Review on 3-D printed ABS polymer for rotary control elements

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Abstract

Purpose – The purpose of this sudy is most popular topic in additive manufacturing (AM) for defining the various three-dimensional (3D) materials according to their desires is Acrylonitrile Butadiene Styrene (ABS). Depending on the particular 3D materials, the ABS concentration is used differently. To increase the ABS polymer's strength, various reinforcement materials are available. The ABS polymer and the three reinforced materials have been covered in this article. Kevlar, carbon fibre (CF) and fibre glass (FG) are the three reinforced materials.

Design/methodology/approach – This study examines the use of ABS for the stainless-steel 3D printing system and other rotating control components is the primary topic of this review. The torsional effect is another. Additionally, the idea of torsional optimisation is explored using various fibres.

Findings – For every reinforced material, the two primary performance metrics elasticity and shear were examined.

Originality/value – This review article provides an overview of ABS and its reinforced composites in AM, particularly emphasizing torsional optimisation and the application of reinforced ABS in stainless steel 3D printing systems. This study concludes with shortcomings and suggestions for future research on the following works.

Keywords Additive manufacturing, 3D printing, Acrylonitrile butadiene styrene, Fusion-deposition-modelling

Paper type Research paper

1. Introduction

One of the rapidly growing technologies in the manufacturing field is additive manufacturing (AM) (Awd Allah *et al.*, 2025). This technology has been used for the automated industries, medical sectors and aviation (Zhang *et al.*, 2023a, 2023b). It allows new layer-by-layer three-dimensional (3D) objects to be produced and clearly eliminates production wastes (Punia and Kandasubramanian, 2025). It offers unlimited facilities for objects with different geometries and complexities and even reshapes the old ones (Saroia *et al.*, 2020). The most widely used method for the AM is the fusion deposition modelling (FDM) (Petrovic *et al.*, 2025). It operates on the material extrusion-based phases. Typically, it uses materials such as Acrylonitrile Butadiene Styrene (ABS), carbon fibres (CFs), stainless steels, etc., for printing (He and Khan, 2021). However, in the past, selecting the relevant printing materials has become the major limitation of the FDM process (Aqailan and Huh, 2025). The mechanical properties of the printed objects can be varied by the materials used for the printing (Sharma *et al.*, 2025). The mechanical properties are attained based on the reinforcing materials, their amount, structure orientation, air void volume and preparation of the polymers before the process (Duan *et al.*, 2025). For example, the object with 28 MPa and 53 MPa of tensile and flexural strength can be increased to 91 MPa and 156 MPa by adding 6.6% of CF (Benal *et al.*, 2022). Current trending research on mechanical properties is the torsional strength analysis, but the other properties also show equal importance (Darsin *et al.*, 2025). There is a lack of information about the torsional strength of the 3D-printed structures (Tse *et al.*, 2021). Therefore, this article expands the extended knowledge of the torsional strength of printed materials using ABS polymers, stainless steel and CFs (Rao *et al.*, 2025). ABS offers the properties of less temperature impact, increased toughness, strength, corrosion and chemical resistance (Doğan and Kamer, 2025). Stainless steel materials exhibit the advantages of durability, low maintenance, maximum strength and resistance (Tezel *et al.*, 2021). In addition to these properties, CFs have electrical conductivity, lightweight, good dimensional stability and low abrasion (Oviedo *et al.*, 2020).

Using these materials in the rotary control elements enhanced treatment quality, particularly in shaping and cleaning efficacy (Ney *et al.*, 2026). However, the rotary element fails because of the heavy torsional load and stresses beyond the control element's capacity (Kuo *et al.*, 2026). The resistance of rotary control elements to torsional loads can be affected by various factors, including their manufacturing process and clinical use. The resistance of the rotary control elements during the torsional loads can be affected by different parameters, such as their manufacturing process and clinical uses (Zhang *et al.*, 2025). The manufacturing process includes features such as alloy, surface and heat treatments, tip size, taper, cross-section design and shaft length (Afshar and Mihut, 2020). According to the cross-section area, the torsional stress spreads differently (Elmrabet and Siegkas, 2020). More even spread of the

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torsional stress makes the element more fatigued (Dizon *et al.*, 2021). The torsional strength of the materials is justified by the values of the entire angulation and torque (Spreeman *et al.*, 2019). The multiple sterilizations of the material will vary the torsional strength and also change the microstructure of the rotor control elements (Yasir and Kim, 2025). When preparing filament, various reinforcing components, such as rubber fragments, powdered glass, carbon fibre and wood flour (Du *et al.*, 2023), must be mixed into the backing material. This is necessary for printing with just one nozzle (Zhang *et al.*, 2023a, 2023b). Therefore, there is a filament of composite materials contained within the spindle itself. To get ready, the fibres are first embedded in an interlocking substance, and then the finished product is wound up like a piece of filament for the purpose of being made (Weeks *et al.*, 2023). Before beginning the printed process with the filament, this step in the technique must first be completed. The nylon filament is subsequently melted or heated in the heater chamber (Xu *et al.*, 2025), after which it is extruded via the tip of the nozzle into the structure plate (Picco *et al.*, 2023). The substance is laid down in successive layers by the sprayer with the assistance of a printing head that moves continually to specific areas of the base plate by adhering to a specified path, that ultimately results in the construction of a final three-dimensional object (Han and Chang, 2023). The method of extrusion is quite comparable to the mechanical hot glue extruded that is performed with a tool for applying glue and capillary dispensing (Hu *et al.*, 2025).

The present review study is structured as Section 2 describes several recent studies of ABS polymer for 3D printing substances. Section 3 detailed the performance analysis, and the conclusion with future recommendations is exposed in Section 4.

2. Three-dimensional printed fibre-reinforced substances

An ongoing study field that should be investigated further is continuous manufacture of fibre-reinforced polymer composites by means of AM technologies (Li *et al.*, 2025a, 2025b), such as 3D printing. Not only does the research concentrate on determining the physical, electrical and thermal attributes of an element (Zhu *et al.*, 2025), but it also looks at ways to improve each of these properties individually or in collaboration with the others (Huang *et al.*, 2023). In addition to this, the use of technology that allows for the digital printing of three-dimensional objects might result in increased mechanical strength (Perera *et al.*, 2023). The durability of the generated composites can be improved by including fibre qualities with modified additives and blending them with thermoplastics or plastic filaments or matrices (Zhao *et al.*, 2023). This is achieved. Studies have demonstrated that this type of equipment is appropriate for the creation of an extensive range of bespoke products, in addition to the aviation and automotive sectors, which are two sectors that traditionally use this method of production (Abutalip *et al.*, 2023). This technology is extremely capable of improving the substance, in conjunction with its framework, volume portion and fibre orientation that can be manipulated at every point in a combination by multifaceted. This technology also has the ability to manage the fibres direction. Because polymer resins do not perform on their own, this technique has a number of drawbacks, the most significant of which are inadequate mechanical characteristics and an absence of structural stability in the goods that are created using the usual method (Mallakpour *et al.*, 2023).

The production of mechanically robust structures for uses within the automotive and aviation industries (HR *et al.*, 2023) using an integration of the physical characteristics of structural elements is the primary objective of the recently proposed novel process for using additive technology. The most recent development in contemporary composite fabrication technologies is known as 3D printing. Unlike traditional manufacturing processes, the process of 3D printing lacks the use of any fabrication equipment (Guo *et al.*, 2023). Researchers have focused their attention on fibre-reinforced composites for a significant amount of time because of the superior mechanical properties possessed by these materials. These properties include outstanding durability, low density, excellent stiffness, affordable prices, relatively easy manufacturing and suitability for an extensive array of purposes (Jeong *et al.*, 2023). A composite material satisfies the demands of either architectural or functional parts through the use of components that make up the composite. Fiber-reinforced plastic composites are one of a kind in the modern era of materials because they showcase features such as high specific strength and performance, improved anti-fatigue and anti-aging cream capabilities (Saroia *et al.*, 2020; Petrovic *et al.*, 2025). These composites also have a large number of other useful capabilities.

Recent years have seen a boom in the field of research about FDM 3D manufactured fibre reinforcement polymer composites (Türk *et al.*, 2017). Prior attempts in 3D FDM printable fibre-reinforced polymers (FRPs) have been examined by a number within, each with a unique emphasis on a particular aspect of the field (Roberson *et al.*, 2015). An inaccuracy in establishing the boiling point of a feedstock could have an impact on both the visual appearance and the structural integrity of the objects that are 3D printed objects (Tunalioglu and Agca, 2022). Throughout the FDM procedure, each filament is extruded via a warmed nozzle, where it immediately hardens and establishes a cross-bond to the neighbouring filaments extruded earlier (Keshavamurthy *et al.*, 2021). Through the procedure of polymer melting, the filaments create a bridge among themselves called the “neck” (Mozdzen *et al.*, 2016). Besides, “intra-layer binding” refers to this connection, which causes the necks to expand inside a layer. It is the thing accountable for this growth (Pellejero *et al.*, 2020). Because the temperature within the already solidified layers remains high, there will be an excellent chance for connections to form among the threads of both subsequent layers (Azadi *et al.*, 2021). This phenomenon, sometimes called “inter-layer bonding,” occurs because identical bonds form among the strands of both layers (Golub *et al.*, 2016).

A study was conducted by Mohammadizadeh *et al.* (2019) to investigate the influence of fibre direction on its mechanical characteristics. Fibre infill orientations were classified into two distinct categories: circumferential and isotropic. A concentrated infill involves the addition of conferential rings throughout the periphery of the sample. The dimensions of the materials constrain the number of rings. In the context of isotropic infill, the fibres were horizontally oriented during laying (Vakharia *et al.*, 2022). The orientation of the fibres can be altered for individual layers. In the context of tensile analysis, the fibre angle was deliberately set to 0 to optimize the durability of uniaxially loaded specimens along the length axis.

The circumferential infill samples have a decreased susceptibility to failure. The spotted phenomenon could potentially be attributed to a decrease in the fibre composition inside the sample. In the case of isotropic blended with a ring-like infill, the fibre volume % remained constant, although the outcomes exhibited variability (Vidakis *et al.*, 2020). This observation highlights the significance of considering the impact of fibre orientations. Any change in fibre orientation leads to modifications in the mechanical characteristics of the component, notwithstanding the constancy of the fibre volumetric content. The AM features are described in Figure 1.

The finite element analysis (FEA) model was developed using the geometric data and filling arrangement specified in the form of numerical files by van de Werken *et al.* (2019). Modelling curvilinear printing filaments may pose challenges because of the varying fibre angle between elements, resulting in position-dependent variations in material characteristics inside the structure. Furthermore, it is necessary to establish the characteristics of the nonreinforced portions (Liu *et al.*, 2025).

The process of generating distinct material characteristics for every component within the structure of the mesh would require significant effort. Consequently, an automated modelling method was developed to generate elements by using the fibre's position, acquired by image analysis of the printed pattern. Determining the neighbourhood material orientations per every component was achieved by layering the component's centroids into the digitized fibre data. This process involved interpolation to identify the local fibre orientations, which were subsequently transferred onto the centre of each component. The use of stress energy served as an indication of convergence within the context of the FEA. It has been seen via prior redesigns that the variable elasticity composites exhibit high sensitivity to mesh sharpness. The shear of fibre is exposed in Figure 2.

This study aims to assess the elastic characteristics of FRP structures fabricated using 3D printing technologies by Al Abadi *et al.* (2018). Both practical and theoretical methodologies are used to examine the efficacy of FRP printing using 3D printer constructions and forecast their elastic characteristics. This study examined three distinct types of FRP substances: Kevlar, Glass and Carbon (Mazzanti *et al.*, 2019). These substances were created by printing in specific configurations of fibre bundles and a matrix composed of Nylon. This research formulated a mathematical framework using the stiffness approach to forecast the elastic characteristics of 3D printed slices. Additionally, a mathematical model was constructed using Abaqus software to anticipate failure mechanisms and damages caused by the FRP on 3D printer coupons subjected to testing. A comprehensive investigation was conducted to derive the mathematical formulations for determining the elastic characteristics of three-dimensional printed structures made of FRP materials ((Hawash, 2025).

Figure 1 Features of additive manufacturing

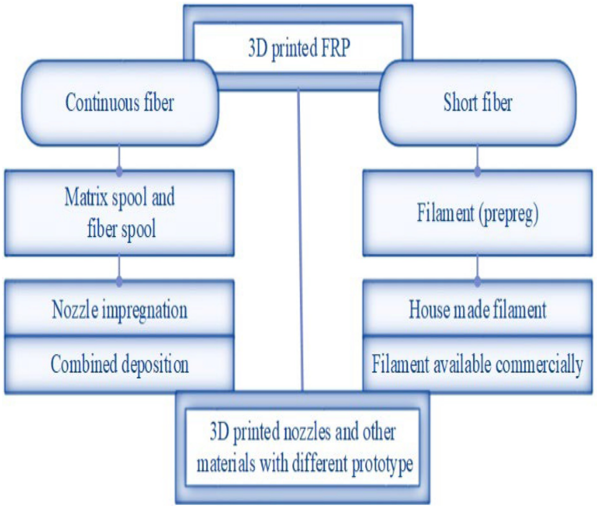
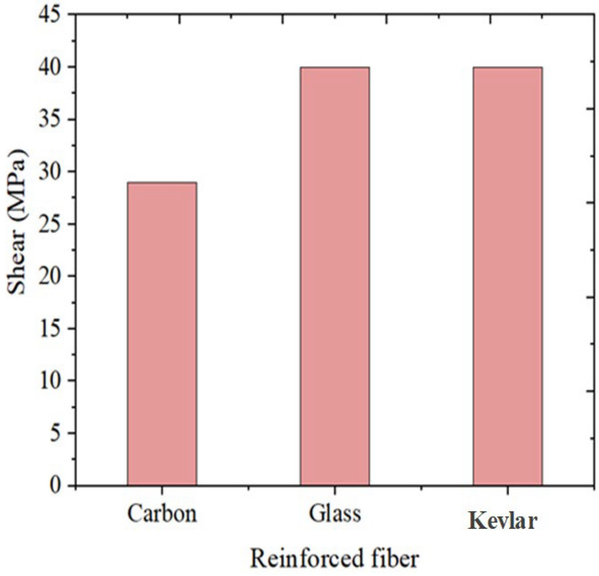


Figure 2 Shear strength of reinforced fibres



A novel volume averaging technique has been used by Melenka *et al.* (2016) to forecast the elastic properties of 3D-printed components reinforced with fibres. The used technique is the volumes averaging method, which is a mathematical model that relies on the volumes average stiffness approach to estimate the actual elastic properties of an object made from 3D printing reinforced with fibres (Benal *et al.*, 2022). These fibre-reinforced components that are 3D printed have multiple distinct regions, each possessing its unique set of constants of elasticity. The use of the quantitative model facilitates the inclusion of individual contributions from every one of those regions, hence enabling the estimation of the actual modulus of elasticity of the sample produced through fibre reinforcement in 3D printing.

2.1 Steel meshes

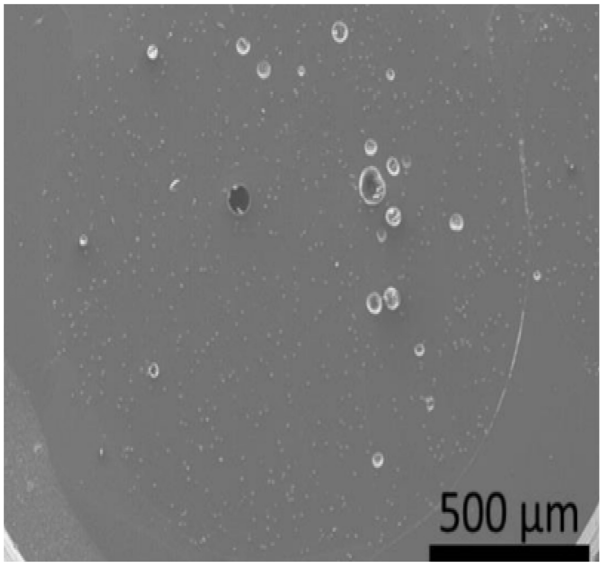
A dispersed manufacturing system might be used to deliver the building, part substitutes and enhancements in the primary frame, as indicated in Shen *et al.* (2025). During the early project, the building block that was decided to be used was

ABS. Despite this, it is essential to have an understanding of mechanical characteristics as well as the dimension precision of the samples created using FDM. It needs to have the device's mechanical characteristics to optimize the drone construction for actual weights and materials. This property is essential because the mechanical attributes of the finished components are influenced by the amounts of the ABS material mixture and the production process (Alaimo *et al.*, 2017; Dura *et al.*, 2025). To give vital details on the limitations that need to be considered, the level of dimensional precision required is absolutely crucial.

The use of continual CF-reinforced thermoplastic composite components is prevalent in aviation and astronautics because of their exceptional specific power, specific rigidity, durability against fatigue and anti-corrosion properties. Nevertheless, the automobile and consumer goods industries have limitations in using these materials because of their high manufacturing costs. Therefore, Hao *et al.* (2018) implemented the broader adoption of these innovative materials will rely on advancing cost-effective manufacturing techniques for fabricating composite frames. Subsequently, the composite laminas and panels were fabricated with an FDM-oriented platform. Ultimately, the mechanical characteristics of the composite lamina were subjected to characterization. The findings indicated that the physical characteristics of these 3D printable thermosetting materials surpassed those of comparable 3D-printed thermoplastic compounds and 3D printable materials reinforced with short CF. The SEM of ABS is described in Figure 3.

A substantial body of research articles addresses the identification of mechanical attributes and characteristics, both empirically and theoretically, as well as the fatigue features of these ABS materials. Bharatish *et al.* (2025) currently have a noticeable dearth of studies and academic literature on curves derived from investigating rotating stretching fatigue in these substances. This research examines rotating bend stress information for 3D printable specimens of specific materials subjected to varying loading conditions.

Figure 3 Acrylonitrile Butadiene Styrene SEM



In the first stages, Ismail *et al.* (2023) defined various design processes, including vibration and the influence of gravity, which were considered. Subsequently, a novel mechanism using a motor to induce agitation in a fibre container was chosen as the primary focus for the present investigation. The design comprises many components, including a spray nozzle, a strengthening container and a rebound system. To facilitate the use of a fibre-reinforced synthetic polymer within the environment of 3D printing, the initial step involves affixing the fibre doser onto a commercially accessible 3D printer using an attachment or frame. The receptacle is filled with reinforcement substances, such as fibres or particles. Upon activation of the DC power source, the driving mechanism promptly transforms the rotational motion into vibratory motion, thereby facilitating reinforcement application. The velocity at which the extra support is applied is directly related to the spin rate with the DC engine, which is regulated by a rotating potentiometer. Subsequently, the velocity of the motor is visually presented on an LCD screen (Wickramasinghe *et al.*, 2020). A composite's fibre composition is subsequently determined using thermogravimetric testing.

Preceding the shredding process, it is important to remove post-consumer trash made of plastic physically. The presence of contaminants not only has a detrimental effect on the general quality of the material but also leads to an increased nozzle frequency blockage in 3D printers. Subsequently, a plastic shredder/granulator of open-source nature was used to facilitate the shredding process of the plastic material. To enhance its accessibility for medium- and small-sized organizations, Zhong and Pearce (2018) established the system's design was modified to accommodate a single-phase electrical power, as opposed to the more prevalent three-phase electricity commonly used by corporate and industrial machinery. The structure of a granulator's feeder is intended to ensure the physical reliability of the granulator. For this, the container's entry has been designed to have a surface area of 200 cm, thereby restricting the dimension of plastic fragments that can enter the granulator. To facilitate the crushing process within the granulator space, it is necessary to manually decrease the size of bigger plastic particles before their deposition in the feeder. Subsequently, these particles can be effectively smashed by rotating fly knives. Triple rotary blades (Cui *et al.*, 2026) are in motion, rotating around a centre point and coming into contact with a fixed bed blade positioned beyond the rotating blades' trajectory.

2.2 Torsional strength of fusion deposition modelling produced hollow specimens

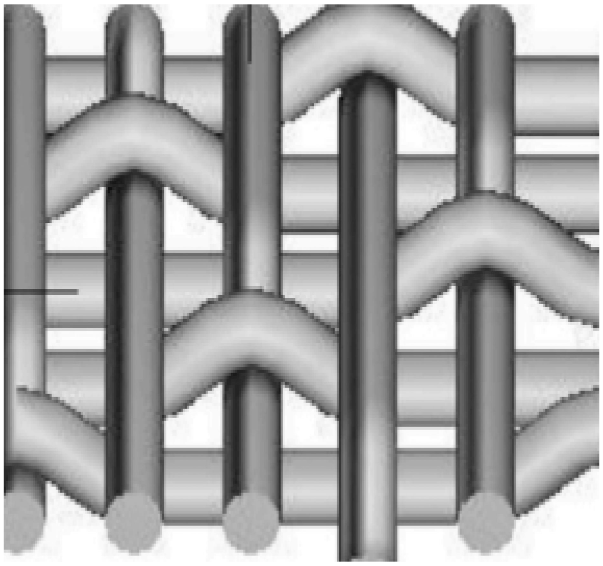
A composite shape was fabricated using the FDM technique, wherein continuous CFs were used to reinforce an onyx matrix. This onyx matrix comprises tiny carbon and nylon fibres (Panicker *et al.*, 2025). A bending test was conducted by Kalova *et al.* (2021) on six manufactured composite samples using the use of tensile equipment. The experimental values were contrasted with those obtained from the computational simulation using the FEM methodology. The mean amount of the empirically derived critical pressure that occurred when the composite profiles experienced failure was 3,102 N.

In contrast, the minimum critical force values obtained by FEM calculation came out as 2,879 N. Hence, the disparity between the validity of the simulations in determining the critical force and the method used in experiments was a mere 7%. The findings from the FEM research indicated that the predominant cause of breakdown in 3D-produced composite components was attributed to failing materials rather than instability. The comparative results demonstrate a high level of precision, indicating the feasibility of using a theoretical framework to forecast the mechanical characteristics of 3D-manufactured laminated composites.

The fluid consistently exhibited a rapid flow rate, moving from the intake to the outlet in around 1.3 s, resulting in a significant portion of the fabric being unsaturated. Here, Salvatori *et al.* have analysed the presence of the separator, which resulted in a pronounced dichotomy in flow magnitudes within the passageways of the spacing and across the woven fabric (Aisyah *et al.*, 2021), wherein a mix of movement in the horizontal direction of the material and flow perpendicular toward the fabric planes was indeed detected. In the initial set of studies, where a brake component was not used, the fluid tended to flow predominantly via the spacer instead of permeating the layers of cloth. A significant volume of fluid emerged from the mould before the complete impregnation on the fabric. Consequently, there was a lack of enhancement in the impermeability time, with instances where it was observed to be longer than that of the standard material (37 at 0.9 bar). Here, the used fabric substances are detailed in Figure 4.

Additionally, Told *et al.* (2021) aimed to design and assess the functionality of a robust and feasible right the top molar pair of force; the experimental procedures involved conducting flexural and torsional fatigue assessments and doing Shore D readings. The tensile strength obtained from the blended material has been measured as well. The results of the flexural testing demonstrated a clear linear relationship between the recorded forces and the degree of bending within the deformation range of 10 mm–30 mm. The use of the scanning electron procedure corroborated the results. Both dental forceps underwent design, 3D printing using CFR, the internet and subsequent validation by five dentists through a rating system called Likert, determined by the outcomes derived from the biomechanical and architectural tests.

Figure 4 Woven fabric



Furthermore, the upward force of removal was assessed using an unusual representation of an upper tooth, with the benchmark experiment conducted using conventional forceps designed for removing an aluminium right top molar. The test results were unexpected as they indicated that there were no statistically significant variations in abduction force among the traditional devices (mean: 84.80 N and standard deviation: 16.96 N) and 3D-printed gadgets (mean: 70.30 N and standard deviation: 4.41 N) within the range of testing. The findings also indicated that the workstation CFR technique is suitable for manufacturing handheld health-care products required to endure significant stresses and fulfil load-bearing roles.

The orthotropic substance constants were further validated for accuracy by using software for finite elements to compare the experimental data obtained from several natural modes. Consequently, a collection of techniques for the quantification and validation of orthotropic characteristics of materials was developed. Using the vibration sensor method, as opposed to general testing equipment, allows for the determination of orthogonal material characteristics with a reduced requirement of just three particular test samples. In addition, an examination was conducted by Huang and Lin (2022) to assess the impact of various printing factors, such as raster position and layer height, on the material characteristics of the specimens. Besides, the carbon steel was analysed by Arslan (2025) for the 3D printable isolation object. However, the thermal loss was recorded while optimizing the torsional behaviour. All the analysed matter is tabulated in Table 1.

2.3 Optimization

In the context of actual applications, layouts in between-finger differences can incorporate three distinct types, namely, gear variations, connection seesaw variations and pulley variations. Gear differentials, commonly used in used vehicles (Gebisa and Lemu, 2019), provide a compact design but come with the trade-off of more complexity and resistance. However, they are capable of handling substantial torque loads. Nevertheless, Lorenzett *et al.* (2025) described the process of 3D printing gears poses significant challenges, leading to frequently unsatisfactory levels of precision. Hyperlink differentials, alternatively referred to as Whiffle-tree variations, use the rotational movement of a bar around staggered pivot points to effectively handle variations in outputs. The range of motion of the pivoted bar, known as the difference or equalizing lever, is constrained by its overall length, hence restricting the versatility of its packing. However, the inflexible and comparatively uncomplicated elements facilitate rapid prototyping and assembling. Pulley variations involve the use of a movable or sliding pulley, originally incorporated in the very first SDM hand. These differentials provide some benefits in terms of packaging efficiency (Kun, 2016). However, it is important to note that they may additionally create supplementary complexities during the assembly process. The potential loosening of the tendon cords in pulley differences might offer benefits in unstructured operational settings, where certain fingers may unintentionally come into contact with external

Table 1 Torsional strength of fusion deposition modelling produced hollow specimens

Authors	Fibre	Software	Remarks
Kalova *et al.* (2021)	Carbon	Image Pro Premium 9.2	The FDM process enables the creation of polymer profiles that exhibit geometric accuracy, repeatability in manufacturing and outstanding resistance to catastrophic deformations. Future researchers may involve the exploration and advancement of both experimental and computing methods to analyse fatigue cracking characteristics of off-axis printable CFRP composites
Salvatori *et al.* (2019)	Woven glass	Sketch up	When using a sacrifice spacer, it is imperative that the substance used for those spacers is acceptable with the polymers being used. Furthermore, the spacer's substance should possess an ignition point that is somewhat higher than that of the polymers. This is crucial as the temperatures might be elevated beyond the melting grade of the spacers once the imprinting process has been concluded
Told *et al.* (2021)	Onyx carbon	Craft ware	Moreover, these gadgets can be used again throughout multiple sessions and operations. The primary objective of these results is to serve as a source of inspiration and assistance for future research endeavours in health-care device development and production using 3D printing technology
Huang and Lin (2022)	Anisotropic stacked	Abaqus	A reduced layer height signifies increased density in the vertically arranged layers, leading to enhanced structural integrity. Nevertheless, while the specified layer height decreases, the extrusion quantity of every length at the filament is correspondingly diminished, resulting in an optimal level height of roughly 0.15 mm
Arslan (2025)	Carbon steel	CAM	Nevertheless, it is important to note that these findings may exhibit discrepancies because of thermal loss caused by the incomplete isolation of the sample from the surrounding environment by resistance

barriers, displacing the affected finger without forcefully disturbing the remaining fingers (Akhoundi and Behravesh, 2019). Nevertheless, it is imperative to consider mechanical factors to prevent the tendons from disengaging from the activating pulleys.

The field of AM is experiencing rapid growth, with particular emphasis on FDM, which is alternatively referred to as fused filament fabrication. When using the FDM technique in component manufacturing, it is imperative to consider two crucial parameters: the component's durability and its dimensional precision (Ferretti *et al.*, 2021). While FDM is widely used in producing prototypes, including intricate geometries and other components with shorter production cycles, it is also subject to some limitations. These limitations encompass suboptimal mechanical qualities and diminished precision in calculating dimensions (Heidari-Rarani *et al.*, 2019). The consequence of multiple process variables on part characteristics is apparent, thus prompting a comprehensive examination of the impact of the subsequent process variables on mechanical assets: filler density, filler patterns, ejection temperatures, thickness of layers, nozzle size, raster position and build direction. Syrlybayev *et al.* (2021) have revealed that the coating thickness is a particularly significant factor among the variables under investigation. The attainment of the optimum combination of procedure variables poses a considerable challenge despite its substantial impact on the aesthetic and structural characteristics of the created component. Therefore, this study examines the impact of pre-processing techniques on the rigidity of printed components. Additionally, it explores emerging research patterns, including vacuum-assisted FDM, which has demonstrated enhanced printing quality through enhanced interlayer bonding. This paper presents an overview of current research and development efforts in materials and technology (Jayanth *et al.*, 2018). One instance where a pre-deposition warming technique, such as the use of an infrared lamp or other similar technologies, has demonstrated a beneficial influence on the structural properties associated with the produced components.

Polylactic acid has become known as a highly favoured thermoplastic material used in the process of FDM. The connection between print settings and qualities is more intricate in semi-transparent materials, such as those under consideration than in crystalline thermoplastics, such as ABS (Patel *et al.*, 2022). This complexity arises from the semi-transparent form of the material. The objective of the present investigation was to examine the effect of two printmaking factors, specifically the thickness of the layers (0.2 mm and 0.4 mm) and plate temperatures (30°C and 160°C), upon the Izod effect strength of produced PLA. Wang *et al.* (2017) analysed the presence of α structures was verified using XRD analysis, which was performed in components that were printed during a plate temperature of 160°C. Conversely, α crystals were observed in components printed with a plate temperature of 30°C. The parts printed under a plate that reached 160°C exhibited a greater degree of crystallinity. Using a polarised optical microscope revealed that when the plate temperatures were set at 160°C with the coating height maintained at 0.2 mm, it resulted in an increase in crystal structure, a reduction in crystal size and the formation of interstitial crystal bands. Apparently, the Izod impact resistance of Printed Poly Lactic Acid (PLA) at elevated plate temperature exhibited a notable increase of up to 114% compared to PLA produced by conventional moulding techniques with standard parameters.

In this research, Kariz *et al.* (2018) aimed to evaluate the influence of wood concentration in 3D printing substances on the attributes of 3D printed objects. A total of six threads were manufactured for 3D printers, using PLA as the base material.

These filaments were fabricated with different loading amounts of wood fragments ranging from 0% to 50% volume. The porosity of ABS and 5% CF is designed in Figure 5. The investigation saw a modest drop in the bulk density of both strands and 3D printing products as their wood content increased. Including woody in the spindles resulted in a rise in tensile toughness between 55 MPa and 57 MPa for a 10% wood level. However, as the hardwood content further rose, the tensile toughness of the threads plummeted to 30MPa for a 50% wood concentration. The surfaces of the produced pieces fabricated solely from the material, without incorporating wood, exhibited enhanced smoothness.

Furthermore, the structural integrity of the printed components was observed to be free from any cavities. As the wood concentration is elevated, the surface texture becomes more uneven, increased voids are observed (Marşavina *et al.*, 2022), and visible agglomerations of wood particles are present, attributable to the grouping and obstruction of wood nanoparticles behind the printing device nozzle. The capacity for storage of 3D printed objects was seen to decrease with an increase in their wood component. The temperature at which the glass transitions remained unaltered while subjected to transverse compression on a rheometer.

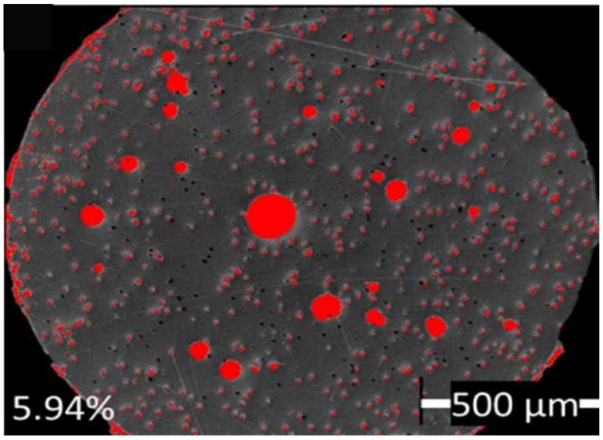
3. Performance analysis

Several ABS polymer studies have existed, but each polymer's specification and durability strengths differed based on the specific composite substances. Hence, this performance analysis section was elaborated to visualize those constraints and the performance. The overview of the reviewed article is exposed in Table 2.

However, additional samples of certain substances tested with a thickness of 10 mm produced comparable results, implying appropriate patterns in the information and decisions. Besides, fracture resistance (Vakharia *et al.*, 2022) was assessed in accordance with ASTM D5045, except for satisfying certain width or plasticity standards.

Based on the observed crack, the fracture toughness parameters were measured. Here, the fracture toughness is observed for different polymer cases that are CNT, premium, 5% CF and pure ABS. These details were defined in Table 3.

Figure 5 Porosity Acrylonitrile Butadiene Styrene and 5% carbon fibre



3.1 Tensile strength

The specimens made from 3D printable ABS material were subjected to a controlled displacement load velocity of 5 mm/min during testing. Measurements of the width and thickness of every sample were conducted at multiple sites within the evaluation section.

The measurement of stress on 3D-manufactured ABS samples was conducted using crosshead movement. The tensile was valued in the form of strain and stress. The highest strain value considered in analysing the stress is 0.08 mm. Also, the recorded highest stress is 37 MPa, defined in Figure 6.

3.2 Elastic modulus

Conventional 0° printed materials exhibited a mean ultimate tensile force of 21.93 MPa, representing a 44.7% increase compared to the 90° printable specimens, which achieved an overall strength level of 12.13 MPa.

Nevertheless, the coefficient of elasticity attained in both instances correspondingly with nearly identical values of 0.73 GPa and 0.72 GPa. The CF substance has reached the elasticity level up to 50 GPa. The elasticity assessment of different fibres is illustrated in Figure 7.

3.3 Shear modulus

The elastic modulus, yielding strength and maximum strength were determined in this shear testing process. However, it should be noted that stress-to-failure computations could not be performed for certain specimens because these samples were successful before the loss of the speckled pattern. Throughout the testing process, it was seen that the polycarbonate samples exhibited a higher likelihood of failure compared with the ABS samples. Besides, the ABS samples showed flexibility, with only a few experiencing complete failure. In contrast to the outcomes observed from the tensile analysis, the shear analysis on the ABS materials revealed multiple instances of anisotropy.

The major components affecting the mechanical properties of ABS polymer are post-processing, parameter constraints, materials, environment and 3D printing capabilities. That detailed description is exposed in Figure 8.

3.3.1 Accuracy of test step

The torsion test setup appears to be a standard design, but it is nonetheless accurate enough for testing rotary control parts (Frieler *et al.*, 2026). Before the experiment, the device was calibrated using standard torque calibration methods to make sure the measurements were accurate. A calibrated lever-arm mechanism optimized the applied torque, and a high-resolution graduated scale monitored the angular displacement. The overall accuracy of the torque measurement is within ± 2%–3%, and the error in angular displacement is kept within ± 1°. Different specimens were tested for repeatability, and the measured torsional strength varied by less than 5%, indicating that the experiments were consistent. Even though the setup is traditional, it delivers reliable, repeatable results for testing how 3D-printed ABS and reinforced composites behave when twisted. Digital torque sensors and automated data-collection systems may be added in future work to make the experimental framework more accurate and up-to-date.

Table 2 Overview of reviewed articles

	Review summary							
References	**Objectives**	**Fibre thickness**	**Reinforced polymer**	**3D printer**	**Micrometre**	**Shear**	**Tool**	**Elastic modulus**
Mohammadizadeh *et al.* (2019)	Microstructural analysis	0.1	Fiberglass, Kevlar and carbon	Markforged	Scanning microscopy	–	Eiger slicer,	–
van de Werken *et al.* (2019)	Post fracture analysis		carbon	Instron	Dynamic-mechanical	0.9	Abaques	50GPa
Al Abadi *et al.* (2018)	Interlaminar damage	2.5	Carbon, glass and Kevlar	MarkOne	Micromechanical analysis	29,40, 40 MPa	Matlab	0.075
Melenka *et al.* (2016)	Elasticity modulus	3.2 mm	Kevlar	Markone	Mitutoyo	0.13–1.3 GPa	Matlab	0.35–3.5 GPa
Hao *et al.* (2018)	Mechanical properties of fibre	1mm	Carbon	MakerBot	Scanning microscopy	–	RepetierHost	20
Brčić *et al.* (2021)	Fused filament	2		Raise3D	Micro-fractographic analysis		Computer-aided analysis	–
Ismail *et al.* (2023)	Fused filament	0.2	Glass	Forcemaker S220	–	–	3D	–
Zhong and Pearce (2018)				RepRap	–	–	Open source ImageJ	–
Ma Raymond *et al.* (2013)	Hard-soft composite	3.18	Steel tendon	Stratasys uPrint	–	–	ROS	–
Syrlybayev *et al.* (2021)	Torsion optimization	0.1		Laser printer	Scanning microscopy	17 MPa	–	1.2–3.6 GPa
Wang *et al.* (2017)	Fused layer		thermoplastic	MakerBot replicator	Polarized microscope	–	–	–
Kariz *et al.* (2018)	Fusion filament		Wooden particles	Zortrax	Different magnificent microscope	–	Exp wooden mill	3.72 GPa

Table 3 Fracture toughness

Crack size (mm)	Fracture toughness (MPa$\sqrt{M}$) CNT	Premium	5% CF	Pure ABS
0.1	2.9	2.9	1.5	2.4
0.2	2.2	1.9	1.7	2
0.3	1.8	1.7	1.6	2.1
0.4	1.7	1.6	1.4	2.1

Figure 6 Tensile strength

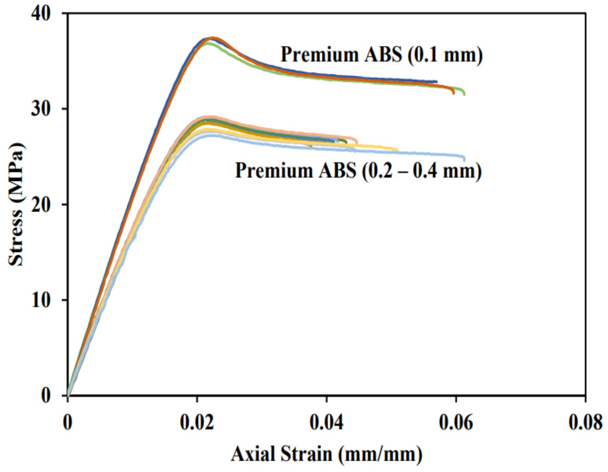


Figure 7 Elasticity assessment

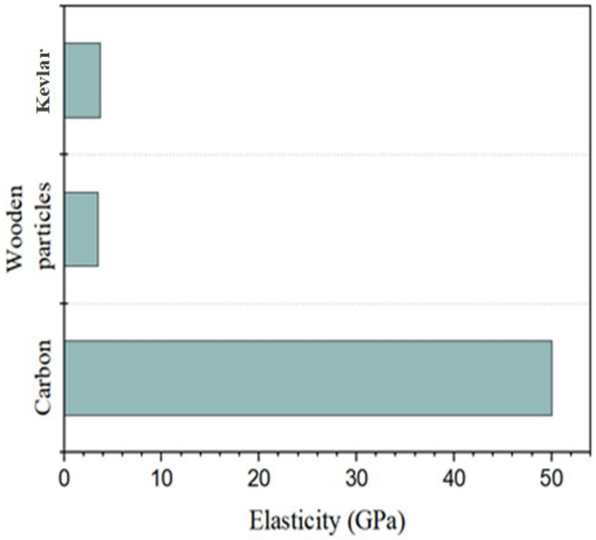
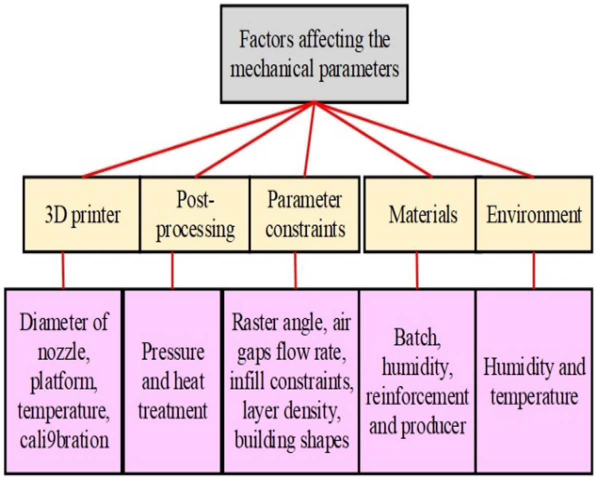


Figure 8 Factor affecting mechanical constraints



3.3.2 Manufacturing work flow

The technique for making 3D-printed ABS parts is rather basic and well-known, especially in FDM. First, computer-aided design software is used to make the part, then it is saved as an STL file. After that, the file is opened in slicing software, where the printing settings are established such as layer thickness, infill density, printing speed and extrusion temperature. When printing, ABS filament is heated and pushed through a nozzle, adding material layer by layer to make the part. A similar function is used for reinforced materials such as carbon fibre, fiberglass or Kevlar-filled ABS. Still, the temperature and print speed are adjusted slightly to account for the material's properties. After printing, a few simple procedures are needed to finish the job, such removing supports, finishing the surface or annealing. In general, the procedure is simple, can be repeated and is well-suited for making rotary control parts with certain mechanical properties.

3.3.3 Practical implication

The results of this review provide crucial information for the design and fabrication of rotary control elements made from 3D-printed ABS and its reinforced composites. With carbon fibre, fiberglass and Kevlar reinforcement, the torsional strength and elasticity of a material can be enhanced. This means that some low-load metal parts can be replaced, especially in lightweight, cost-sensitive applications. AM methods like Fused Deposition Modelling can help industries such as automotive, robotics, consumer goods and small-scale machine manufacturing by enabling the production of bespoke parts quickly and in small batches.

Also, engineers can adjust a part's mechanical characteristics to meet torque requirements by selecting appropriate materials and optimizing printing settings. This reduces waste and manufacturing time. The simpler manufacturing process enables on-demand production and distribution across different locations. However, before using these materials in rotary systems that must support a lot of weight or are critical to safety, you need to carefully consider how well they stick together, how they behave in different directions and how long they will last. Overall, reinforced ABS composites are a good, cost-effective choice for medium-duty torsional applications.

4. Conclusion

Several recent papers were analysed for the ABS polymer with different fibres for 3D printing and other steel applications. Most of the papers described that torsional is the major effect that reduces the durability of the ABS polymer. Hence, the review article has reviewed that changing lay orientation to a different angle might show a diverse torsional effect. Besides, the torsional behaviour of the hollow specimens was analysed for the different fibre and fabric substances. Fibre substances like carbon and steel wire mesh have shown the finest outcome for 3D printing. But, in some cases, it affects thermal conduction because of the high torsional effect. The recommendation from the current review is designing the intelligent optimization model along with the lay orientation of the hallow specimen will give the optimal torsional effect. It would be more effective when this test is made in the software environment.

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Further reading

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