

Modeling and Analysis Thrust Force in Drilling Al-SiC-Graphite Hybrid Metal Matrix Composite Using Fuzzy Logic Approach

Dr. A. Munia Raj¹, S. Hanish Anand², P.Manigandan³

Professor, Department of Mechanical Engineering, Kings Engineering College, Irungattukottai, Sriperumbudur,
Chennai, India¹

Assistant Professor, Department of Mechanical Engineering, Kings Engineering College, Irungattukottai,
Sriperumbudur, Chennai, India²

Assistant Professor, Department of Mechanical Engineering, Kings Engineering College, Irungattukottai,
Sriperumbudur, Chennai, India³

ABSTRACT: The main aim of this paper is to analysis the influence of machining parameters on hybrid metal matrix composite (Al-SiC-Gr).This hybrid metal matrix composite material is fabricated using 50 micron sized SiC and graphite particles are reinforced into aluminium matrix by using stir- casting technique. The Drilling experiments were conducted on a vertical machining centre using Taguchi design of experiments. Taguchi L₂₇ orthogonal array is designed with three levels of drilling parameters such as spindle speed, feed rate and drill diameter on Al 6065-15% - SiC- 5% Gr composite with tin coated solid carbide twist drills under dry drilling environment. The thrust force is considered as experimental result and it is predicted using fuzzy logic. The results indicate that the predicted responses values and experimental values are close to each

KEYWORDS: Hybrid metal matrix composite, Drilling, Thrust force, Fuzzy logic

I. INTRODUCTION

Aluminum based metal matrix composites are gaining wide spread importance in several engineering applications. The common applications are bearings, cylinder block linear, vehicle drive shafts, automotive pistons, bicycle frames, etc. because of their improved properties over those of non-reinforced alloys [1, 2, 3]. Extensive research has been carried out on the mechanical properties of Aluminium based composites involving a single reinforcement. Use of single reinforcement in aluminium matrix may sometimes lead to deterioration in its physical properties. [4] Aluminium metal matrix reinforced with hard ceramic phase Silicon carbide and another one is soft lubricating phase graphite. Various researches have adopted the above techniques in developing varieties of metal matrix composites. Further, of the several approaches to synthesize aluminium based composites liquid metallurgy route is the most suitable and economical technique [5].

Jinfeng et al., [6] reported the machinability of particulate metal matrix composites (PMMCs) is improved by reinforcing the soft particles like graphite along with hard ceramic particles. The addition of graphite content in AMCs reduces the cutting forces and this has been attributed to the solid lubrication of Gr particulates. During the machining

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of Al-Gr composites, graphite particles act as a chip breaker which results in discontinuous chips, less tool wear and low power consumption. The percentage reinforcement of Gr in Al-Gr composite and SiC in Al-SiC composite is limited to certain level beyond which it is not beneficial to add either Gr or SiC as reinforcement.

The use of multiple reinforcements yields hybrid composites to possess better tribological properties over the composites with single reinforcement [7]. Tsao et al. [8] have studied the drilling of metal matrix composite. Here the approach carried was carried out based on Taguchi techniques and analysis of variance. The main focus of this work is to have a correlation between drill diameter, feed rate and spindle speed.

The experiments were carried out at 3 levels. The phenomenon of interaction was not considered and the results indicated that the drill diameter have a significant contribution to the overall performance. For modeling thrust force in drilling of composite materials fuzzy logic approach is used in this work. Artificial intelligence tools are playing an important role in modeling and analysis. Fuzzy logic is relatively easier to develop and require less hardware and software resources.

Yue Jiao et al [9] used fuzzy adaptive networks in machining process modelling. They have used fuzzy logics for surface roughness prediction in turning operations. Balazinski and Jemielnaik [10] introduced the fuzzy decision support system for the estimation of the depth of cut and flank wear during the turning process. Palanikumar et al. [11] used fuzzy logic for optimizing the multiple performance characteristics. Arghavani et al. [12] used fuzzy logic approach for the selection of gaskets in sealing performance. Fuzzy logic controller is the successful application of fuzzy set theory and was introduced by Zadeh in 1965 [13] as an extension of the set theory by the replacement of the characteristic function of a set by a membership function whose value range from 0 to 1. Considerable amounts of investigations have been directed towards the prediction and measurement of thrust forces. The thrust force generated during drilling have a direct influence on the cutting of material. Wear on the tool, accuracy of the work piece and quality of the hole obtained in drilling are mainly depends on thrust force.

In the present work, a user-friendly fuzzy logic based system has been designed for the prediction of thrust force and in drilling of metal matrix composites. The experiments are conducted on computer numerical control machining centre. L_{27} orthogonal array is used for experimentation. TiN-coated solid carbide twist drill is used for the investigation. The results indicated that the fuzzy logic model could be effectively used for the drilling of composites.

II. EXPERIMENTAL RESULTS

The material used for the investigation is Aluminium alloy reinforced with Silicon carbide and Graphite hybrid metal matrix composites. In the present study the hybrid metal matrix composites material used for the investigation is manufactured through Stir-Casting process. The drilling tests were performed on ARIX-VMC machining centre manufactured by ARIX CNC machine Co. Ltd, Taiwan. The drill bits used in the investigations are TiN coated solid carbide drill having diameter 4 mm, 8 mm and 12 mm that are supplied by Onsrud Corporation, U.S.A and are presented in Fig. 1.



Fig. 1. TiN coated solid carbide twist drill bits used for the experimentation

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The machining operations are carried out as per Taguchi's L_{27} experimental design. This experimental design is chosen for incorporating 3 variables such as feed rate, spindle speed and drill diameters and their interactions at 3 levels. The mean thrust force and torque developed in drilling the composite material was measured using Kistler piezoelectric dynamometer.

The drilling thrust force signals were transmitted to Kistler charge amplifier and stored in Pentium IV computer for further analysis. The machining parameters used and the experimental conditions are presented in Table I. The holes drilled at different feed rates are presented in Fig.2.

Table 1 Machining Parameters and Their Levels

Notations	Machining Parameters	Levels		
		1	2	3
A	Spindle speed (rpm)	1000	2000	3000
B	Feed rate (mm/rev)	0.05	0.10	0.15
C	Drill bit diameter (mm)	4	8	12

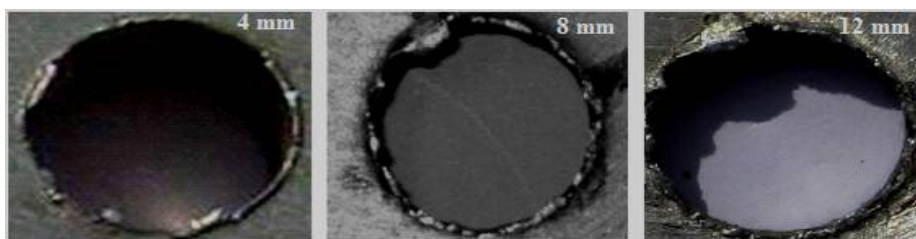


Fig. 2. Drilled holes on Hybrid metal matrix composite

III. FUZZY RULE BASED MODEL FOR THRUST FORCE IN DRILLING OF METAL MATRIX COMPOSITES

The structure of Fuzzy logic systems consists of three conceptual components: a fuzzy rule base, which contains a selection of fuzzy rules; a data base (or dictionary), which defines the membership functions used in the fuzzy rules; and a reasoning mechanism, which performs the inference procedure upon rules and given facts to derive a reasonable output or conclusion [14-16].

The fuzzy reasoning for three-input-two-output fuzzy logic unit is described as follows: The fuzzy rule base consists of a group of IF- THEN statements with three x_1 , x_2 and x_3 an output y , i.e.

Rule 1: if x_1 is A_1 and x_2 is B_1 and x_3 is C_1 then y_1 is D_1 and y_2 is E_1 else

Rule 1: if x_1 is A_2 and x_2 is B_2 and x_3 is C_2 then y_1 is D_2 and y_2 is E_2 else

Rule n: if x_1 is A_n and x_2 is B_n and x_3 is C_n then y_1 is D_n and y_2 is E_n else (1)

A_i , B_i , C_i , D_i and E_i are fuzzy subsets defined by the corresponding membership functions, i.e. μ_{A_i} , μ_{B_i} , μ_{C_i} , μ_{D_i} and μ_{E_i} . The membership functions used for the drilling parameters are spindle speed, feed rate and drill diameter is presented in Figures 3, 4 and 5.

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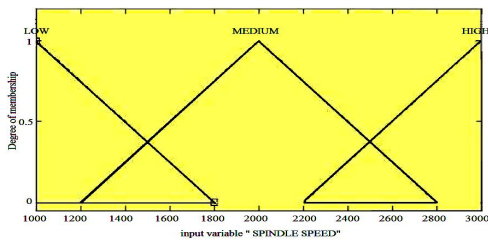


Fig. 3. Membership function for input parameter spindle speed

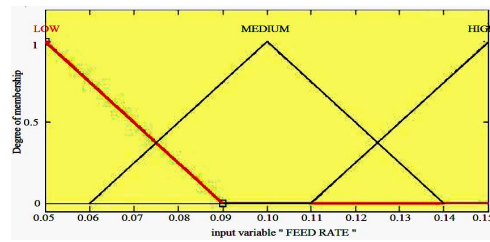


Fig. 4. Membership function for input parameter feed

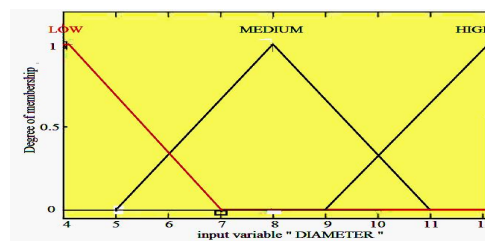


Fig. 5. Membership function for input parameter Diameter

Similarly, the membership function used for the output responses thrust force is presented in Figs. 6. The number of membership functions used for the output response is nine such as LOWEST, LOWER, LOW, LOW MEDIUM, MEDIUM, HIGH MEDIUM, HIGH, HIGHER AND HIGHEST. More results that are precise can be obtained by using more number of membership functions and hence 9-membership functions were selected for the present work. The experiments are repeated for 3 times and the average thrust force and torque is used for fuzzy logic rule based modeling of drilling parameters in drilling metal matrix composites.

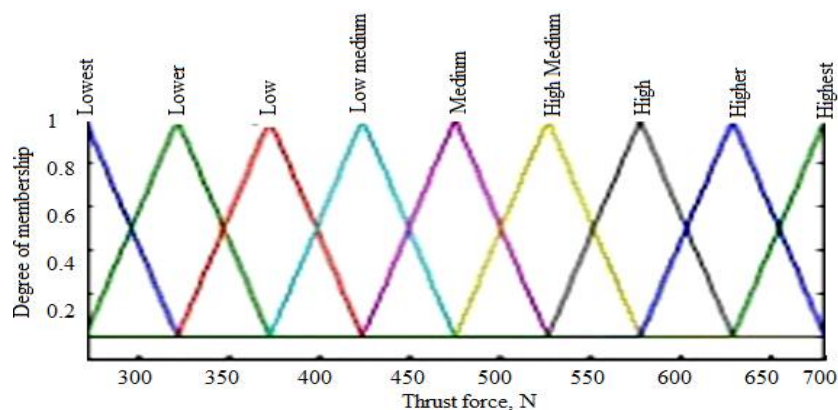


Fig. 6. Membership function for thrust force

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IV. RESULTS AND DISCUSSION

Hybrid metal matrix composite are materials, which combine a tough metallic matrix with high strength ceramic reinforcement to deliver superior properties like wear resistance, high strength to weight ratio, low sensitivity to temperature change and corrosion resistance. Metal Matrix Composite (MMC) materials are either in use or being prototyped for the commercial airplanes, space shuttle, automobile industry and a variety of other application. [17]. The joining of structures is an important concern. Normally the structures are joined by drilling and riveting and or by using fastener. The effective joining is achieved by using proper drilled holes in the workpiece material. Due to the non-homogeneity of Metal Matrix composites, the joining is difficult [18].

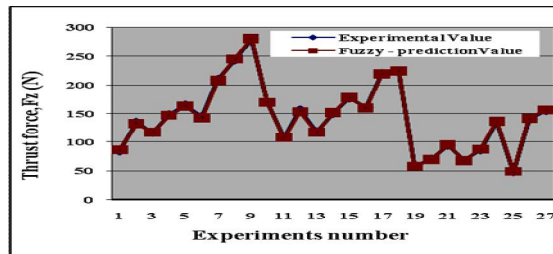


Fig. 7. Comparison of Results between Fuzzy and Experimental Result for Thrust Force

Due to the thrust developed during drilling, many common problems exist. Some of the problem causes in drilling are matrix cracking, matrix debonding, SiC that are pull-out composite material, micro cracks, grooves, and burr formation.

The thrust force and torque developed in drilling operation is an important concern. Monitoring of thrust force in drilling is required for the industry. To prepare a model and analyze the thrust force in drilling of hybrid metal matrix composite materials, fuzzy logic rule based model is introduced in this work. Fuzzy logic is an important tool and it can be very useful for modeling the mechanical processes.

Fig. 7 shows the comparison of experimental value and fuzzy prediction result value for thrust force in drilling of hybrid metal matrix composites. The investigation of machining parameters on thrust force is an important concern. The results indicated that the thrust force varies with the experimental conditions.

The results indicated that the increase of spindle speed reduces the burr formation in drilling of composites. The reason being at higher cutting speed, the material removal rate is high and it leads to less burr formation on the drilled composites plates this in turn reduces the thrust force in drilling of composite materials.

The thrust force is increased with the increase in feed rate and drill diameter in drilling of composite material. The increase of drill diameter and feed rate increases the contact between the work piece material and it leads to higher thrust force. By keeping the low feed rate and drill diameter one can reduces the burr formation in drilling of composite hybrid metal matrix materials.

The adequacy of the developed fuzzy logic model has been verified through R-sq value. The quantity R-Sq called as coefficient of determination is used to judge the adequacy of regression models developed. $0 \leq R - Sq$. R-Sq value is the variability in the data accounted by the model in percentage as

$$R - Sq = 1 - \frac{SSE_{error}}{SS_{total}} \quad (2)$$

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Where SS_{Error} is sum of square error and SS_{total} is sum of square total. The coefficient of determination is calculated using the above expression and does more than 98% for the present investigation for thrust force, which shows that there is high correlation that exists between the experimental and predicted values.

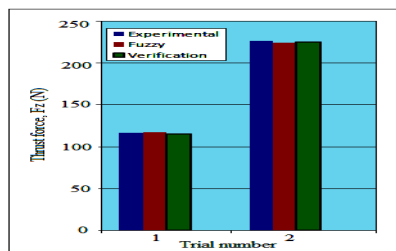


Fig. 8. Verification Test Results

Fig. 8 shows the Verification test results for thrust force, the experiment and verification test are very small and hence fuzzy rule based modeling technique can be effectively used for the prediction of thrust force drilling of hybrid metal matrix composites

V. CONCLUSIONS

The thrust force developed during drilling of hybrid metal matrix composites has been investigated. Fuzzy rule based model has been developed for predicting thrust force in drilling of composites. Based on the experimental and fuzzy modeling results, the following conclusions are drawn:

1. Rule based fuzzy logic model for thrust force is developed from the experimental data.
2. The predicted fuzzy output values and measured values are fairly close to each other, which indicate that the fuzzy logic model can be effectively used to predict the thrust force in drilling of hybrid metal matrix composites.
3. The verification test results reveal that the fuzzy rule based model is suitable for predicting the thrust force in drilling of hybrid metal matrix composites.

Further improvement of model can be possible by introducing more number of variables and wider range of machining conditions.

REFERENCES

- [1] Dabade, U.A., Joshi, S.S., Balasubramaniam, R., and Bhanuprasad, V.V., "Surface finish and integrity of machined surfaces on Al/SiCp composites", *J Mater Process Technol*, Vol.192, pp.166–174, 2007.
- [2] Joshi, S. S., Ramakrishnan, N., Sarathy, D., and Ramakrishnan, P., "Development of the technology for discontinuously reinforced aluminium composites", *Integrated Design and Process Technology, The First World Conference on Integrated Design and Process Technology. Austin, Vol. 1, pp.492–497,1995.*
- [3] Kocazac, M.J., Khatri, S.C., Allison, J.E., and Bader, M.G., "MMCs, for ground vehicle, aerospace and industrial applications", *Fundamentals of Metal Matrix Composites*, Butterworth, Guildford, UK, pp. 297-300,1993.
- [4] Grigoris Kiourtsidis, E., Stefanos Skolianos, M., "Wear Behavior of Artificially Aged AA2024/40 μ m SiCp Composites in Comparison with Conventionally Wear Resistance Ferrous Materials", *Wear*, Vol. 253, pp. 946 – 956, 2002.
- [5] Ramesh, C.S., Abrar Ahamed, B.H., Channabasappa, R., Keshavamurthy., "Development of Al 6063–TiB₂ in situ composites", *Materials & Design*, Vol.31, Issue 4, pp. 2230-2236, 2010.
- [6] Jinfeng Leng, Gaohui, W.u., Qingbo Zhou, Zuoyong Dou, and XiaoLi Huang., "Mechanical properties of SiC/Gr/Al composites fabricated by squeeze casting technology", *Scripta Materialia*, Vol.59, pp.619-622,2008.
- [7] Suresha, S., and Sridhara, B.K., "Effect of addition of graphite particulates on the wear behavior in aluminium–silicon carbide–graphite composites", *Materials and Design*, Vol. 3, pp.1804-1812, 2010.
- [8] Tsao, C.C., and Hocheng, H., "Taguchi analysis of delamination associated with various drill bits in drilling of composite material," *International journal of Machine tools & manufacture*, Vol.44, pp.1085-1090, 2004.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

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- [9] Yue Jiao, Shuting Lei, Pei, Z.J., and Lee, E.S., "Fuzzy adaptive networks in machining process modeling: surface roughness prediction for turning," International Journal of Machine Tools & Manufacture, vol.44, pp.1643-1651, 2004.
- [10] Balazinski, M., and Jemielnaik, K., "Tool condition monitoring using fuzzy decision support system", In: V CIRP," International conference on monitoring and automatic supervision in manufacturing, Miedzesyn near Warsaw, pp.115-121, 1998.
- [11] Palanikumar, K., Karunamoorthy, L., Karthikeyan, R., and Latha, B., "Optimization of machining parameters in turning GFRP composites using a carbide (K10) tool based on the Taguchi method with fuzzy logics," Metals and Materials International, Vol.12, pp.483-491, 2006.
- [12] Arghavani, M., Derenne, M., and Marchand, L., "Fuzzy logic application in gasket selection and sealing performance," International Journal of Advanced Manufacturing Technology, Vol.18, pp.67-68, 2001.
- [13] Zadeh, L., "Fuzzy sets, information and control," Vol.8, pp.338-353, 1965.
- [14] Oguzhan Yilmaz, Omer Eyercioglu, and Nabil, N.Z., Gindy., "A user-friendly fuzzy-based system for the selection of electro discharge machining process parameters," Journal of Materials Processing Technology, Vol.172, pp.363-371, 2006.
- [15] Jang, J.Sr., Sun, C.T., and Mizutani, E., "Neuro-fuzzy and soft computing - a computational approach to learning and machine intelligence", Pearson Education, 2005.
- [16] Lin, J.L., Wang, K.S., Yan, B.H., and Tarn, G., "Optimization of the electrical discharge machining process based on the Taguchi method with fuzzy logic," Journal of materials Processing technology, Vol.102, pp.48-55, 2000.
- [17] Ibrahim, I.A., Mohamed, F. A., Lavernia, E. J., Journal of Material Science, Vol. 26, pp.1137-1157, 1991.
- [18] Vimal Sam Singh, R., Latha, B., Senthilkumar, V.S., "International Journal of Recent Trends in Engineering", Vol.1, No. 5, pp. 66-70, 2009