory (Indoor) Testing of the engine with newly developed All Aluminium cylinder block,

4.4.6 Comparison of the results,

4.4.7 Conclusions from the analysis of the results.

4.5 Chapter summery

The market survey required to identify actual need of the present technology was essential. That was conducted by identifying various major manufacturers and the details are given in section 4.2 of the present chapter. Results are discussed in the later part of the chapter. Chapter ends with further steps in completion of the Research Work which is given in section 4.4 of this chapter.

Chapter 5

ENGINE CYLINDER BLOCK MANUFACTURING AND CFD ANALYSIS

5.1 Introduction

After conducting the market survey, it was decided to undertake the research work to manufacture the Aluminium Alloy engine cylinder block for the motorcycle engine and started the work. As the aim was to replace the old heavy Cast Iron engine cylinder block with light weight and thermally efficient material, the material was selected as LM25. After selection of suitable material of the block, it was necessary to manufacture the block. So, the patterns were prepared which is discussed in section 5.2 of this chapter. After preparation of patterns, the casting was produced by using LM25 as the material of the block. Then the casting was machined and heat treated. So, that it was ready to fit on engine. Then its CFD analysis was done which is given in the later part of this chapter.

5.2 Manufacturing of Pattern, Cores

To determine the dimensions of an engine cylinder block it was necessary to do the 3D scanning of existing cylinder block. After the 3D scanning, the wire drawing of the cylinder block was available. Then the modelling was done in the software NX7. Following are the images of model and patterns.

NX7 Software

NX7 is the software which is used worldwide to analyse the problems based on CAD/CAM/CAE product development solutions. Complex products can be simplified with ease.

The NX7 software is a useful tool with the integration of knowledge based principles, geometric modelling, industry designs, simulation in graphics, etc. features. Any complex shape like airfoils and manifolds can be designed. NX7 is the powerful tool that merges solid and surface modelling techniques.

Design of patterns and core boxes required for manufacturing

(A) Central core box

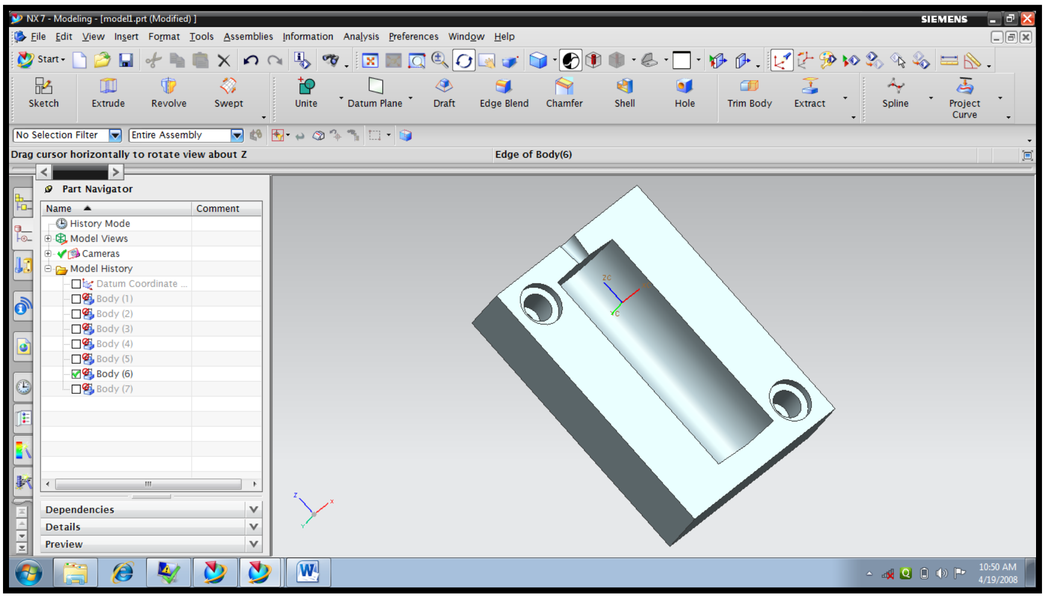


Figure 5.1, Central core box 'A'

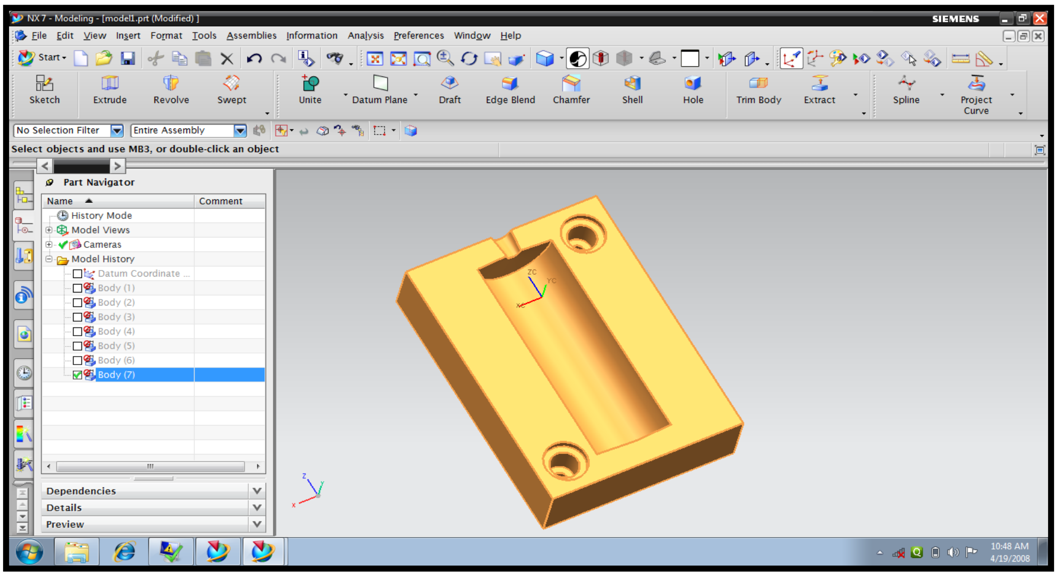


Figure 5.2, Central core box 'B'

The central core boxes were required to produce main central core which provides the main central hole to accommodate the piston. It was produced in two parts as shown in the figures 5.1 and 5.2 i.e. part 'A' and part 'B'. Later they assembled together with the help of dowels as shown in the above figures.

Assembly of central core box

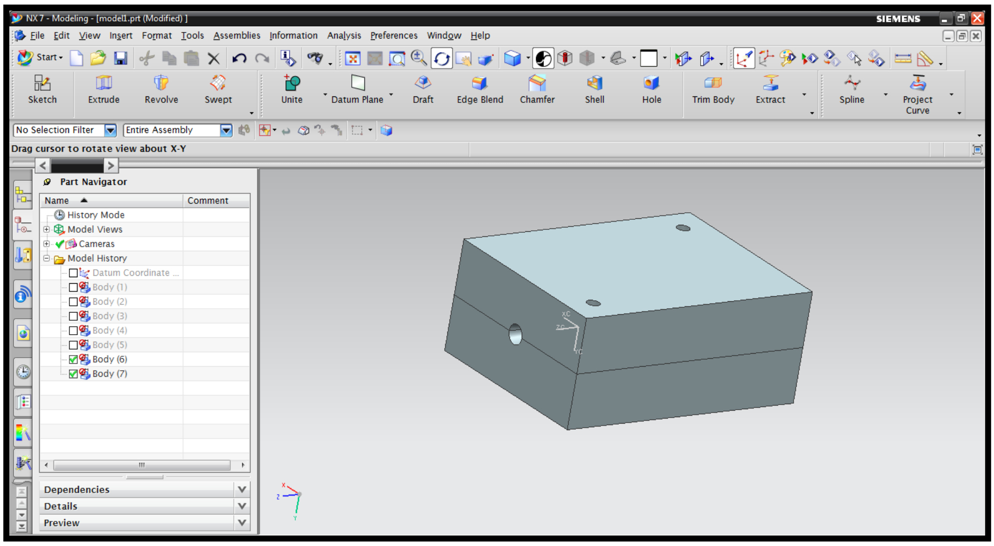


Figure 5.3, Assembly of central core box

The assembly of the central core box was as shown in figure 5.3 with the help of which the central main core can be produced.

(B) Pattern 1

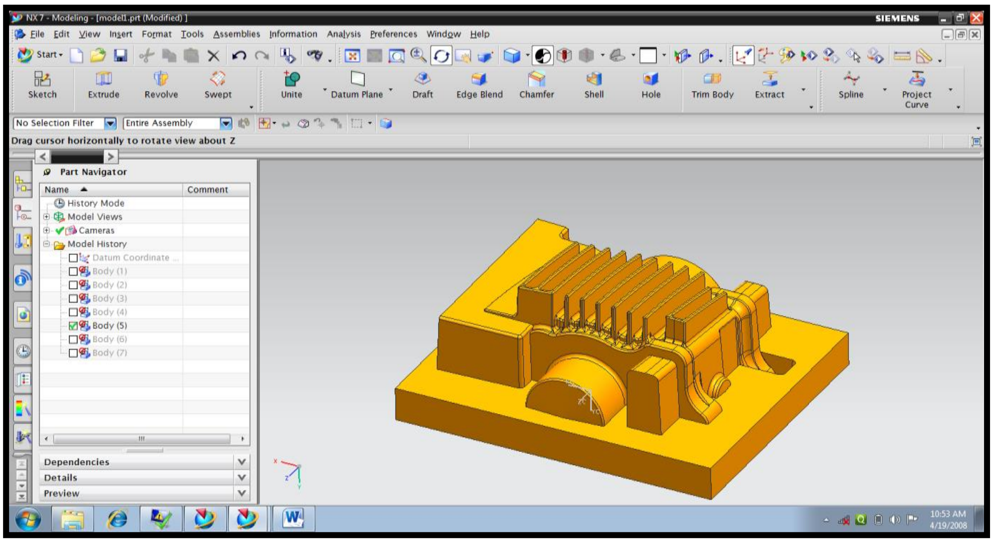


Figure 5.4, Pattern 1

Pattern 1 forms the side of the cylinder block. It provides the impression for the fins on the cylinder block and is as shown in figure 5.4.

(C) Pattern 2

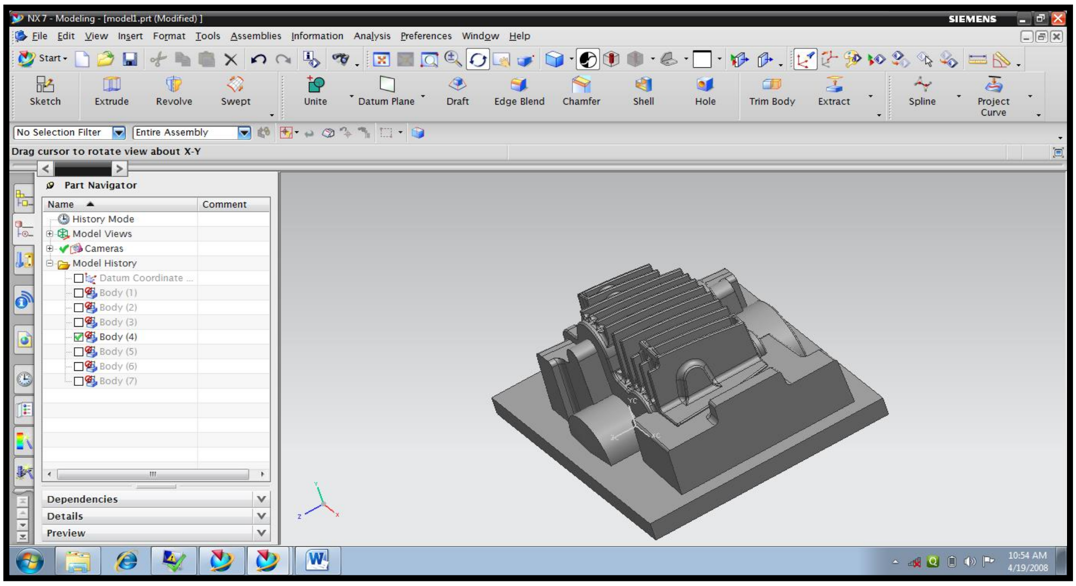


Figure 5.5, Pattern 2

Figure 5.5 shows the Pattern 2 which forms the side of the cylinder block. It provides the impression for the fins on the cylinder block.

Assembly of patterns

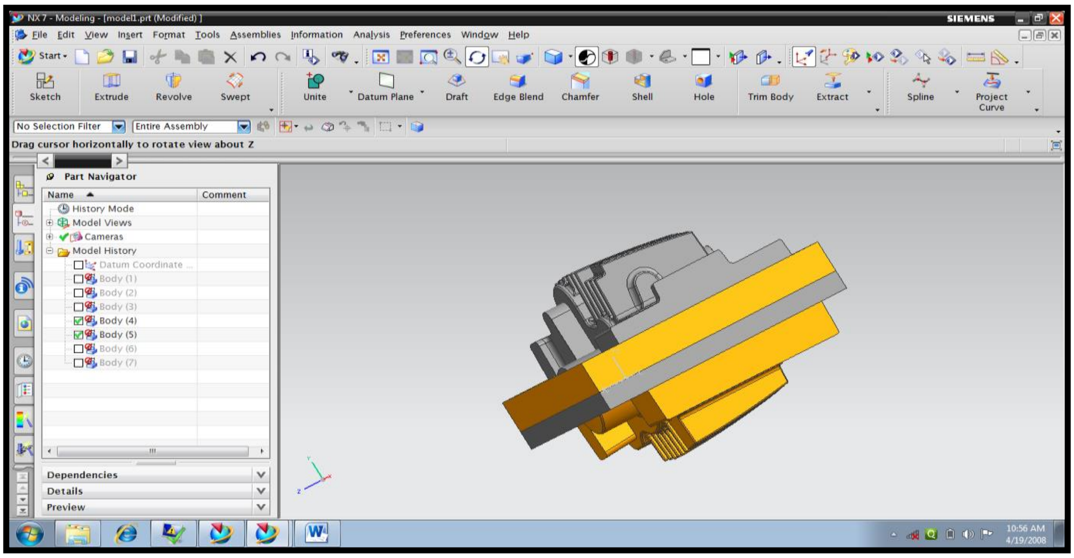


Figure 5.6, Assembly of patterns

Pattern 1 and 2 are assembled together to form the assembly of the patterns as shown in figure 5.6.

(D) Side core box 1

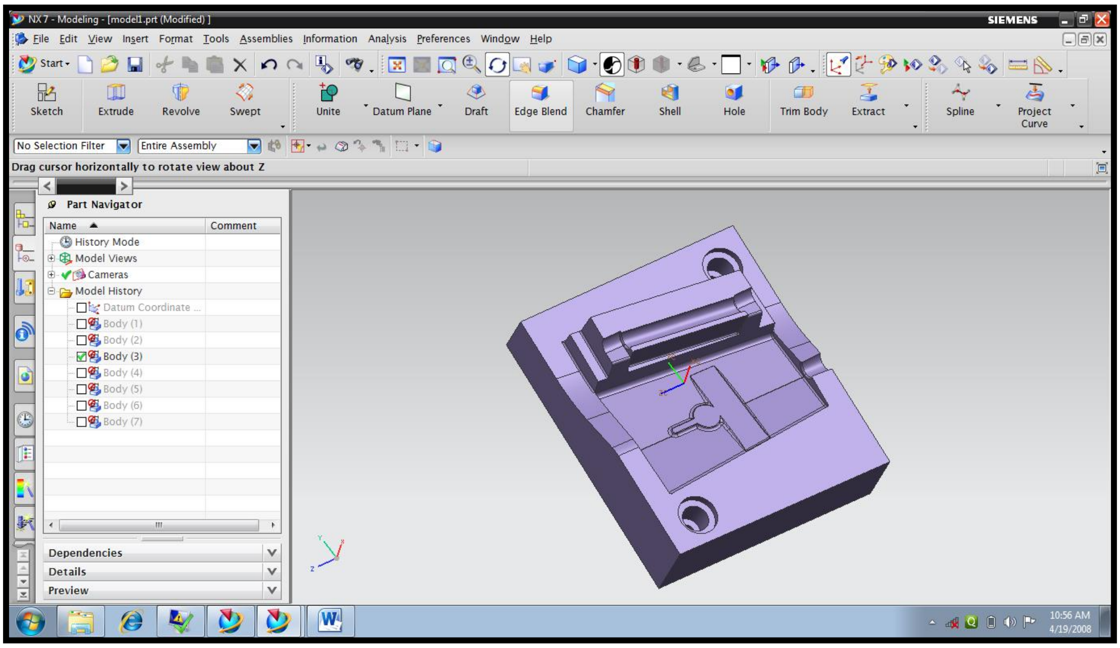


Figure 5.7, Side Core Box 1

Side core box 2

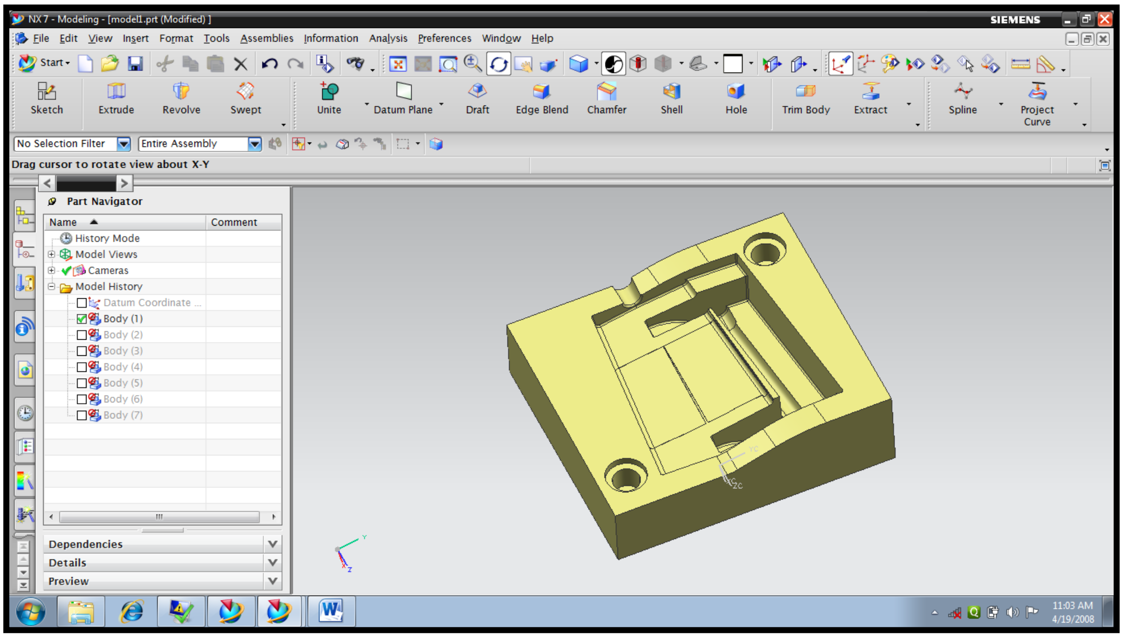


Figure 5.8, Side Core Box 2

Figure 5.7 and 5.8 illustrates side core boxes which are the part of the assembly of all the patterns which will provide the cores for sides of the block.

Assembly of side core boxes

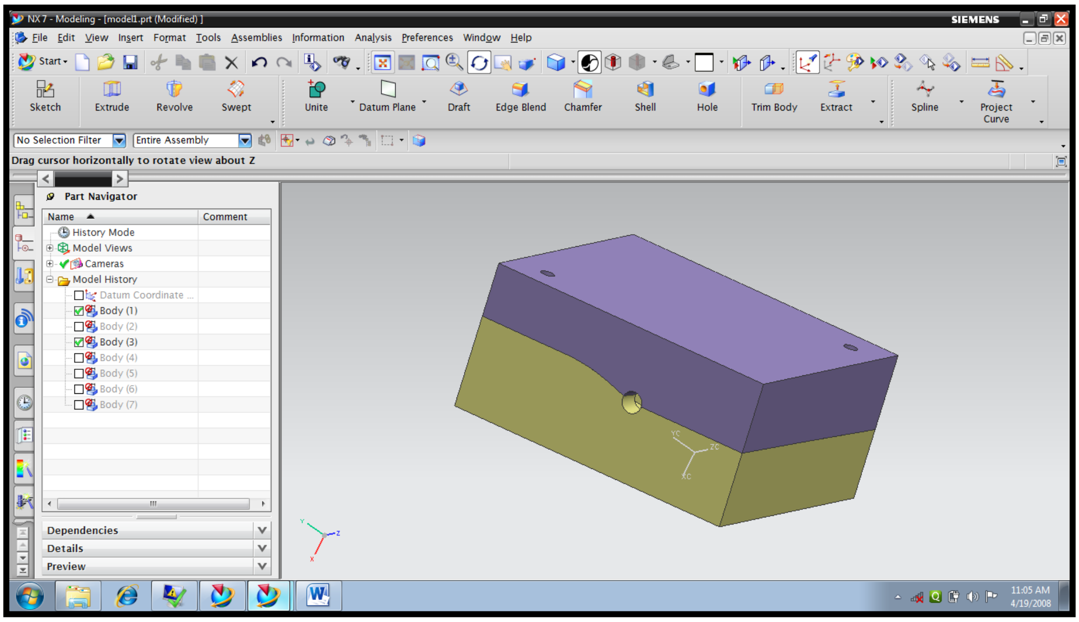


Figure 5.9, Assembly of Side Core Boxes

(E) Side core box 3

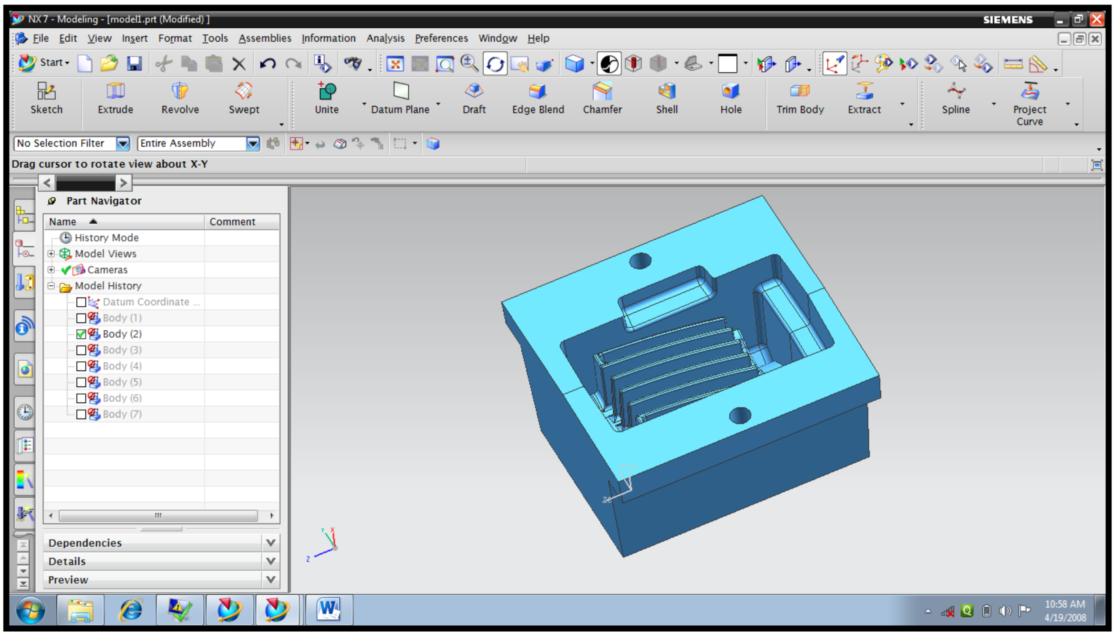


Figure 5.10, Side core box 3

Figure 5.10 shows the side core box was separately produced which will provide the core for the other side of the engine cylinder block.

(F) Assembly of all patterns and core boxes

By following the guidelines decided earlier, the patterns required to cast the cylinder block were prepared which are shown in the following photographs. After getting the designs of patterns and core boxes, next step was to manufacture the patterns. The production of patterns was done at M/s A.P. INDUSTRIES, SHIROLI MIDC, Kolhapur. The patterns and core boxes were made by using wood as material. The machining of patterns was done on CNC machines which were provided at their workshop.

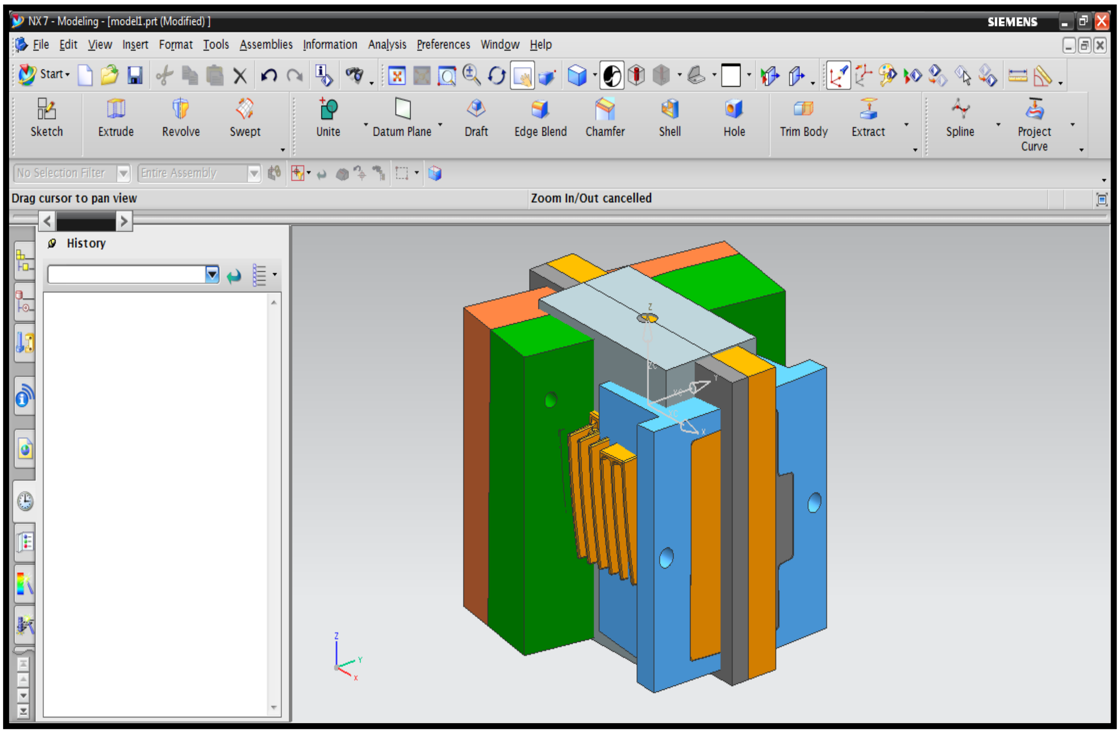


Figure 5.11, Assembly of all patterns and core boxes

Figure 5.11 shows the Assembly of all patterns and core boxes and in ready to use form.

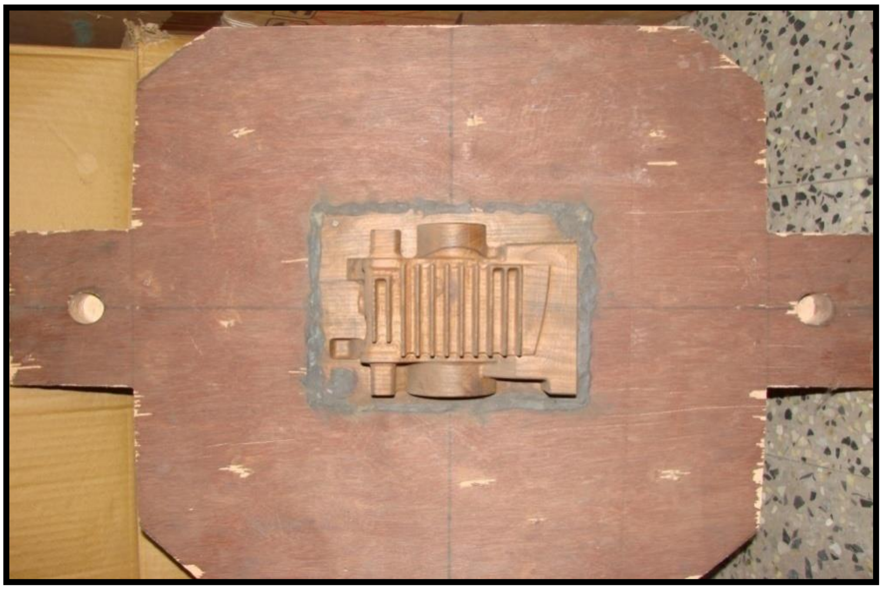


Figure 5.12, Photography of pattern 2

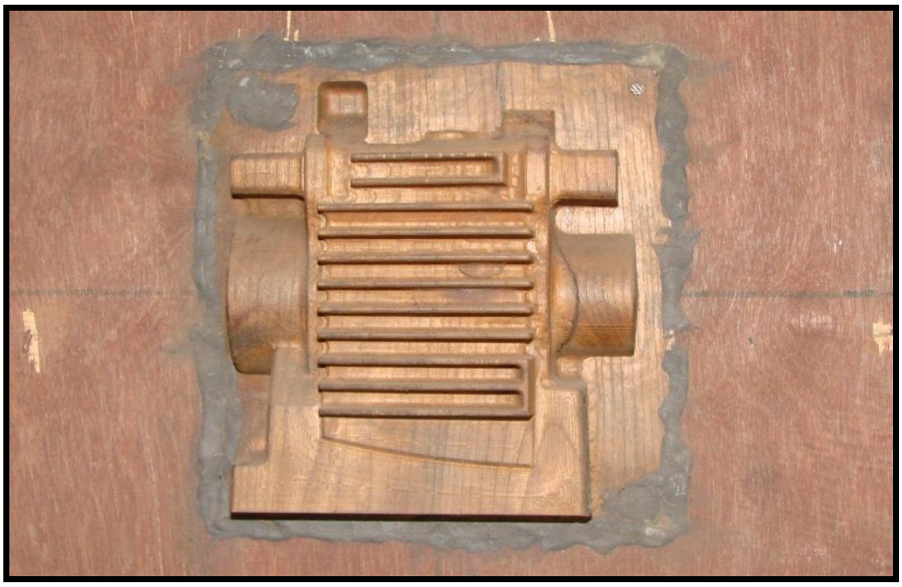


Figure 5.13, Photography of pattern 2, top view

This is the pattern 2 shown in figures 5.12 and 5.13 ready to use in the moulding box. The pattern 2 was made of wood and was as shown in figure and was fitted on the wooden plank.

Figure 5.14, Photography of pattern 1

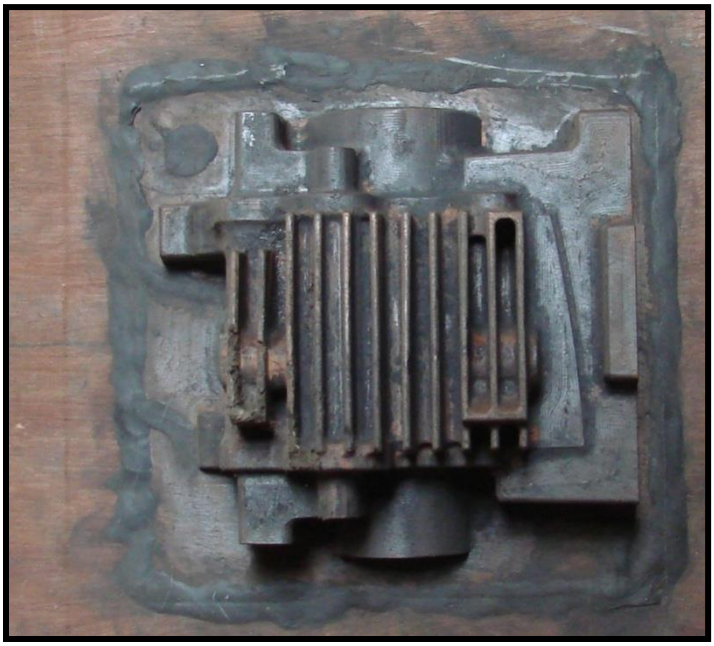


Figure 5.15, Photography of pattern 1, top view

This is the pattern 1 in figures 5.14 and 5.15 is ready to use in the moulding box. The pattern 1 is made of wood and is as shown and was fitted on the wooden plank.

Figure 5.16, Photography of side core boxes

Figure 5.17, Photography of central core boxes ‘A’ & ‘B’

These are the patterns for side and central core boxes ready to use in the moulding box. The side core boxes and central core boxes ‘A’ and ‘B’ were made up of wood and are as shown in figures 5.16 and 5.17.

Figure 5.18, Photography of cores

The actual side and central cores which were produced in foundry are shown in this figure 5.18. They were used in moulding box.

5.3 Comparison of properties of Grey Cast Iron and LM25 Aluminium Alloy:

From the collected literature, it was understood that LM25 (TF) is the material very commonly used as the material to manufacture the cylinder blocks. Hence, it was selected and the properties comparison of both the materials i.e. Grey Cast Iron and LM25 (TF) are summarized below in tabular form:

Table 5.1, Comparison of properties of Grey Cast Iron and Aluminium Alloy

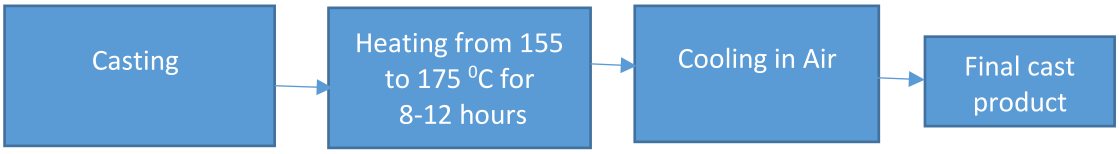
SR. NO.	PROPERTY	GREY CAST IRON	LM25 (TF)*
1	BRINELL HARDNESS	160-300	90-110
2	COMPRESSIVE STRENGTH (MPa) (CRUSHING)	570-1290 (83-190X10^3 psi)	566.60
3	DENSITY (Kg/$m^{3)}$	7,200	2,670
4	ELASTIC MODULUS (GPa) (YOUNG'S, TENSILE)	82-140 (12-20X10^6 psi)	71
5	ELONGATION AT BREAK (%)	0.51	5
6	FATIGUE STRENGTH (ENDURANCE LIMIT) (MPa)	69-170 (10-25X10^3 psi)	60 (5X10^8CYCLES±N/mm^2)
7	FRACTURE TOUGHNESS (MPa-$m^{½}$)	10-20	14-28
8	MELTING ONSET (SOLIDUS) (^{0}C)	1180	615
9	MODULUS OF RESILIENCE (KJ/m^3) (UNIT RESILIENCE)	59-480	41-230
10	POISSON'S RATIO	0.26	0.33
11	SHEAR STRENGTH (MPa)	180-610 (26-88X10^3 psi)	180
12	STRENGTH TO WEIGHT RATIO (KN.m/Kg)	21-63	41-85
13	TENSILE STRENGTH (ULTIMATE) (UTS) (MPa)	150-450 (22-65X10^3 psi)	230-280
14	TENSILE STRENGTH (MPa) (YIELD)(PROOF)	98-280 (14-41X10^3 psi)	200-250 (0.2 % PROOF STRESS)
15	THERMAL CONDUCTIVITY (W/m.K)	46	237
16	THERMAL EXPANSION (µm/m.K)	11	22
17	UNIT RUPTURE WORK (ULTIMATE RESILIENCE)	0.68-1.0 MJ/m^3	0.000022 (PER ^{0}C AT 20-100 ^{0}C)
18	ELECTRICAL CONDUCTIVITY (% COPPER STD AT 20^{0}C)	----	39
19	SPECIFIC GRAVITY	6.8-7.8	2.68
20	FREEZING RANGE (^{0}C) APPROX.	--	615-550
21	SOLIDIFICATION SHRINKAGE (PATTERN MAKERS) %AGE	1.65	1.3
22	SP.HEAT CAPACITY (J/Kg.K)	490	970
23	THERMAL DIFFUSIVITY (m^2/S)	1.7306X10^{-5}	57
24	ELECTRICAL RESISTIVITY (Ω.M)	1.1X10^{-7}	4.205X10^{-8}

(*Fully Heat Treated)

5.4 Heat treatments for LM25

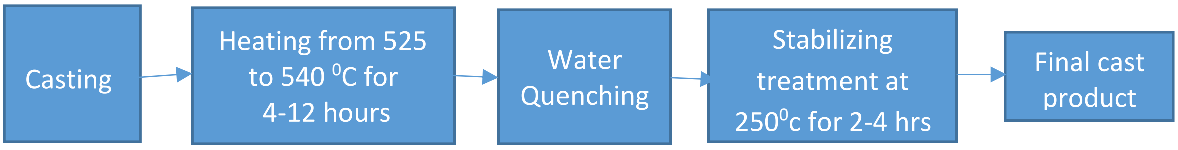
[01] LM25-TE (Precipitation treated):

Heat the casting for 8 to 12 hours at 155 to 175 ^{0}C and allow it to cool in air.



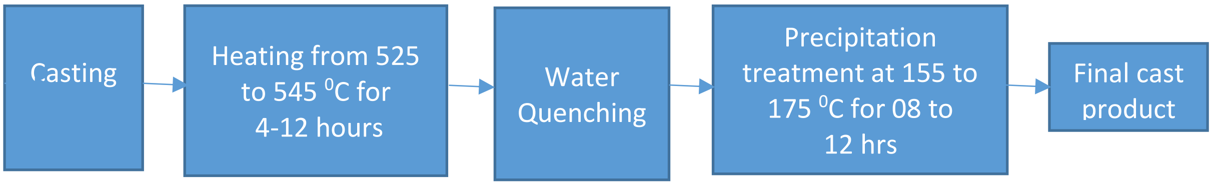
[02] LM25-TB7 (Solution treated and stabilized):

Heat the casting for 4 to 12 hours at 525 to 545 ^{0}C and quench in hot water followed by a stabilizing treatment at 250 ^{0}C for 2 to 4 hours.



[03] LM25-TF (Fully heat treated):

Heat the casting for 4 to 12 hours at 525 to 545 ^{0}C and quench in hot water followed by precipitation treatment of 8 to 12 hours at 155 to 175 ^{0}C.



Out of the above three types of Aluminium Alloy LM25-TF which is fully treated, the properties which are given in the above table are comparable with Grey Cast Iron. Hence, it was selected for the blocks as the material of manufacture over Grey Cast Iron for the present research work according to the scope.

5.5 The original Cast Iron cylinder block

After selecting the '***Splendor+***' as the model for the experimentation of the present research work, its engine was separated from motorcycle. Its original cylinder block was removed from the engine. It is quiet heavy. The comparison on weight basis is given in the coming sessions of the chapter.

Figure 5.19, C. I. block, top view **Figure 5.20, C. I. block, Side View**

As the present research work is related to the investigation of Aluminium Alloy engine cylinder block to replace the Cast Iron engine cylinder in two wheeler engine, therefore it was essential to refer the original Cast Iron engine cylinder block which is shown in figures 5.19 to 5.28. Hence, first of all it was studied carefully over here. So, this section gives the photographs of such a cylinder block which is removed from the engine of the bike.

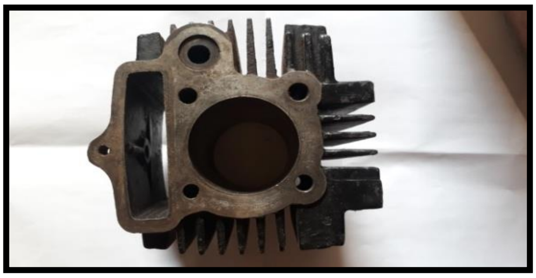


Figure 5.21, C. I. block, top view **Figure 5.22, C. I. block, right side view**

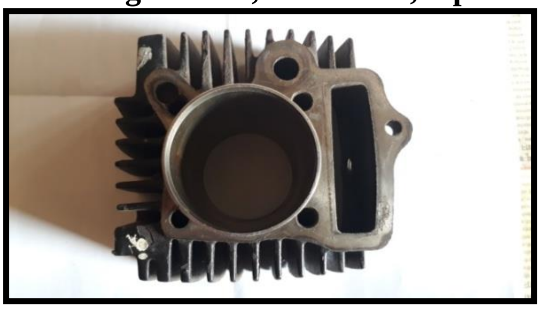


Figure 5.23, C. I. block, bottom view **Figure 5.24, C. I. block, top surface**

Figure 5.25, C. I. block, top and side wall

Figure 5.26, C. I. block, bottom and side

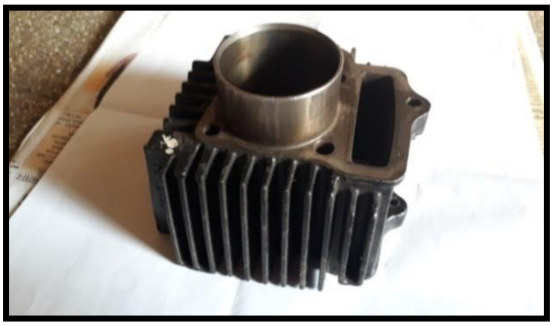


Figure 5.27, C. I. block, bottom and side

Figure 5.28, C. I. block, top and left side

5.6 The unfinished Aluminium Alloy engine cylinder casting

Out of the three types of Aluminium Alloy which are already discussed in section 5.4, LM25-TF which is fully treated, the properties which are given in the above table 5.1 are comparable with Grey Cast Iron. Hence, it was selected for the manufacturing of cylinder blocks as the material of manufacture over Gray Cast Iron for the present research work according to the scope. Accordingly, the patterns were prepared and the castings were produced. Two castings were prepared at M/s Purva Metals, G.M. Industrial Estate, Miraj. They are as shown in the following photographs. In order to confirm the composition of LM25, the test certificate which was obtained from M/s Purva Metals and issued by M/s Suhan Audyogik Sahakari Sanstha Maryadit, Chandur, Taluka Hatkanagale, District Kolhapur was also obtained which is given below. Figures 5.29 to 5.35 shows the Aluminium Alloy engine cylinder block casting in different positions.

Figure 5.29, Aluminium alloy engine cylinder block Casting, right side

Figure 5.30, Aluminium Alloy engine cylinder block Casting, left side

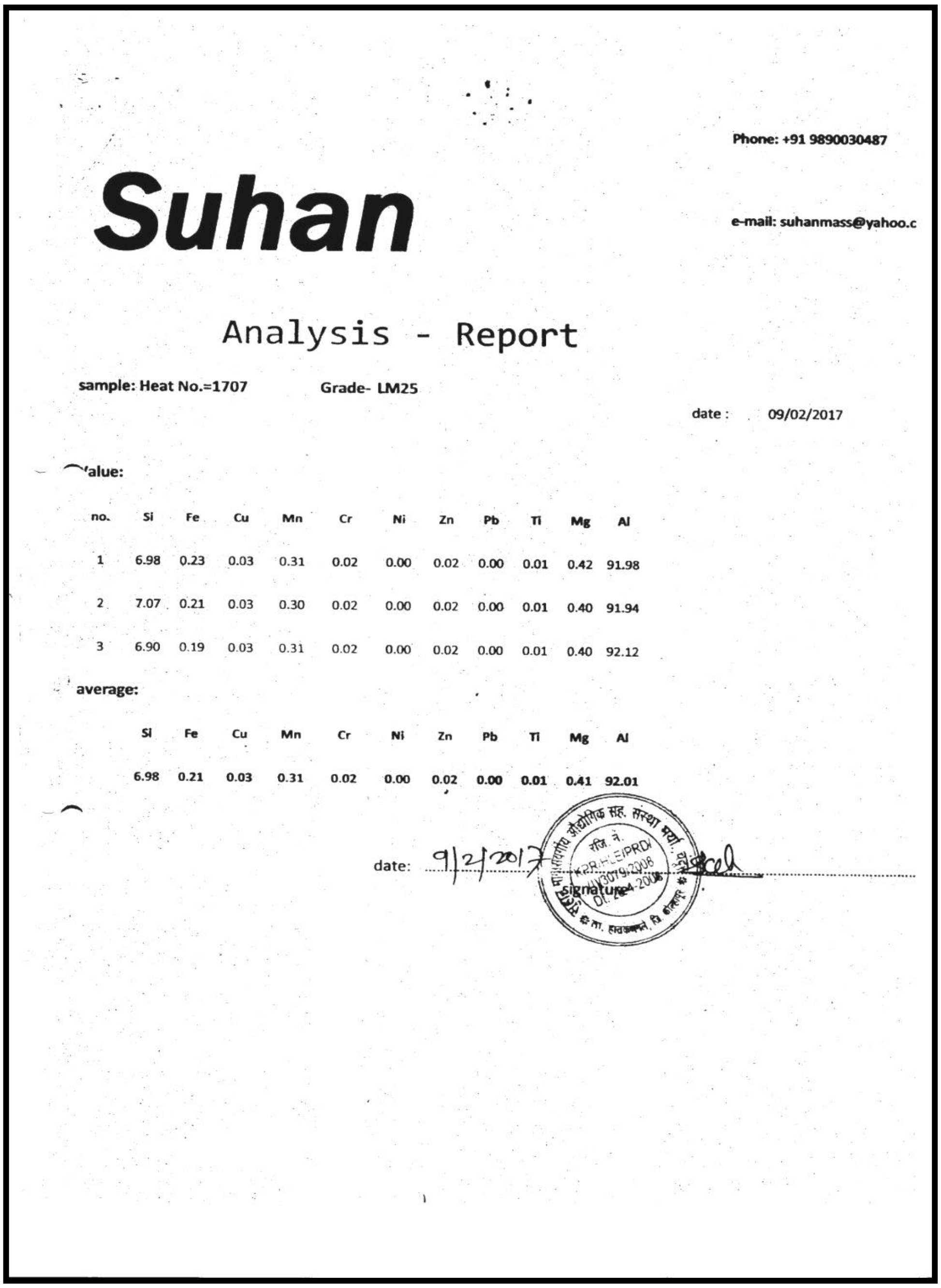
Figure 5.31, Aluminium alloy engine cylinder block casting, left side

Figure 5.32, Aluminium Alloy engine cylinder block casting, bottom surface

Figure 5.33, Aluminium Alloy engine cylinder block casting, right side view

Figure 5.34, Aluminium alloy engine cylinder block casting, right side and bottom

Figure 5.35, Aluminium Alloy engine cylinder block casting, right side and top



Phone: +91 9890030487

Suhan

e-mail: suhanmass@yahoo.c

Analysis - Report

sample: Heat No.=1707 Grade- LM25

date : 09/02/2017

value:

no.	Si	Fe	Cu	Mn	Cr	Ni	Zn	Pb	Ti	Mg	Al
1	6.98	0.23	0.03	0.31	0.02	0.00	0.02	0.00	0.01	0.42	91.98
2	7.07	0.21	0.03	0.30	0.02	0.00	0.02	0.00	0.01	0.40	91.94
3	6.90	0.19	0.03	0.31	0.02	0.00	0.02	0.00	0.01	0.40	92.12

average:

Si	Fe	Cu	Mn	Cr	Ni	Zn	Pb	Ti	Mg	Al
6.98	0.21	0.03	0.31	0.02	0.00	0.02	0.00	0.01	0.41	92.01

date: 9/2/2017

signature

Figure 5.36, Analysis Report for LM25 /Aluminium Alloy composition

Table 5.2, Chemical composition of standard Aluminium Alloy LM25 (As per BS 1490:1988 Std.)

Si	Fe	Cu	Mn	Cr	Ni	Zn	Pb	Ti	Mg	Sn	Al
6.5-7.5	0.5	0.2	0.3	--	0.1	0.1	0.1	0.2	0.2-0.6	0.05	Rest

Table 5.3, Chemical composition of Aluminium Alloy LM25 available to produce the block (As per test report in Fig 5.36)

Si	Fe	Cu	Mn	Cr	Ni	Zn	Pb	Ti	Mg	Al
6.98	0.21	0.03	0.31	0.02	0.00	0.02	0.00	0.01	0.41	92.01

After preparation of moulding box, before pouring as Aluminium Alloy (LM25) was selected as the material, it was checked for its composition. The composition is given in the certificate as shown in the figure 5.36 given above and is almost the same as per BS 1490:1988. The composition is given in Tables 5.2 and 5.3.

5.7 The semi finished casting

The raw casting obtained from foundry was machined i.e. semifinished at Machine Shop of M/s Ganapati Enterprises, Shivaji Udyamnagar, Kolhapur. The fins were cleared out of excess metal along and both the faces were also machined. The semi-finished block is as shown in following figures 5.37 to 5.45.

Figure 5.37, Photography of semi-finished casting, lower surface machined

Figure 5.38, Photography of semi-finished casting, fins machined

Figure 5.39, Photography of semi finished casting, Left side machined

Figure 5.40 Photography of semi finished casting, bottom surface machined

Figure 5.41, Photography of semi-finished casting, right side machined

Figure 5.42, Photography of semi-finished casting, top face machined

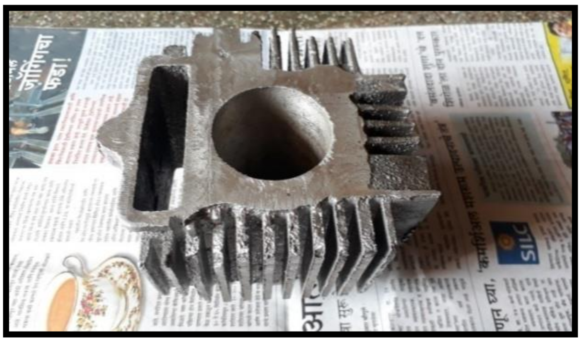


Figure 5.43, Photography of semi-finished casting, top face machined

Figure 5.44, Photography of semi-finished casting, top face machined

Figure 5.45, Photography of semi-finished casting, bottom face machined

5.8 Casting after heat treatment

After the semi finishing i.e. finishing the outside of the Aluminium Alloy casting, it was heat treated at M/s Indrani/Mahalaxmi Heat Treaters, Mahalaxmi Industrial Estate, A/P Nagaon, Kolhapur. The casting has undergone the water quenching after 3 hours of heating at 550 ^{0}C. Then, heated at 180 ^{0}C for 12 hours and cooled naturally by using air as cooling media. The hardness was measured by using hardness testing machine facility available at the same industry. It was found to be 82-84 BHN. Following photographs are showing the block after heat treatment. After checking of hardness, the test report/certificate is also obtained which is also given here in this section.

Figure 5.46, Photography of hardness tester

Figure 5.47, Photography of casting post heat treatment showing hardness

Figure 5.48, Photography of calibration certificate of hardness tester

INDRANI	METALLURGICAL TEST CERTIFICATE	IHT/ QC / F / 06 - 01
		Rev. Date - 16.08.2015

A) IDENTIFICATION

Lab. Ref. Number	IHT/ NA / 04-17 / 01	HT Batch Number	IQD - E - 61
Date	20.04.2017	Operation Over	T6
Part Name	Engine Cylinder Block	Customer Name	A D Patil
Part Number	----	Material	LM - 25
Quantity	01 Nos	Heat code	---
Your D.C No & Date		Our D.C No. & Date	

B) METALLURGICAL TEST :

Metallurgical Parameters	Specification	Observation
Surface Hardness	80 - 95 BHN	82 - 84 BHN

SURFACE HARDNESS CHECKING REPORT

1	82	BHN						
2	84	BHN						

C) Micro hardness traverse :

Distance from surface(mm)	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1	1.1	1.2
Hardness (HV)												

N.A

IMAGE OF MICROSCOPE

N.A

OBSERVATION

1	Temp. Matrensite	-
2	Ferrite	-
3	R.A	-
4	Carbide	-

Anticarb paste application : N.A.

Remark : 100% hardness checked found ok

INDRANI HEAT TREATERS ★ KOLHAPUR ★

Laboratory Engineer

Head of the Dept. (Sr. Manager - HT)

Figure 5.49, Metallurgical test certificate for casting

5.9 Casting after drilling holes and final Boring of cylinder with piston in bore

After heat treatment on the block, all holes as shown in following figure were drilled. Four holes are required for to insert the block in studs, one oil hole and other three holes were drilled at M/s CST Machine Tools, MIDC, Shiroli. After completion of this work, finally block has undergone the final boring and honing operation with the completion of which the block was ready to fit on the engine. Final boring and honing on the block was done at Machine Tool Works, Shivaji Udyamnagar, Kolhapur. The block is as shown in following figures 5.50 and 5.51.

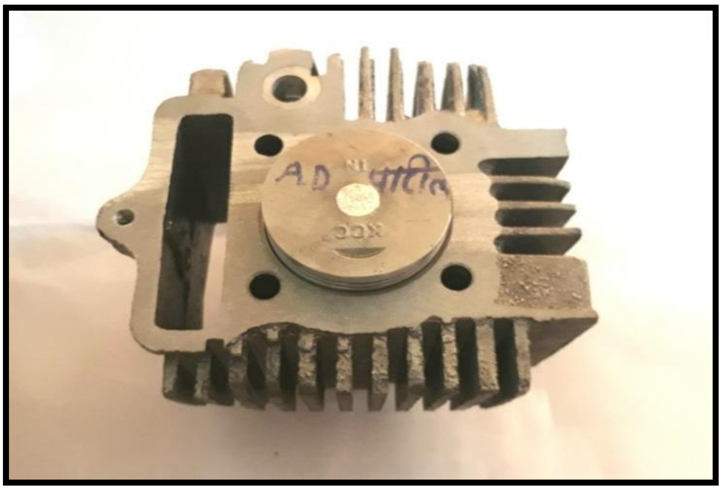


Figure 5.50, Photography of finished casting with piston in bore, top view

Figure 5.51, Photography of finished casting with piston in bore, bottom view

5.10 Percent reduction in weight of Aluminium Alloy engine cylinder block in comparison with Cast Iron engine cylinder block

Table 5.4, Weighing balance observations/weight of engine cylinder blocks

Sr. No.	Type of block	Initial weight (kg)	Final weight (kg)	% age reduction in weight
1	Original cast iron block	2.492	----	----
2	Casting by using LM25 (unfinished)	----	1.771	28.9325
3	Casting by using LM25 (finished and ready to install on engine)	----	1.208	51.5248

% Reduction in weight of casting can be calculated as:

%age reduction in weight of unfinished casting = [(2.492-1.771)/2.492] X 100 = 28.9325 %

%age reduction in weight of finished & ready casting = [(2.492-1.208)/2.492] X 100=51.5248 %

There is the total weight reduction of 51.5248 %

5.11 CFD analysis of the engine cylinder block :

Before CFD analysis of the engine cylinder block, as it was necessary to prepare the model, the first step in this was 3D scanning. The photograph given below shows the FARO make 3D scanner. This scanner is used in the scanning of the block due to its complex shape on outside surface. As the fins of different size and shape are used, it was not possible to prepare on the modelling software, so the block was 3D scanned by using the scanner shown in the photographs 5.52 to 5.54 given below.

Figure 5.52, Photographic view of Faro Make 3D Scanner

Figure 5.53, Photography of Faro Make 3D Scanner

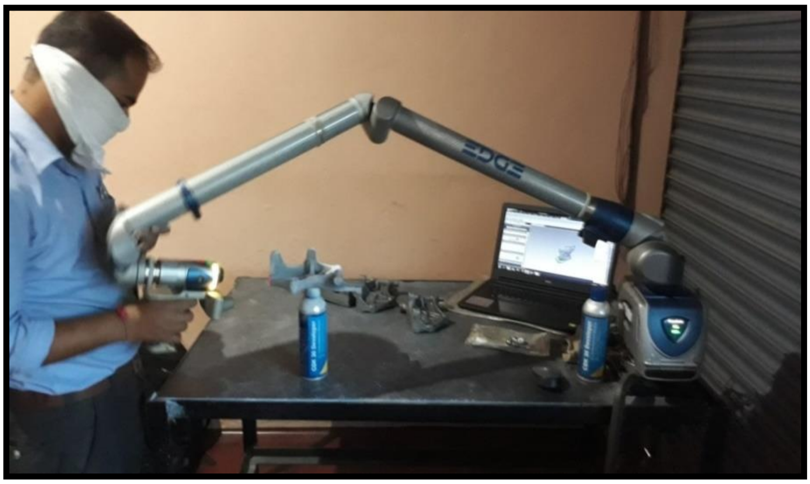
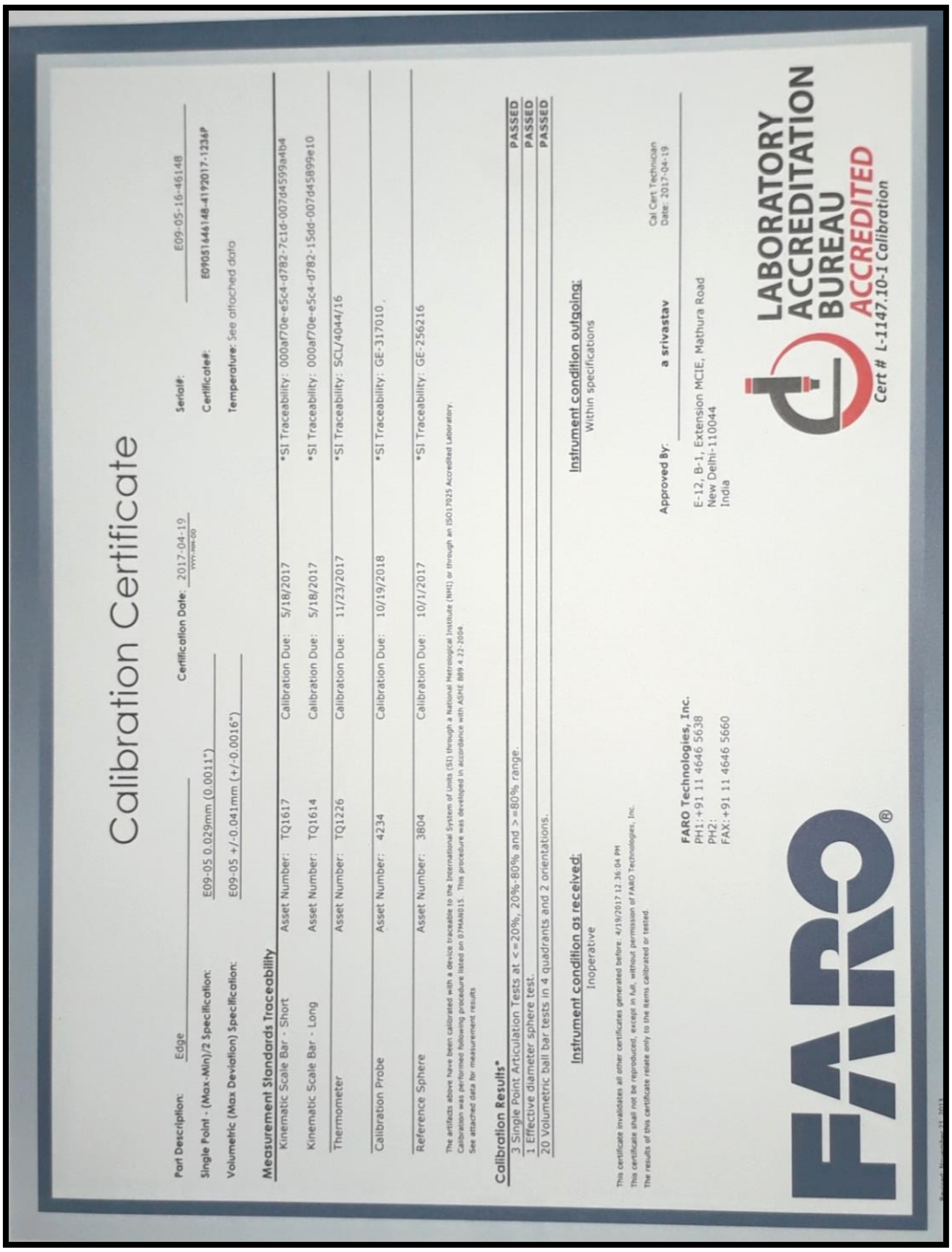


Figure 5.54, Photographic view during scanning of component



Calibration Certificate

Part Description: Edge

Certification Date: 2017-04-19 (yyyy-mm-dd)

Serial#: E09-05-16-46148

Single Point - (Max-Min)/2 Specification: E09-05 0.029mm (0.0011")

Certificate#: E09051646148-4192017-1236P

Volumetric (Max Deviation) Specification: E09-05 +/-0.041mm (+/-0.0016")

Temperature: See attached data

Measurement Standards Traceability

Kinematic Scale Bar - Short	Asset Number: TQ1617	Calibration Due: 5/18/2017	*SI Traceability: 000af70e-e5c4-d782-7c1d-007d4599a4b4
Kinematic Scale Bar - Long	Asset Number: TQ1614	Calibration Due: 5/18/2017	*SI Traceability: 000af70e-e5c4-d782-15dd-007d45899e10
Thermometer	Asset Number: TQ1226	Calibration Due: 11/23/2017	*SI Traceability: SCL/4044/16
Calibration Probe	Asset Number: 4234	Calibration Due: 10/19/2018	*SI Traceability: GE-317010
Reference Sphere	Asset Number: 3804	Calibration Due: 10/1/2017	*SI Traceability: GE-256216

The artifacts above have been calibrated with a device traceable to the International System of Units (SI) through a National Metrological Institute (NMI) or through an ISO17025 Accredited Laboratory. Calibration was performed following procedure listed on 07MAN015. This procedure was developed in accordance with ASME B89.4.22-2004. See attached data for measurement results

Calibration Results*

3 Single Point Articulation Tests at <=20%, 20%-80% and >=80% range.	PASSED
1 Effective diameter sphere test.	PASSED
20 Volumetric ball bar tests in 4 quadrants and 2 orientations.	PASSED

Instrument condition as received: Inoperative

Instrument condition outgoing: Within specifications

This certificate invalidates all other certificates generated before 4/19/2017 12:36:04 PM
This certificate shall not be reproduced, except in full, without permission of FARO Technologies, Inc.
The results of this certificate relate only to the items calibrated or tested

Approved By: a srivastav
Cal Cert Technician
Date: 2017-04-19

FARO Technologies, Inc.
PH1: +91 11 4646 5638
PH2:
FAX: +91 11 4646 5660

E-12, B-1, Extension MCIE, Mathura Road
New Delhi-110044
India

LABORATORY ACCREDITATION BUREAU ACCREDITED
Cert # L-1147.10-1 Calibration

FARO®

Figure 5.55,
Calibration certificate for Faro make 3D scanner

This is a forensic scan arm 3D scanner which is portable and non-contact type. Its characteristics are like compact, lightweight, simple to use, highly accurate, repeatable, high resolution data, non-contact 3D scanning and measurement, rapid scanning speed, portable & manoeuvrable, no target or spray required, simple user interface and hard probing capabilities. It finds application in forensic anthropology, crime labs, medical examination, facial reconstruction, digital archiving of evidence and 3D printing replications of evidence. This offers benefits to the designer like reduced measurement time, generate automatic reporting, increased productivity and efficiency, meets quality standards and deliver products more quickly. After scanning, the model was prepared which was ready to analyse by using CFD techniques. Unigraphics is the software used for this with version NX7.

To get the results of CFD analysis of the model of the engine cylinder block, it was transported to SOLIDWORKS 2015 for further analysis. It was opened and by considering the variables like natural & forced convection, material of the blocks, air velocity and heat transfer coefficients, etc. were processed. The results were obtained and mentioned below:

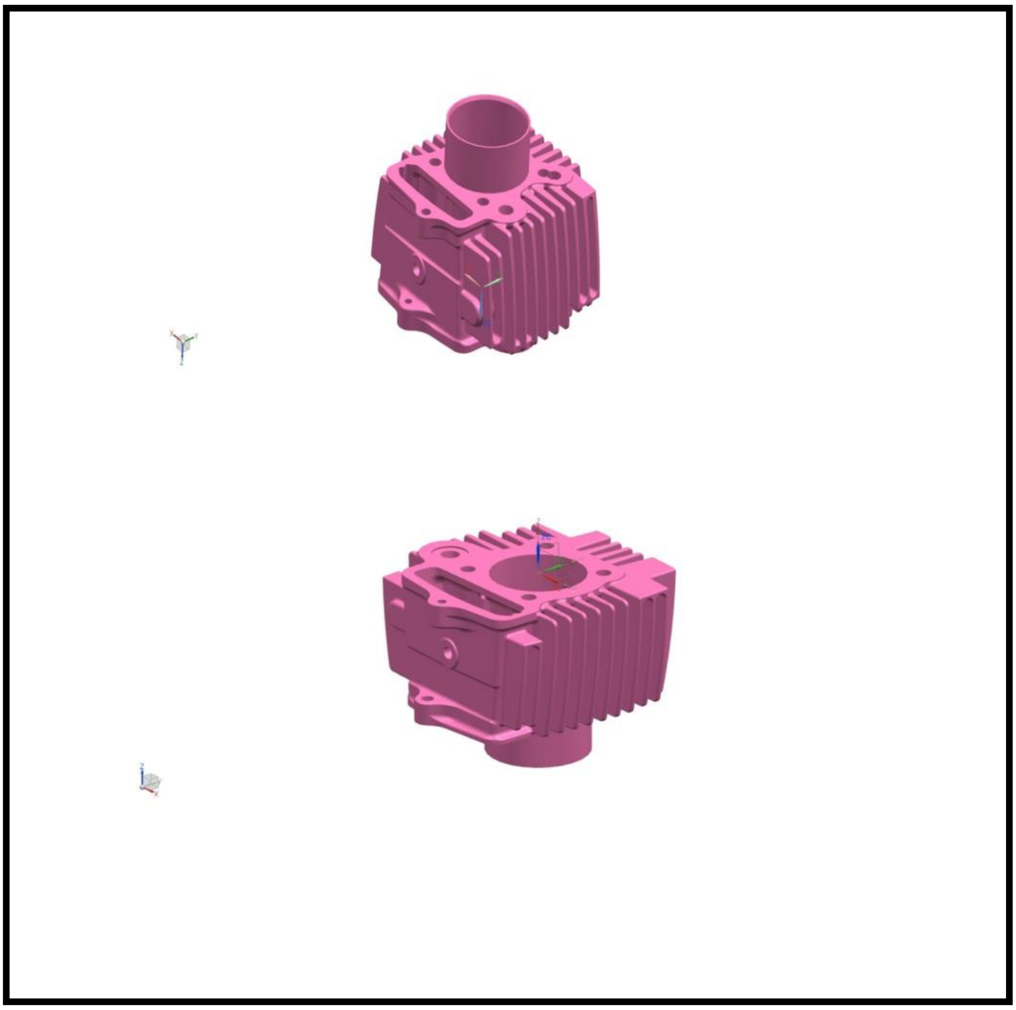


Figure 5.56, 3D Model prepared after scanning

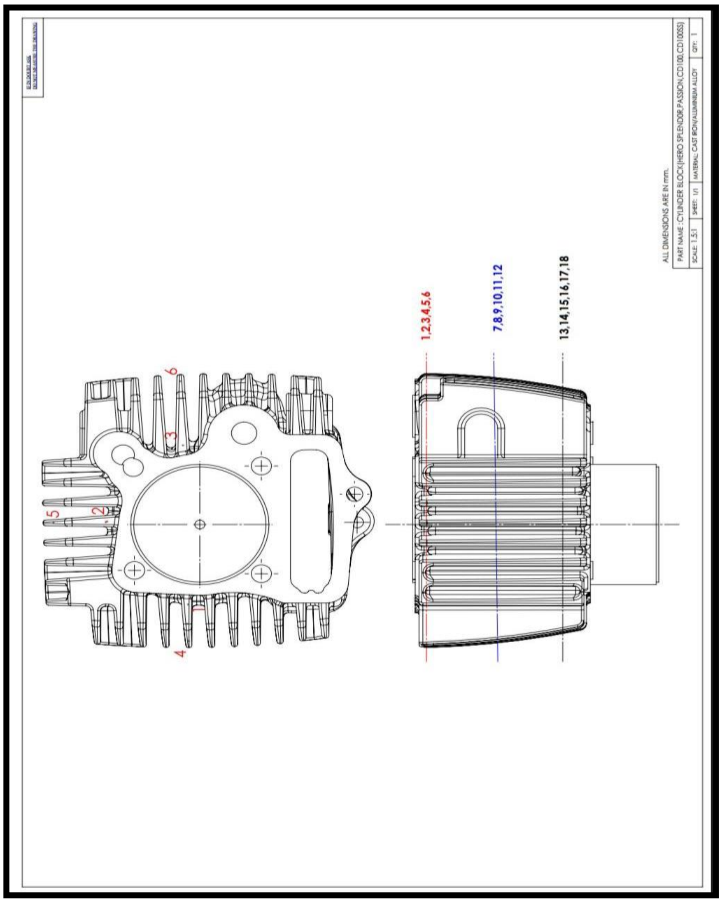


Figure 5.57, 2D Model prepared with 18 reference points

5.11.1 Results of CFD analysis of Cast Iron engine cylinder block

The block after modelling was analysed by using CFD technique. The results are given below. The variables like natural & forced convection, material of the blocks, air velocity, heat transfer coefficients, material properties, etc. were considered for the analysis. The Velocity values were selected based on the anemometric data collected for different vehicle speeds, refer Table 6.8 and page 135. The conditions are:

(1) If the bike is on stand, the engine is stationary, so that the vehicle speed = 0 km/hr and V = 0 m/s.
(2) When bike will start to run, engine will receive air with increased velocity. For this speed variation from 0 to 70 km/hr, air velocity was measured and taken for CFD analysis.

5.11.1.1 Cast Iron engine cylinder block, Natural convection, V = 0 m/s, Base temperature = 530 K

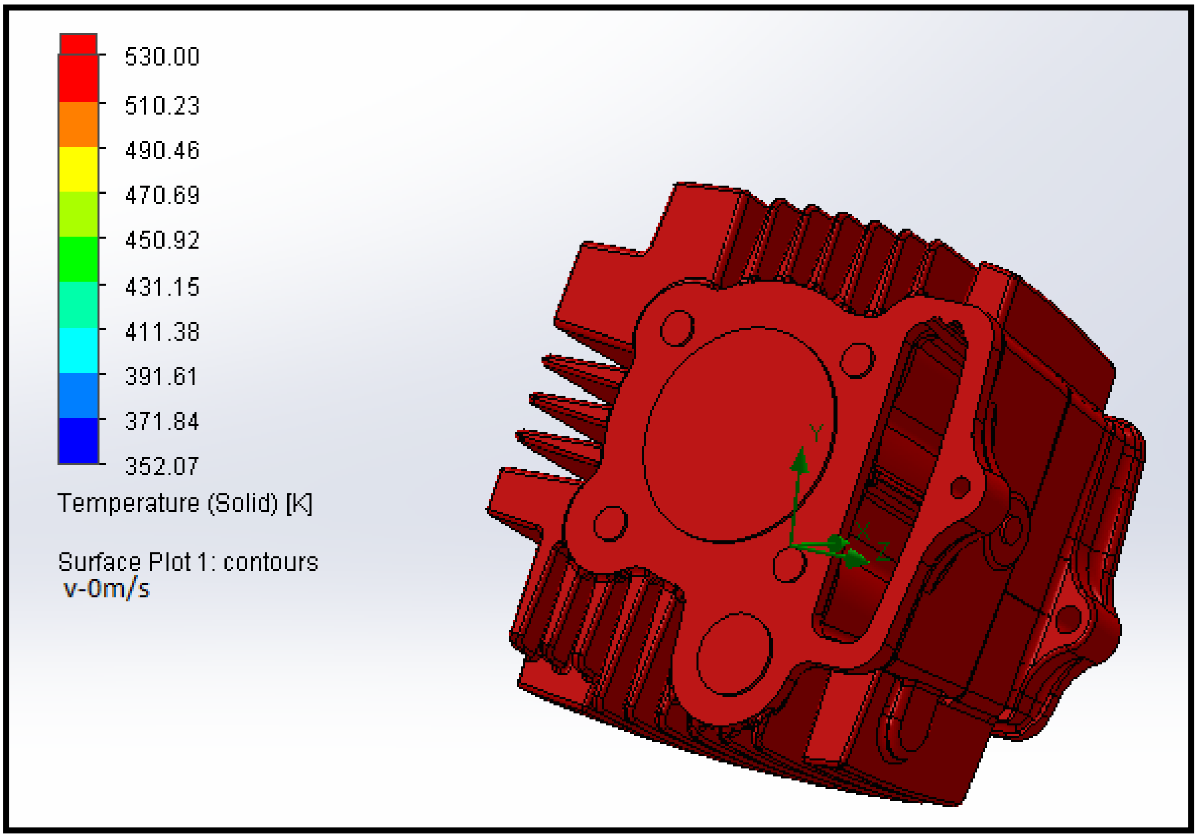


Figure 5.58, Cast Iron engine cylinder block
Natural convection, V = 0 m/s, Base temperature = 530 K

The natural convection condition was considered for the Cast Iron engine cylinder block. So, the velocity is assumed equal to 0 m/s. The temperature of the block is considered as 530 K on the inner surface. There is equal distribution of heat from inner surface of cylinder to the outer surface of fins and block as far as the results of CFD are concerned. Temperature on the outer surface is almost the same as compared to the inner surface.

5.11.1.2 Cast Iron Engine Cylinder Block, Forced convection, V = 5 m/s, Base temperature = 530 K

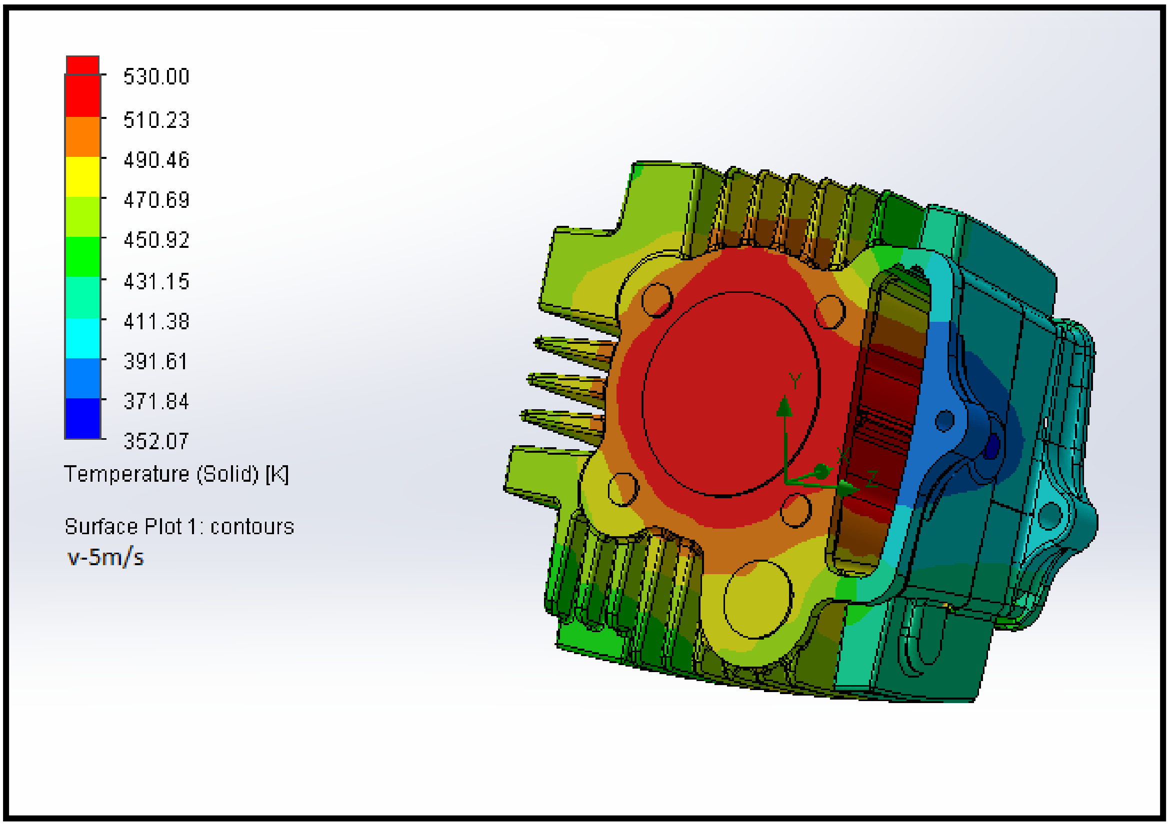


Figure 5.59, Cast Iron Engine Cylinder Block
Forced convection, V = 5 m/s, Base temperature = 530 K

The forced convection condition is considered for the Cast Iron engine cylinder block. So, the velocity is assumed to be equal to 5 m/s. The temperature of the block is considered as 530 K on the inner surface. There is unequal distribution of heat from inner surface of cylinder to the outer surface of fins and block as far as the results of CFD are concerned. Lowermost temperature on the outer surface is 352 K on the outer surface due to the exposure of the block to the air.

5.11.1.3 Cast Iron engine cylinder block, Forced convection, V = 20 m/s, Base temperature = 530 K

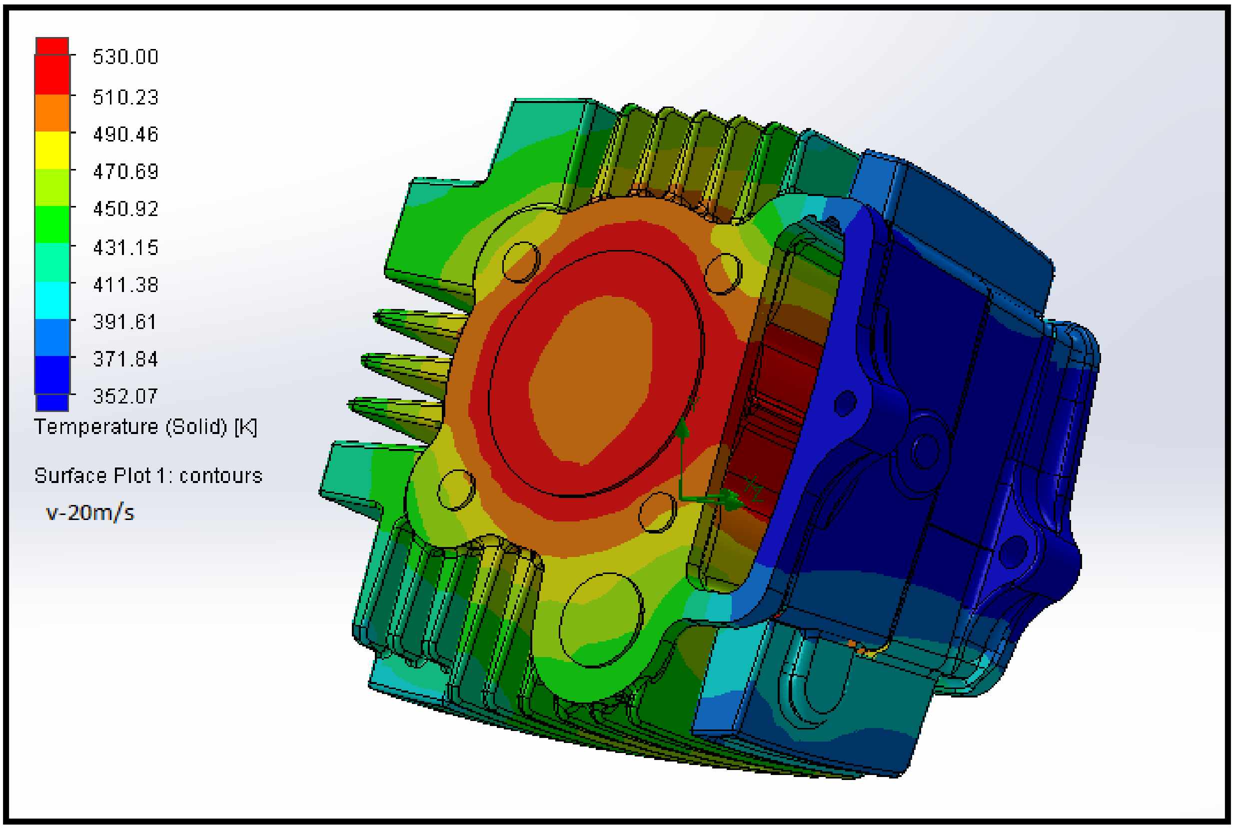


Figure 5.60, Cast Iron engine cylinder block
Forced convection, V = 20 m/s, Base temperature = 530 K

The forced convection condition is considered for the Cast Iron engine cylinder block. So, the velocity is assumed to be equal to 20 m/s. The temperature of the block is considered as 530 K on the inner surface. There is unequal distribution of heat from inner surface of cylinder to the outer surface of fins and block as far as the results of CFD are concerned. Lowermost temperature on the outer surface is 352 K on the outer surface due to the exposure of the block to the air and this zone is increased than earlier iteration.

5.11.1.4 Cast Iron engine cylinder block, Forced convection, V = 30 m/s, Base temperature = 530 K

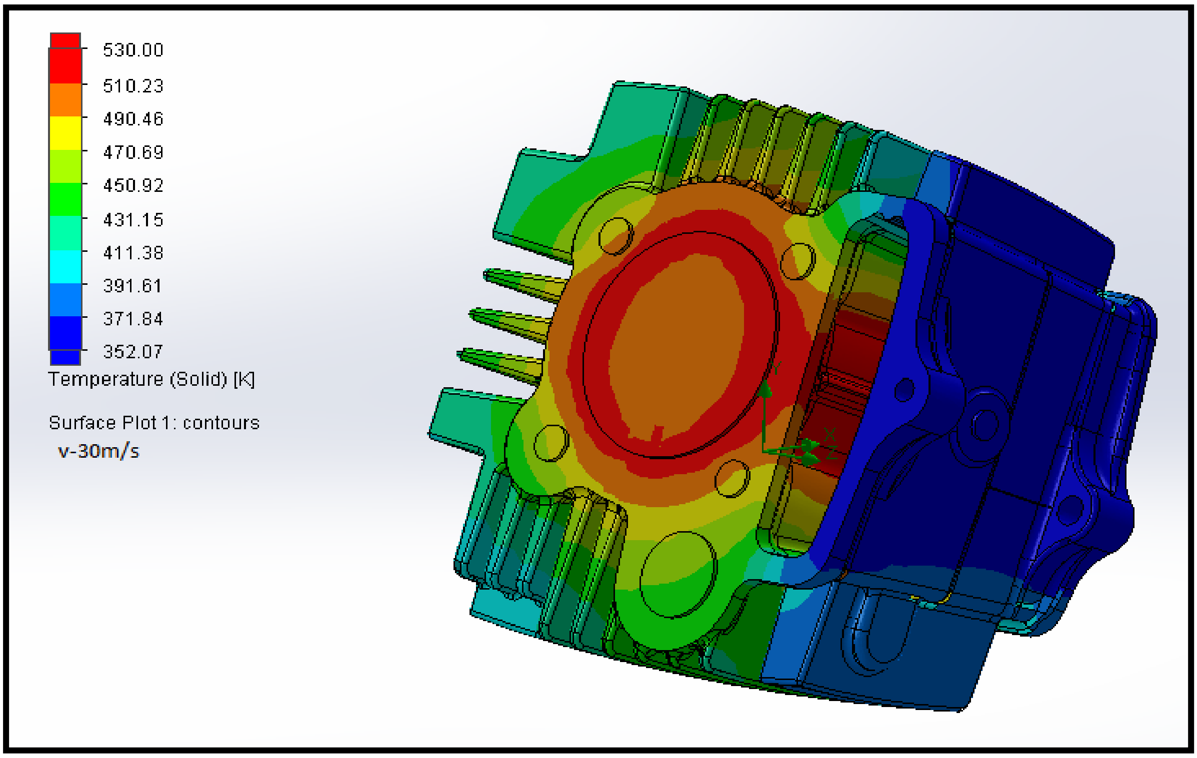


Figure 5.61, Cast Iron engine cylinder block
Forced convection, V = 30 m/s, Base temperature = 530 K

The forced convection condition is considered for the Cast Iron engine cylinder block. So, the velocity is assumed to be equal to 30 m/s. The temperature of the block is considered as 530 K on the inner surface. There is unequal distribution of heat from inner surface of cylinder to the outer surface of fins and block as far as the results of CFD are concerned. Lowermost temperature on the outer surface is 352 K on the outer surface due to the exposure of the block to the air and this zone is increased than earlier iteration.

5.11.1.5 Cast Iron engine cylinder block, Forced convection, V = 40 m/s, Base temperature = 530 K

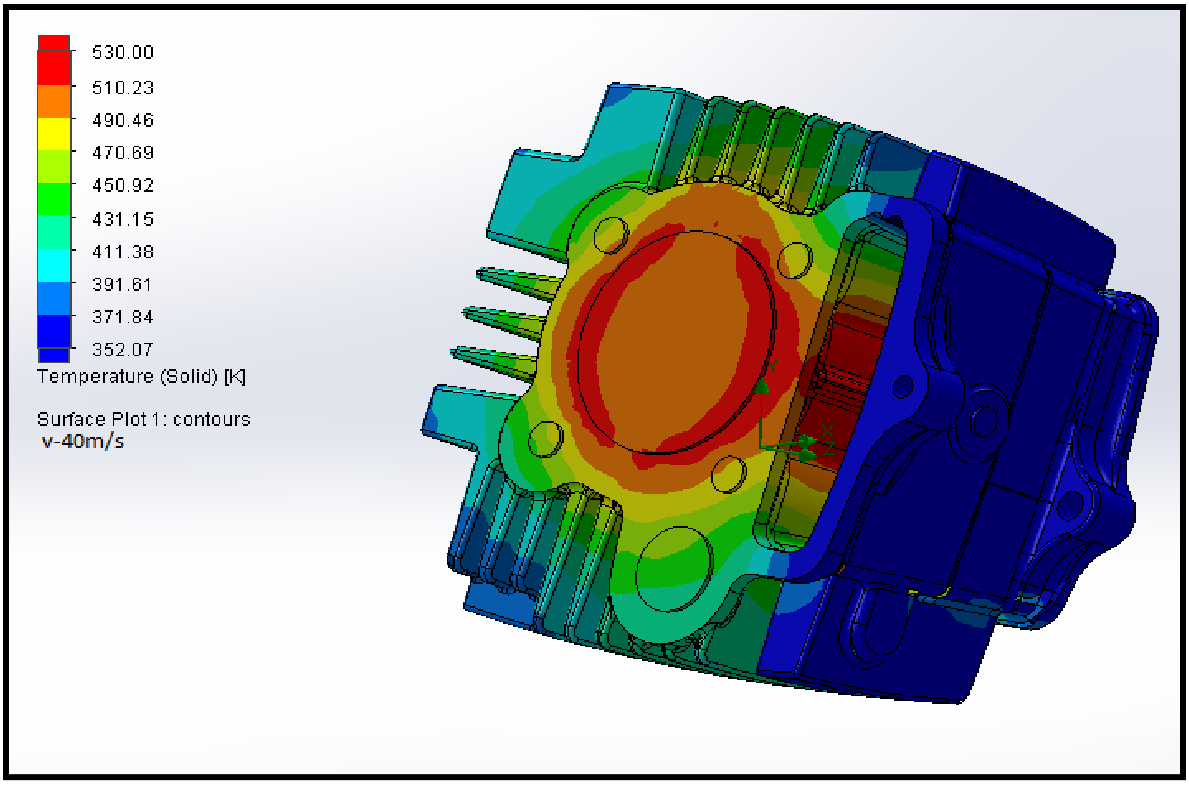


Figure 5.62, Cast Iron engine cylinder block
Forced convection, V = 40 m/s, Base temperature = 530 K

The forced convection condition is considered for the Cast Iron engine cylinder block. So, the velocity is assumed to be equal to 40 m/s. The temperature of the block is considered as 530 K on the inner surface. There is unequal distribution of heat from inner surface of cylinder to the outer surface of fins and block as far as the results of CFD are concerned. Lowermost temperature on the outer surface is 352 K on the outer surface due to the exposure of the block to the air and this zone is increased than earlier iteration.

5.11.1.6 Cast Iron engine cylinder block, Forced convection, V = 50 m/s, Base temperature = 530 K

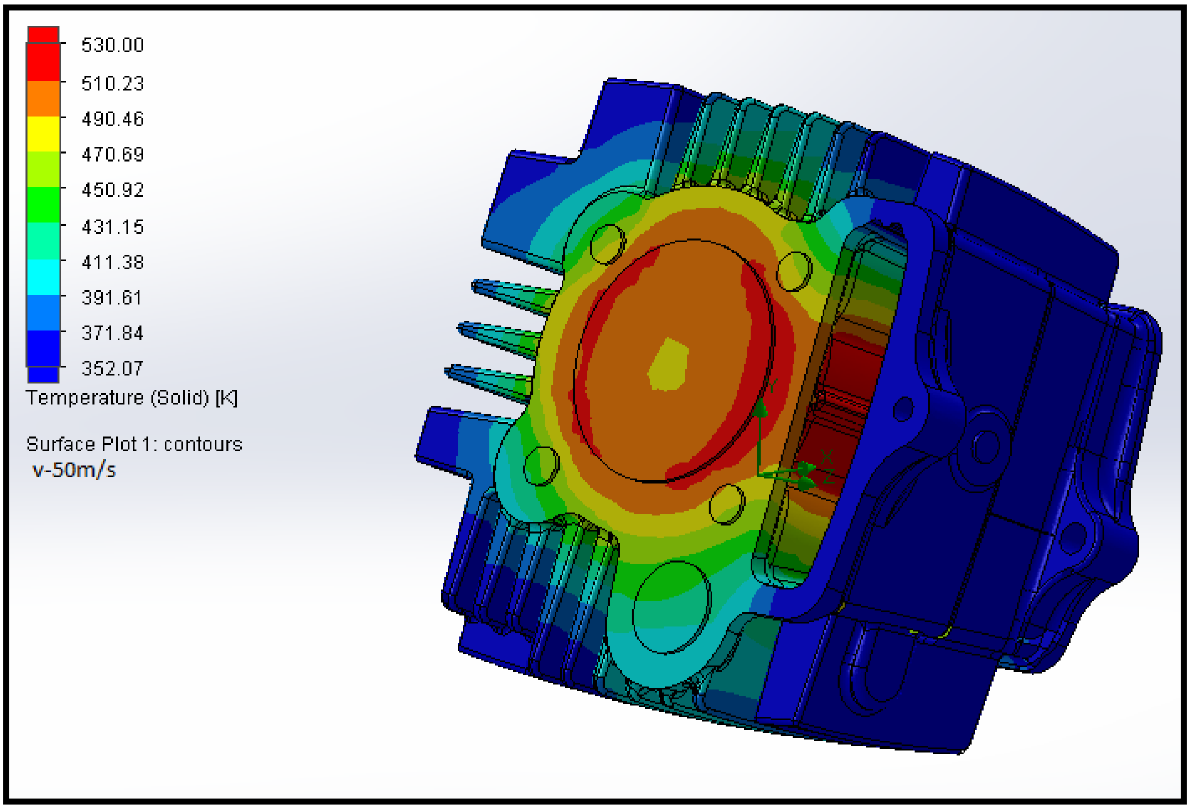


Figure 5.63, Cast Iron engine cylinder block
Forced convection, V = 50 m/s, Base temperature = 530 K

The forced convection condition is considered for the Cast Iron engine cylinder block. So, the velocity is assumed to be equal to 50 m/s. The temperature of the block is considered as 530 K on the inner surface. There is unequal distribution of heat from inner surface of cylinder to the outer surface of fins and block as far as the results of CFD are concerned. Lowermost temperature on the outer surface is 352 K on the outer surface due to the exposure of the block to the air and this zone is increased than earlier iteration.

5.11.1.7 Cast Iron Engine cylinder block, Forced convection, V = 60 m/s, Base temperature = 530 K

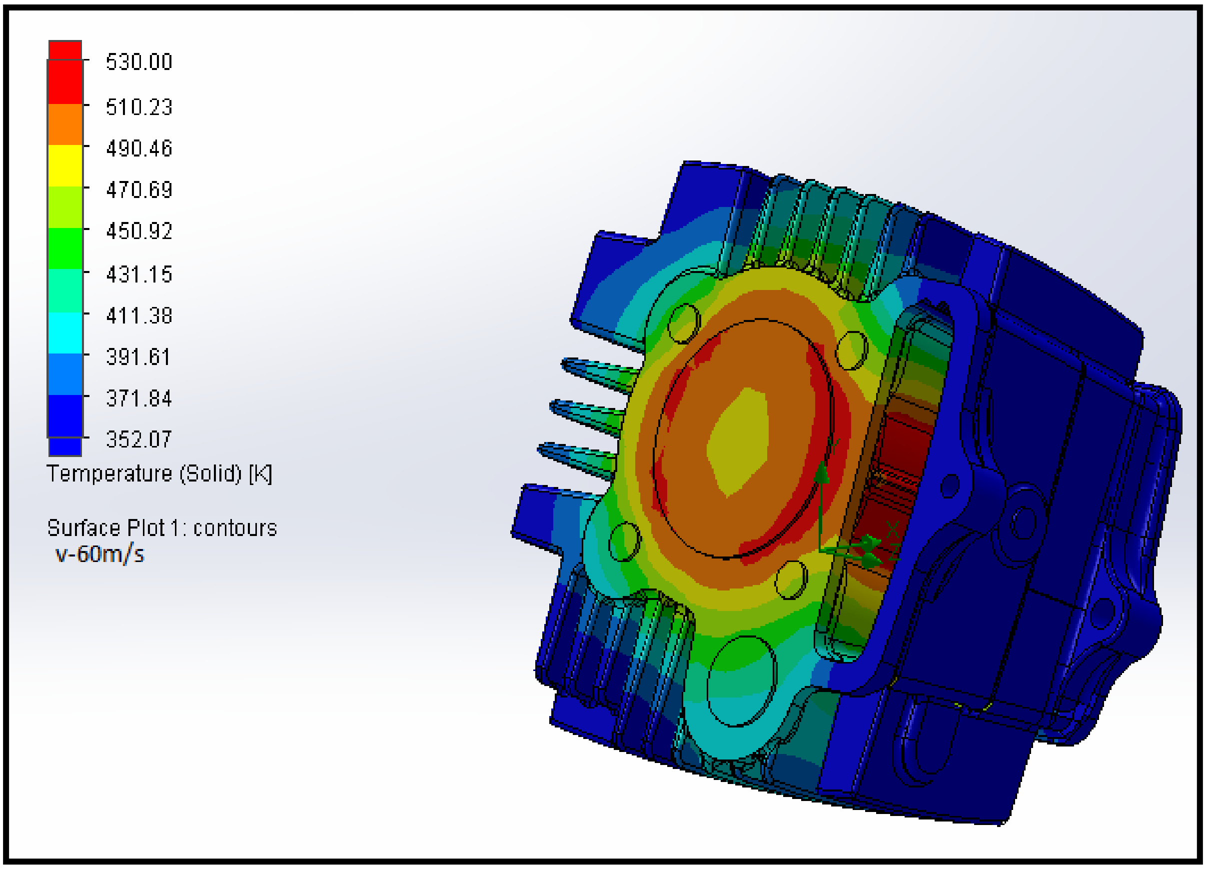


Figure 5.64, Cast Iron Engine cylinder block
Forced convection, V = 60 m/s, Base temperature = 530 K

The forced convection condition is considered for the Cast Iron engine cylinder block. So, the velocity is assumed to be equal to 60 m/s. The temperature of the block is considered as 530 K on the inner surface. There is unequal distribution of heat from inner surface of cylinder to the outer surface of fins and block. Lowermost temperature on the outer surface is 352 K on the outer surface due to the exposure of the block to the air and this zone is increased than earlier iteration. There is maximum portion of the block at minimum temperature of the order of 352 K due to high thermal resistance of the Cast Iron.

5.11.2 Results of CFD analysis of Aluminium Alloy engine cylinder block

The Aluminium Alloy engine cylinder block after modelling was analysed by using CFD technique on computer. The results are given below. The variables like natural & forced convection, material of the blocks, wind velocity, heat transfer coefficients, material properties, etc. were considered for the analysis.

5.11.2.1 Aluminium Alloy engine cylinder block, Natural convection, V = 0 m/s, Base temperature = 530 K

The natural convection condition was considered for the Aluminium Alloy engine cylinder block. So, the velocity is assumed to be equal to 0 m/s. The temperature of the block is considered as 530 K on the inner surface. There is equal distribution of heat from inner surface of cylinder to the outer surface of fins and block as far as the results of CFD are concerned. Temperature on the outer surface is almost the same as compared to the inner surface.

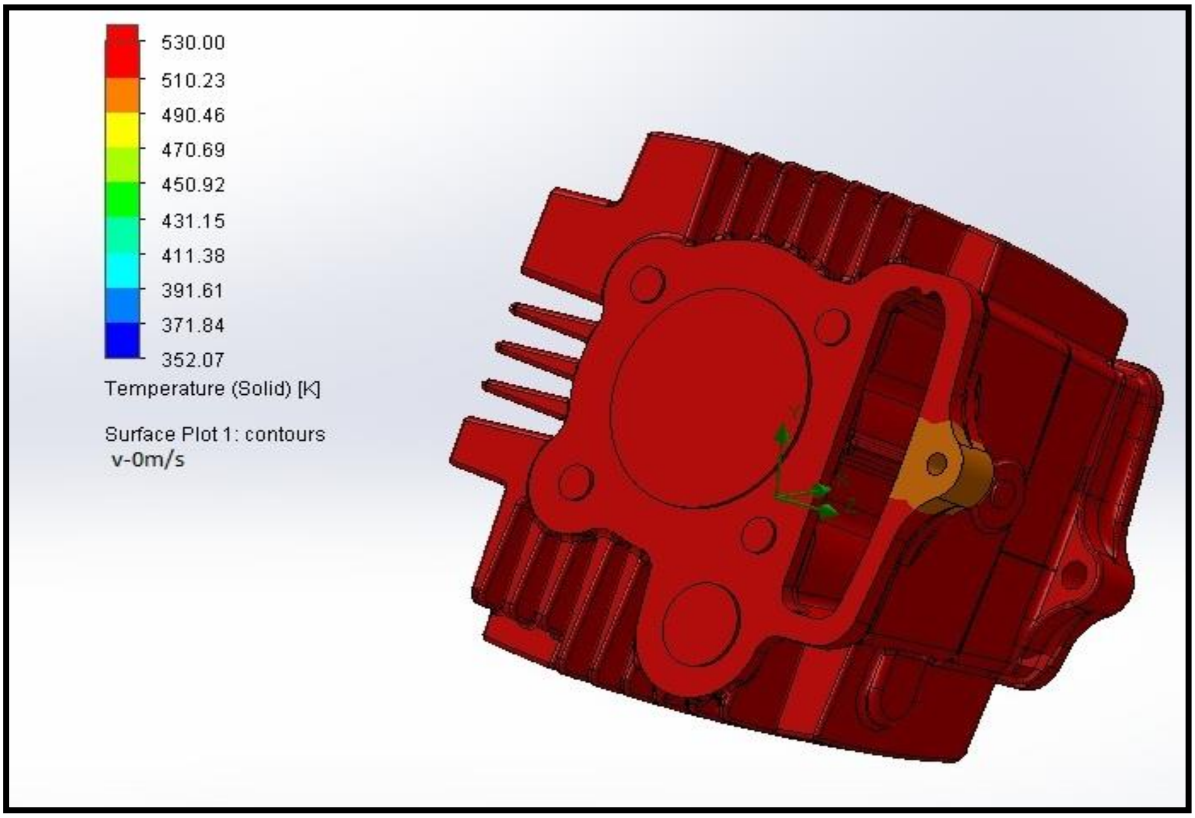


Figure 5.65, Aluminium Alloy engine cylinder block
Natural convection, V = 0 m/s, Base temperature = 530 K

5.11.2.2 Aluminium Alloy engine cylinder block, Forced convection, V = 5 m/s, Base temperature = 530 K

The forced convection condition is considered for the Aluminium Alloy engine cylinder block. So, the velocity is assumed to be equal to 5 m/s. The temperature of the block is considered as 530 K on the inner surface. There is unequal distribution of heat from inner surface of cylinder to the outer surface of fins and block as far as the results of CFD are concerned. Lowermost temperature on the outer surface is 352 K on the outer surface due to the exposure of the block to the air and this zone is increased than earlier iteration.

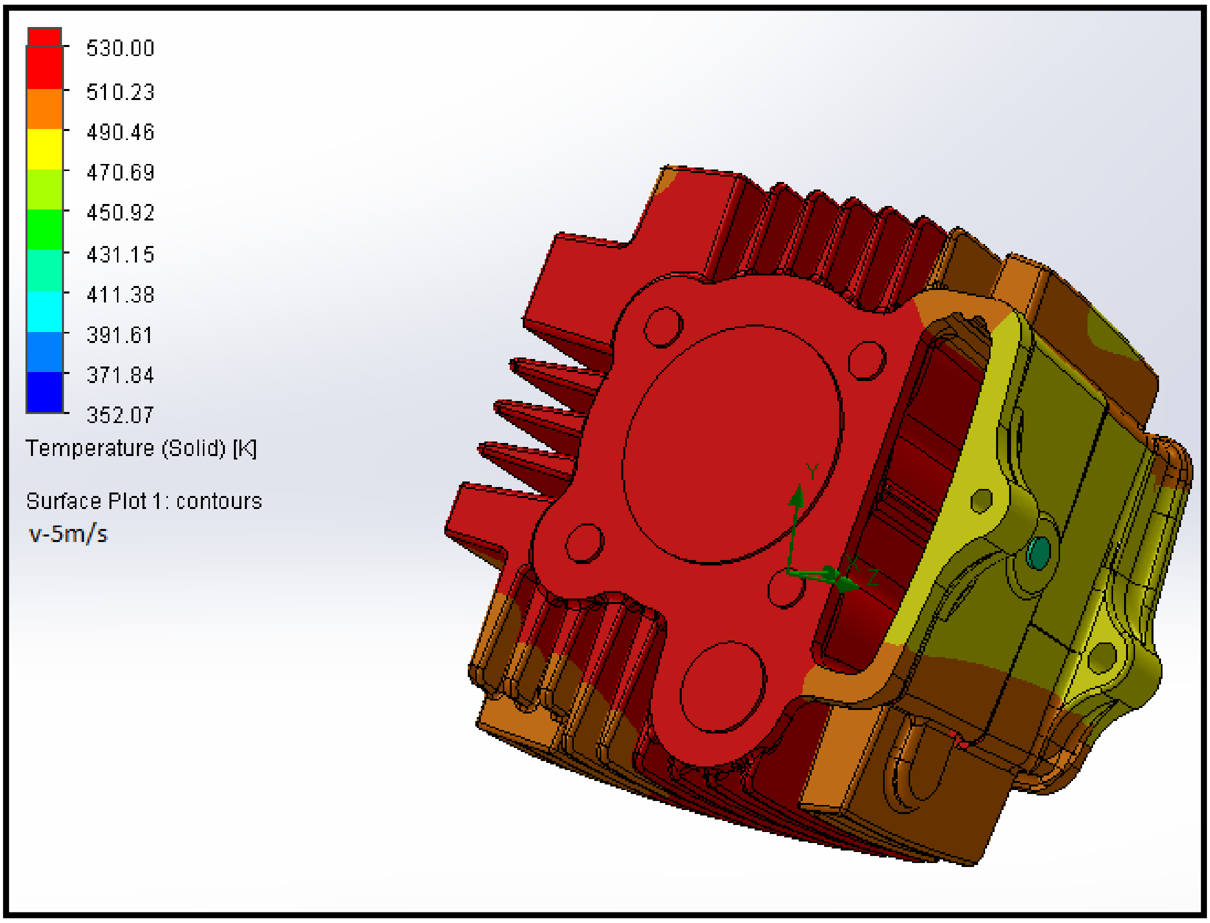


Figure 5.66, Aluminium Alloy engine cylinder block Forced convection, V = 5 m/s, Base temperature = 530 K

5.11.2.3 Aluminium Alloy engine cylinder block, Forced convection, V = 20 m/s, Base temperature = 530 K

The forced convection condition is considered for the Aluminium Alloy engine cylinder block. So, the velocity is assumed to be equal to 20 m/s. The temperature of the block is considered as 530 K on the inner surface. There is unequal distribution of heat from inner surface of cylinder to the outer surface of fins and block as far as the results of CFD are concerned. Lowermost temperature on the outer surface is 352 K on the outer surface due to the exposure of the block to the air and this zone is increased than earlier iteration.

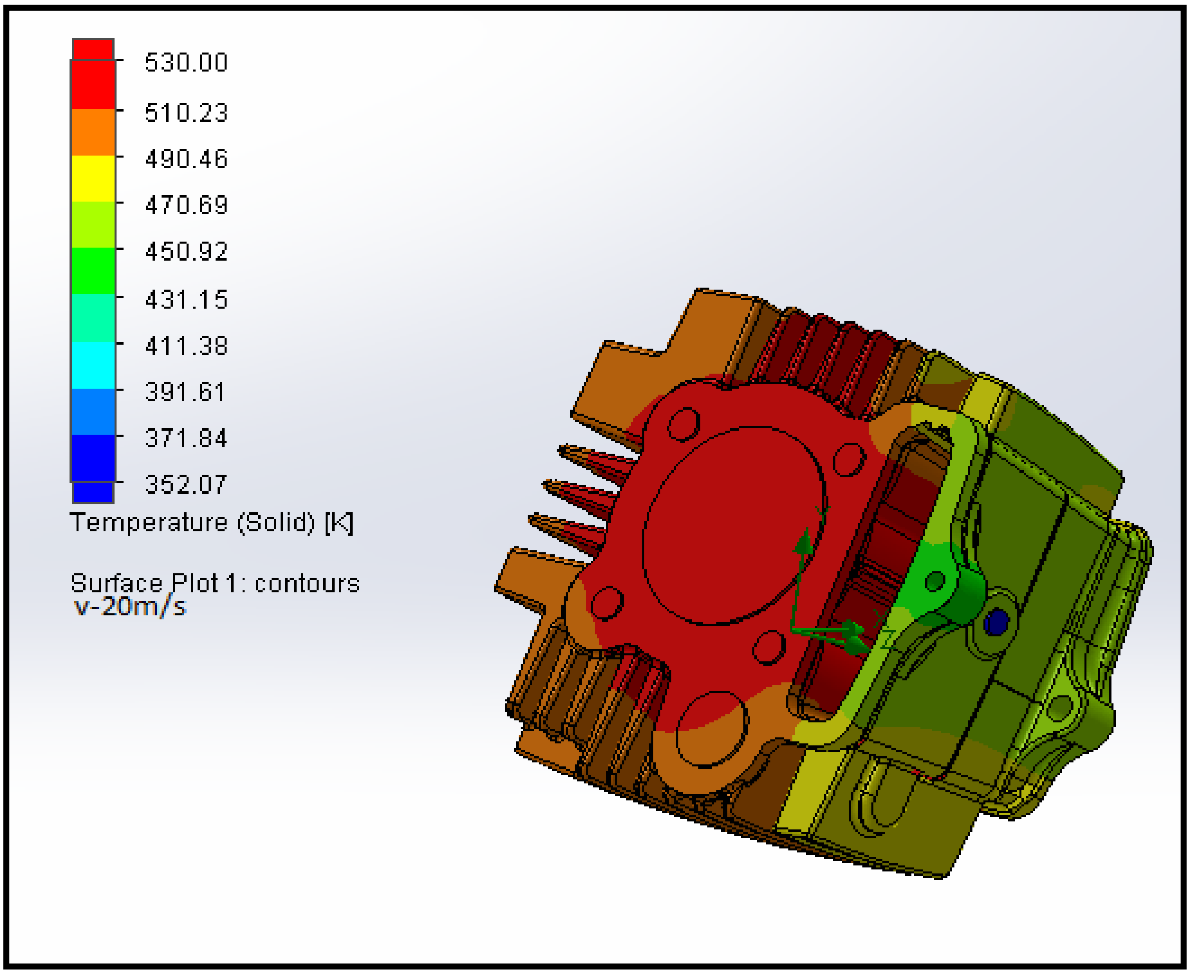


Figure 5.67, Aluminium Alloy engine cylinder block Forced convection, V = 20 m/s, Base temperature = 530 K

5.11.2.4 Aluminium Alloy engine cylinder block, Forced convection, V = 30 m/s, Base temperature = 530 K

The forced convection condition is considered for the Aluminium Alloy engine cylinder block. So, the velocity is assumed to be equal to 30 m/s. The temperature of the block is considered as 530 K on the inner surface. There is unequal distribution of heat from inner surface of cylinder to the outer surface of fins and block as far as the results of CFD are concerned. Lowermost temperature on the outer surface is 352 K on the outer surface due to the exposure of the block to the air and this zone is increased than earlier iteration.

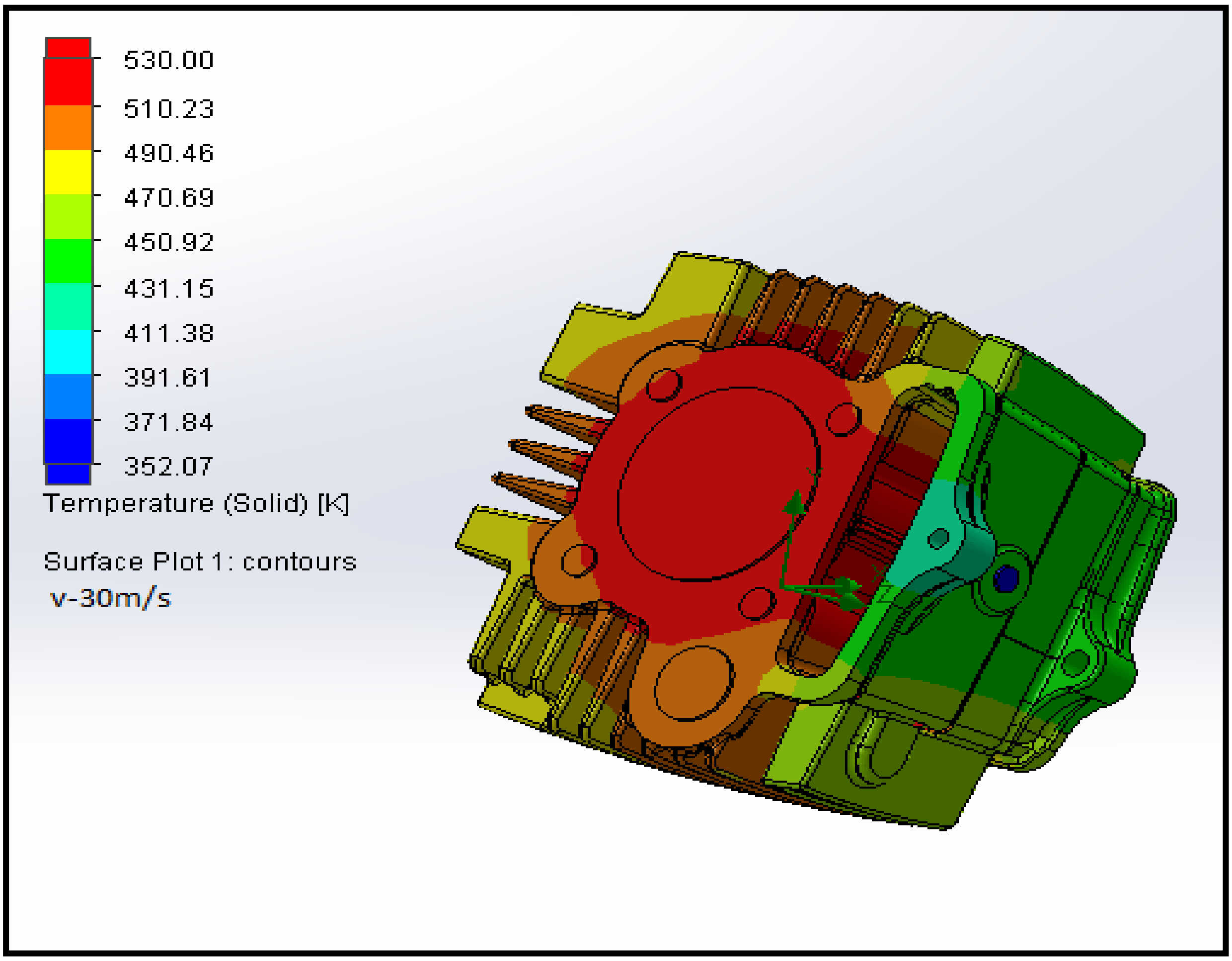


Figure 5.68, Aluminium Alloy engine cylinder block
Forced convection, V = 30 m/s, Base temperature = 530 K

5.11.2.5 Aluminium Alloy engine cylinder block, Forced convection, V = 40 m/s, Base temperature = 530 K

The forced convection condition is considered for the Aluminium Alloy engine cylinder block. So, the velocity is assumed to be equal to 40 m/s. The temperature of the block is considered as 530 K on the inner surface. There is unequal distribution of heat from inner surface of cylinder to the outer surface of fins and block as far as the results of CFD are concerned. Lowermost temperature on the outer surface is 352 K on the outer surface due to the exposure of the block to the air and this zone is increased than earlier iteration.

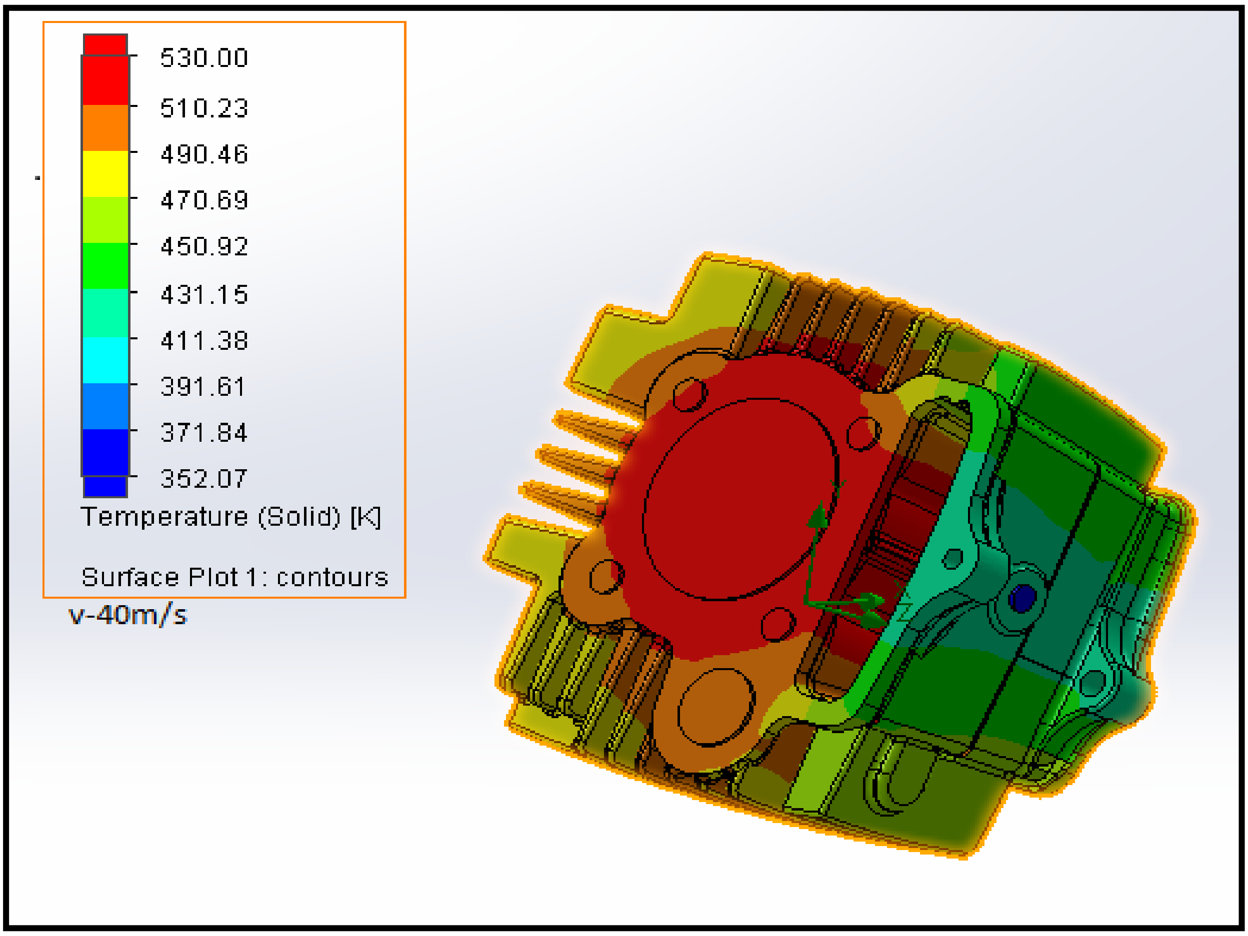


Figure 5.69, Aluminium Alloy engine cylinder block
Forced convection, V = 40 m/s, Base temperature = 530 K

5.11.2.6 Aluminium Alloy engine cylinder block, Forced convection, V = 50 m/s, Base temperature = 530 K

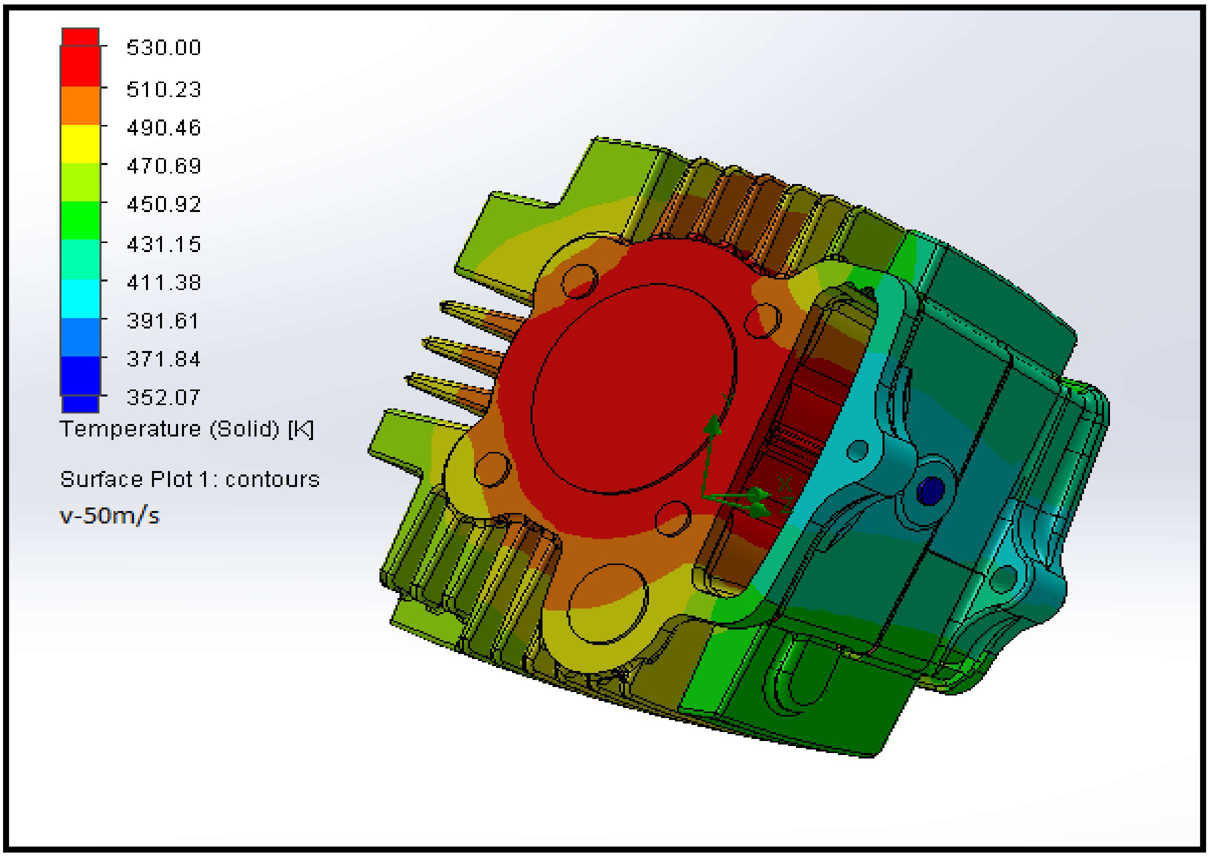


Figure 5.70, Aluminium Alloy engine cylinder block
Forced convection, V = 50 m/s, Base temperature = 530 K

The forced convection condition is considered for the Aluminium Alloy engine cylinder block. So, the velocity is assumed to be equal to 50 m/s. The temperature of the block is considered as 530 K on the inner surface. There is unequal distribution of heat from inner surface of cylinder to the outer surface of fins and block as far as the results of CFD are concerned. Lowermost temperature on the outer surface is 352 K on the outer surface due to the exposure of the block to the air and this zone is increased than earlier iteration.

5.11.2.7 Aluminium Alloy engine cylinder block, Forced convection, V = 60 m/s, Base temperature = 530 K

The forced convection condition is considered for the Aluminium Alloy engine cylinder block. So, the velocity is assumed to be equal to 60 m/s. The temperature of the block is considered as 530 K on the inner surface. There is unequal distribution of heat from inner surface of cylinder to the outer surface of fins and block as far as the results of CFD are concerned. Lowermost temperature on the outer surface is 352 K on the outer surface due to the exposure of the block to the air and this zone is increased than earlier iteration. There is maximum portion of the block at maximum temperature of the order of 450 K due to high thermal resistance of the Cast Iron. From the above study, the overall conclusion can be drawn as due to the high thermal resistance of the Cast Iron, the temperatures on the surface of the block are very low as heat is not dissipated properly. But for Aluminium Alloy, as thermal conductivity is high, temperatures on surface of the block are also high. So, there is better heat dissipation.

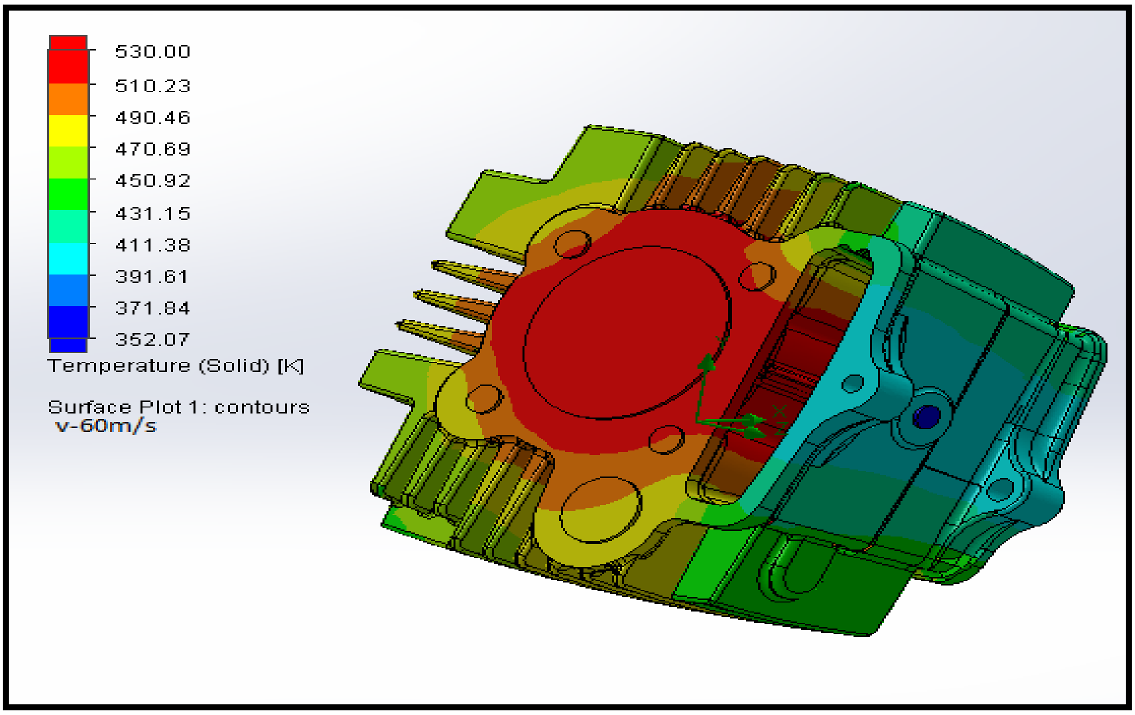


Figure 5.71, Aluminium Alloy engine cylinder block Forced convection, V = 60 m/s, Base temperature = 530 K

5.12 Conclusion of CFD Analysis

It is clear from the results of CFD that as the velocity increases, the temperature of the blocks goes on decreasing considerably so cooling is better in forced convection. With the change in the block material, the temperatures achieved were higher at the tip of the Aluminium alloy engine cylinder block in comparison with Cast Iron engine cylinder block due to higher value of thermal conductivity and heat dissipation was better.

5.13 Chapter summery

Entire manufacturing process and steps involved are described in this chapter right from beginning till the actual fitment of piston in the block. Chapter ends with CFD analysis of Cast Iron & Aluminium Alloy Engine cylinder blocks.

After conducting the market survey, it was decided to undertake the research work to manufacture the Aluminium Alloy engine cylinder block for the motorcycle engine and started the work. As the aim was to replace the old heavy Cast Iron engine cylinder block with light weight and thermally efficient material, the material was selected as LM25. After selection of suitable material of the block, it was necessary to manufacture the block. So, the patterns were prepared which is discussed in section 5.2 of this chapter. After preparation of patterns, the casting was produced by using LM25 as the material of the block. Then the casting was machined and then heat treated. So, that it was ready to fit on engine. Then its CFD analysis was done which is given in the later part of this chapter.

Chapter 6

EXPERIMENTAL DETAILS

6.1 Introduction

It was decided to carry out the experimental studies on use of Aluminium Alloy engine cylinder blocks in two wheelers. The most important component of the present research work was to manufacture the test cylinder block with the same size and shape like actually used by the manufacturer on their model ***'Splendor+'***, selected as the test model for this work.

As the cast cylinder block offers required characteristics discussed in section 1.4, so it was decided to manufacture the block by using casting technique. Initially the old block was scanned and 3D model was prepared. Then the patterns and core boxes were fabricated. Accordingly, LM25 was the material selected for the cylinder block, was used to produce the casting. Then it was machined on different machines like milling, drilling, etc. Finally, it was heat treated and by taking into account the standard size piston and piston rings, it was bored which was ready to use on the engine for testing purpose.

Other requirements of experimental studies are as per following:

[01] To provide firm base to mount the engine

[02] To provide necessary instrumentation to carry out heat transfer calculations

[03] To provide necessary instrumentation to measure the torque produced by the engine

[04] To provide suitable arrangement of water for Calorimeter

[05] To provide suitable arrangement to measure air and fuel consumption

By taking into consideration all the points given above, the experimental set up was fabricated and prepared which is discussed in the following sections.

6.2 The Experimental Set-Up

Figure 6.1 [A], Photography of the Experimental Set-Up

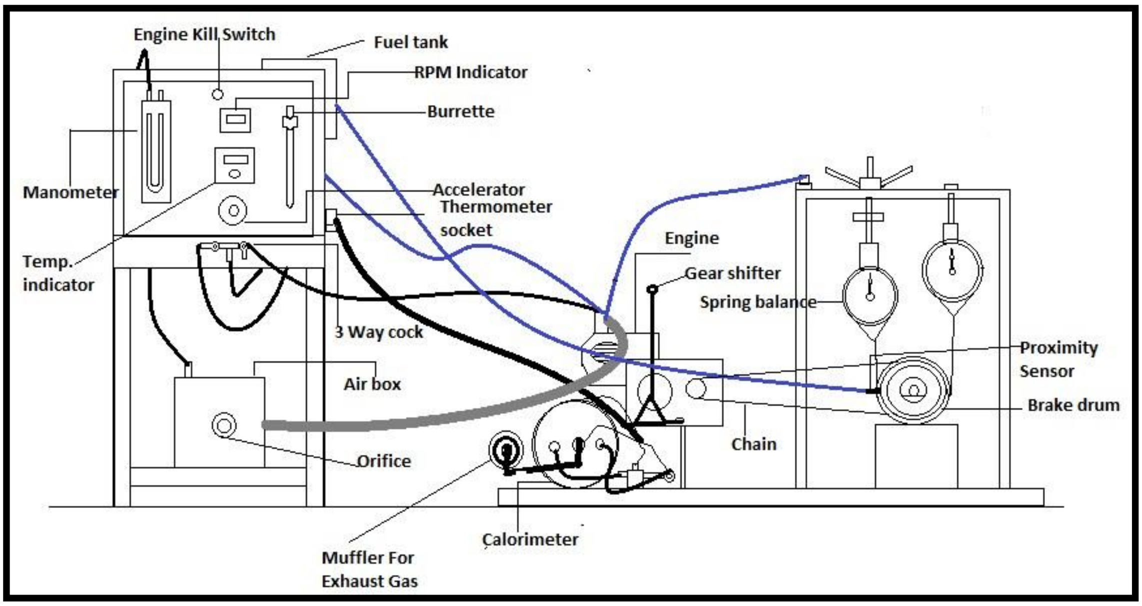


Figure 6.1 [B], Schematic Diagram of the Experimental Set-Up

The experimental set-up consists of main base frame which provides the support to hold the engine in its position. Frame also holds the rope brake dynamometer along with the calorimeter. Other part of experimental set-up holds the control panel with necessary instrumentation to measure temperatures, speed, fuel consumption and pressure difference of air entering the engine and atmosphere. These are elaborated in the paragraphs given below.

6.2.1 Base Frame

A ‘C’ sectioned frame is fabricated in Steel by cutting and welding the section into various pieces and then by welding. The frame supports mainly the engine, rope brake dynamometer and the calorimeter along with the exhaust muffler. Its size is 800 mm X 1160 mm X 75 mm.

6.2.2 The Engine

The engine of ‘***Splendor +***’ by Hero Motocorp was selected for the present research work, it was necessary to know about the specifications of the engine which consists of number of strokes, type of fuel, cooling system, bore and stroke, compression ratio, maximum power and torque developed by the engine. The specifications were collected by referring the service and owner’s manual by the manufacturer which are given below. These specifications plays important role in design and development of the block as well as in different calculations in performance analysis of the engine.

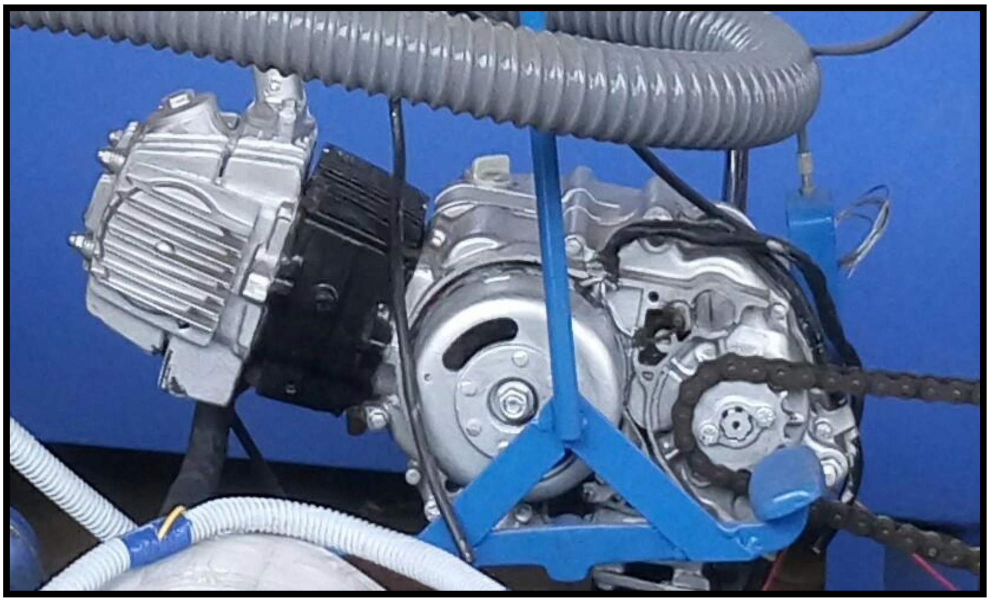


Figure 6.2, Photography of the engine with Cast Iron cylinder block

Table 6.1,
HERO MOTOCORP (former HERO HONDA) '*Splendor* +'
Engine Specifications

SR. NO.	PARTICULARS	DETAILS
01	Engine Type	Four stroke
02	Type of fuel	Gasoline
03	Cooling System	Air cooling
04	Number of cylinders	One
05	Bore (mm)	50.0
06	Stroke (mm)	49.5
07	Displacement (CC)	97.2 (5.93 cubic inches)
08	Compression Ratio (CR)	9.9:1
09	Maximum Power	7.5 bhp @ 8000 rpm
10	No of revolutions per cycle	2 (Two)
11	Maximum Torque	8.05 N.m @ 5000 rpm

Engine is main component in the present experimentation. So, the engine with the above specifications was selected which is shown in Figure No. 6.2. The engine produces maximum power of 7.5 bhp @ 8000 RPM and offers maximum torque of 8.05 N.m @ 5000 RPM.

6.2.3 Air Box

The volumetric efficiency of the engine is required to be calculated as a performance parameter. It is nothing but the ratio of actual quantity of air inhaled during suction stroke to the swept volume of the engine cylinder. The actual quantity of air taken by the engine can be measured by using the air box in the present experimentation. It is an empty chamber on the inlet of most combustion engines. It collects air from outside and feeds it to the intake hoses of cylinder. The air box allows the use of one air filter instead of many. The air box used over here is fabricated out of M.S. sheets with size 300 mm X 300 mm X 300 mm with a total volume of 0.027 m^3. All the plates are welded together to form the air box. On one side of it, an orifice with diameter of 15 mm is fitted through which atmospheric air enters in the air box. It was necessary to measure the pressure difference between surrounding and engine suction, a pressure tap is also provided at the top of the air box which is connected to the U tube manometer which gives the required pressure difference which can be used to calculate the actual mass flow rate of air.

Figure 6.3, Photography of Air Box

With the help of which both actual quantity of air entering the engine cylinder and Air to Fuel ratio can be calculated. This air box is fitted on the base frame as shown in the figure 6.3.

6.2.4 Rope Brake Dynamometer

Rope brake dynamometer is used in experimental setup. The power available at the crankshaft can be measured by using rope brake. A rope is wound around the drum fitted on output shaft of the engine. One end of the rope is connected to a spring balance and the other end to a loading device.

Figure 6.4, Photography of Rope Brake Dynamometer

The drum diameter is of 155 mm and is mounted on the frame with the help of two bearings as shown in figure. A frame is fabricated to hold the rope with diameter of 20 mm which is wound around the turned cast iron brake drum. The shaft on which the drum is mounted, other end is extended as overhang and on this the big sprocket is bolted with the help of a circular plate with the help of which the power generated by the engine can be transmitted to the drum for further measurement in the form of brake power. Two spring balances are used to measure the net load on the drum. Out of these two, the one on right hand side gives the 'S' reading while the balance on left hand gives the actual load applied on the drum given by 'W'. With the help of these two readings, the net load on the drum can be calculated by taking the difference as (W-S) in Kg. In order to adjust the net load, one spring balance is fitted to the loading arrangement as shown in figure. It consists of a handle which can be rotated so that the tension in the rope can be adjusted according to the requirement. In order to retain this load, a locking nut is also provided. Both the balances are held in proper position with the help of a frame. Power from engine sprocket is transmitted to the brake drum by using the original chain drive of the motorcycle.

6.2.5 Spring Balance

Two round spring balances are used on the dynamometer side. Out of these two, the one on right hand side gives the 'S' reading while the balance on left hand gives the actual load applied on the brake drum given by 'W'. With the help of these two readings, the net load on the brake drum can be calculated by taking the difference as (W-S) in Kg. The first spring balance is of capacity 50 Kg and another of 10 Kg. Their capacities, least counts and errors in measurement as declared by the manufacturer are given in the table.

Table 6.2,
Capacities of Spring Balances

Capacity	Max	10 kg	50 kg
----	Min	0.5 kg	2 kg
----	Error	50 g	200 g

Figure 6.5,
Photography of Spring Balance

6.2.6 Burette

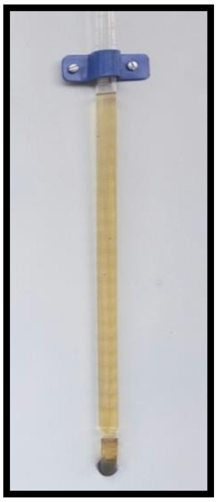


Figure 6.6, Photography of the Burette

A burette is a device used in engine testing to measure the time required for particular quantity of fuel consumed by the engine. There is need to find out the fuel consumption in terms of ‘Kg/s’ in calculation of the total amount of heat energy supplied to the engine cylinder in heat balance sheet. It is also required in calculation of Air to Fuel ratio. It is a glass tube with graduations in mililitres. Any quantity can be considered for measurement like 10 ml, 20 ml, etc. and time required for this much consumption when engine will be in running condition is measured. On dividing the quantity after conversion from ‘ml’ to ‘kg’, mass flow rate of the fuel can be calculated.

6.2.7 Calorimeter

The calorimeter used in the experimental set-up is a shell and coil type heat exchanger. It has horizontal shell through which the exhaust gases are flowing. In this shell, the copper coils are provided through which the water at ambient condition is circulated and supplied from the overhead tank. Here, four temperatures are required to be recorded. The temperatures which are to be measured are:

Temperature of water entering the calorimeter $= T_{wi} = T_1$

Temperature of water coming out of the calorimeter $= T_{wo} = T_2$

Temperature of hot exhaust gas entering the calorimeter $= T_{gi} = T_3$

Temperature of hot exhaust gas coming out of the calorimeter $= T_{go} = T_4$

For the measurement of these temperatures, thermocouples are used as shown in figure. Exhaust gas enters into the calorimeter and gives the heat to the coils. As the cold water flows through the coils, heat taken by the coils is transferred to the water. Then by using the heat balance technique of heat exchangers on both the sides i.e. hot and cold fluid side, exhaust gas carries the heat can be quantified which forms one of the way for expenditure of the total heat supplied by the fuel.

In construction, it has a cylindrical shell with diameter of 200 mm and length 275 mm. It is provided with the insulation of rope with a thickness of 16 mm and cushion type Heatlon insulation with a thickness of 10 mm on its outer surface to avoid the loss of heat to the surrounding. Both the sides of shell are closed by providing the end plates bolted to the shell flange insulated.

Figure 6.7, Photography of the Calorimeter

6.2.8 Tachometer

Figure 6.8, Photography of the
Digital Tachometer with probes

The tachometer used here is of digital and contact type instrument. During the measurement of speed, the probe is required to be brought in contact with the rotating shaft by making the tachometer ‘ON’. Immediately the speed of the shaft will be displayed on the display screen digitlly directly in terms of ‘RPM’.

6.2.9 Proximity Switch

The proximity switch is used in order to sense the brake drum shaft speed. It is held in position with the help of a bracket as shown in figure, senses the shaft speed and sends the signal to the display unit. After necessary conversion, it shows the shaft speed directly in terms of 'RPM'.

Figure 6.9, Photography of Proximity Switch

6.2.10 RPM Indicator

Figure 6.10, Photography of RPM Indicator

It is digital RPM Indicator used for speed measurement of dynamometer by using the proximity switch. Specifications of the RPM indicator are given below:

Table 6.3, Specifications of RPM Indicator

Make	SELEC (SELEC Controls Pvt. Ltd., Mumbai-400 710)
Model	RC5100A (V3.00.2.00)
Commercial Name	Rate Indicator
Supply Voltage	90 to 270 VAC/DC; AC:50/60 Hz
Display	4 digit, 7 segment LED, 0.3" height bright red LED
Working Range	Auto ranging (4.00 to 9999 RPM)
Accuracy of measurement	0.05 %
Sensor Supply	12 VDC (±10%), 30 mA
Input	(a) Voltage pulse : 3 to 30 VDC from proximity switches (PNP type) encoders or solid state devices (b) Potential free contact from limit switch relay or micro switch.
Operating Temperature	0-50 ^{0}C
Humidity	95 % RH
Housing	CE marked products : Flame retardant plastic
Weight	150 gms

6.2.11 Temperature Indicator

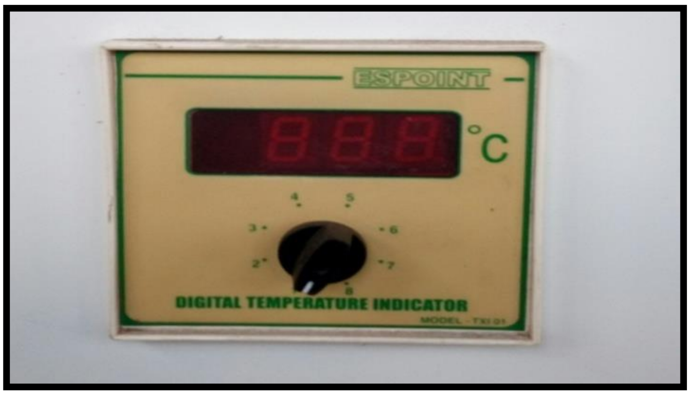


Figure 6.11, Photography of Temperature Indicator

During the experimentation, it was essential to record the temperatures accurately. The temperatures recorded with the help of the indicator are used to calculate the heat carried away by exhaust gases. For this purpose, a digital temperature indicator was used which gives the temperatures in degree centigrade at different points as mentioned earlier. In all eight temperatures can be measured by using this multichannel digital temperature indicator. But from the view point of the present experimentation, only four are significant. Hence, first four positions of the knob are used here to express the temperatures. Just by rotating the knob on positions 1 to 4, these temperatures can be displayed on the indicator display.

6.2.12 U-Tube Manometer

U-tube manometer is used in the experimentation to measure the difference in ambient pressure and suction pressure of the engine to calculate the mass flow rate of the air taken by the engine cylinder. Further this is used to calculate the volumetric efficiency and air to fuel ratio.

Figure 6.12, Photography of U-Tube Manometer

6.2.13 Three Way Cock

According to the need of experimentation, it was necessary to measure the fuel consumed by the engine. There are two purposes to do this, first to find out the total heat energy to be supplied to the engine cylinder and second is to calculate the Air to Fuel ratio. During the measurement of the time required for particular quantity of the fuel with the help of the burette, it is necessary to cut the supply of the fuel from the fuel tank. There are two valves, first on the left hand side as shown in the figure above which is connected to the fuel tank side with two positions 'OPEN' and 'CLOSED'. Similarly, the second valve on the right side of 'T' has two positions which is connected to the pipe which goes to the carburetor. One branch running in downward direction is connected to the burette with the help of plastic tubes. During the measurement of time required to consume particular quantity of petrol say 10 ml, the cock on fuel tank side is kept on 'CLOSED' position. So that the petrol present in the burette goes to engine and level drops. From the initial level to cover next 10 ml level, the time is measured with the help of stopwatch from which the mass flow rate of the fuel can be calculated in terms of 'Kg/s', further used to calculate the total heat energy supplied to the engine cylinder in heat balance sheet and Air to Fuel ratio.

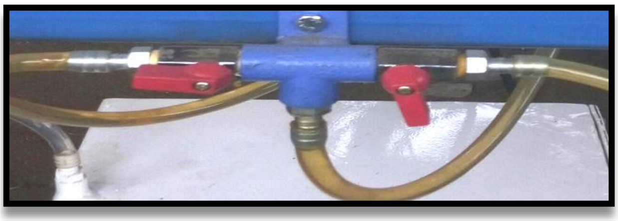


Figure 6.13, Photography of three way cock

6.2.14 Fuel Tank

Figure 6.14, Photography of the Fuel Tank

Here, Kirloskar make fuel tank is used to store the gasoline (petrol) which is to be supplied to the engine during the experimentation. The fuel tank with sufficient storage capacity of 05 (Five) litres is used to last the fuel for all the trials. It has the main cap to fill the fuel. Vent plug is also provided to escape the vapor formed during working. One way cock provides the fuel to the engine carburetor when it is kept on 'OPEN' position otherwise stops the fuel supply if kept on 'CLOSED' position.

6.2.15 Thermocouples

During the experimentation, it was necessary to record the temperatures of exhaust gas and water circulated through the calorimeter at inlet and outlet. These temperatures are required to calculate the heat carried away by the exhaust gas in order to prepare the heat balance sheet. For this purpose four thermocouples are used. They are of ‘K’ Chromel/Alumel type. Chromel has 90 % Nickel and 10 % Chromium while Alumel has 95 % Nickel, 2 % Manganese, 2 % Aluminium and 1 % Silicon. This combination generally will work in most application because they are Nickel based and have good corrosion resistance. The thermocouples are connected to the digital temperature indicator which converts the electrical signals into the temperature and displays them digitally. The temperatures which are to be measured are:

Temperature of water entering the calorimeter $= T_{wi} = T_1$

Temperature of water coming out of the calorimeter $= T_{wo} = T_2$

Temperature of hot exhaust gas entering the calorimeter $= T_{gi} = T_3$

Temperature of hot exhaust gas coming out of the calorimeter $= T_{go} = T_4$

Table 6.4, Calibration report for the temperature indicator
Input : Using Millivolt source as input

Input in mV	Temperature indicator ^oC
0.00	00.00
0.40	10.00
0.80	20.00
2.02	50.00
2.43	60.00
2.85	70.00
3.26	80.00
3.86	90.00
3.93	96.00
4.10	101.00
4.92	121.00
6.53	161.00
8.13	201.00

Table 6.5, Calibration report for the temperature indicator
'K' type Chromel/Alumel thermocouple using ice bath and water bath method, compared with standard temperature indicator

Water bath temperature in ^{o}C	Temperature indicator reading ^{o}C	Standard temperature indicator ^{o}C
30	30	30
40	40	40
50	49	50
60	61	61
70	70	71
80	81	80
90	90	89
94	95	96

6.2.16 Round Accelerator

A round knob is mounted on the front side of the control panel to operate the engine at required speeds. By rotating the knob in clockwise direction, the engine can be accelerated and vice versa. The knob is fitted with the cable and outer which goes to the carburetor throttle.

6.2.17 Auto Exhaust/Multi Gas Analyzer

Figure 6.15, Photography of 'NETEL' make 'Auto Exhaust / Multigas Analyzer'

In order to analyze the exhaust gas for CO, HC, CO_2 and O_2, 'NETEL AUTO EXHAUST/MULTIGAS ANALYSER', Model NPM-MGA 2004-15 which is CMVR approved and with approval certificate with No. ARAI/TA (4G) NETEL/NPM-MGA/2004-15, SR.NO.629 and manufactured during 2013 was and analyzed the exhaust gas samples.

6.3 Experimentation

The experimental set up developed in the present research work is described at beginning of this Chapter. In this part of the chapter, the scope of the experimental studies as are carried out in the present work is given in the section 6.3.1. Section 6.3.2 explains precautions and 6.3.3 gives the experimental procedure for conducting experiments in detail followed by the observation tables with observations recorded during the experimentation in section 6.4.1 and 6.4.2.

6.3.1 Scope of the experimental work

Number of trials were conducted by using the set up developed for the present research work to test the engine used on the motorcycle '***splendor+***'. The experimentation was conducted in two steps. First the engine with original cylinder block which is made up of Grey Cast Iron was tested and observations were recorded. Then after satisfactory completion of data collection, the old Cast Iron cylinder block was replaced with the newly produced all aluminium alloy cylinder block. Again the same procedure was repeated and data in the form of observations was again collected which is useful to draw some meaningful results of the experimentation.

6.3.2 Precautions during conducting the trials

[01] To check the oil level in engine with the help of dipstick and fuel level in fuel tank before starting the engine.

[02] To ensure the electric supply of temperature indicator, RPM indicator, etc. instruments.

[03] To ensure the water connection to the calorimeter with required mass flow rate.

[04] To start the blower with required discharge (volume flow rate) of air to the engine.

[05] To run the engine at least for ten minutes before starting the trial.

[06] The engine should not be started or stopped in loaded condition.

[07] Temperature indicator should not be switched 'ON' before starting the engine.

[08] Choke should be used while starting engine and once after getting started the engine, to keep the choke on 'OFF' position

[09] Electric connection should not be handled without the consultance with the expert.

[10] Loading / release of load on dynamometer should be gradual.

[11] The experimental setup should be handled with care.

6.3.3 Experimental procedure

[01] Calculated maximum load to be applied to the engine dynamometer.

[02] Checked the petrol in tank, supply of water in the calorimeter and engine oil.

[03] Ensured no load condition.

[04] Initially the engine was kept in running condition for some time.

[05] The loads were applied gradually by using loading arrangement and the engine was run at constant speed.

[06] Ensured the water is supplied to the brake drum and the calorimeter too.

[07] Loaded the engine in steps.

[08] Noted the observations both the spring balances, time required for circulation of particular quantity of water supplied to the calorimeter, time required for consumption of particular quantity of fuel, manometer reading, water inlet and outlet temperatures, exhaust gas inlet and outlet temperature from calorimeter, etc.

[09] Unloaded the engine by removing the load gradually to stop.

6.3.4 Standard data recorded during the experimentation

[01] Specific heat of water : 4.187 KJ/kg.K

[02] Calorific value for the fuel (Gasoline) : 43,890 KJ/kg

[03] Ambient temperature : 29 ^{0}C

[04] Barometric pressure (Pa) : 1.032 X 10^5 N/m^2

[05] Mass density of air (ρ_a) : [P_a/R X T_a] : 1.1424 kg/m^3

[06] Air Box orifice diameter : 15 mm

6.4 Observations recorded during the experimentation on the engine
6.4.1 with cast iron cylinder block

Table 6.6, Observations on engine with Cast Iron engine cylinder block

Particulars/Load(Kg)	20	27.7	34.5	39.5	49.5
[A] POWER SECTION :					
(a) Net load on dynamometer (W-S) in kg	20.0	27.7	34.5	39.5	49.5
(b) Speed (rpm)	500	500	500	500	500
[B] FUEL SECTION :					
Time for 5 ml of fuel consumption (t_f) in sec	25.94	20.11	17.64	16.34	13.85
[C] CALORIEMETER SECTION : (ºC)					
(a) Inlet water temperature (T_{wi})	28	29	29	29	29
(b) Outlet water temperature (T_{wo})	32	32	31	31	31
(c) Exhaust gas inlet temperature (T_{gi})	219	185	208	273	230
(e) Exhaust gas outlet temperature (T_{go})	143	124	138	146	149
(f) Time for 1 litre collection of water (sec)	26.5	26.5	26.5	26.5	26.5
[D] AIR BOX MANOMETER READING (CM OF WATER)	1.2	1.2	1.2	1.2	1.2

6.4.2 with Aluminium Alloy cylinder block

Table 6.7, Observations on engine with Aluminium Alloy engine cylinder block

Particulars/Load(Kg)	20	27.7	34.5	39.5	49.5
[A] POWER SECTION :					
(a) Net load on dynamometer (W-S) in kg	20.0	27.7	34.5	39.5	49.5
(b) Speed (rpm)	500	500	500	500	500
[B] FUEL SECTION :					
Time for 5 ml of fuel consumption (t_f) in sec	24.74	21.58	18.02	16.95	14.10
[C] CALORIEMETER SECTION : (ºC)					
(a) Inlet water temperature (T_{wi})	29	29	29	29	29
(b) Outlet water temperature (T_{wo})	33	32	32	31	31
(c) Exhaust gas inlet temperature (T_{gi})	185	199	201	215	230
(e) Exhaust gas outlet temperature (T_{go})	110	119	121	137	145
(f) Time for 1 litre collection of water (sec)	26.5	26.5	26.5	26.5	26.5
[D] AIR BOX MANOMETER READING (CM OF WATER)	1.2	1.2	1.2	1.2	1.2

6.5 Motor cycle speed and air velocity during running condition of the engine

Wind speed plays very important role in dissipating the heat from engine cooling system. As air cooled engine is a part of experimental work, it was essential to know the air velocity to which the engine is exposed during actual running condition. For this purpose, the anemometric survey was conducted by operating the motor cycle on the road. LUTRON make anemometer (Model AM - 4201) shown in Figure No. 6.16 capable to measure the air velocity in terms of km/hr, m/s, ft/min and knots is used to measure the air velocity for different vehicle speeds.. The data collected from the survey is presented in tabular form.

Table 6.8, Motor Cycle speed and air velocity during running condition of the motor cycle

Obs. No.	Motor cycle speed (km/hr)	Air velocity (m/s)	Working zone
1	05	00.90	----
2	10	03.70	----
3	15	07.50	----
4	20	08.50	----
5	25	09.80	----
6	30	13.70	ECONOMY
7	35	20.50	ECONOMY
8	40	22.70	ECONOMY
9	45	23.70	ECONOMY
10	50	25.90	ECONOMY
11	55	27.20	----
12	60	31.40	----
13	65	32.30	----
14	70	32.70	----

From the collected data given in this table, as the motor cycle speed increases, air velocity increases. This data is required in CFD analysis of the engine cylinder block under consideration.

Figure 6.16, Photography of 'LUTRON' make Anemometer (Model AM-4201)

6.6 Outdoor/Road mileage test of the engine

As per the requirement of the present research work, it was necessary to check the mileage by conducting the outdoor/road mileage test of the engine by fitting both the engine cylinder blocks. The test was conducted on the test bike by fitting engine with both the blocks, the results are given below.

'PENTA' make mileage checker gauge of 300 ml capacity shown in Figure NO. 6.17 was used to obtain the distance covered by the test bike with certain quantity of gasoline fuel. The operating for the mileage checker gauge was as per following:

[01] Filled the petrol in the mileage checker gauge to the required level.
[02] Disconnected supply hose from the vehicle fuel tank to the carburettor of the test bike.
[03] Connected the mileage checker gauge outlet hose to the carburettor of the test bike.
[04] Opened the tap for flow of petrol.
[05] Suspended the mileage checker on the handle bar.
[06] Ridden till consumption of 50 ml petrol and recorded the distance covered from odometer.
[07] Calculated the average.

6.6.1 With Cast Iron engine cylinder block

Table 6.9, Outdoor/Road Mileage Test by fitting the engine with Cast Iron Engine Cylinder Block

Observation No.	Quantity of fuel (ml)	Distance covered (kms)	Per litre mileage (kmpl)	Average (kmpl)
1	50	3.85	77	----
2	50	3.75	75	75
3	50	3.65	73	----

6.6.2 With Aluminium Alloy engine cylinder block

Table 6.10, Outdoor/Road Mileage Test by fitting the engine with Aluminium Alloy Engine cylinder block

Observation No.	Quantity of fuel (ml)	Distance covered (kms)	Per litre mileage (kmpl)	Average (kmpl)
1	50	4.4	88.00	----
2	50	4.2	84.00	84.66
3	50	4.1	82.00	----

Figure 6.17, Photography of 'PENTA' make mileage checker gauge

Figure 6.18, Photography of test bike fitted with 'PENTA' make mileage checker gauge

6.7 'Pollution Under Control' (PUC) testing of the engine

PUC is an abbreviation of "Pollution Under Control". It is a certificate that is given to the vehicle after having passes a PUC Test. The certificate confirms that the emissions passed from the vehicles meet the pollution control standards. Under the Central Motor Vehicle Rule, 1989, a PUC certificate is a mandatory document requirement for a vehicle. Validity of PUC for new vehicle is one year from the date of registration.

The PUC is an authorized certification granted to vehicles that successfully pass the regulated PUC test. Since the validity of the PUC certificate is only for six months, every vehicle owner needs to get their vehicle tested twice in a year.

Any vehicle which is operational on Indian roads is required to carry a valid PUC certification. The PUC machine checks the sample of exhaust gas for CO, HC, CO_2 & O_2 levels.

As the present work was related with the use of engine cylinder developed on motorcycle application, it was necessary to check the engine from the view point of PUC which was necessary to conduct the road test. So, the engine by using Cast Iron engine cylinder first

& then by fitting Aluminium Alloy engine cylinder block was mounted on the test vehicle (bike) and it was tested by using NETEL make PUC testing machine at M/S Pankaj Motors, Sangli. The observations were recorded during the testing which are given below.

Table 6.11, PUC test observations

Sr. No.	Net Load (kg)	Pollutants in exhaust gas sample of									
		Engine with C.I. block					Engine with A.A. block				
		CO (%)	HC (PPM)	CO_2 (%)	O_2 (%)	NO_X (%)	CO (%)	HC (PPM)	CO_2 (%)	O_2 (%)	NO_X (%)
1	20.0	12.26	223	7.40	0.81	1	12.56	234	7.60	1.65	0
2	27.7	14.55	253	6.00	0.77	0	10.78	249	7.10	2.02	0
3	34.5	14.16	284	6.20	0.78	1	12.88	273	5.90	1.88	0
2	39.5	14.16	318	6.20	0.80	0	10.75	297	4.40	0.92	0
2	49.5	11.31	270	4.50	0.86	0	06.38	303	2.20	0.95	0

6.8 Computer Program to calculate the performance parameters

```
#include<stdio.h>
main()
{
 float torque,w,s,R,Drum_dia,Rope_dia,N,BP,BP1,IP,nm;
 float mf,tf,BSFC;
 float hf,cv=43890,mw=0.03773,fp=1.1,hbp;
 float nbth,cpw;
 float t1,t2,t3,t4,heg,meg,meg_cpeg,cpeg;
 printf("Enter Diameter of Drum:");
 scanf("%f",&Drum_dia);
 printf("Enter Diameter of Rope:");
 scanf("%f",&Rope_dia);
 R=(Drum_dia+Rope_dia)/2;
 printf("Radius of Drum : %f \n",R);
 printf("Enter W:");
 scanf("%f",&w);
 printf("Enter s:");
 scanf("%f",&s);
 torque=(w-s)*9.81*R;
 printf("Torque : %f \n",torque);
 printf("Enter speed in rpm :");
 scanf("%f",&N);
 BP=(2*3.1415*N*torque)/(60000);
 printf("Brake Power : %f \n",BP);
 BP1=BP/0.9;
 printf("Actual Brake Power : %f \n",BP1);
```

```
printf("Enter time for fuel consumption :",tf);
scanf("%f",&tf);
mf=(5/tf)*(0.7/1000);
printf("Mass of Fuel : %f \n",mf);
BSFC=(mf/BP1);
printf("Brake specific fuel consumption :%f Kg/Kw.s \n",BSFC);
hf=(mf*cv);
printf("Heat supplied by fuel : %f Kw \n",hf);
hbp=BP1;
printf("Heat equivalent to BP : %f \n",hbp);
nbth=(hbp/hf)*100;
printf("Brake thermal efficiency : %f \n",nbth);
printf("Enter Water inlet temperature :");
scanf("%f",&t1);
printf("Enter Water outlet temperature :");
scanf("%f",&t2);
printf("Enter Exhuast gas inlet temperature :");
scanf("%f",&t3);
printf("Enter Exhuast gas outlet temperature :");
scanf("%f",&t4);
meg_cpeg=(mw*4.187*(t2-t1))/(t3-t4);
printf("meg*cpeg:%f \n",meg_cpeg);;
heg=meg_cpeg*(t3-t4);
printf("heg: %f \n",heg);
IP=(BP1+fp);
nm=(BP1/IP);
printf("Mechanical efficiency :  %f \n",nm);
}
```

6.9 Sample calculation to calculate the performance parameters of the engine fitted with Cast Iron engine cylinder block

[01] Torque (T)

$T = (W\text{-}S)\times 9.81\times R_b$ ………. (6.1)

Where,
(W-S) = Net load on dynamometer in Kg,
R_b = Mean radius of drum in meter 'm' = D+d/2=0.158+0.02/2=0.089 m

$T = 20\times 9.81\times 0.089$

T = 17.4618 N.m

[02] Brake Power (Bp)

$BP = \frac{2\pi N\times(w-s)\times Rb}{60\times 10\text{^}3}$ ………. (6.2)

BP=[2 X Π X 500 X 17.4618] / [60,000]

BP = 0.91429 KW

[03] Actual Brake Power (Bp_1)

BP_1 = BP/0.90 ……….. (6.3)

= 0.91429/0.90

= 1.0158 KW

[04] Fuel Consumption (m_f)

m_f = h_w/t_f×(0.7/1000) ……….. (6.4)

m_f = 5/25.94×(0.7/1000)

= 1.3492×10^-4 kg/s

[05] Brake Specific Fuel Consumption (BSFC)

BSFC= m_f/BP_1 ………. (6.5)

= 1.3492×10^-4/1.0158

= 1.3282×10^-^{3} kg/KW.s

[06] Heat Supplied By Fuel (HF)

HF= m_f × CV ………. (6.6)

= 1.3492×10^-4×43890

= 5.9216 KW

[07] Heat equivalent to BP (HBP)

HBP = BP_1 ………. (6.7)

= 1.0158 KW

[08] Brake Thermal Efficiency (η_{bth})

η_{bth} = (HBP/HF)×100 ………. (6.8)

$= (1.0158 / 5.9216) \times 100$

$= 17.15\%$

[09] Air Density (ρ_a)

$\rho_a = 1\times10^5/R \times (273+Ta)$ ………. (6.9)

$= 1\times10^5/287 \times (273+29)$

$= 1.1424\ kg/m^3$

[10] Mass flow rate of Air (m_a)

$m_a = cd \times (\pi/4\times d_o^2) \times \sqrt{2}g\times\rho_a\times\rho_w\times h_a$ ………. (6.10)

cd = Coefficient of discharge = 0.64

$g = 9.81\ m/s^2$

d_o = Orifice Diameter = 15 mm

$m_a = 0.64\times\{(\pi/4\times(0.015)^2\}\times(\sqrt{2}\times9.81\times1.14\times1000\times0.012)\times3600$

$m_a = 1.8528\times10^3$ Kg/s

[11] Air to Fuel Ratio (A/F)

$m_a/m_f = 1.8528 \times10^3/1.3492 \times 10^{-4}$ ………. (6.11)

$= 13.7331$

[12] Fuel to Air Ratio (F/A)

$m_f/m_a = 1.3492 \times 10^{-4}/1.8528 \times 10^3$ ………. (6.12)

$= 0.07281$

[13] Heat carried away by exhaust gas (H_{eg})

$H_{eg} = m_{eg} \times Cp_g \times (T_{gi}-T_{go})$ in KJ/hr ………. (6.13)

$m_{eg}\times Cp_g = [m_w \times Cp_w \times (T_{wo}-T_{wi})]/(T_{gi}-T_{go})$

Mass of water (m_w) for 1 litre = $1/t_w$

t_w = time for 1 litre water collection in seconds.

$m_w = 1/26.5$

$m_w = 0.03773$ kg/s

I. $(m_{eg} \times C_{pg}) = [0.03773 \times 4.18 \times (32-28)]/(219-143)$

$= 8.3018 \times 10^{-3}$ KW/hr

II. $H_{eg} = 8.3018 \times 10^{-3} \times (219-143)$

$= 0.630$ KW

[14] Mechanical Efficiency

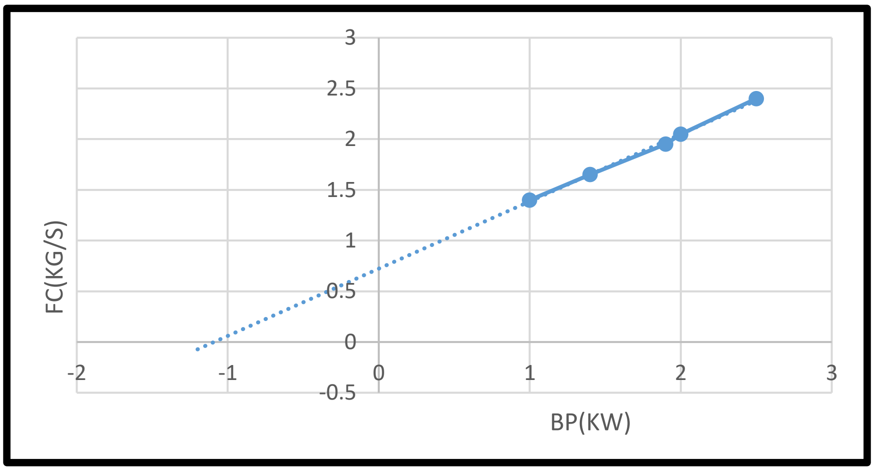


Figure 6.19, Willans line diagram for Friction Power for engine block

From Willan's line graph, Figure 6.19 shown above, FP=1.1 KW

IP=BP+FP=1.0158+1.1=2.1158 KW .... (6.14)

η_m= (BP/IP) X 100 = (1.0158/2.1158) X 100 = 48.01 %

Table 6.12, Heat Balance Sheet

Heat credit	KW	%	Heat debit	KW	%
Heat supplied by fuel	5.9216	100	**[01] Brake power**	1.0158	(1.0158/5.9216)×100 =17.15%
			[02] Heat carried away by exhaust gases	0.630	(0.630/5.9216)×100 =11.72%
			[03] Unaccounted heat	5.9216-(1.0158+0.630) =4.2758	(4.2758/5.9216)×100 =72.21%
Total	5.9216	100	**Total**	5.9216	100

Table 6.13, Result Sheet

Particulars/Load(Kg)	20	27.7	34.5	39.5	49.5
[01] Brake power (KW)	1.0158	1.4094	1.8446	2.0063	2.5016
[02] Brake thermal efficiency (%)	17.15	18.45	21.51	21.34	22.55
[03] BSFC (kg/kw.hr)	1.3282×10^{-3}	$1.2345x10^{-3}$	$1.0756x10^{-3}$	$1.0675x10^{-3}$	$1.0107x10^{-3}$
[04]Mechanical Efficiency (%)	48.01	48.61	62.64	64.60	69.45

6.10 Chapter summery

The work on **"**Experimental investigation of Aluminium Alloy Engine Cylinder Block in Two Wheelers" requires the experimental set-up to conduct the experimentation which is discussed in paragraphs at the beginning of this chapter. The main components are base frame, engine, air box, dynamometer, spring balance, burette, calorimeter, tachometer, proximity switch, RPM indicator, temperature indicator, U-Tube manometer, three way cock, fuel tank, thermocouples and accelerator.

This chapter also explains the experimentation of the present research work. It gives the scope of the experimental work which consists of the parameter like the material of the engine blocks. All the observations required to evaluate the performance parameters are recorded during the experimentation for both the blocks separately. All the observations for indoor and outdoor test which were recorded are presented in tabular form suitable for further analysis. The later part of the chapter consists of the results of the experimentation along with sample calculation.

Chapter 7

THE RESULTS AND DISCUSSION

7.1 Introduction

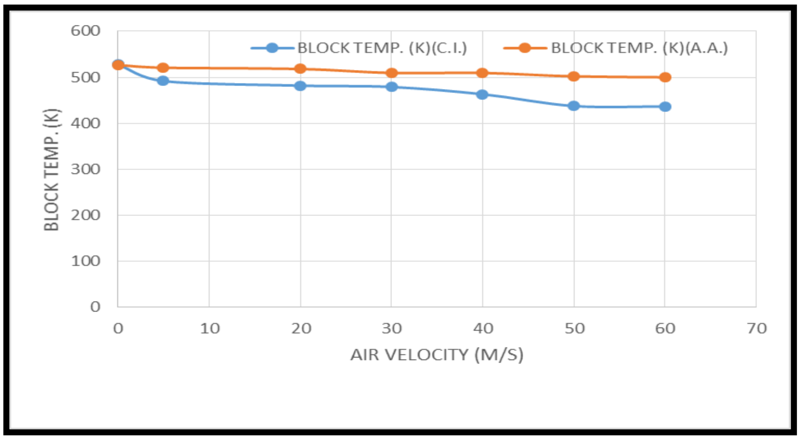
On the basis of the observations recorded during the experimentation, various governing and performance parameters of the engine with natural and forced convection are calculated. The results are presented in tabular form in table

7.2 Results of CFD analysis

The results of the CFD analysis are presented here in tabular form and also discussed from view point of the changes in temperatures due to the type of convection based on velocities at which the engine is operated.

Table 7.1, Results of CFD analysis of Cast Iron and Aluminium Alloy engine cylinder blocks

Obs. No.	Air Velocity (M/S)	Cast Iron Engine Cylinder Block Temperatures (K)				Aluminium Alloy Engine Cylinder Block Temperatures (K)			
		A	B	C	Mean	A	B	C	Mean
1	00.00	529.32	527.15	527.72	528.07	525.13	526.74	528.01	526.62
2	05.00	483.75	491.73	498.09	491.99	518.90	521.06	522.74	520.90
3	20.00	471.39	483.82	490.77	481.99	515.08	518.63	520.60	518.10
4	30.00	466.84	481.59	488.75	479.02	503.92	510.57	513.86	509.53
5	40.00	450.97	464.92	474.03	463.31	505.27	509.97	513.37	509.53
6	50.00	427.16	437.06	448.77	437.66	500.36	500.56	505.44	502.12
7	60.00	425.51	436.28	447.97	436.59	494.92	500.14	505.10	500.05



CI-Cast Iron AA-Aluminium Alloy

Figure 7.1, Results of CFD Analysis

Effect of fin material

To analyse the effect of material, Cast Iron and Aluminium Alloy are used as the material of blocks for best heat dissipation considering both in Natural and forced convection. Two different fin materials were simulated under same operating conditions i.e. 530 K as the temperature of cylinder inner wall and wind velocities from 0-60 m/s.

Figure 7.1 shows the temperature profiles for both the materials. From temperature distributions, it is clear that temperature achieved with Aluminium Alloy is greater than the temperatures achieved with Cast Iron. As the thermal conduction of Aluminium Alloy is greater than Cast Iron, it is obvious that more heat would be conducted hence temperatures on Aluminium Alloy block fins are higher.

Effect of air velocity

The heat dissipation can take place by both the types of convection i.e. natural and forced. As the engine which is selected for the present experimental work is from an automobile, it may face both the types of convection given above. When vehicle is stationary, the air velocity is equal to zero. So, convection heat transfer will be minimum.

If the vehicle is brought into working, the velocity increases. Hence, forced convection becomes significant and hence temperature drops as more heat is carried out. Initially, the block temperature assumed is same but as air velocity increases, block temperature decreases.

The study reveals that the fin material with the greatest effective cooling is the Aluminium Alloy. Hence, it is selected for the present study.

7.3 Results of the Experimentation

The data from the experiment were compared with the CFD data for the validation. From the results of CFD that as the velocity increases, the temperature of the blocks goes on decreasing considerably so cooling is better in forced convection. With the change in the block material, the temperatures achieved were higher at the tip of the Aluminium alloy engine cylinder block in comparison with Cast Iron engine cylinder block due to higher value of thermal conductivity. The values like, brake power (KW), Brake thermal efficiency (%) and Brake specific fuel consumption (BSFC) (kg/kw.hr) are calculated on the basis of the observations recorded during the experimentation and calculated for both the engine cylinder blocks. The values match each other.

7.3.1 The performance test on various parameters of the Engine fitted with Cast Iron Engine Cylinder Block

Table 7.2, Results of the experimentation on engine with Cast Iron engine cylinder block

Particulars/Net load(Kg)	20	27.7	34.5	39.5	49.5
Brake power (KW)	1.0158	1.4094	1.8446	2.0063	2.5016
Indicated power (KW)	2.1158	2.8994	2.9447	3.1057	3.6020
Brake thermal efficiency (%)	17.15	18.45	21.51	21.34	22.55
BSFC (kg/kw.hr)	1.3282×10^{-3}	$1.2345x10^{-3}$	$1.0756x10^{-3}$	$1.0675x10^{-3}$	$1.0107x10^{-3}$
Mechanical Efficiency (%)	48.01	48.61	62.64	64.60	69.45

7.3.2 The performance test on various parameters of the engine fitted with Aluminium Alloy engine cylinder block

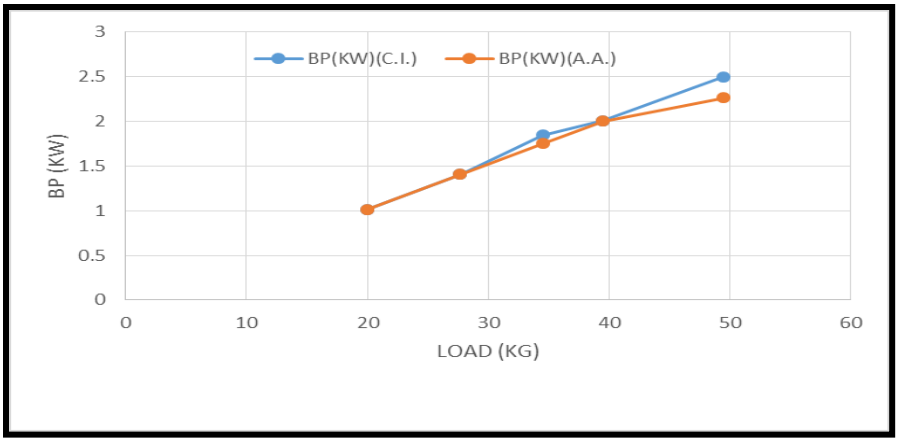
Table 7.3, Results of the experimentation on engine with Aluminium Alloy engine cylinder block

Particular/Net load(kg)	20	27.7	34.5	39.5	49.5
Brake power (KW)	1.0158	1.4066	1.7522	2.0058	2.2624
Indicated power (KW)	2.1158	2.5068	2.8523	3.1059	3.2529
Brake thermal efficiency (%)	17.15	19.76	20.55	22.13	23.07
BSFC (kg/kw.hr)	$1.3926X10^{-3}$	$1.1524X10^{-3}$	$1.1084X10^{-3}$	$1.0294X10^{-3}$	$0.9874X10^{-3}$
Mechanical Efficiency (%)	48.01	56.11	61.43	64.58	69.55

7.3.3 The performance curves for the engine fitted with Cast Iron and Aluminium Alloy engine cylinder block

The performance curves for the parameters like brake power, brake thermal efficiency, brake specific fuel consumption and mechanical efficiency are obtained by using the results presented in Table No.7.2 from previous session and are given below.

7.3.3.1 Load (kg) Vs Brake Power (KW)



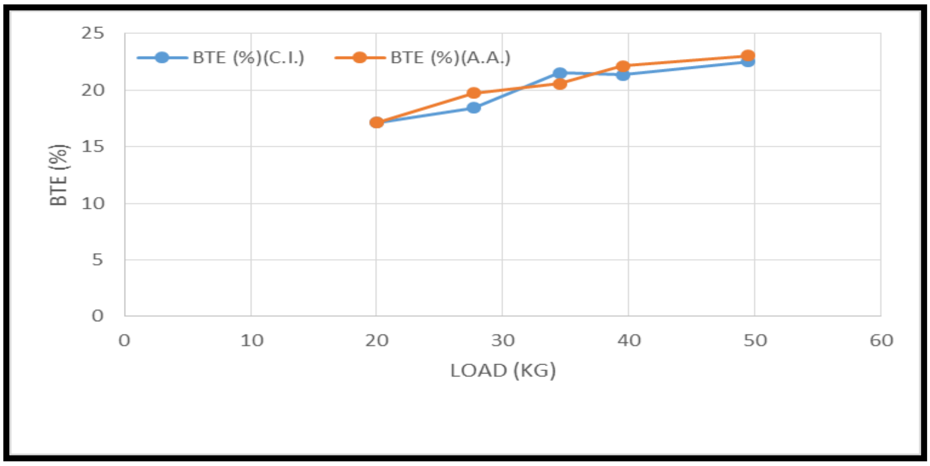
CI-Cast Iron AA-Aluminium Alloy

Figure 7.2, Comparison of brake power delivered by engine with Cast Iron and Aluminium Alloy engine cylinder blocks

From the standard operating characteristics for variable speed testing of S.I. Engines, it is clear that as load increases, obviously there will be increase in BP. When compared with the data from experimentation, it is found that, curves for both the engines are following the standard performance curves. At higher loads, slight drop in BP is found as shown in figure 7.2. This may be due to the condition of old Cast Iron block which was already in use but Aluminium Alloy block is newly developed and brought into working.

As the bore and stroke are unchanged for both the blocks, therefore no much change in the output power of the engine was expected.

7.3.3.2 Load (kg) Vs Brake thermal efficiency (%)



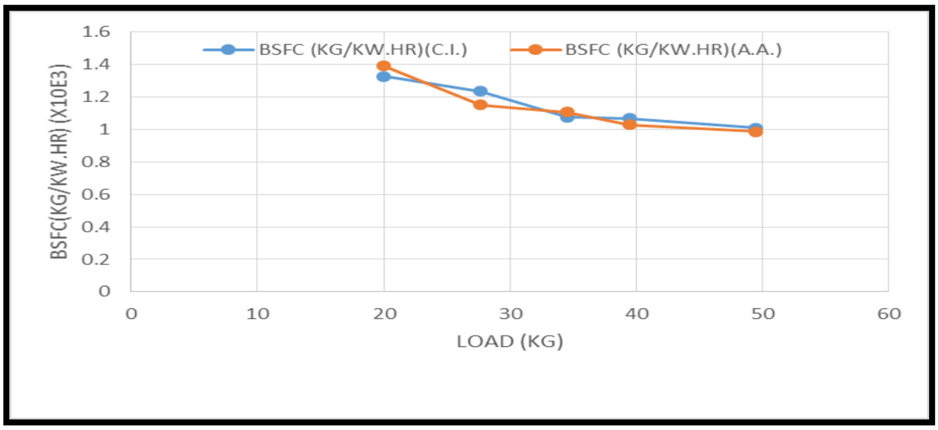
CI-Cast Iron AA-Aluminium Alloy

Figure 7.3, Comparison of brake thermal efficiency by engine with Cast Iron and Aluminium Alloy engine cylinder blocks

As brake thermal efficiency also depends upon BP of the engine, the engine with both the blocks are behaving in similar fashion. As load increases, increase in brake thermal efficiency is found as shown in figure 7.3 for both the blocks. Brake thermal efficiency of Aluminium engine is slightly greater for some loads, which may be due to condition of the cylinder walls as well as the operating conditions of the engine.

As the engine with both the blocks is tested at same operating conditions, so there should not be change in brake thermal power of the engine.

7.3.3.3 Load (kg) Vs Brake specific fuel consumption (kg/KWh)

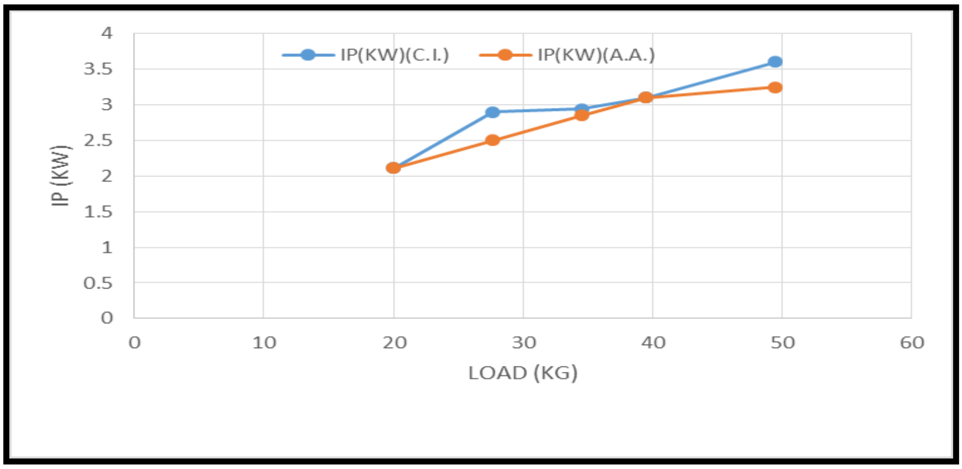


CI-Cast Iron AA-Aluminium Alloy

Figure 7.4, Comparison of brake specific fuel consumption by engine with Cast Iron and Aluminium Alloy engine cylinder blocks

As the load increases, BP increases and due to this, BSFC decreases as far as standard performance curves are concerned. Here also, same type of response is exhibited by engine with both the blocks. From the performance curve actually obtained over here shown in figure 7.4, it is clear that no much deviation is found over here. All values of BSFC for both the blocks are overlapping each other. As there is no any change in any design parameters of the engine.

7.3.3.4 Load (kg) Vs Indicated Power (KW)



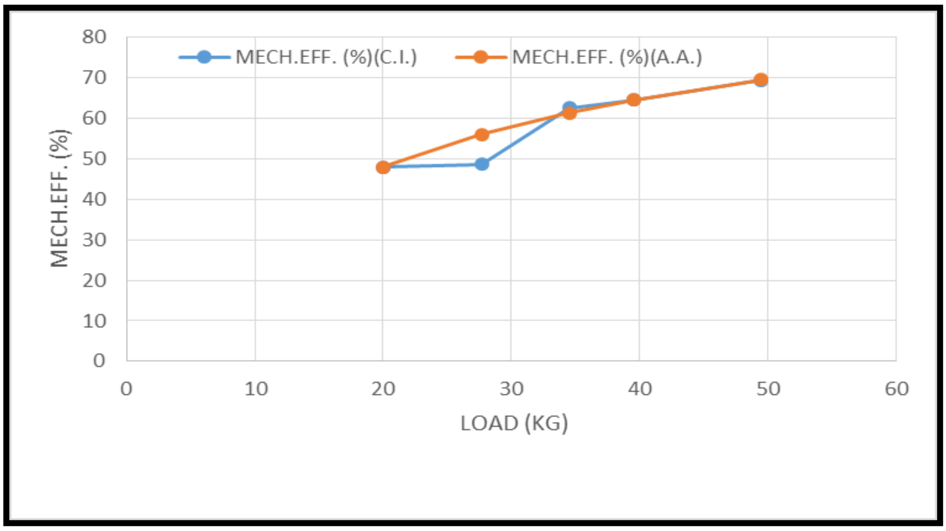
CI-Cast Iron AA-Aluminium Alloy

Figure 7.5, Comparison of indicated power by engine with Cast Iron and Aluminium Alloy engine cylinder blocks

Indicated power of the engine also increases with load in proportion of the BP as generally friction power remains constant for all the loads. Very smooth power delivery was observed from the graph for engine with Aluminium Alloy in comparison with engine with CI blocks as the cylinder block was fresh and newly brought into working.

As the load increases, the indicated power also increases. Engine by using both the blocks is exhibiting almost same outputs.

7.3.3.5 Load (kg) Vs Mechanical efficiency (%)



CI-Cast Iron AA-Aluminium Alloy

Figure 7.6, Comparison of mechanical efficiency by engine with Cast Iron and Aluminium Alloy engine cylinder blocks

Standard characteristics curves for load and mechanical efficiency reveals that as the load increases indicated and brake power also increases. From the results obtained and presented in figure 7.6, it is clear that mechanical efficiency for many load values remains fairly constant as there is overlapping of values for both the blocks. This happens due to the reason that both the engines are having with same design parameters and operated at almost same environmental conditions.

7.3.4 Overall Discussion from the performance curves

As there was no any modification in dimensions i.e. bore and stroke of both the engine cylinder blocks, it was expected that engine with both the blocks will perform in a similar manner. As far as the results of the experimentation along with the graphs is concerned, it is true that engine with both the blocks exhibits almost same characteristics and totally satisfies the expectations.

7.4 Results of the Outdoor/Road Mileage Test of the engine

The **Outdoor/Road** test on bike gave a mileage of 75.00 kmpl with the Cast Iron cylinder block, and with the Aluminium engine cylinder block on the engine resulted 84.66 kmpl. The percentage increase in the mileage based on the data collected and presented in section 6.7 can be calculated as given below:

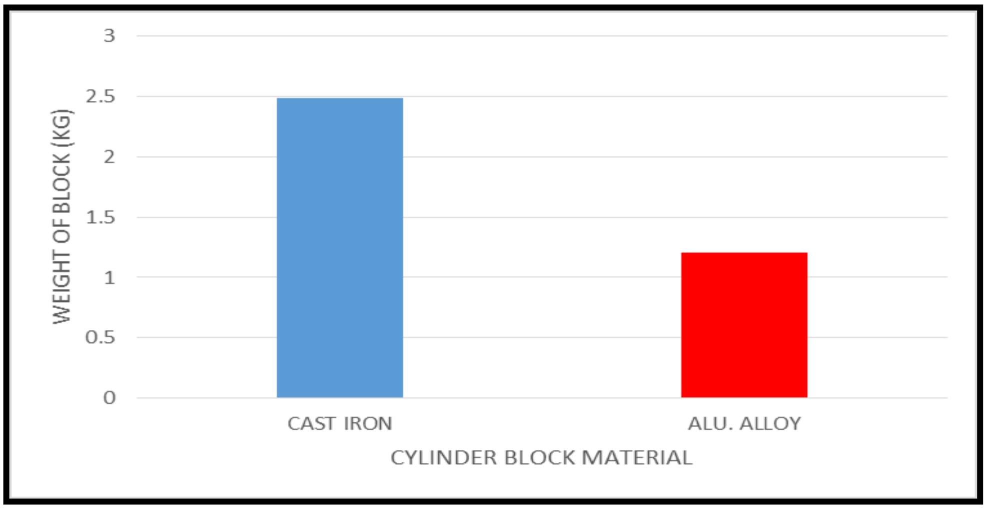
% age increase in mileage = [(84.66-75.00)/84.66] X 100 = 11.41 % more mileage

From the % age increase in mileage by 11.41 %, it is clear that the present work is successful and achieved the goal of saving of the fuel, i.e. by increasing the mileage with the use of low weight Aluminium alloy engine cylinder block in two wheelers which is developed. This is possible only due to 51.52% weight reduction of the Aluminium Alloy engine cylinder block which is elaborated in the next section.

7.5 Percent reduction on weight of Aluminium Alloy engine cylinder block in comparison with Grey Cast Iron block

Table 7.4, Percentage reduction in weight of Aluminium Alloy engine cylinder block

Sr. No.	Type of block	Initial weight (kg)	Final weight (kg)	% age reduction In weight
1	Original Cast Iron Block	2.492	----	----
2	Casting by using LM25 (Unfinished)	----	1.771	28.9325
3	Casting by using LM25 (Finished and ready to install on engine)	----	1.208	51.5248



CI-Cast Iron AA-Aluminium Alloy

Figure 7.7, Comparison of weights of Cast Iron and Aluminium Alloy engine cylinder blocks

% Reduction in weight of casting can be calculated as:

% age reduction in weight of unfinished casting = [(2.492-1.771)/2.492] X 100 = 28.9325 %

% age reduction in weight of finished & ready casting=[(2.492-1.208)/2.492]X100

= 51.5248 %

There is the total weight reduction of 51.5248 %

Hence, it can be said that the newly manufactured Aluminium alloy engine cylinder block is quiet lighter

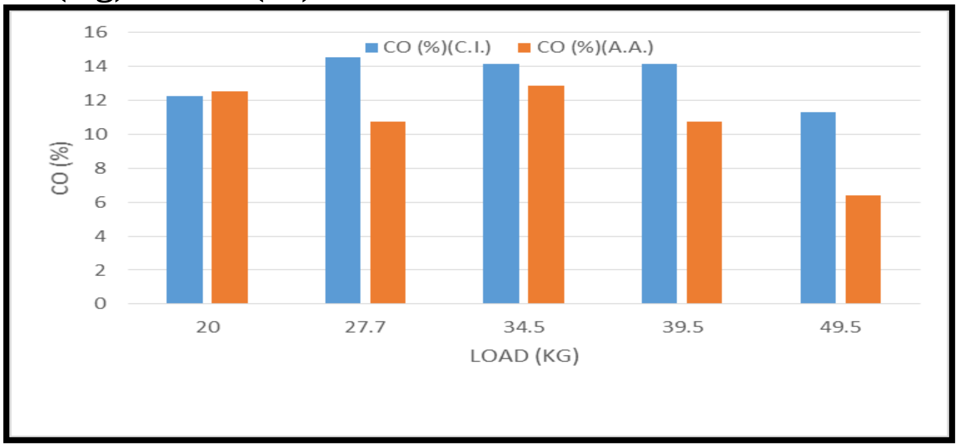
7.6 Results of PUC test

After analysing the exhaust gas from engine at different loads, the some observations of the PUC Test are obtained which are given in tabular form. The average values are used for the comparison of pollutants from the engine fitted with Cast Iron and Aluminium Alloy engine cylinder blocks.

Table 7.5, PUC test results

Sr No	Net Load (kg)	Pollutants In Exhaust Gas Sample Of									
		Engine With C.I. Block					Engine With A.A. Block				
		CO (%)	HC (PPM)	CO_2 (%)	O_2 (%)	NO_X (%)	CO (%)	HC (PPM)	CO_2 (%)	O_2 (%)	NO_X (%)
1	20.0	12.26	223	7.40	0.81	1	12.56	234	7.60	1.65	0
2	27.7	14.55	253	6.00	0.77	0	10.78	249	7.10	2.02	0
3	34.5	14.16	284	6.20	0.78	1	12.88	273	5.90	1.88	0
4	39.5	14.16	318	6.20	0.80	2	10.75	297	4.40	0.92	0
5	49.5	11.31	270	4.50	0.86	2	06.38	303	2.20	0.95	0

7.6.1 Load (Kg) Vs CO (%)



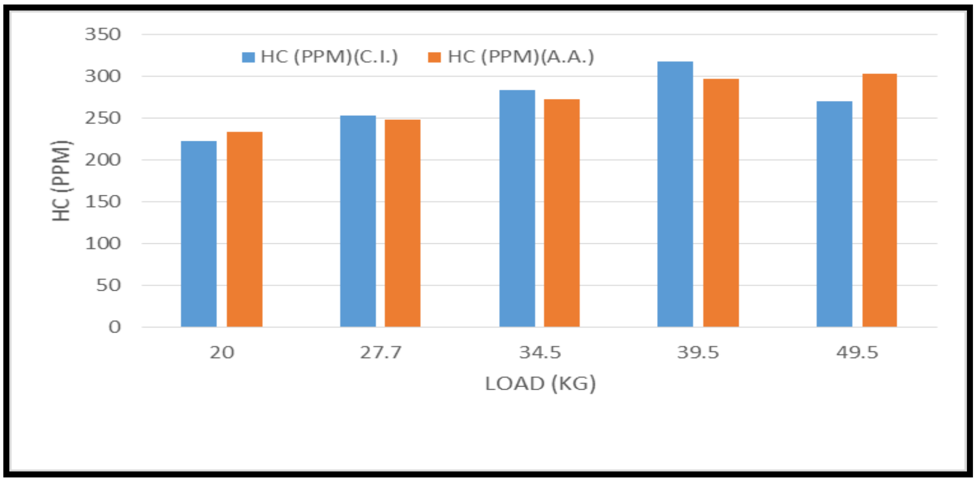
CI-Cast Iron AA-Aluminium Alloy

Figure 7.8, Comparison of percentage of 'CO' by engine with Cast Iron and Aluminium Alloy engine cylinder blocks

Generally speaking, as the engine is running in rich condition, the exhaust will contain large amount of CO emission, because there is not sufficient Oxygen to convert all carbon atoms of fuel into CO_2. Thus the most important parameter that affects CO emission is air/fuel equivalence ratios. With air/fuel equivalent ratio approaching unity, CO emission diminishes and even becomes zero in lean condition.

Hence, from figure 7.8, it is clear that CO percentages for Aluminium alloy engine cylinder block at all the load conditions is always less than engine with Cast Iron blocks only due to cleaner cylinder and cylinder head

7.6.2 Load (Kg) Vs HC (PPM)

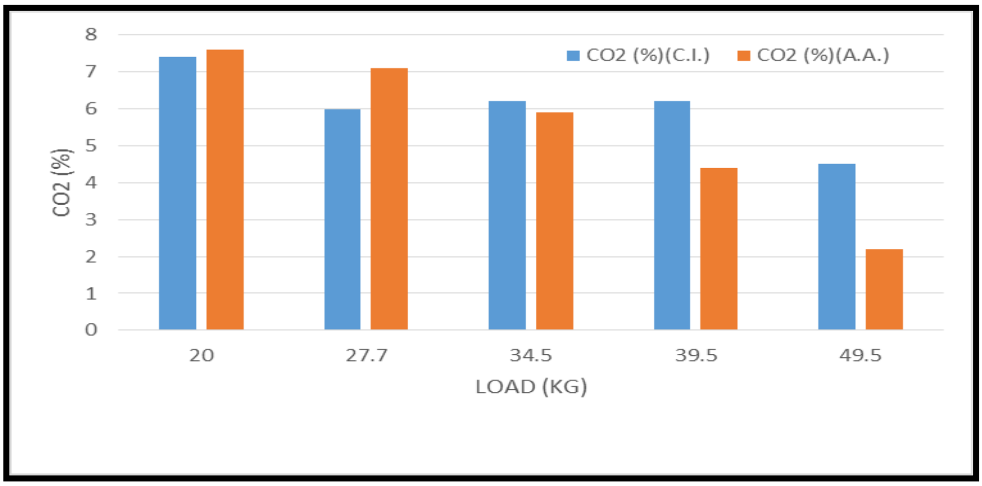


CI-Cast Iron AA-Aluminium Alloy

Figure 7.9, Comparison of 'HC' (PPM) by engine with Cast Iron and Aluminium Alloy engine cylinder blocks

It is observed that minimum HC emissions occurs in the condition of slightly lean combustion under which there is sufficient air to make unburnt HC participate in oxidation reaction. Here due to proper combustion of fuel, percentage HC is less for maximum readings which is a very good indication for Aluminium Alloy engine cylinder. Again cylinder combustion chamber is cleaner during combustion and due to that leaner mixtures are required hence low HC in the exhaust hence more mileage is achieved. Figure 7.9 gives clear indication of lower HC emissions for new block. Another cause of excessive HC emissions related to combustion chamber deposits. As carbon deposits are porous, hydrocarbon is forced into there in pores as air/fuel mixture is compressed. When combustion takes place, this fuel does not burn. However, as the piston begins its exhaust stroke, the HC are released into exhaust. Excess HC can also be influenced by temperature of air/fuel mixture as it enters the combustion chamber.

7.6.3 Load (kg) Vs CO_2 (%)

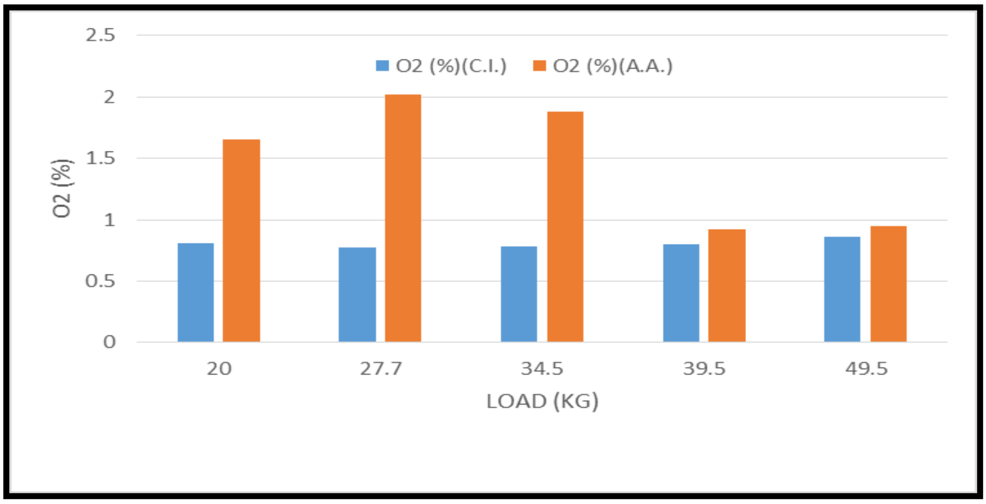


CI-Cast Iron AA-Aluminium Alloy

Figure 7.10, Comparison of percentage of 'CO_2'by engine with Cast Iron and Aluminium Alloy engine cylinder blocks

Always it is expected that more CO_2 in combustion reaction of fuels in engines. That indicates complete reaction/combustion. Here also maximum CO_2 at maximum observations recorded. Hence, it can be said that combustion is complete in Aluminium Alloy engine cylinder due to its fine and clean surface. Figure 7.10 shows that percentage of CO_2 in exhaust gas for engine by using Aluminium Alloy engine cylinder block is almost the same by using Cast Iron engine cylinder block.

7.6.4 Load (kg) Vs O_2 (%)

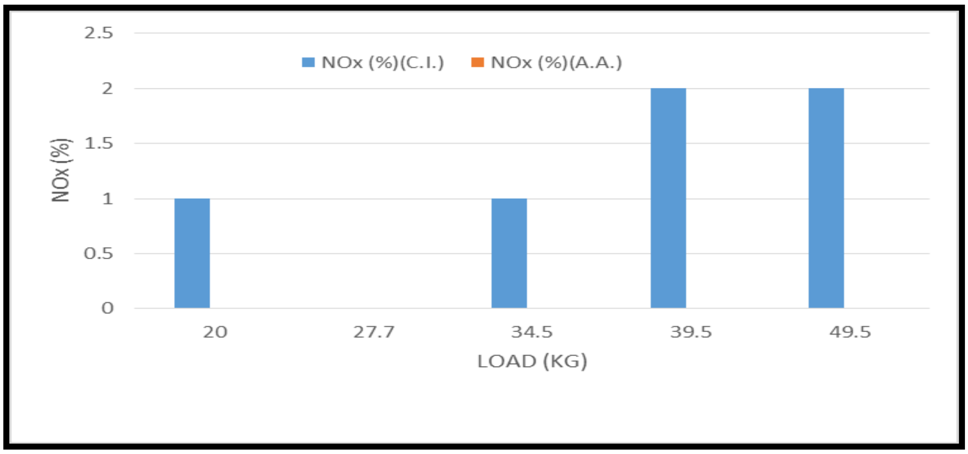


CI-Cast Iron AA-Aluminium Alloy

Figure 7.11, Comparison of percentage of 'O_2' by engine with Cast Iron and Aluminium Alloy engine cylinder blocks

Oxygen from atmospheric air utilized for the combustion of fuel in combustion chamber. During combustion maximum quantity of oxygen is taking part in combustion reaction out of total 21 % in air and somewhat 1 to 2 % Oxygen goes out via exhaust. Figure 7.11 reveals that Cast Iron block engine requires more Oxygen as it leaves less Oxygen ranging from 0.6 to 0.8 % while Aluminium Alloy block engine leaves more Oxygen in the range approximately 0.8 to 2 %. This clearly indicates that Oxygen needed is also less for complete combustion in engine with Aluminium Alloy block.

7.6.5 Load (kg) Vs NO_x (%)



CI-Cast Iron AA-Aluminium Alloy

Figure 7.12, Comparison of 'NO_X'(%) by engine with Cast Iron and Aluminium Alloy engine cylinder blocks

High cylinder temperature and pressure, which occur during the combustion process can cause nitrogen to react with oxygen to form Oxides of Nitrogen. Generally speaking, the largest amount of NOx is produced during moderate to heavy load conditions when combustion pressures and temperatures are their highest. However, small amounts of NOx can also be produced during cruise and light load, light throttle operation. Common causes of excessive NOx include faulty EGR system operation, lean air/fuel mixture, high temperature intake air, overheated engine, excessive spark advance, etc.

Figure 7.12 shows that NOx is almost absent for the engine with Aluminium Alloy engine cylinder block in comparison with engine with Cast Iron block which is a great achievement of this work. Proper air to fuel mixture and proper combustion of fuel, low cylinder temperatures and hence there is no rise to formation of NOx over here.

7.6.6 Overall discussion for the PUC testing of the engine

As from the graphs of PUC testing, it can be seen that there is slight variation in the results of the engine by using both the engine cylinder blocks. The PUC test was carried out on the engine with Cast Iron engine cylinder block before fitting of the Aluminium Alloy engine cylinder block. When engine was disassembled to fit the Aluminium Alloy block, it was found that there were some carbon deposits on the parts like valves, combustion chamber and piston crown, etc. So, before fitting new cylinder block, the engine was totally decarbonised and then new block was fitted and afterwards the PUC testing was carried out. This may be the reason of slight variation in the results of PUC testing.

7.7 Chapter summery

This chapter gives the results of the experimentation of the present research work. It also gives the discussions related to the results of the experimental work which consists of the parameters like the material of the engine blocks. All the observations required to evaluate the performance parameters are recorded during the experimentation for both the blocks separately. Then they are processed to get the results.

Chapter 8

CONLCUSIONS AND RECOMMENDATIONS FOR FURTHER RESEARCH

8.1 Conclusions

The conclusions which are based on the results and discussions of the present investigation are given below:

1. The blocks manufactured in the present research work are compatible to use with all the models of the two wheelers manufactured by Hero Honda/Hero Motocorp. Old cylinder blocks can directly be replaced with lightweight Aluminium alloy cylinder block without any modification in existing engines i.e. the main feature of this technology developed in present work. The list of motorcycles with which this block is compatible is given below:

[a] *Splendor Plus – All varients*
[b] *Splendor Pro – All varients*
[c] *Splendor Pro Classic*
[d] *Splendor NXG – All varients*
[e] *Splendor i-smart*
[f] *Passion Pro – All varients*
[g] *Passion Plus – All varients*
[h] *HF Delux*
[i] *HF Dawn*
[j] *Joy*
[k] *CD Dawn*
[l] *CD Delux – All varients*
[m] *CD100*
[n] *CD100 SS*
[o] *Sleek*
[p] *Street Smart*

Other manufacturers also can use same cylinder blocks developed.

[a] *Mahindra 2 Wheelers : Mahindra Centuro – All varients*

[b] *Kinetic Engineering Limited: Kinetic K4, Kinetic Boss.*

2. It is clear from the results of CFD analysis that as the velocity increases, the temperature of the blocks goes on decreasing considerably so cooling is better in forced convection. With the change in the block material, the temperatures achieved were higher at the tip of the Aluminium alloy engine cylinder block in comparison with Cast Iron engine cylinder block due to higher value of thermal conductivity and heat dissipation was better.

3. The experimental results show clearly that the engine with both the blocks exhibit the same performance.

4. From the percentage increase in mileage by 11.41 %, it is clear that the present work is successful and achieved the saving of the fuel with the use of low weight Aluminium alloy engine cylinder block in two wheelers which is developed.

5. The total weight reduction achieved is 51.5248 % showing that Aluminium alloy engine cylinder block is quiet lighter.

6. From exhaust testing of the engine with both the cylinder blocks, it was found that the percentage of CO, HC, CO_2, O_2 and NO_x in exhaust are same due to no change in engine design parameters like combustion chamber, engine dimensions, etc.

8.2 Recommendations for further research

1. The production of the engine cylinder block can be made by using the die casting method instead of Sand Casting to get better finish and accuracy.

2. An additional part in present engine set-up can be developed and added to study the combustion analysis and to get the p-ϴ plots on computerized basis. For this, the crank position sensor and cylinder pressure sensor are required to be used with the help of which the knocking characteristics can also be evaluated with the help of some newly developed computer software/hardware.

REFERENCES

[01] *Grosselle, Fabio, Timelli Giulio, Bonollo, Franco, et. Al., "Correlation between microstructure and mechanical properties of Al-Si die-cast engine blocks"*, Metallurgical Science and Technology, Volume 27-2; Ed 2009.

[02] *Valtierra-Gallardo, Salvador et al., "Wear-Resistant Aluminium Alloy for Casting Engine Blocks with Linerless Cylinders",* Patent Application – Publication Number: WO 2008/053363 A2. 8 May 2008.

[03] *"Wear",* Wikipedia, The Free Encyclopedia, Wikimedia Foundation, Inc. http://en.wikipedia.org/wiki/Wear.

[04] *Hirst W., "Scuffing and its prevention"*, Tribology, Practical Reviews, I Mechanical Engineer, Copyright 1975.

[05] *Kolbenschmidt Pierburg, "Low-pressure die cast cylinder blocks – the optimum for SI engines in V arrangement and high-performance diesel engines (for passenger cars)"*, Press Release.

[06] *Donahue, Raymond Ph. D., Philip A. Fabiyi, "Manufacturing Feasibility of All-Aluminium Automotive Engines Via Application of High Silicon Aluminium Alloy"*, Society of Automotive Engineers, Inc., 2000.

[07] www.yamaha-motor-india.com/r15

[08] *"Service Tips and Information:Reconditioning of Aluminium Engine Blocks", MSI Motor Service International GmbH*, KOLBENSCHMIDT, PIERBURG AND TRW, Edition August 2006.

[09] *A. Rabiei[(a)], D. R. Mumm[(a)], J. W. Hutchinson[(a)], R. Schweinfest[(c)], M. Ru¨ hle [(c)], G. Evans[(b)], "Microstructure, deformation and cracking characteristics of thermal spray ferrous coatings"*, (a) *Division of Engineering and Applied Sciences*, *Harvard University*, 40, *Oxford Street*, *Cambridge*, *MA* 02138, *USA* (b) *Princeton Materials Institute*, *Bowen Hall*, 70, *Prospect Avenue*, *Princeton*, *NJ* 08540, *USA* (c)*Max Planck Institute*, *Stuttgart*, *Germany* Materials Science and Engineering A269 (1999) 152–165.

[10] *Fabio Grosselle, Giulio Timelli, Franco Bonollo, Roberto Molina,"Microstructure and mechanical properties of four cylinders-in-line cylinder block"*, Department of management and Engineering, DTG, University of Padova, Vicenza, Italy, Teksid Aluminum, Carmagnola, Italy, Metallurgical Science and Technology, Vol. 27-2, Ed. 2009, 2-10.

[11] *Alan A. Luo, Anil K. Sachdev and Bob R. Powell*, *"Advanced casting technologies for lightweight automotive components"*, General Motors Global research and development centre, Warren, MI, USA The 69th World Foundry Congress, Hangzhou, China Paper, November 2010, 463-469.

[12] *Ravindra R. Navthar, Prashant A. Narwade, "Design and Analysis of Cylinder and Cylinder head of 4-stroke SI Engine for weight reduction"*, International Journal of Engineering Science and Technology (IJEST), ISSN : 0975-5462, Vol. 4, No.03, March 2012, 847-853.

[13] *Dr. Raymond Donahue, Mercury Marine and Philip A. Fabiyi, Daubert Chemical Company, "Manufacturing Feasibility of All-Aluminum Automotive Engines Via Application of High Silicon Aluminum Alloy"*, 00M-89**,** 2000, Society of Automotive Engineers, Inc., 1-10.

[14] *Hieu Nguyen, "Manufacturing Processes and Engineering Materials Used in Automotive Engine Blocks"*, April 8, 2005.

[15] *L. Heusler, F. J. Feikus, M. O. Otte, VAW aluminium AG, Bonn, Germany "Alloy and Casting Process Optimization for Engine Block Application"*, 2001 American Foundry Society, AFS Transactions 01-050 (Page 1 of 9).

[16] *Reza Roumina, "Mechanical properties of a recovered Al-Mg-Sc ALLOY"*, A Thesis submitted for the degree of Doctor of Philosophy in Materials Engineering to The University of British Columbia, (Vancouver), March 2009.

[17] *Salvador Valtierra-Gallardo, Jose Talamantes-Silva, Andres Fernando Rodrigues-Jasso, Jose Alejantro Gonzalez-villarreal, "Wear Resistant Aluminium alloy for casting Engine blocks with linerless cylinders"*, Patent application publication, Publication No. US2008/0031768 A1, Publication Date : February 7, 2008.

[18] *Nakashima K., Sakakibara Y., Teramoto S., Yoshida M. et al., "Thermal Characterization of Air-Cooled Aluminum Die-Cast Cylinder Blocks with Various Cast Iron and Aluminum Liners,"* SAE Technical Paper 2011-01-0316, 2011, doi:10.4271/2011-01-0316.

[19] *Nakashima K., Teramoto S., Murakami Y., Ishihara S. et. al., "Improving Cylinder Cooling Using Tapered Fins and Baffle Plates between Fins in Air-Cooled Engines,"* Paper #:2010-01-0323, Published:2010-04-12, DOI:10.4271/2010-01-0323, Citation : SAE Technical Paper.

[20] *Yoshida M., Ishihara S., Murakami Y., Nakashima K. et. al., "Optimum Fin Layout of Air-Cooled Engine Cylinder in Air Stream"*, SAE Technical Paper, 2006-01-1229, 2006, doi:10.4271/2006-01-1229.

[21] *Krishtal M., Chudinov B., Pavlikhin S., and Polunin V., "A Wear-Resistant Coating for Aluminium-Silicon Alloys Using Micro arc Oxidation and an Application to an Aluminium Cylinder Block"*, SAE Technical Paper, 2002-01-0626, 2002, doi:10.4271/2002-01-0626.

[22] *Legge R., Smith D., and Henkel G., "Improved Aluminium Alloy for Engine Applications"*, Paper # 860558, Published : 1986-03-01, DOI:10.4271/860558.

[23] *Dos Santos Filho D., "An Approach of the Engine Cylinder Block Material"*, SAE Technical Paper, 2013-36-0113, 2013, doi: 10.4271/2013-36-0113.

[24] *Thornhill D., Stewart A., Cuningham G., Troxler P. et al., "Experimental Investigation into the Temperature and Heat Transfer Distribution around Air-Cooled Cylinders"*, SAE Technical Paper, 2006-32-0039, 2006, doi:10.4271/2006-32-0039.

[25] '*BIKE INDIA'*, NEXTGEN PUBLISHING PVT.LTD., MUMBAI, VOLUME 11, ISSUE 012, JULY 2016, WWW.BIKEINDIA.COM, PP. 124-139.

[26] *S. Das, "Development of Aluminium Alloy composites for Engineering Applications"*, Trans. Indian Inst. Met., Volume 57, No.4, August 2004, pp. 325-334, 2004.

[27] *"Latest Machining Techniques for Aluminium Cylinder bores (Alusil and Lokasil)"*, SI0018, For Technical Personnel only, www.ms-motor-service.com, MS Motor Service International GmbH- 74196, Neuenstadt, Germany.

[28] *A. Hadleigh Castings (Aluminium Technology) brochure of LM25 Aluminium Casting Alloy*, pp.1-3.

[29] *The Aluminium Automotive Manual, Vesion 2011*, European Aluminium Association (auto@eaa.be), KS Aluminium-Technologie GmbH, Hafenstra 25-74172, Neckarsulm, Germany.

[30] *BS:1490:1988, Alloys and Approximated Equivalents*.

[31] *Cast and Alloys, an ISO 9001:2000 company*, pp.1-2.

[32] *Jonathan A. Lee, "Cast Aluminium Alloy for High Temperature Applications"*, The 132nd TMS Annual Meeting & Exhibition, San Diego Convention Center, San Diego, CA, March 2-6, 2003.

[33] *Benjamin Pinkel, "Heat Transfer processes in Air Cooled Engine Cylinders"*, Langley Memorial Aeronautical Laboratory, Report No. 612, US Government Printing Office, 1938.

[34] *C.S. Wang, G.F. Berry, "Heat Transfer in Internal Combustion Engines"*, The American Society of Mechanical Engineers, Winter annual Meeting, Miami Beach, Florida, November 17-21, 1985, pp.1-7.

[35] *A. Sanli et.al, "Numerical Evaluation by models of Load and Spark timing effects on the in-cylinder Heat Transfer of a SI Engine"*, Numerical Heat Transfer, ISSN:1040-7782 print/1521-0634 online, Part A, 56:444-458, 2009.

[36] *Pulkit Agarwal et.al., "Heat Transfer Simulation by CFD from fins of an air cooled motorcycle engine under varying climatic conditions"*, proceedings of the World Congress on Engineering 2011, Volume III, WCE 2011, July 6-8, 2011, London, U.K.

[37] *Amit V. Paratwar et.al., "Surface Temperature Prediction and Thermal Analysis of cylinder head in Diesel Engine"*, International Journal of Engineering Research and Applications (IJERA), ISSN:2248-9622, Vol. 3, Issue 4, Jul-Aug 2013, pp. 892-902.

[38] *Amit Kumar Gupta et.al., "Optimization of the fins to the four stroke single cylinder petrol engine"*, International Journal of Research in Aeronautical and Mechanical Engineering, Vol. 2, Issue 5, May 2014, pp. 77-82.

[39] *Christopher Depcik et.al., "Instructional use of a single-zone, premixed charge, spark-ignition engine heat release simulation"*, International Journal of Mechanical Engineering Education 35/1, pp. 1-31.

[40] *Herman H. Ellerbroce et.al.,"Surface Heat-Transfer Coefficients of finned cylinders"*, Report No. 676, National Advisory Committee for Aeronautics, pp.651-664.

[41] *Mohand Said Lounici et.al., "Investigation on heat transfer evaluation for a more efficient two-zone combustion model in the case of natural gas SI Engines"*, Applied Thermal Engineering, Elsevier, 2010, 31 (2-3), pp.1-30.

[42] *Oleg Spitsov, "Heat Transfer inside internal combustion engine:modeling and comparison with experimental data"*, Master's thesis, Lappeenranta University of Technology, 2013.

[43] *V.L. Maleev, "Internal Combustion Engines"*, McGraw-Hill Book Company, Inc. London, 2nd Edition, 1945.

[44] *P.M. Heldt, "High Speed Combustion Engines"*, Oxford & IBH Publishing Co. Pvt. Ltd., New Delhi, Bombay, Calcutta, pp. 588-589, 596-597, 1993.

[45] *N. Petrovsky, "Marine I.C. Engines"*, Moscow, MIR Publishers, 1976.

[46] *Federico Brusiania, Stefania Falfaria, Claudio Fortea, Giulio Cazzolia, "Definition of a CFD Methodology to Evaluate the Cylinder Temperature Distribution in Two-Stroke Air Cooled Engines"*, ELSEVIER Energy Procedia 81, 765 – 774, 2015.

[47] *Mishra A.K., Nawal S. and Thundil Karuppa Raj R., "Heat Transfer Augmentation of Air Cooled Internal Combustion Engine Using Fins through Numerical Techniques"*, Research Journal of Engineering Sciences, ISSN 2278 – 9472, Vol. 1(2), 32-40, August (2012).

[48] *Pulkit Agarwal, Mayur Shrikhande and P. Srinivasan, "Heat Transfer Simulation by CFD from Fins of an Air Cooled Motorcycle Engine under Varying Climatic Conditions"*, Proceedings of the World Congress on Engineering 2011 Vol III WCE 2011, July 6 - 8, 2011, London, U.K.

[49] *C.S. Sharma, T.N.C. Anand and R.V. Ravikrishna, "A methodology for analysis of diesel engine in-cylinder flow and combustion"*, Progress in computational Fluid Dynamics, Vol x, No. x,200x, Inderscience Enterprises Ltd.

[50] *B.N. Niroop Kumar Gowd and Ramatulasi, "Calculating Heat Transfer Rate Of Cylinder Fin Body By Varying Geometry And Material"*, Int. J. Mech. Eng. & Rob. Res. 2014, 642-657, 2014.

[51] *Prof. Arvind S.Sorathiya, Ashishkumar N. Parmar, Prof. (Dr.) Pravin P. Rathod, "Review Paper on Effect of Cylinder Block Fin Geometry on Heat Transfer Rate of Air-Cooled 4S SI Engine"*, International Journal of Recent Development in Engineering and Technology, ISSN 2347 - 6435 (Online), Volume 2, Issue 1, January 2014, 33-38.

[52] *Hardik S Rajput, Vivek B Patel,"Maximizing The Heat Transfer Rate By Changing The Fin Geometry Using CFD As A Tool"*, IJSRD - International Journal for Scientific Research & Development| Vol. 2, Issue 03, 2014 | ISSN (online): 2321-061, 554-556.

[53] *P.T. Nitnaware, Prachi S. Giri, "Design Optimization Of An Air Cooled Internal Combustion Engine Fin Using CFD"*, Journal of Multidisciplinary Engineering Science and Technology (JMEST) ISSN: 3159-0040 Vol. 2 Issue 11, November – 2015, pp 3129-3131.

[54] *Amit Ranjan and D.S. Das, "Heat transfer analysis of motorcycle engine using CFD under various fin geometries and speed condition"*, Applied Mechanics and materials, ISSN:1662-7482, Vols. 592-594, pp 1612-1616, 2014.

[55] *Abhishek Chakraborty, Shivam sharma, "Performance Analysis of Two Stroke Petrol Engine On The Basis Of Variation in Carburetor Main-Jet Diameter"*, International Journal of Engineering Research and Applications (IJERA), ISSN: 2248-9622, www.ijera.com Vol. 3, Issue 4, Jul-Aug 2013, pp.1911-1915

[56] *Siddharth Shukla, Pranav Ravi, "Working and Performance Analysis of Gasoline Fuelled Engine with Biogas"*, IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 12, Issue 2 Ver. II (Mar - Apr. 2015), PP 104-109 www.iosrjournals.org.

[57] *R. Bhaskar Reddy, B. Siddeswararao, " Performance Characteristics and Analysis of 4-Stroke Single Cylinder Diesel Engine Blend With 50% of Honne Oil at Various Fuel Injection*

Pressures", Int. Journal of Engineering Research and Applications, www.ijera.com ISSN : 2248-9622, Vol. 4, Issue 8(Version 1), August 2014, pp.10-20.

[58] *Blessen Sam Edison, Christy Binu, "Experimental Investigation of Performance and Emission Characteristics of Hybrid Fuel Engine"*, IJIRST –International Journal for Innovative Research in Science & Technology| Volume 1 | Issue 11 | April 2015 ISSN (online): 2349-6010.

[59] *Amit Ashokrao Gulalkari, Vijay G. Gore, Aniket P. Pathre, Manoj J. Watane, "Design and Fabrication of Portable Average (Mileage) Testing Machine for Two Wheeler Vehicles"*, International Research Journal of Engineering and Technology (IRJET), e-ISSN: 2395-0056 Volume: 02 Issue: 08, Nov-2015, www.irjet.net.

[60] Swarup Kumar Nayaka, Bhabani Prasanna Pattanaika, "Experimental Investigation on Performance and Emission Characteristics of a Diesel Engine Fuelled with Mahua Biodiesel Using Additive", 4th International Conference on Advances in Energy Research 2013, ICAER 2013, Energy Procedia 54 (2014) 569 – 579.

[61] Sulaiman, M. Y., Ayob, M. Ra and Meran, I., "Performance of Single Cylinder Spark Ignition Engine Fueled by LPG", Malaysian Technical Universities Conference on Engineering & Technology 2012, MUCET 2012 Part 2 Mechanical And Manufacturing Engineering, Procedia Engineering 53 (2013) 579 – 585.

[62] Yuh-Yih Wu, Bo-Chiuan Chen, Anh-Trung Tran, "Pollutant Emission Reduction and Engine Performance Improvement by Using a Semi-Direct Injection Spark Ignition Engine Fuelled by LPG", Aerosol and Air Quality Research, 12: 1289–1297, 2012.

[63] E. Ramjee and K. Vijaya Kumar Reddy, "Performance analysis of a 4-stroke SI engine using CNG as an alternative fuel", Indian Journal of Science and Technology, Vol. 4 No. 7 (July 2011), 801-804.

[64] Avinash Kumar Agarwal, Atul Dhar, "Performance, Emissions and Combustion Characterization of Biodiesel in A Generator Engine", Engine Research Laboratory, Department of Mechanical Engineering Indian Institute of Technology Kanpur, Kanpur-208016, India.

[65] Sandeep M. Joshi, Raahul Krishna, Balagouda A. Patil, Aneesh C. Gangal, "Performance Evaluation of Petrol-Ethanol Blends and Testing on Multicylinder 4-Stroke SI Engine", Journal of Alternate Energy Sources and Technologies ISSN: 2230-7982(online), ISSN: 2321-5186(print) Volume 6, Issue 1, JoAEST (2015), pp 41-45.

APPENDICES

[A1] List of Publications from the present Research Work

[01] *Patil A.D., Dr. R.G.Tikotkar, "Development of Aluminium Alloy Composites for Engine cylinder Application"*, International Journal for Scientific Research & Development (IJSRD), ISSN (ONLINE) 2321 0613, Volume 4, Issue 6, August 2016.

[02] *Patil A.D., Dr. R.G.Tikotkar,* "*Evaluation of the Thermal Performance of Aluminium Alloy Cylinder Block for A Single Cylinder, Four Stroke, Air-Cooled Spark Ignition Engine for Motor Cycle Application by using CFD Technique*", International Journal of Emerging Technology and Advanced Engineering (IJETAE), (ISSN 2250-2459, ISO 9001:2008 Certified Journal, Volume 8, Issue 1, January 2018), 341-346.

[03] *Patil A.D., Dr. R.G.Tikotkar, "Development and Testing of the Nonferrous Engine Cylinder Block for Single Cylinder, Four Stroke, Air Cooled Spark Ignition Engine for Two Wheelers",* International Journal of Emerging Technology and Advanced Engineering (IJETAE), (ISSN 2250-2459, ISO 9001:2008 Certified Journal, Volume 8, Issue 1, January 2018), 353-360.

[04] *Patil A.D., Dr. R.G.Tikotkar, "Comparative experimental study of ON-ROAD performance of air cooled, four stroke, single cylinder spark ignition two wheeler engine with Cast Iron and Aluminium Alloy cylinder blocks*", Journal of Mechanical Engineering and sciences (JMES), ISSN:2289-4659, Paper submitted.

[05] *Patil A.D., Dr. R.G.Tikotkar, "Experimental study of emission characteristics of air cooled single cylinder S.I. Engine by using Cast Iron and Aluminium Alloy cylinder blocks*", Journal of Mechanical Engineering and sciences (JMES), ISSN:2289-4659, Paper submitted.

[A2] 'Hero Motocorp' (Earlier 'Hero-Honda') Specifications of some products relevant to the research work

HF-DAWN (CD-DAWN)
Engine Air cooled, 4-stroke single cylinder OHC
Displacement 97.2 cc
Max Power 5.44 KW (7.4 PS) @ 8000 rpm
Max Torque 0.79 Kg-m @ 5000 rpm
Bore x Stroke 50.0 x 49.5 mm
Compression Ratio 8.8: 1
Starting Kick Start
Clutch Multiplate wet
Gear Box 4 speed constant mesh
Frame Tubular double cradle

Suspension (Front) Telescopic Hydraulic Shock Absorber
Suspension (Rear) Swing Arm with Hydraulic Shock Absorber
Tyre (Front) 2.75 x 18-4 PR
Tyre (Rear) 2.75 x 18-6 PR
Battery 12V — 2.5 Ah
Head Lamp 35W / 35W — Halogen Bulb
Fuel Tank Capacity 10.5 Litres (Reserve 1.8 Litres)
Dimensions (Lx W x H) 1980 x 720 x 1045 mm
Wheelbase 1230 mm
Ground Clearance 150 mm
Kerb Weight 108 Kgs.

HF-DELUX (CD DELUX)

Engine Air cooled, 4-stroke single cylinder, ohc
Displacement 97.2 cc
Maximum power 5.4Kw (7.4PS) @ 8000 rpm
Maximum Torque Q0.79 kg — m @ 5000 rpm
Bore x stroke 50.0 x 49.5 mm
Compression ratio 8.8: 1
Starting Kick start
Clutch Multi plate wet
Gear box 4 speed constant mesh
Frame Tubular double cradle
Suspension (Front) Telescopic Hydraulic
Suspension (Rear) Hydraulic shock absorber with swing arm
Tyre (front) 2.75 x 18.4 PR
Tyre (rear) 2.75 x 18.6 PR
Brake type (Front) Internal Expanding shoe type 130mm dia
Brake type (Rear) Internal Expanding shoetype 110tnm dia
Battery 12 v 2.5 ah
Head lamp Rectangular Multi Focal Reflector
35W/35W — Halogen Bulb
Fuel tank capacity 10.5 ltr (reserve 1.8 ltr)
Dimensions (LxWxH) 1970 x 720 x 1045 mm
Wheel base 1230 mm
Ground clearance 159 mm
Kerb weight 108 kgs.

SPLENDOR+

Engine 4-Stroke, Single Cylinder Air cooled, Ohc
Displacement 97.2 cc.
Transmission 4-Speed constant 1
Head Light 12v 35/35w — Multi-reflector Halogen Bulb
Wheel Base 1230 mm
Front Fork Telescopic Hydraulic Type
Rear Fork Rectangular swing arm with hydraulic shock absorber
Ground Clearance 159 mm
Kerb Weight 109 Kg.
Tyre size, front 2.75 x 18.4 PR
Tyre size, rear 2.75 x 18.6 PR
Front Brake Drum Type - Dia 130 mm Disc Type-Dia -240 mm (Optional)

Rear Brake Drum Type Dia 110 mm
Power 7.5 PS @ 8000 rpm/5.5 KW @ 8000 rpm
Speed 85 Kmph
Fuel tank 10.5 litre (reserve 1.4 litre)
Colour 10 color
PASSION+
Engine 4-Stroke, Single Cylinder, Air-Cooler OHC
Displacement 97.2 cc
Maximum Power 7.5 Ps at 8000 rpm
Gear Box 4 Speed constant Mesh
Clutch Multi-plate wet type
Max. Speed 85 Kmph
Frame Tubular Double Cradle
Suspension (Front) Telescopic Hydraulic Fork
(Rear) Swing Arm with 5 step adjustable Hydraulic Dampers
Tyres (Front) 2.75 x 18 —4 PR / 42 p
(Rear) 3.00 x 18.4/6 PR
Brakes (Front) Internal Expanding Shoes
Type (130 mm) / Hydraulic
Disc Type (Optional)
(Rear) Internal Expanding Shoes
Type (130 mm)
Battery 12 V — 2.5 Ah
Ignition Electronic CDI
Starting Kick Starter
Wheelbase 1235 mm
Ground Clearance 160 mm
Dimensions (L x W H) 1980 mm/720 mm/1060 mm
Kerb Weight 116 Kgs.
Fuel Tank Capacity 12.8 litres (Reserve 1.1 ltrs)
Headlight Halogen Bulb 12 v /35 W / 35 W

[A3] Brief Bio-data of the Author

The author, Mr. Appasaheb Dinkar Patil, graduated from Shivaji University, Kolhapur, Maharashtra State in Mechanical Engineering in the year 1994. He did his postgraduate study in ‘Heat Power Engineering’ with specialization ‘Internal Combustion Engines’ from Walchand College of Engineering, Sangli during the year 1997. The author served at;

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