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Development of Fuzzy Logic Tool to predict Wear Rate in Aluminum Composite

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***Abstract*— Industrial automation is the need of the hour. Success and failure of automation depends on the selection and efficient utilization of soft computing tools such as artificial neural network , expert systems, and fuzzy logic. This article explores the idea of constructing a fuzzy logic model to predict wear rate of fabricated composites under predetermined conditions of input variables such as applied load, sliding velocity and distance travelled. Taguchi design of experiments is employed for experimentation. 27 sets of experiments are performed by varying the parameters of applied load, sliding velocity and distance travelled. Experiment is repeated for average values of wear rate are measured to reduce experimental error. Matlab toolbox functions are used to build the model. Confirmatory experiments are done and the results are measured in terms of accuracy and time. It is found that the developed model predicts wear rate with acceptable limit. Hence the constructed model can be forwarded to predict wear rate of the developed composite under different conditions.**

Keywords—Fuzzy Logic; Composite; Taguchi Method; wear rate;

I. INTRODUCTION

Recently, application of composite materials has been drastically increased in automotive, marine and aeronautical sectors due to light weight ratio and excellent mechanical properties. Commercial, defence and industrial firms use composite materials in an efficient way [1]. The guarantee of any product depends on wear rate. It is essential to check the tribological properties of the new developed materials (2,3). Better understanding of the relationship between the parameters involved, work materials and working conditions is an essential requirement for the prediction of wear rate (4). It is time consuming and tedious task to identify the relationship of the parameters involved. Mathematical modeling needs lot of time for computation. Hence the problem is solved by the usage of soft computing tools. Intelligent techniques such as fuzzy logic, ANN, and ANFIS can address this issue. Many authors have applied these techniques for wear rate prediction of the developed composite. ANN is applied to predict wear (5-8) mechanical (9) and tribological (10) properties. Radial basis functional neural network is applied to characterize the wear model of nano composite (11). This paper addresses the prediction of wear characteristics using fuzzy modeling.

II. PROPOSED METHODOLOGY

The scheme of development of fuzzy model is shown in figure 1. The stages of development are a) Design and conduction of the experiment b) Development of fuzzy logic model c) Validation of the developed model.

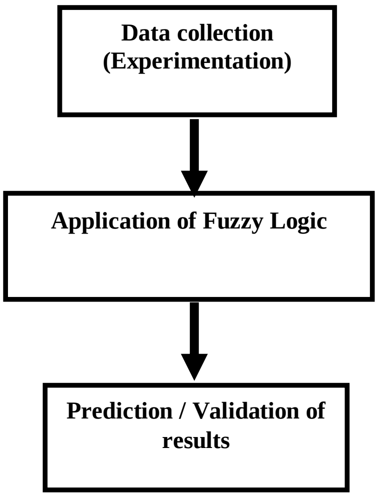

Fig.1. Scheme of Proposed methodology

III. EXPERIMENTATION

Taguchi experimental design is employed to conduct experiments and to establish an correlation model between the input and output parameters and the optimization of response. The input factors are sliding velocity, applied load and distance travelled. Wear rate is the output variable. 27 experiments were performed under cutting environment by design of experiments. Wear experiments were carried out using computerized wear testing machine (pin on Disc) (DUCOM, TR-20LE-PHM-400) by ASTM-G99 standards. The design layout is as shown in Table 1. Before testing the pins and disc surface were cleaned with acetone. The wear test specimen (8 mm diameter and 20 mm length) was subjected to the load range 10,15,20 N at varying speed .

TABLE I. TAGUCHI DESIGN MATRIX

Level	Sliding Velocity(m/s)	Distance Travelled(m)	Applied load (N)	Wear Rate (x10mm^3/m)
1	1	200	10	30.45
2	1	200	10	30.5
3	1	200	10	31.62
4	1	350	15	35
5	1	350	15	34.09
6	1	350	15	33.69
7	1	500	20	41.02
8	1	500	20	39.06
9	1	500	20	40.05
10	1.5	200	15	35.02
11	1.5	200	15	35.05
12	1.5	200	15	35.07
13	1.5	350	20	40.06
14	1.5	350	20	40.79
15	1.5	350	20	40.33
16	1.5	500	10	30.12
17	1.5	500	10	30.32
18	1.5	500	10	30.33
19	2	200	20	41.03
20	2	200	20	40.95
21	2	200	20	41.11
22	2	350	10	31.09
23	2	350	10	31.11
24	2	350	10	31.32
25	2	500	15	36.09
26	2	500	15	36.14
27	2	500	15	35.99

IV. DEVELOPMENT OF FUZZY LOGIC SYSTEM

The first step in fuzzy logic model is to accept the inputs and determine the degree to which they belong to each of the appropriate fuzzy sets through membership functions. In the proposed fuzzy logic model, the input is a crisp numerical value limited to the universe of discourse of the input parameter. The input factors are sliding velocity, applied load and distance travelled. The crisp values are listed in Table 2. The output function is a fuzzy degree of membership function is the qualifying linguistic set. Fuzzy logic modeling is based on rules and each of the rules leans on solving the inputs into a number of different fuzzy linguistic sets. Before the rules are set, the inputs are fuzzified to each of these linguistic sets. The inputs variables are fuzzified and the degree to which each part of the antecedent is accommodated for each rule. The input to the fuzzy operator is two or more membership values from fuzzified input factors. Membership functions for output factor is in Figure 2.Output variable is a single truth-value. Defuzzification method used in developing the model is centroid technique. Membership function for wear rate prediction, sliding velocity and distance travelled is shown in figures 3, 6 and 7. Rules and rule viewer is in figures 4 and 5.

TABLE II CRISP FUZZY VALUES

Input	Crisp Values
Sliding velocity	1 to 2 m/sec
Applied Load	12 to 19 N
Distance travelled	250 to 450 m

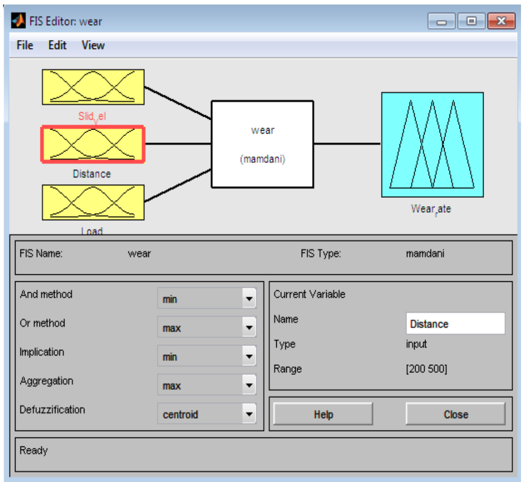

Fig.2. Developed Fuzzy logic structure

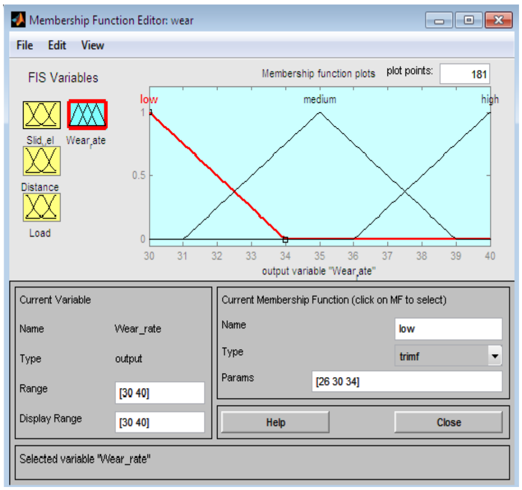

Fig.3. Membership for wear rate

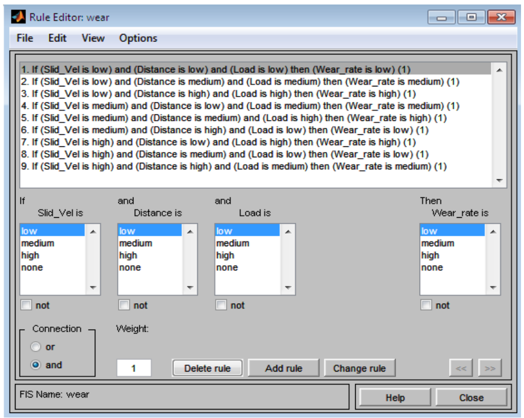

Fig.4. Rules for wear rate

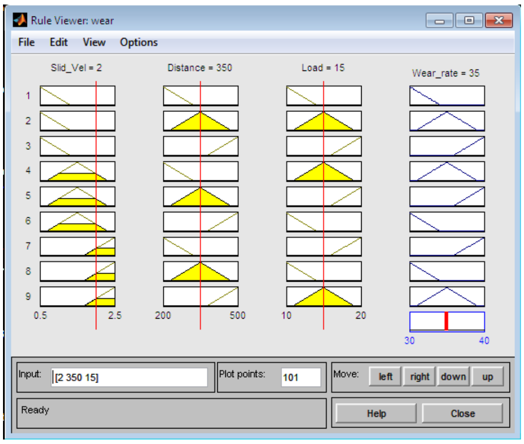

Fig. 5 Rule viewer for wear rate prediction

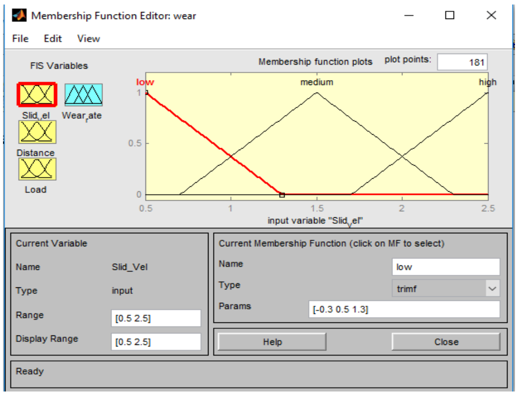

Fig.6. Membership for sliding velocity

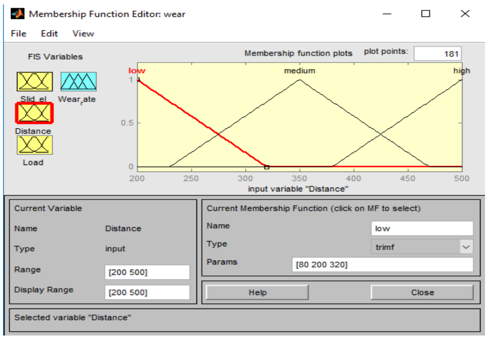

Fig.7. Membership for distance travelled

V. RESULTS AND DISCUSSION

The behaviour wear of Al 7075 titanium carbide composite fabricated by stir casting method was investigated using a pin-on-disc type wear rig by varying the parameters of sliding distance, applied load and distance travelled respectively. After developing the fuzzy logic system for the prediction of wear rate, the model is tested by giving various different values using fuzzy rule viewer.

If the input values are changed, the corresponding output is automatically obtained from the developed model. Confirmatory experiments are done to validate the developed fuzzy model and results are given in Table 3. Input parameters for the confirmatory experiments are given in Table 4. The errors in wear rate prediction very rarely exceed by 7 %, and thus the developed fuzzy model was able to predict with significant accuracy. The developed model is recommended and forwarded to predict wear rate under different conditions.

TABLE III CONFIRMATORY EXPERIMENT RESULTS

Experimental values	Predicted values	% error
32.06	34.13	6.065
37.16	34.91	6.445
41.07	39.77	3.268

TABLE IV INPUT VALUES

Sliding velocity	Distance travelled	Axial load
1	250	12
1.5	300	17
2	450	19

VI. CONCLUSIONS

Experiments are designed and conducted develop fuzzy logic model to predict wear rate. The multiple performance dry sliding characteristics of aluminum hybrid composites was optimized using orthogonal array which is a procedure from Taguchi method. Observations from the proposed model are compared with experimental results. Results indicate that the developed model shows a good agreement with real results. Further confirmatory trials are carried out to validate the proposed approach. With these encouraging results the developed model can be further improved by including other cutting parameters such as vibration which affects wear rate. Electronic components are to be built up for online wear rate monitoring.

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