

# Study and Analysis of Polymer Composites

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**ABSTRACT:** Fiber reinforced polymer (FRP) composites have been steadily replacing metals as choice engineering materials for various applications. In order to drill holes efficiently with the least waste and defects, it is essential to understand the machining behavior of FRP. Drilling is one of the most frequently practiced machining processes in industries owing to the need for component assembly in mechanical structures. In this work, experiments were conducted. The process parameters investigated are spindle speed, feed rate and drill diameter. Static and dynamic analysis is developed to predict thrust force and torque in drilling of FRP composites. The results indicated that the model can be effectively used for predicting the response variable by means of which delamination can be controlled.

## I. INTRODUCTION

Fiber Reinforced Polymer (FRP) composite materials are finding increased applications in variety of engineering fields such as aeronautical, automotive, etc and subsequently, the need for accurate machining of composites has increased enormously. The mechanism behind the machining of fiber reinforced polymer composite is quite different from that of metals, and it brings about many undesirable results, such as rapid tool wear, rough surface finishes on finished components, and a defective sub-surface layer with cracks and delamination.

In order to drill holes efficiently with the least waste and defects, it is essential to understand the experiments to understand machining behavior, but as materials get more complex obtaining results from experiments can become very cumbersome. Hence there is a need to turn to alternate methods of experimental techniques and this is where we find analytical and numerical modeling techniques useful. Let us first take a look at what FRP composites are and why such a modeling approach is preferred. Composites have a low co-efficient of thermal expansion, which can provide a greater dimensional stability when required. The machining of fiber reinforced composite materials is not the same as the machining of conventional metals. Hence, the spindle speed, drill diameter, feed rate of the machining operation should be selected carefully in the machining of fiber composite materials.

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## II. SCOPE AND METHODOLOGY

This study has presented multi - objective optimization of drilling process by using modeling and finite element analysis. This finite element analysis was used to predict thrust forces and torque during drilling and kistler piezoelectric dynamometer was used to measure the thrust force and torque. The drilling tests were performed on digital read out machine for finding the cutting speed and feed rate. This research can be extended to minimize the delamination when the FRP material is subjected to drilling.

1. Numerical Method
2. Fuzzy Logic Method
3. Experimental Method

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**Table 1. Control Parameters and their Levels**

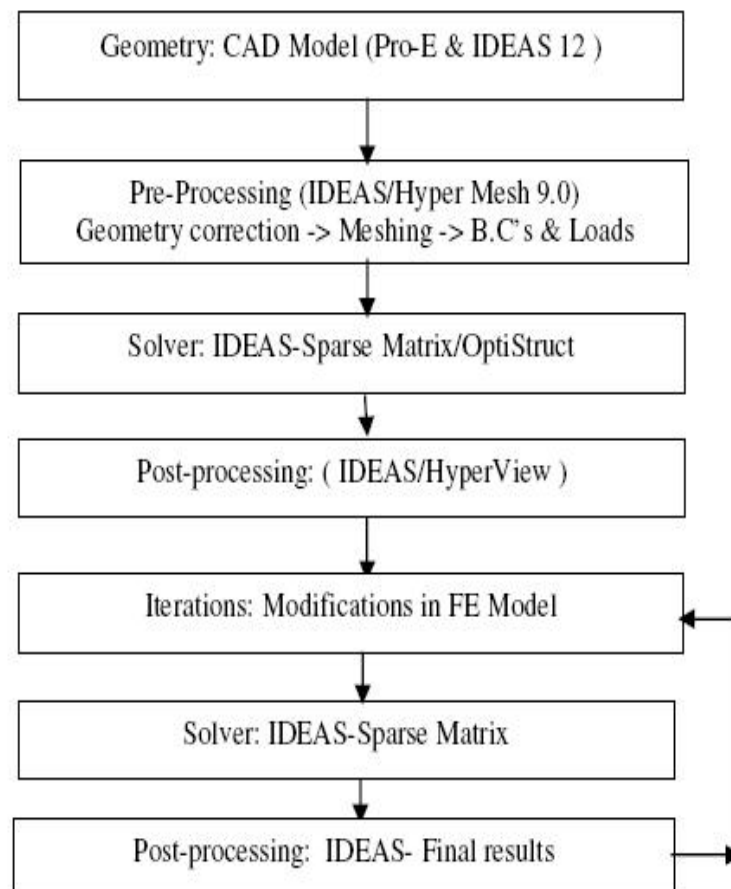
Parameters	Levels		
Spindle speed (rpm)	210	420	1750
Feed rate (mm/min)	40	80	120
Drill diameter (mm)	8	10	12
Torque (N-m)	0.62	1.75	2.86
Thrust force (N)	249	435	505

### A. Finite Element Analysis

Finite element analysis helps in accelerating design and development process by minimizing number of physical tests thereby reducing the cost and time for prototyping and testing. Finite Element Analysis is one of the CAE technologies having a wide application in the field of mechanical Engineering design process.

- ✓ Numerical method to determine structural behavior.
- ✓ Solves linear equations to find response under load.
- ✓ Results are thrust force and torque
- ✓ Results of design analyses used to select speed and feed rate for selected diameters

FEA consists of various steps as follows



**Figure 1. Flowchart of analysis steps**

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## B. Fuzzy Logic

FL incorporates a simple, rule-based IF X AND Y THEN Z approach to a solving control problem rather than attempting to model a system mathematically. The FL model is empirically-based, relying on an operator's experience rather than their technical understanding of the system. This method was evaluated using the experimental data and by a self-classification test (monitoring indices included the cutting conditions).

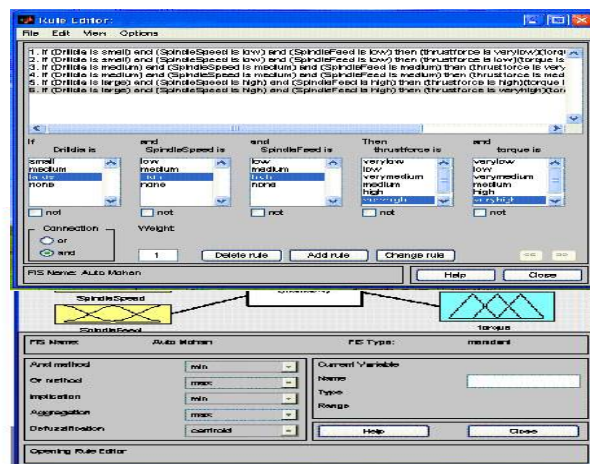


Figure.2 The fuzzy model for tool condition monitoring

The fuzzy C-mean method was first proposed by Bezdek [23]. It uses the cost function defined below:

$$J(U, V, X) = \sum_{k=1}^N \sum_{j=1}^n \sum_{i=1}^m u^v(k, j) \|x(k, i) - v(j, i)\|^v \quad (1)$$

here  $V = \{v(j, i)\}$  is the fuzzy cluster center,  
 $X = \{x(k, i)\}$  is the monitoring indices of the samples,  
 $U = \{u(k, j), u(k, j) \in [0, 1]\}$



Figure 3. Arrangement of number of Inputs and Outputs

## III. EXPERIMENTAL WORK

The material used for the investigation is glass fiber reinforced polymer composites with polyester resin. In the present study the composites material used for the investigation is manufactured through hand lay-up process.

- ✓ Work piece material thickness is 5mm.
- ✓ The material contains 60% of GFRP remaining is polyester resin.

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- ✓ Material is coated with wax polish.
- ✓ The drilling tests were performed on digital read out machine.
- ✓ The drill bits used in the investigations are HSS drill having diameter 8 mm, 10 mm and 12 mm.
- ✓ Three levels of speeds are 210rpm, 420rpm, and 1750rpm.
- ✓ Three levels of feeds are 40m/min, 80m/min and 150m/min.



Figure. 4 Multi-facet drill bits used for the experimentation

## IV. RESULTS AND DISCUSSION

In this work, fuzzy rule based modeling is used for the prediction of thrust force and torque in drilling of composite materials. It can be asserted that the results obtained through the fuzzy logic model are almost similar to that of the experimental results. For confirmation of the fuzzy logic rule based modeling technique, verification tests are conducted at two different selected conditions. The test results for thrust force and torque, the difference between the predicted delamination factor by the fuzzy rule based model, the experiment and Numerical test are very small and hence fuzzy rule based modeling technique can be effectively used for the prediction of thrust force and torque in drilling of FRP composites.

Hole No.	Experimental result		Fuzzy Logic Result		Analytical Result	
	Thrust force (N)	Torque (N-M)	Thrust force (N)	Torque (N-M)	Thrust force (N)	Torque (N-M)
01	373	1.20	369.2	1.09	373.46	0.95
02	482	1.38	480	1.26	467.81	1.19
03	631	1.62	629.0	1.56	583.78	1.49
04	534	1.75	540	1.69	466.83	1.49
05	632	1.99	635.6	2.03	584.76	1.87
06	750	2.58	761.9	2.53	729.72	2.33
07	674	2.39	687.1	2.46	560.19	2.15
08	792	2.74	788	2.84	701.71	2.69
09	938	3.36	938	3.26	875.87	3.36

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### V. CONCLUSION

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

1. Rule based fuzzy logic model for thrust force and torque is developed from the experimental data. 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 and torque in drilling FRP composites.
2. The verification results reveal that the fuzzy rule based model is suitable for predicting the thrust force and torque in drilling of composites.
3. Utilization of this system can improve the quality of drilled part; if online monitoring is introduced. This system can reduce the tedious model making, computational cost and time.
4. Further improvement of model can be possible by introducing more number of variables and wider range of cutting conditions.

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