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Artificial Intelligence Modelling and Analysis of Pivotal Parameters in Drilling Hybrid Fiber Composite (HFC)

Composite materials have the perk of combining a number of properties, which are not usually found together in a single material. The Hybrid Fiber composite solves the increasing need for Eco friendly materials coupled with high durability and strength. HFC has a wide range of applications in the field of aerospace, auto motives, civil constructions and electronics at a cost, which is lower than that of the traditional fibers like GFRP. Drilling is one of the primary operations adopted by industries for material working and component building. In this paper, the seminal process parameters - spindle speed, feed rate and the drill diameter are analysed and a Fuzzy model is burgeoned predicting the Thrust force and Torque for drilling Hybrid fiber Composite (HFC). The results indicate that the Fuzzy prediction model is effective and facilitates a better and easier artificial intelligence modelling.

Keywords: *Hybrid composites, Fuzzy Model, Artificial intelligence modelling*

1. INTRODUCTION

Composite materials have been extensively used in many technical applications, where high strength and stiffness are required, but with a lower component weight. The said properties are mainly due to the low density of applied matrix systems and the embedded fibers. The composite parts are made during the production by orientating the reinforcing fibers in the directions of the applied load. Conventional fiber reinforced polymers like GFRP pose problems with respect to their re use or recycling at the end of their usable lifetime which is mainly because of the stable fibers and matrices. Landfill disposal of these materials is dangerous due to the resulting problems of environmental sensitivity. Hence, environmentally compatible alternatives like Natural and hybrid Fiber composites made of renewable resources are extensively used.

Many advances have been made with respect to the hybrid fiber composites. Jawaid [1] has stated that the Hybrid composites using cellulosic fibers are economical and provide versatility to the fiber-reinforced composites. Padma priya & Rai [2] has presented the characteristics of mechanical reinforcement obtained by the introduction of glass fibers in cellulosic fibers (silk fabric)-reinforced epoxy composites. It is observed that when a small amount of glass fabric is added to the silk fabric reinforced epoxy matrix, the mechanical property gets augmented. Hybridization of silk fibers with glass fiber resulted in the increase in weight fraction of reinforcement and the water uptake of hybrid composites was lower than that of non-hybridized composites. A.U. Ude [3] has stated that the Natural fibers are biodegradable and are renewable and a natural source. These two characteristics play a major role in disposal of the components at the end. Darshil U [4] has found that the silk reinforcements are more compressible than the plant and glass fibers. Unlike the plant fibers such as flax and hemp, which are commonly found as bundles, silk from the silkworm Bombyx mori is obtained as long, smooth and individual threads. These threads or filaments can reach up to 1500 m and have triangular shaped cross sections that can fit together more precisely when compared to the cylindrical fibers. The Silk fiber reinforcements edges out the plant fibers with better bending capacity without fracture, improving the mechanical performance of the composite. According to the researchers, silk fibers can overcome the bottleneck problem faced by the plant fiber reinforcements. Also, silk fiber reinforcements offer a unique opportunity in the production of high natural fiber composites. R.A. Eshkoor [5] has investigated the energy absorption response of a rectangular woven natural silk composite tube when subjected to an axial quasi-static crushing test using a trigger mechanism. The rectangular tubes were prepared by hand lay up technique, in which 24 different layers of silk fabric were used, each with a thickness of 3.4 mm and tube lengths 50, 80, and 120 mm.

Many researchers have analyzed drilling of composite materials. V. Santhanam [6] has stated that the Banana Glass fiber reinforced Epoxy composites were prepared by using hand layup method. Drilling experiments were conducted on the chopped fiber and laminated woven fiber composites using a standard twist drill. Experiments were conducted by varying the speed and feed rate. Optimum drilling parameters were determined for selected samples each from chopped fiber and woven

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fiber composite. Machine vision technology was used to measure the quality of drilled Hole.

B.V.Kavad [7] has stated that the drilling is an important process for assembling components made from GFRP. Various processes like conventional drilling, vibration assisted drilling and ultrasonic assisted drilling have been used in order to maintain the integrity of the material and obtain the precision in drilling of GFRP. In conventional machining feed rate, tool material and cutting speed are the most influential factor on the delamination hence machining at higher speed, using harder tool material and lower feed rate have lesser delamination of the GFRP. In this work an artificial intelligence model is built using fuzzy logic based system for the prediction of thrust force and torque for drilling of hybrid fiber reinforced composites.

Special 8 facet drill is used for the investigation. The results obtained shows that the artificial intelligence model using fuzzy logic can be effectively used for the drilling of composites.

Palanikumar [8] has clearly stated on how conventional machining feed rate, tool material and cutting speed are the most influential factor on the delamination and as a result of that machining at higher speed, using harder tool material and lower feed rate have lesser delamination of the GFRP. This is one of the main assumption used while building the fuzzy model.

Soft Computing is one of the most common modeling methodology which facilitates in getting solutions to real-life problems. Mathematically, building models and performing experiments are tedious and difficult. fusion of methodologies that were designed to model and enable solutions to real world problems, which are not modeled or too difficult to model, mathematically. The main ideology is to create ways of computation, which gives an acceptable solution at low cost.

2. EXPERIMENTAL SETUP

The material investigated is the hybrid fiber composites. The HFC used for the testing is fabricated using Hand Lay-up process. Hand lay-up moulding is used for fabrication due to the minimum investment for the mould. The Fabrication is done by applying the following elements successively onto to the mould surface by the hand lay-up process.

1. Layer of liquid Epoxy Resin [Viscosity between 0.3 and 0.4 Pa.s and of medium reactivity]
2. 6 Layers of Uni-directional E-glass fiber and Silk fiber [Sandwich of the layers in two directions, 0º and 90º arranged alternatively]
3. Hardener [Araldite] HY 951 [IUPAC name - NNO-bis (2aminoethylethane-1,2diamin) and viscosity of 10-20 poise at 25ºC]
4. Gel coat
5. Releasing agent

Impregnation of the reinforcement layer is done using a roller. This operation is repeated for every other layer so as to obtain the desired thickness. The drilling tests were performed on drilling machine with variable feed drive which is shown in the Fig 2.The drill bits used in the investigations are 8-facet carbide drill having diameter 4 mm, 6 mm and 8 mm which are supplied by Onsrud Corporation, U.S.A and are represented in the Fig. 1.

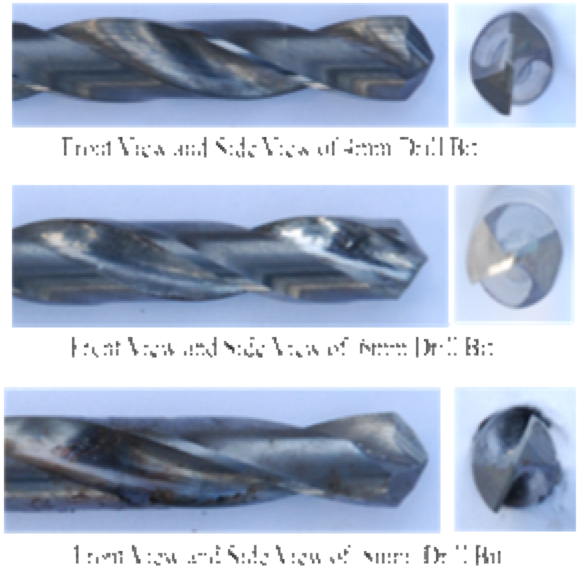


Figure 1. 8-Facet carbide drill

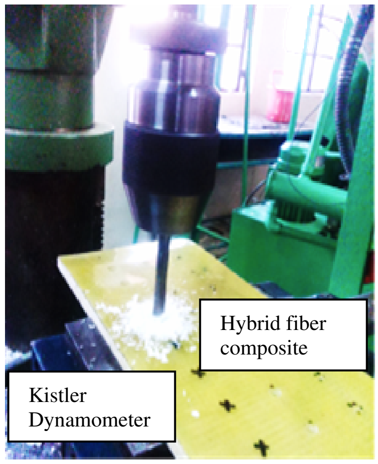


Figure 2. Experimental Setup

The experimental design is chosen for 3 variables namely, Spindle speed (RPM), Feed rate (mm/min), Drill diameter (mm) and across 3 levels for the Spindle speed 500 RPM, 1000 RPM, 1500 RPM, Feed rate 100 mm/min, 300 mm/min, 500 mm/min and Drill diameters 4 mm, 6 mm, 8 mm.

Table I. Control Parameters and Various levels

Cipher	Parameters	Levels		
		1	2	3
A	Spindle Speed (RPM)	500	1000	1500
B	Feed Rate (mm/min)	100	300	500
C	Drill diameter (mm)	4	6	8

The Taguchi matrix L27 design is chosen for the machining operation considering the control parameters and their levels. The values of the mean thrust force and torque developed during the process of drilling composite material were measured by Kistler piezoelectric dynamometer. The thrust force signals were transmitted to the charge amplifier and were stored in a personal computer for the statistical analysis. The control parameters and the experimental levels are presented in the Table I.

3. ARTIFICIAL INTELLIGENCE MODELLING AND ANALYSIS OF THE SEMINAL VARIABLES USING FUZZY LOGIC BASED MODEL IN DRILLING HYBRID FIBER COMPOSITES

The Fuzzy logic algorithm is built by 3 components:

1. Fuzzy logic rule base [Congregation of the Fuzzy logic rules]
2. A Directory or Database system [Defines the membership functions used in Fuzzy logic]
3. Reasoning mechanism [Performs operations based upon the rules and facts given, to derive a reasonable conclusion]

The Fuzzy logic base is represented by

When,

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

The membership functions of the drill diameter, spindle speed and feed rate are presented in the below figures.

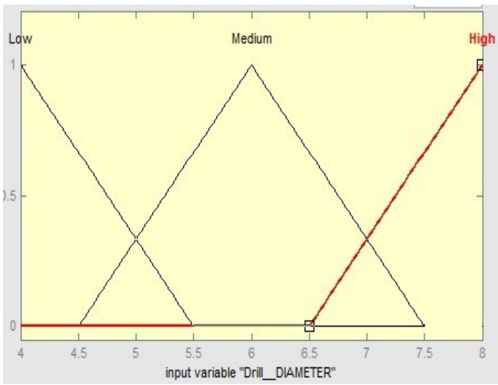


Figure 3. Membership function for input parameter Drill Diameter

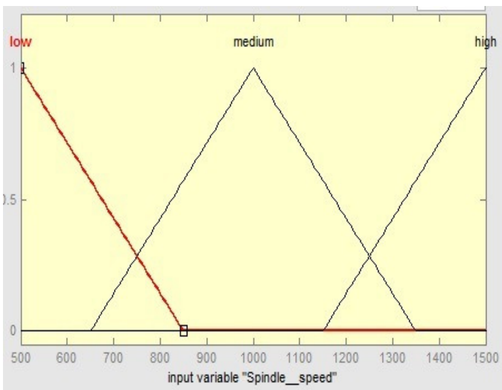


Figure 4. Membership function for input parameter Spindle speed

The Membership functions for the output functions - thrust force and torque is presented in the figures 6,7. The Membership functions for the output response were considered as nine. They are ULTRA LOW, VERY LOW, LOW, LOW MEDIUM, MEDIUM, HIGH MEDIUM, HIGH, and VERY HIGH AND ULTRA HIGH. The precision of the results is increased by using more number of membership functions.

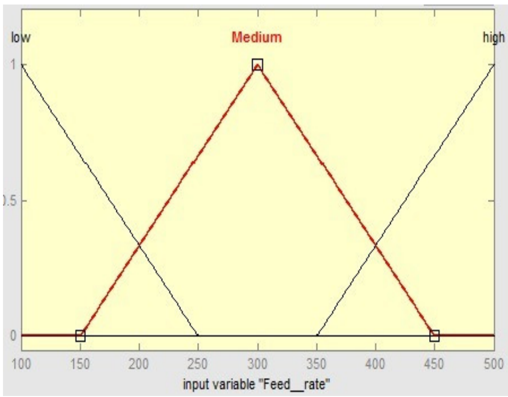


Figure 5. Membership function for input parameter Feed rate

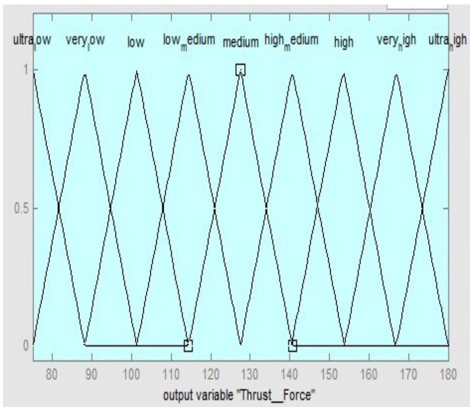


Figure 6. Membership function for output parameter Thrust force

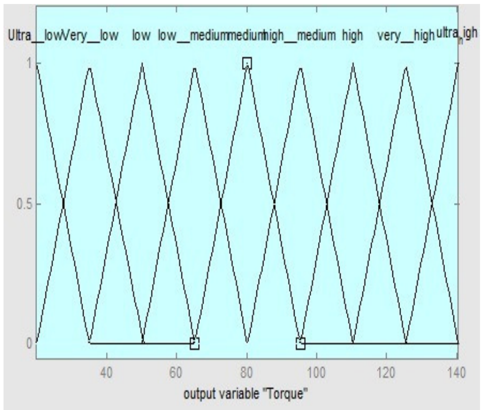


Figure 7. Membership function for output parameter Torque

The Experiments are conducted thrice and the average thrust force and torque is used for the artificial intelligence modelling of drilling parameters using Fuzzy logic for drilling HFC.

4. RESULTS AND INFERENCE

Fiber reinforced composite materials are one of the pivotal materials used today because of their peerless properties. These materials have a decisive application in building and structural industries. One major concern is the difficulty in joining these structures. The structures can be joined by drilling and riveting and or by using fasteners. The effective joining is achieved only by using proper-drilled holes in the structural material. Because of its property of non-homogeneity, the thrust developed during drilling, many result in many problems like

a. Breaking of fibers
b. Pull Out
c. Matrix De bonding
d. Delamination
e. Fiber cracking
f. Thermal degradation
g. Spalling

Hence, the thrust force and torque developed in drilling operation is an important factor and the monitoring of these parameters during drilling is very much needed in the industry. To build an artificial intelligence model and simulate the thrust force in drilling of composite materials, Fuzzy logic based model is introduced in this work. Fuzzy logic is a substantial tool used for modelling and analysis of the mechanical processes.

Fig 8 depicts the comparison of the values of the thrust force in drilling HFC, obtained experimentally and that of the Fuzzy prediction model.

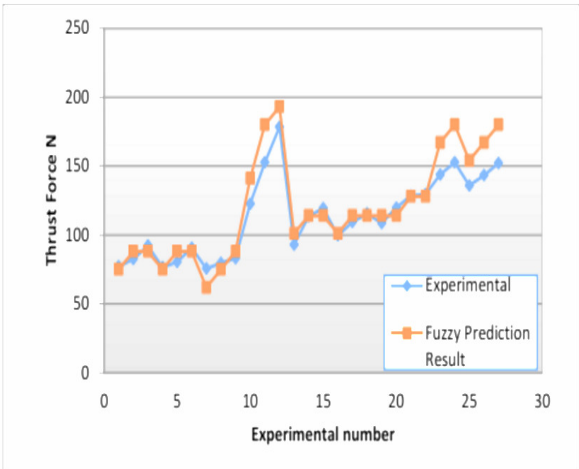
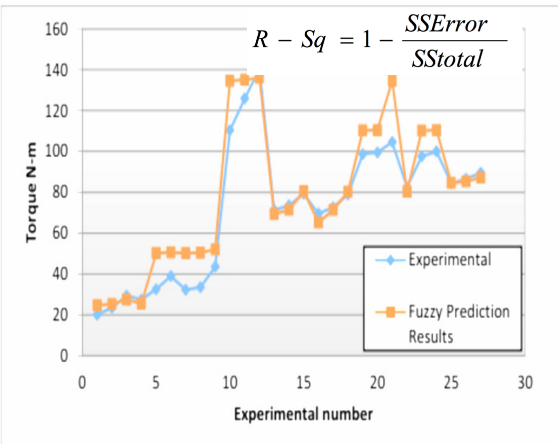


Figure 8. Comparison of Results between Fuzzy and Experimental Result



$$R - Sq = 1 - \frac{SSError}{SStotal}$$

Figure 9. Comparison of Results between Fuzzy and Experimental

Fig.9 shows the trends of the experimental and fuzzy results for torque in drilling HFC. The results have indicated that the parameters thrust force and torque varies with the experimental conditions. The graph is drawn for various experimental conditions with respect to the thrust force and torque. The thrust force and torque developed in drilling is directly proportional to the impact of damage that occurs in the composite plates around the hole. If the property of the material is such a way if it's hard, the delamination will be more. When the tool thrust is high, the damage in the composite laminates equally high. The impact of thrust force and torque is said to be reduced. For reducing that, procedures like artificial intelligence modelling, simulation and optimisation of process parameters are necessary. Vimal Samsingh [9] has obtained similar results and the values obtained prove to be fruitful. Ester Florence Sundarsingh [10] has used a comparison methodology, which has been adopted in this research article. In this paper, fuzzy rule based modelling is used for the artificial intelligence modelling and the prediction of thrust force and torque in drilling of composite materials. From the Figures 9 and 10, it can be concluded that the output obtained through the fuzzy logic based model are very much closer to that of the experimental results. Other inferences obtained through the analysis are

1. The Spindle speed in inversely proportional delimitation rate during drilling [At higher cutting speed, the rate material removal is high which leads to low delamination of the drilled composites plates which in turn reduces the thrust force and torque]
2. The feed rate and drill diameter is directly proportional to the thrust force and torque
3. The drill diameter and feed rate is directly proportional to the contact between the workpiece material and hence proportional to thrust force and torque
4. Having low feed rate and drill diameter can reduce the delamination and torque

The pertinence of the artificial intelligence model is substantiated by R square test.

For $0 \le R - Sq$:

Here $SSError$ refers to the sum of square error and $SStotal$ refers to the sum of square total. The coefficient of determination is calculated and is found to be more than 93% for the current investigation of the thrust force and torque, which clearly shows that the is correlation between the experimental and predicted Fuzzy values are very high.

Fig. 10 and 11 shows the test results for the thrust force and torque. We can thus augur that the difference between the experiment value and that of the predicted ones are very minor and hence the fuzzy logic based artificial intelligence modelling technique can be adopted used for the prediction of the thrust force and torque in drilling of Hybrid fiber composites.

At three different selected conditions verification tests are conducted for endorsement of the fuzzy logic rule based modeling technique,. Fig. 12 shows the test results for thrust force and torque, the difference between the predicted delamination factor by the fuzzy rule based model, 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 and torque in drilling of GFRP composites.

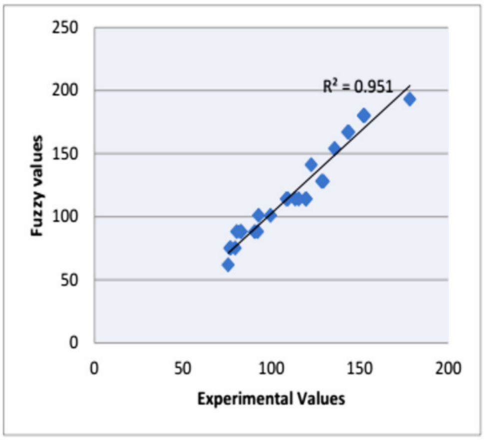


Figure 10. Correlation graph for Thrust Force using Fuzzy Logic

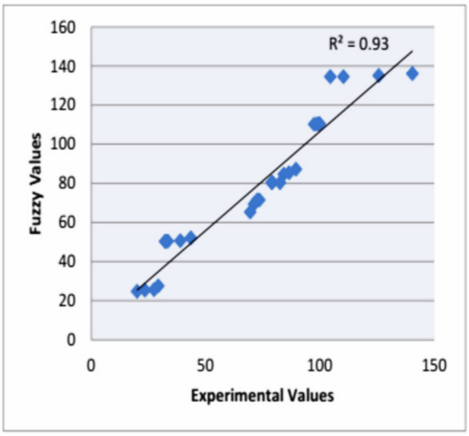


Figure 11. Correlation graph for Torque using Fuzzy Logic

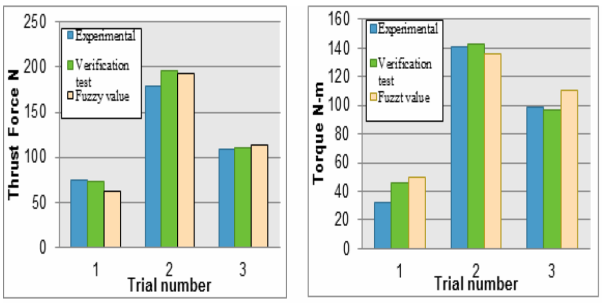


Figure 12. Verification of test results

5. CONCLUSION

The thrust force and torque developed during the process of drilling hybrid fiber composites has been investigated in accordance with the Taguchi L27 matrix. Fuzzy rule based artificial intelligence model has been built for predicting the thrust force and torque in drilling of HFC. From the experimental and fuzzy results, following conclusions were drawn:

1. The predicted fuzzy logic output and measured experimental values are fairly close, which indicates the effectiveness of the fuzzy logic model and can be used for predicting the thrust force and torque in drilling Hybrid fiber composites
2. The quality of the drilled part can be improved when monitored by this system
3. This system reduces the tedious process of model making, computational cost and precious time
4. The model can be augmented further by using more number of process variables and wider range of available cutting conditions

REFERENCES

[1] M. Jawaid, H.P.S. Abdul Khalil: Cellulosic / synthetic fiber reinforced polymer hybrid composites, Carbohydrate Polymers 86 (2011) Volume 86 1– 18

[2] Padma Priya S, Rai SK, Varada Rajulu, A: Impact, compression, density, void content, and weight reduction studies on waste silk fabric/epoxy composites. J, Reinforced Plastic Composites 2005; 24:1605–10.

[3] A.U. Ude, Ariffin A.K. and Azhari, C.H.: Bombyx mori silk fiber and its composite: A review of contemporary developments, Materials & Design May 2014 Volume 57 Pages 298–30

[4] Darshil U. and Shah, D.U.: Silk fibers come on strong in composites. Materials Today _ Volume 17, Number 6 _ July/August 2014

[5] R.A. Eshkoor et al: Failure mechanism of woven natural silk/epoxy rectangular composite tubes under axial quasi-static crushing test using trigger mechanism, International Journal of Impact Engineering (2014) Volume 64 Pages 53 to 61

[6] V. Santhanam and M.Chandrasekaran: A Study on Drilling Behavior of Banana-Glass Fiber Reinforced Epoxy Composite, Volume: 4 Issue: 11 November 2014 ISSN - 2249-555.

[7] B.V.Kavat et al: A Review Paper on Effects of Drilling on Glass Fiber Reinforced Plastic , Procedia Technology 14 (2014) 457 – 464

[8] K. Palanikumar, B. Latha, V.S. Senthilkumar, J. Paulo Davim: Analysis on Drilling of Glass Fiber–Reinforced Polymer (GFRP) Composites Using Grey Relational Analysis, Materials and Manufacturing Processes, 27: 297–305, 2012

[9] R. Vimal Samsingh, B. Latha, V.S. Senthilkumar: Modeling and Analysis of Thrust Force and Torque in Drilling GFRP Composites by Multi-Facet Drill Using Fuzzy Logic, International Journal of Recent Trends in Engineering, Vol. 1, No. 5, May 2009

[10] Esther Florence Sundarsingh, Vimal Samsingh Ramalingam, Malathi Kanagasabai: Statistical analysis on the bandwidth of a dualfrequency textile antenna, IET Microwaves, Antennas & Propagation, ISSN 1751-8725

[11] Visveshwar N, Vishal, V, Vishal Venkatesh, Vimal Samsingh, Karthik Pragadish. Calitatea: Acces la Success; Bucharest18.157 (Apr 2017): 61-64

МОДЕЛИРАЊЕ ВЕШТАЧКЕ ИНТЕЛИГЕНЦИЈЕ И АНАЛИЗА ГЛАВНИХ ПАРАМЕТАРА КОД БУШЕЊА ХИБРИДНОГ КОМПОЗИТА

В. Нагарајан, В. Кумар, В. Самсинг Р.

Композитни материјали укључују истовремено неколико својстава што се обично не среће код једнокомпонентних материјала. Хибридни композит решава проблем све већих потреба за еколошким материјалима и материјалима који се одликују трајношћу и чврстоћом. Хибридни композит има широку примену у области ваздухопловства, аутомобилске индустрије, грађевинарства, електронике и јефтинији је од класичног ГФРП. Бушење је једна од основних операција која се користи у индустрији за обраду материјала и производњу компонената. У раду се анализирају основни параметри процеса бушења – брзина вретена, брзина помоћног кретања и пречник бушилице и развијен је фази модел за предвиђање потисне силе и обртног момента код бушења хибридног композита. Резултати показују да је фази модел предвиђања ефикасан и да олакшава и побољшава моделирање вештачке интелигенције.