Application of fuzzy logic for predication of depth of penetration in MIG welding

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Application of Fuzzy Logic for Predication of Depth of Penetration In Mig Welding

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Abstract ---- In most of the mechanical industries the fabrication of product is done through welding due to its convenience, rapid availability and economically feasibility. Welding is the processes in which two similar and dissimilar materials are joined through integration of molten metal. The quality of weldbead in the process are influenced by parameters. So due to this significance it is necessary to optimize the welding parameters to obtain best quality of weldbead and its properties. So in this regard a study has been made by conducting welding on specimen considering welding parameters like angle of torch, wire feedrate, standoff distance, welding speed and welding current through design of experiment Taguchi technique by using MIG welding for material Al 6061 alloy. The results of depth of penetration of weldbead are compared with predicated values through Fuzzy logic application.

Key words: MIG, Depth of penetration, Fuzzy Logic

I INTRODUCTION

The significance of good quality of welding joint will reflect in good service and in life of weldments. Since in most of the fabricated part of weld fails due to inadequate property of weld bead, thus it is importance to investigate weldbead properties. The strength of a weld is defined in terms of weldbead geometry and its properties such as Front width, Front height, Back height, Back width, depth of penetration, hardness and other mechanical properties.

In this view many of investigation found that the bead of weld is reflected by bead geometry and the quality of weldbead depends on the amount of deposition material which reveals in terms of metallurgical aspects **[1].** Defines that pentration Shape Factor is the ratio of the weld width to the depth of penetration and, also defined Weld Reinforcement **[2].**Reveals the study of weld bead geometry deals with the evaluation of penetration of depth, and weld bead shape **[3].[4,5]** has focused his work on weld bead geometrical changes and its shape factor as a result of changes in welding parameters. In his study reported that there is an increase in heat generated which intern increases the depth of penetration until the optimum welding speed and then the heat generated declines which results in decreasing penetration due to further increase in welding speed. Made an effort to study an influence of current, voltage and welding speed on Al 6061 on depth of penetration and tensile strength and reported that welding current is most significant factor compared to voltage and welding velocity on tensile strength, depth of penetration and toughness **[6, 7].**Concluded that the strength of a welded joint is effected by the composition of metal over material, distortion of the heat affected zone and also the weld bead shape [**8**]**.** An approach is made to study weld bead geometries produced by Metal inert gas welding using different protective gases. The results showed that the use of alternating shielding gases caused incline in penetration of depth and effective throat thickness of fillet weld while the leg length is reduced, and it also showed that welding speed plays critical role on heat input **[9].** Since Welding process is a most important process in the field of mechanical engineering. It had made significant tool for Engineers and Scientists for continuous improvement in manufacturing process. A lack of continuous improvement in quality a literature survey made motivation to realize that Metal Inert Gas welding parameters and there possible effect on mechanical properties and depth of penetration of Al 6061-T6 alloy. The deposition of metal creates the welded joint of structural members where failures occur due to weld enforcement in intern occurs due to the deformation of grains in metals and absorption. In this study, it had been concentrated on deposition of material over a joint to be welded by applying fuzzy logic to predict the response depth of penetration. This research influences for improving the excellence in quality and Joint strength of weld bead shape factors and geometry.

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II MATERIAL AND METHOD OF EXPERIMENTS

During a traditional method of welding operation the operator has to control all welding variables, which will affect in building weldbead geometry and all mechanical properties. To achieve satisfactory quality of welded joints it is necessary to select proper welding variables. However, these welding parameters are not completely independent and since by change over one parameter requires the change of other parameters in order to achieve the good quality of product. When all variables are in appropriate balance, the operator can have quality welded joint and produce sound weldments. So to study the effect of welding parameters over weldbead geometry aluminum alloy Al 6061 was considered.

Since in all mechanical industries a structural material used is mild steel because of its desirable properties but, a major disadvantage of steel is its weight and corrosion. But several applications like aeronautical and marine industries both of above mentioned properties are significant. So recent technology development made steel can easily replaceable by aluminum and its alloys to reduce weight density ratio and also corrosion. But most of the big structures cannot be manufactured by traditional methods and this can be easily overcome by source of MIG welding in case of aluminum material without losing mechanical properties with greater extent. Thus in this work aluminum alloy 6061 is considered to check material properties and weldbead geometry if material is welded with MIG welding.

III MODELING AND PREDICATION USING FUZZY LOGIC

[10] The authors applied fuzzy logic for predicating weld bead geometry for performance of API X65 steel and results shows that Fuzy system can accurately predict the weld ebad geometry parameters. [11] The authors applied Fuzzy logic to optimize properties of welding properties in submersible arc welding by using different optimal level of compositions.[12] the study reveals that application of fuzzy logic for controlling temperature parameter in Friction stir welding. Base on the literature review, the Fuzzy logic are used for prediction of weld bead geometry. The results show that the designed Fuzzy system can accurately predict the weld bead geometry parameters.[13] The study reveals that all welding parameters effects over weldbead geometry.

A fuzzy logic approach is a method in which nonlinear inputs are converted to a set of scalar output data. The process of fuzzification starts with converting a fuzzy set of data's into linguistic variables and along with fuzzy linguistic terms and membership functions. The setup rules are interfaced input and output. The process of defuzzification follows the mapping of fuzzy output to crisp output using the functions of membership in fuzzy logic. The Fig.1 represents the procedure involved in Fuzzy logic system and the following Table I shows welding process parameters considered for carrying experiments. And Table II shows experimental results carried using MIG welding.

TABLE I: Welding parameters and with limitations

MIG Welding Parameters	*Limits of Welding*	*Unit*
Torch angle of Gun	60-90	Degree
Wire feedrate	55-65	mm/min
Standoff distance	8-12	mm
Welding Speed	8.5-11.5	mm/sec
Welding Current	120-150	Amps

Torch Angle –A, Wire feedrate –W, Standoff distance-SD, Welding speed-S, Welding Current-I

TABLE II: Experimental result for the depth of penetration

Run	*A*	*W*	*SD*	*S*	*I*	*Depth of Penetration*
1	60	55	8	8.5	120	1.52
2	60	55	8	8.5	150	2.44
3	60	55	8	11.5	120	3.18
4	60	55	8	11.5	150	3.06
5	60	55	12	8.5	120	3.34
6	60	55	12	8.5	150	2.40
7	60	55	12	11.5	120	2.57

Run	*A*	*W*	*SD*	*S*	*I*	*Depth of Penetration*
8	60	55	12	11.5	150	2.16
9	60	65	8	8.5	120	2.97
10	60	65	8	8.5	150	3.71
11	60	65	8	11.5	120	1.40
12	60	65	8	11.5	150	3.74
13	60	65	12	8.5	120	2.87
14	60	65	12	8.5	150	3.81
15	60	65	12	11.5	120	2.12
16	60	65	12	11.5	150	1.98
17	90	55	8	8.5	120	2.55
18	90	55	8	8.5	150	3.53
19	90	55	8	11.5	120	1.22
20	90	55	8	11.5	150	2.19
21	90	55	12	8.5	120	1.25
22	90	55	12	8.5	150	2.09
23	90	55	12	11.5	120	1.28
24	90	55	12	11.5	150	1.80
25	90	65	8	8.5	120	2.72
26	90	65	8	8.5	150	3.01
27	90	65	8	11.5	120	2.51
28	90	65	8	11.5	150	3.75
29	90	65	12	8.5	120	3.53
30	90	65	12	8.5	150	3.85
31	90	65	12	11.5	120	4.70
32	90	65	12	11.5	150	5.00
R1	75	60	10	10	135	2.82
R2	75	60	12	10	135	2.75

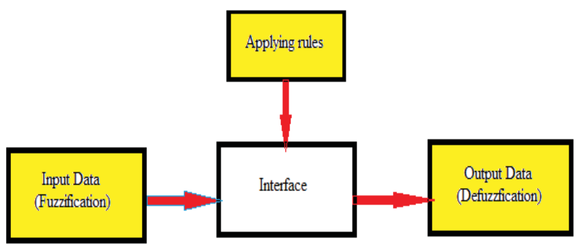

Fig. 1 Fuzzy Logic Interface System

3.1 PREDICATION OF DEPTH OF PENETRATION USING FUZZY LOGIC

Linguistic variables are input parameters or output results of the fuzzy logic system whose values are added as numerical values. In this view the welding process parameters for predicting the Depth of penetration are Angle of torch, Wire feedrate, Standoff distance, Welding speed and Welding current are considered as linguistic terms

In this research, the fuzzy logic variables and their range of values included are

1) Angle of torch: Range from 60 to 90 in degree;
2) Wire feedrate :Range from 55 to 65 mm/min;
3) Standoff distance: Range from 8 to12mm;
4) Welding speed; Range from 8.5 to 11.5mm/sec

5) Welding current; Range from 120 to 150amps

The limits of input and output data are represented in Table I and Table II represents fuzzy logic tool box that defines input and output variable (data) Fig. 2

1) Defining the Inputs and Output Membership Function

The fuzzification and defuzzification process are influenced by membership functions to relate non fuzzy input data to fuzzy linguistic terms and vice versa. A membership function adopted to quantify a linguistic term. An important aspect of fuzzy logic is that a numerical value does not have to be fuzzified using only one function of membership. i,e, a value can belong to multiple sets at the same time. As it was considered, five membership functions were selected for each input and output variable namely; Low, Moderate and High.

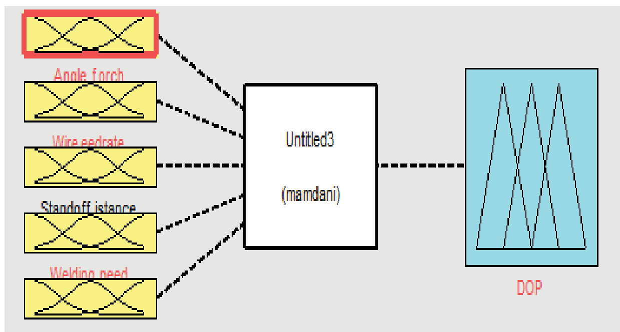

Fig .2 Defining input and output variables

The Fig..3 represent the membership function for angle of torch. The angle of torch limit is defined as (60 90) while the membership set that is angle of torch is given as (60 75 90) considering triangular membership function
The Fig. 4 reveals the membership function for Wire feedrate. The Wire feedrate limit is defined as (55 65) while the membership set that is wire feedrate is given as (55 60 65) considering triangular membership function.

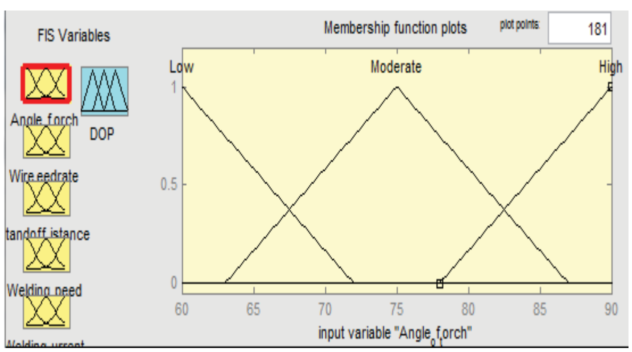

Fig. 3 Membership function for Angle of torch

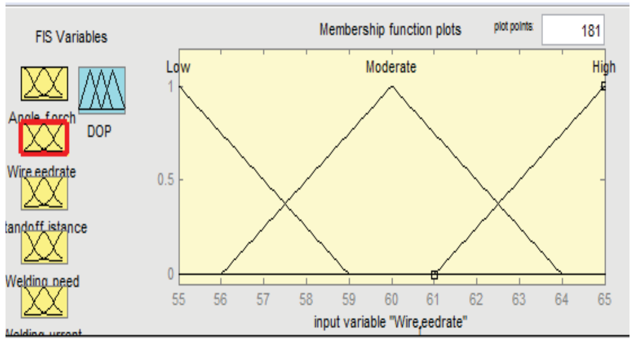

Fig. 4 Membership function for Wire feedrate

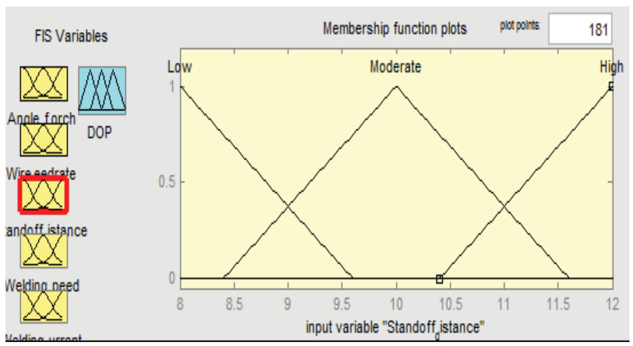

Fig. 5 Membership function for standoff distance

The Fig.5 shows the function of membership for standoff distance. The standoff distance is defined as (8 12) while the membership set that is standoff distance is given as (8 10 12) considering non linear (triangular) membership function.

The Fig.6 shows the function of membership for welding speed. The welding speed is defined as (8.5 11.5) while the membership set that is welding speed is given as (8.5 10 11.5) considering non linear (triangular) membership function

The Fig.7 shows the function of membership for welding current. The welding current is defined as (120 150) while the membership set that is welding current is given as (120 135 150) considering non linear (triangular) membership function.

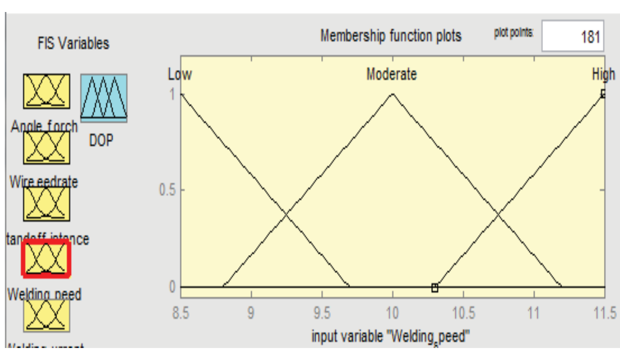

Fig 6 Membership function for welding speed

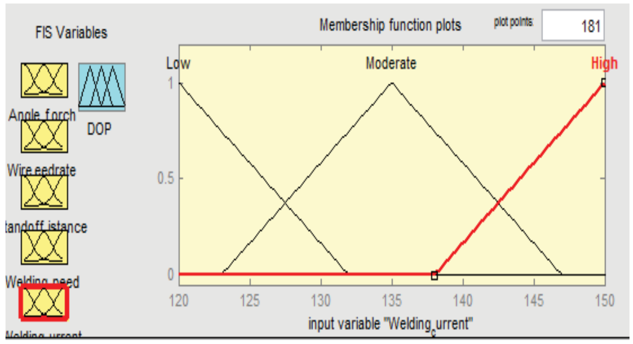

Fig. 7 Membership function for welding current

The Fig.8 shows the function of membership for Depth of penetration. The DOP is defined as (1.22 5) while the membership set that is welding current is given as (1.22 3.11 5) considering non linear (triangular) membership function

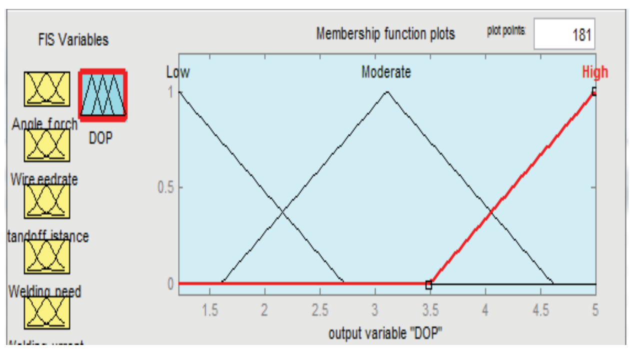

Fig. 8 Membership function for DOP

2) Fuzzy Rules

A simple fuzzy logic code is involved to care the output results . Fuzzy rule is composes of an "IF-THEN" rule along with a condition and a conclusion. In our problem 253 rules are created based upon fuzzy logic process and processed through rule based editor in Matlab and some them are shown in Fig 9 and as follows

1. If angle of torch is moderate and wire feedrate is elevated and standoff distance is high and welding speed is declined and welding current is low then DOP is high
2. If angle of torch is elevated and wire feedrate is average and standoff distance is moderate and welding speed is low and welding current is low then DOP is low.
3. If angle of torch is elevated and wire feedrate is more and standoff distance is low and welding speed is average and welding current is low then DOP is high.
4. If angle of torch is elevated and wire feedrate is low and standoff distance is low and welding speed is average and welding current is elevated then DOP is low.
5. If angle of torch is moderate and wire feedrate is moderate and standoff distance is elevated and welding speed is high and welding current is average then DOP is low.

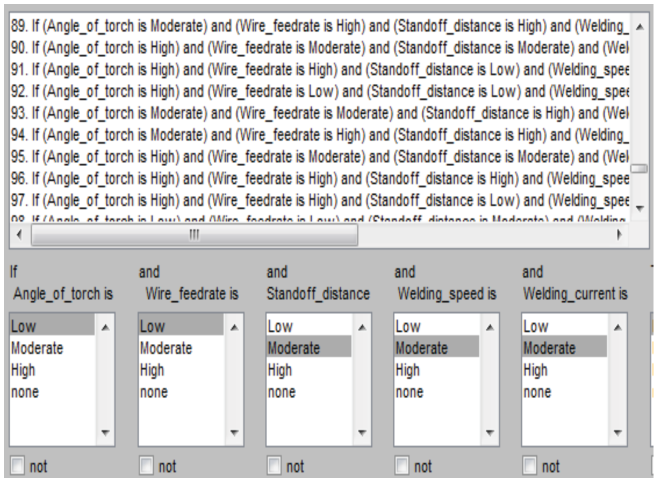

Fig .9 Fuzzy Logic rules

IV RESULTS AND DISCUSSION

4.1 Predicting of Depth of Penetration using Fuzzy logic MatLab Tool

Fig 11 shows the predictions of depth of penetration interface for fuzzy logic systems using Matlab and Fig 10 presents actual bead geometry. From the result of Fig 11 it was observed that; Angle of torch of 75 degree, Wire feedrate of 60mm/min, Standoff distance of 10mm, Welding speed of 12 mm/sec and Welding current of 135amps the Predicted Depth of penetration is 3.11 mm. The same procedure was applied in generating the other results as shown in Fig 11. To validate the prediction precision of results of the fuzzy logic tool, values form Table 2 were selected at random and compared with our fuzzy logic predicated values corresponding to the same process parameters, where the results are presented in Table III. In Table III in gives reveals actual experiment results and Fuzzy logic which are very close to each other.

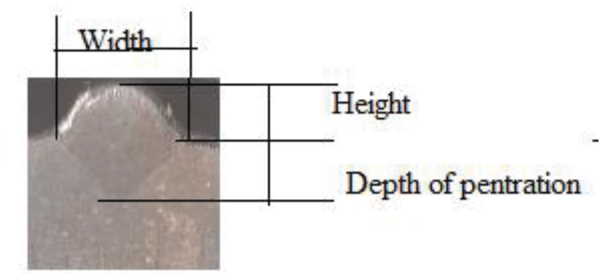

Fig 10 Actual bead geometry

Table III: Experimental and predication (Fuzzy Logic) Results of Depth of penetration

S.No	*A*	*W*	*SD*	*S*	*I*	*Actual DOP*	*Predicated DOP*
1	60	55	8	8.5	120	1.52	1.80
7	60	55	12	11.5	120	2.57	3.11
12	60	65	8	11.5	150	3.74	4.51
28	90	65	8	11.5	150	3.75	4.05
29	90	65	12	8.5	120	3.53	4.34
R1	75	60	10	10	135	2.60	2.82
R2	75	60	12	10	135	2.75	3.11

Where R: Random input

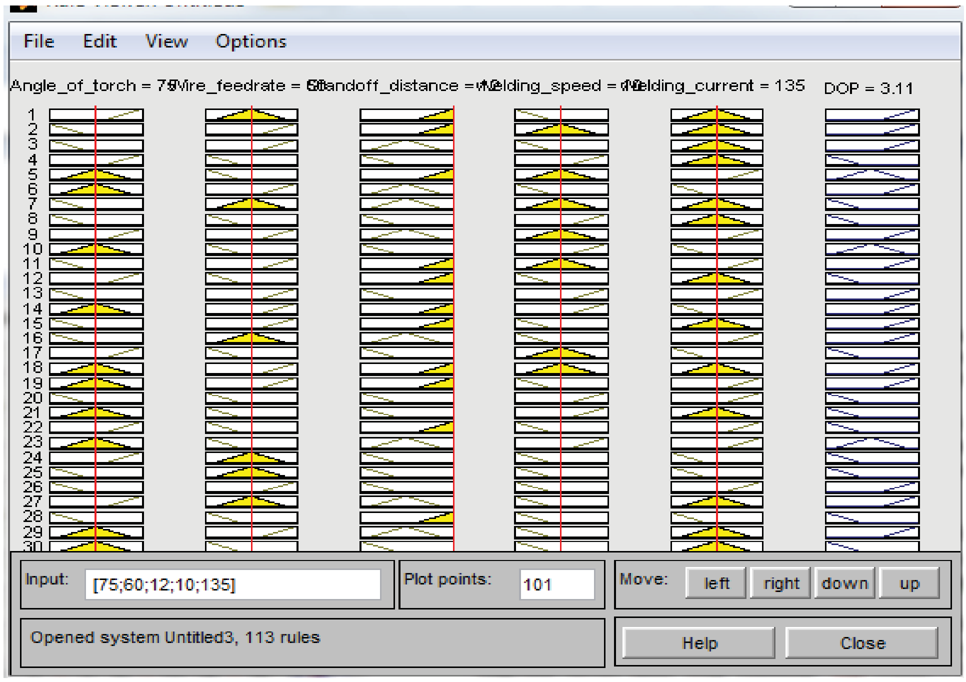

Fig 11 Predication of depth of penetration using Fuzzy Logic

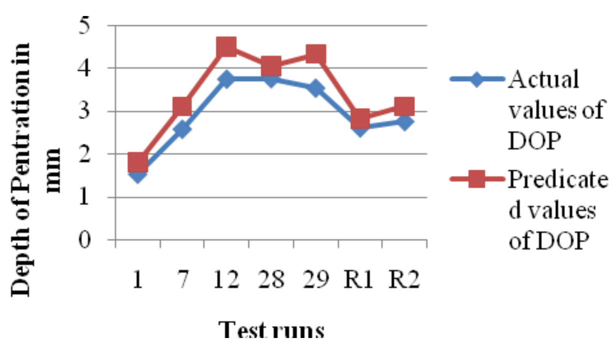

Fig. 12 Validation graph for DOP

The Fig. 12 shows validation graph for depth of penetration. It is observed from that during the initial run there is deviation of results i,e at run 1,where as experimental runs such as 7,12,28 and 29 run experiment shows the results are parallel with less deviation .The random experiments R1and R2 results shows that the actual and predicated values using Fuzzy logic are same.

V CONCLUSION

A concept of modeling tool was analyzed to predict welding process parameters (Angle of torch, Wire feedrate, Standoff distance, Welding speed and Welding current) on Depth of penetration (DOP) for improvement of quality weldments. The comparison was made actual and predicated and indicated in Table IV along with percentage variation and the error of percentage is minimum.

Table IV Comparison of actual and predicated results

S.No	*Actual DOP*	*Predicated DOP*	*Error*	*% of error*
1	1.52	1.80	0.28	18.41
7	2.57	3.11	0.54	21.10
12	3.74	4.51	0.77	20.58
28	3.75	4.05	0.30	8.00
29	3.53	4.34	0.81	22.94
R1	2.60	2.82	0.22	8.46
R2	2.75	3.11	0.36	13.09

This study will also reduce the cost of material to be employed during welding operation and it in turn a can maximize quality of their products with minimal stress and eliminate time used for trial and error experiment during welding. This fuzzy logic technique can be applied for predicating mechanical properties and other weldbead geometry parameters.

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