International Journal of Advance Research in Science and Engineering
Vol. No.6, Issue No. 08, August 2017
www.ijarse.com
IJARSE
ISSN (O) 2319 - 8354
ISSN (P) 2319 - 8346

Estimating the Drilling Induced Damage and Simulating the Optimised Parameters through the Regression integrated Simulated Annealing seed Tabu Search Algorithm on Sandwich FRP Composites Machining

Dr.D.Ramalingam*[1], R.RinuKaarthikeyen[2], Dr.S.Muthu[3], Dr.V.Sankar[4]

*[1]*Associate Professor, Nehru Institute of Technology, Coimbatore, (India)*

**corresponding author*

[2]*Research Associate, Manager – Engineering, TCMPFL, Chennai,(India)*

[3]*Principal, Adithya Institute of Technology, Coimbatore,(India)*

[4]*Professor, Nehru Institute of Engineering and Technology, Coimbatore,(India)*

ABSTRACT

The composite materials are attracting the high importance in the wide range of fields and are substituted to many traditional engineering materials. Producing the parts with the FRP materials into this desired dimensional accuracy is the prime challenge in the manufacturing operations. At the same time unlike the metals FRP composites are facing the delamination problems as an added issue. A large dismissal rate is recorder in manufacturing which in addition impacts on the long-term performance of the composite structures with drilled holes owing to the drilling induced damage. Huge number of attempts has been adopted to bring down such damage but still a common analytical model for estimating the drilling induced damage eludes the composite's alliance. The present study is an effort to employ the Simulated Annealing Algorithm and the concept of Tabu Search Algorithm in the gradient based training of neural network in the MATLAB platform programming to optimize and hence to develop a predictive model for estimating the drilling induced damage in Sandwich FRP laminates. The values of the experimental observation while drilling the sandwich frp composite laminates of different fibre volume ratios are the base for this investigation. Statistical projections is carried out in MINITAB software and afterwards the regression equations are fed as input as a hybridization and the simulation is performed. The results of the model are in good agreement with the training and the testing data. Henceforth the developed projecting model is sestablishing the suitability within the range of levels for different variables and for selection of optimal drilling parameters to achieve damage free drilling in composite laminates.

Keywords

Sandwich frp composites, Drilling, Regression, Simulated Annealing Algorithm, Tabu Search Algorithm, Simulated Annealing seed Tabu Search, hybridization, Minitab, MATLAB.

IJARSE
ISSN (O) 2319 - 8354
ISSN (P) 2319 - 8346

I. INTRODUCTION

Composite materials are becoming increasingly important in a wide range of fields and are replacing many traditional engineering materials. Composite materials such as fibre-reinforced plastics are broadly used in aerospace, automotive and civil applications due to their exceptional mechanical properties. The quality of the products being manufactured acting with the main accountability in the current scenario in terms functional aspect as well as the life of the product with consistent performance. At time of manufacturing it is very essential to control the quality parameters regarding all attributes of the product concern within the acceptable range in order to fulfill the end usage. In this context, the quality of the hole produced during the drilling operations is influenced by several factors which are impending into the process. The feed rate of the tool and spindle speed are the prime factors in drilling operations which reflects on the end product quality in addition with other properties of the materials being processed and the tool materials. Though it is burdensome to take the complete factors under the control while processing, to the maximum extent possible attempts are being taken by proper selection of machining parameters which trade in high influence on the end product quality. Application of optimisation techniques is the commonly accepted and exercised approach in this context. With this objective and clear understanding of the specific effects of machining parameters in various machining operations, many researchers are using both the traditional and nontraditional optimization techniques to resolve the issues.

II. RELATED LITERATURE

Much research effort has been done in examining drilling induced damages in polymer matrix composites. Zhang et al. [1] have demonstrated on the assessment of the exit defects in CFRP plates caused by drilling and concluded that delamination are the major mechanism in an exit defect caused by drilling. Chen [2] has revealed on the variations of cutting forces with or without onset damage during the drilling operations and concluded that the damage-free drilling processes may be obtained by the proper selections of tool geometry and drilling parameters. Caprino and Tagliaferri [3] have conducted investigational experiments to compare the interaction mechanisms between drilling tool and material. The results obtained are useful describing the damage and pave path to design drill geometries specifically conceived for composite machining. They also confirmed that the amount of damage induced in a composite material at time of machining is sturdily dependent on the feed factor. V. Tagliaferri et al. [4, 5] accomplished through an experimental study on woven glass fiber reinforced plastic (GFRP) composites that correlated the width of the damage zone to the ratio between the drilling speed and the feed rate. C. C. Tsao et al [6] suggested further an analytical approach based on the linear elastic fracture mechanics (LEFM) to predict the onset of delamination in drilling of composite laminates. G. Caprino et al. [7] concluded that the type of damage induced in a composite material during drilling is strongly dependent on the feed rate. J. Mathew et al. [8] have experimented on the crack propagation around the drilled holes and found it to be more severe when the cutting lips pass through the bottom sub-laminates. Di Paolo et al. [9] have addressed three significant damage mechanisms that cause the growth of delamination such as plate bulge, crack opening and fiber tearing/twisting. R. Piquet et al [10] proved that it is the geometry of the drill point that significantly influences the damage that takes place during drilling. E. Capello et al [11, 12] have executed experiments and mapped that the damage in GFRP laminates resulting due to the drilling action and concluded

IJARSE
ISSN (O) 2319 - 8354
ISSN (P) 2319 - 8346

that feed rate is the most critical parameter that influences the damage. In this attempt, the consequences of such main parameters machining speed, tool feed rate on the frp laminate material towards the hole diameter damage factor (delamination) is analysed and optimization of input machining parameters is carried out. Simulated Annealing and Tabu Search Algorithms (with the feed of Regression relationship) are employed in MATLAB for the optimisation.

III.EXPERIMENT DATA

On the sandwich composite laminates which was made by hand layup method the drilling experiment was conducted by Naveen et al [13] to evaluate the performance of the operations and outcome (delamination factor of the hole produced). Investigations of the delamination effect on the produced hole was carried out through conducting experiment on three different Four-layered unidirectional glass, hemp and sandwich fiber composite laminates with three different fibre volume fraction. Machining speed and tool feed are considered as input machining variables and (delamination) diameter damage factor as the outcome parameter for the investigation. The dimension of the specimen were 100 mm x 50 mm x 3 mm with 10, 20, 30 % volume fractions. The produced hole damages were observed using dye penetrate test to measure the diameter of the hole outcome. The damaged factor of the hole diameter calculated with the relationship D_{max} / D; where D max is the maximum hole diameter observed, D is the standard hole diameter. The parameter selection in three levels is shown in the Table 3.1 and data obtained through the experiment is mentioned in the Table 3.2

Table 3.1 Machining input variables selection

Machining input parameters	Level 1	Level 2	Level 3
Machining speed (m / min)	40	60	80
Feed (mm /min)	0.1	0.2	0.3

Table 3.2 Experimental result (Delamination factor)

Exp	Cutting Speed	Feed	Volume Fraction of FRP		
			10%	20%	30%
			DF_1	DF_2	DF_3
1	40	0.1	1.004	1.007	1.008
2	40	0.2	1.005	1.012	1.017
3	40	0.3	1.008	1.021	1.033
4	40	0.5	1.035	1.038	1.040
5	60	0.1	1.003	1.005	1.007
6	60	0.2	1.004	1.012	1.015
7	60	0.3	1.010	1.020	1.025
8	60	0.5	1.028	1.025	1.030
9	80	0.1	1.002	1.003	1.003
10	80	0.2	1.003	1.007	1.010
11	80	0.3	1.008	1.015	1.018
12	80	0.5	1.025	1.023	1.029

IJARSE
ISSN (O) 2319 - 8354
ISSN (P) 2319 - 8346

Where Cs represents the cutting speed, F represents the feed and DF_1, DF_2, DF_3 represents the drill hole damage factor of 10% , 20 % and 30 % fibre volume fraction specimen.

VI. STATISTICAL PROJECTIONS

Since the mathematical relationship between the process parameters are projecting the real connectivity between the input and output of any experimental work out, with the commercial Minitab 17 software the statistical projection carried out and the statistical Fit regression model to the responses of the drill hole delamination factor with the input machining parameters cutting speed, feed as continuous predictors of order 2 interactions are taken. From the 95 % confidence level of two sided confidence level interval for the second order regression analysis of DF_1, DF_2, DF_3 Vs Cs, F, and the model summary is noted in Table 4.1.

Table 4.1 Regression model: DF_1, DF_2, DF_3 Vs Cs, F

Parameter	S	R-sq	R-sq(adj)	R-sq(pred)	Durbin - Watson
DF_1 (10% fibre)	0.0028637	95.06%	90.95%	86.77%	3.41239
DF_2 (20% fibre)	0.0020381	97.88%	96.11%	93.83%	3.41098
DF_3 (20% fibre)	0.0013609	99.21%	98.55%	97.85%	3.14374

The second order relations which are statistically significant since reveals that the R-sq value as along with the R-Sq (adj) and R-Sq (pred) values as close. Regression Equations framed for all the three DF_1, DF_2, DF_3 with the coefficient of variables as follows through the Minitab software. The equations reveal that the feed rate F is highly influencing parameter on the Drill hole damage factors than the machining speed.

DF_1 = (0.9977) – (0.000139*Speed) + (0.1107*Feed) + (0.000001*Speed^2) – (0.0530*Feed^2) – (0.000336*Speed*Feed)

DF_2 = (1.0064) – (0.000224*Speed) + (0.0877*Feed) + (0.000001*Speed^2) – (0.0462*Feed^2) + (0.000086*Speed*Feed)

DF_3 = (1.01472) – (0.000544*Speed) + (0.1249*Feed) + (0.000003*Speed^2) – (0.0803*Feed^2) – (0.000114*Speed*Feed)

V. OPTIMIZATION METHODOLOGIES

The MATLAB (R2014a) software with Elman Back Propagation is used for coding Simulated annealing optimisation and Tabu Search algorithm. The algorithm is coded to the execution in the Gradient Descent with Momentum & Adaptive Learning. The performance indicator is the mean square error. Based on the objectives, the coding was developed towards optimization, i.e. delamination to the minimum value as the objective functions. Initially the simulation is trained for 50000 iterations. Figure 5.1 shows the MATLAB menu of 50000 iterations on progress.

IJARSE
ISSN (O) 2319 - 8354
ISSN (P) 2319 - 8346

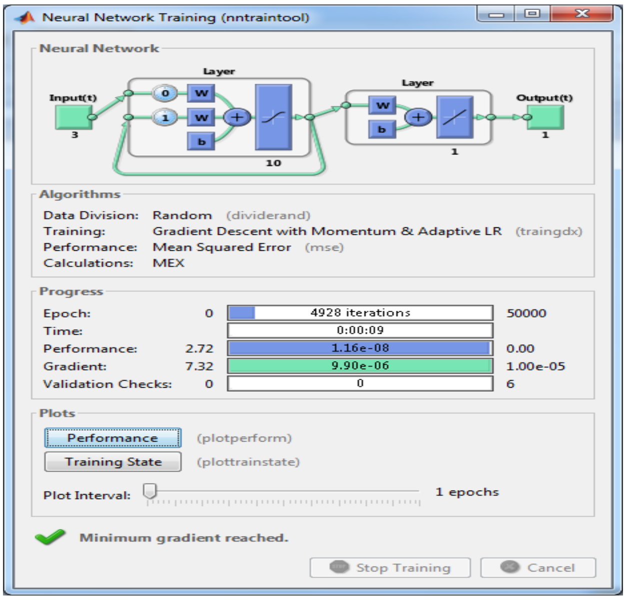

Figure 5.1 Matlab Menu of 50000 iterations

Mean squared error in computation is found as 0.001154407 for Simulated Annealing Algorithm and 0.000789091 for the Tabu Search Algorithm. In this simulation the regression relationship equations generated by the Minitab is fed into the programme for the closeness in resulting the simulation instead of random selection. While comparing the outcome of the both selected algorithms Tabu Search Algorithm projects better responses than the Simulated Annealing Algorithm and henceforth the new approach with the seeding method is employed, i.e the outcome of the Simulated Annealing Algorithm values is taken as the seed as the input to the Tabu Search Algorithm and further simulation is carried out. The MSE value is found to be further reduced as 0.0001084567 which are shown in the Table 5.1. Further to that, the values for the periodical interval between the parameter selection into 15 step up values chosen as (40:2.666667) for the speed parameter and (0.1:0.026667:0.3) for the feed parameters. The computed values through this hybrid approach are given in the Table 5.2 to Table 5.4.

Table 5.1 MSE error rate in simulation

Algorithm	Error rate in simulation
Simulated Annealing Algorithm	0.001154407
Tabu Search Algorithm	0.000789091
Simulated Annealing seed Tabu	0.0001084567

Table 5.2 Computed values of DF_1, DF_2, DF_3 Vs F for speed 40, and 45 and 50 m / min

Feed	Speed 40 m / min			Speed 45 m / min			Speed 50 m / min		
	DF1	DF2	DF3	DF1	DF2	DF3	DF1	DF2	DF3
0.10	1.005	1.007	1.008	1.004	1.008	1.009	1.004	1.007	1.007
0.12	1.001	1.006	1.010	1.007	1.009	1.018	1.006	1.009	1.017
0.14	0.999	1.005	1.026	1.002	1.009	1.016	1.001	1.009	1.014
0.16	1.010	1.006	1.015	1.006	1.009	1.017	1.005	1.009	1.015
0.18	1.010	1.009	1.022	1.010	1.010	1.020	1.010	1.010	1.018

0.20	1.012	1.011	1.024	1.012	1.012	1.020	1.011	1.011	1.018
0.22	1.014	1.014	1.021	1.013	1.014	1.021	1.012	1.013	1.019
0.24	1.016	1.018	1.025	1.014	1.016	1.023	1.013	1.015	1.021
0.26	1.016	1.021	1.026	1.016	1.019	1.023	1.015	1.017	1.021
0.28	1.018	1.023	1.025	1.017	1.021	1.024	1.016	1.019	1.022
0.30	1.019	1.025	1.027	1.018	1.023	1.025	1.017	1.021	1.024

Table 5.3 Computed values of DF_1, DF_2, DF_3 Vs F for speed 55, 60 and 65 m / min

Feed	Speed 55 m / min			Speed 60 m / min			Speed 65 m / min		
	DF1	DF2	DF3	DF1	DF2	DF3	DF1	DF2	DF3
0.10	1.003	1.006	1.006	1.002	1.005	1.004	0.999	1.005	1.003
0.12	1.004	1.009	1.014	1.002	1.009	1.012	1.000	1.008	1.010
0.14	1.001	1.009	1.012	1.000	1.008	1.010	0.998	1.008	1.009
0.16	1.004	1.009	1.014	1.003	1.008	1.012	1.002	1.008	1.011
0.18	1.009	1.010	1.016	1.008	1.009	1.014	1.006	1.009	1.012
0.20	1.010	1.011	1.016	1.008	1.010	1.014	1.006	1.009	1.013
0.22	1.011	1.012	1.017	1.009	1.011	1.016	1.007	1.010	1.014
0.24	1.012	1.013	1.019	1.011	1.012	1.017	1.010	1.011	1.016
0.26	1.014	1.015	1.020	1.013	1.013	1.018	1.012	1.012	1.017
0.28	1.015	1.017	1.021	1.014	1.015	1.019	1.013	1.013	1.018
0.30	1.017	1.019	1.022	1.016	1.016	1.020	1.015	1.014	1.019

Table 5.4 Computed values of DF_1, DF_2, DF_3 Vs F for speed 70, 75 and 80 m / min

Feed	Speed 70			Speed 75			Speed 80		
	DF1	DF2	DF3	DF1	DF2	DF3	DF1	DF2	DF3
0.10	0.996	1.005	1.002	1.000	1.005	1.001	0.982	1.005	1.000
0.12	0.997	1.008	1.008	0.990	1.008	1.006	1.020	1.007	1.005
0.14	0.997	1.008	1.008	1.010	1.007	1.007	0.986	1.007	1.006
0.16	1.001	1.008	1.010	0.989	1.008	1.009	1.022	1.007	1.008
0.18	1.004	1.008	1.011	1.018	1.008	1.009	0.990	1.008	1.008
0.20	1.004	1.009	1.012	0.991	1.008	1.011	1.025	1.008	1.010
0.22	1.004	1.009	1.013	1.025	1.009	1.012	0.994	1.008	1.012
0.24	1.010	1.010	1.014	0.995	1.009	1.013	1.026	1.008	1.013
0.26	1.009	1.011	1.016	1.028	1.010	1.015	0.999	1.009	1.014
0.28	1.013	1.011	1.017	0.999	1.010	1.016	1.026	1.009	1.015
0.30	1.009	1.012	1.018	1.029	1.011	1.017	1.003	1.010	1.017

IJARSE
ISSN (O) 2319 - 8354
ISSN (P) 2319 - 8346

Table5.5 gives the time consumed for the simulation by the employed algorithms. The hybrid Simulated Annealing seed Tabu Search Algorithm takes higher time for converging than the algorithms individually converges.

Table 5.5 Time pulses for simulation of algorithms

Algorithm	Time for simulation
Simulated Annealing Algorithm	7.827
Tabu Search Algorithm	11.711
Simulated Annealing seed Tabu Search Algorithm	22.653

The graphical plots for all such combinations of speed, feed and depth of cut are depicted in the Figures 5.2 to 5.10.

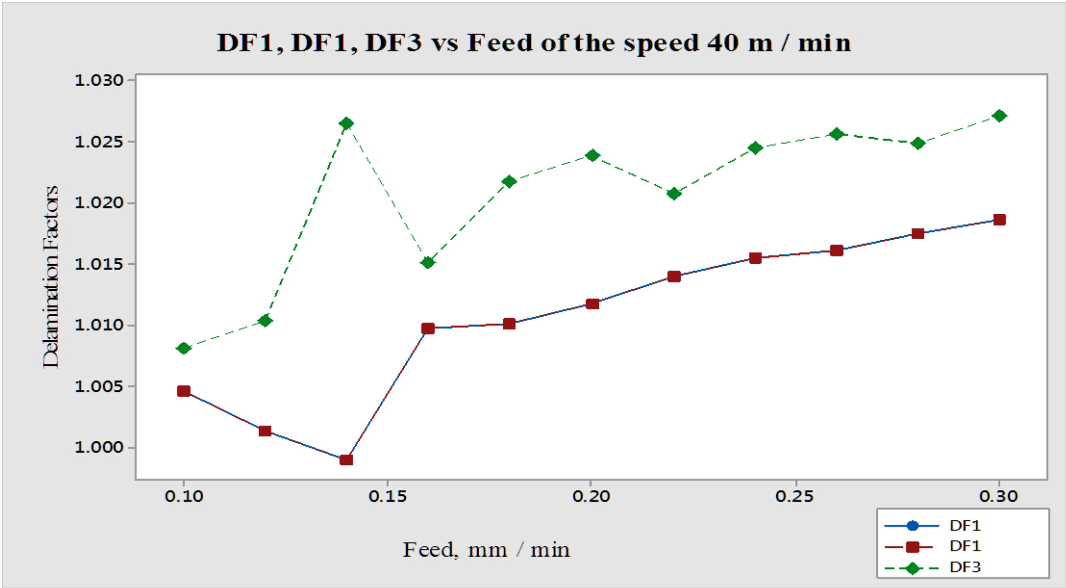

Figure 5.2 DF_1, DF_2, DF_3 Vs F for Speed 40 m / min

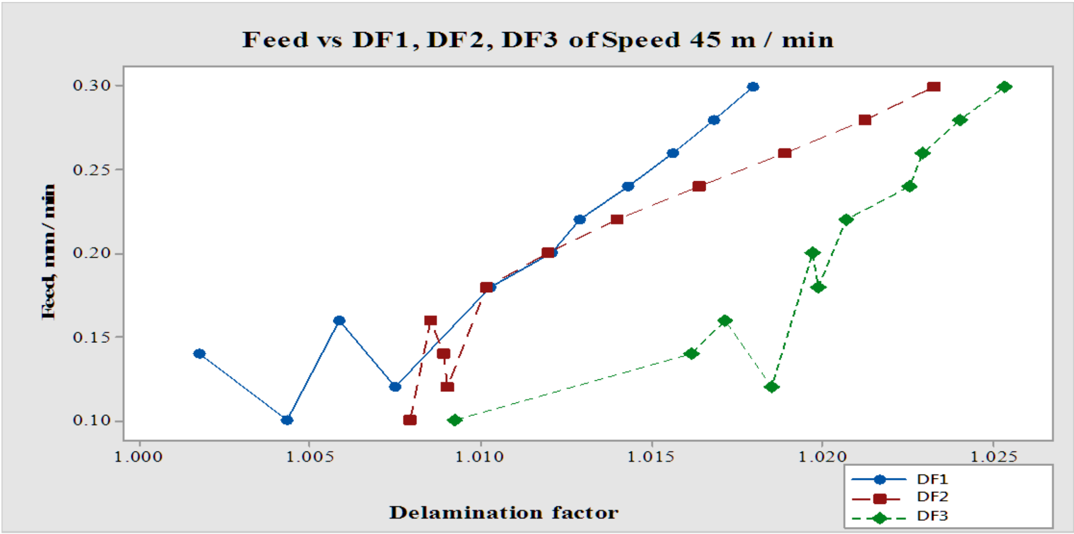

Figure 5.3 DF_1, DF_2, DF_3 Vs F for Speed 45 m /min

International Journal of Advance Research in Science and Engineering
Vol. No.6, Issue No. 08, August 2017
www.ijarse.com
IJARSE
ISSN (O) 2319 - 8354
ISSN (P) 2319 - 8346

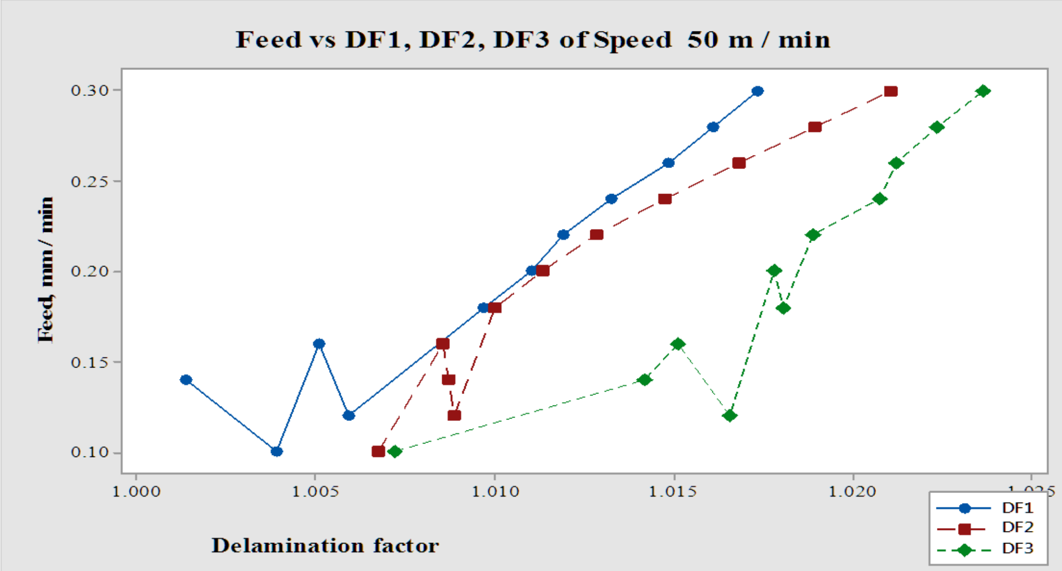

Figure 5.4 DF$_1$, DF$_2$, DF$_3$ Vs F for Speed 50 m /min

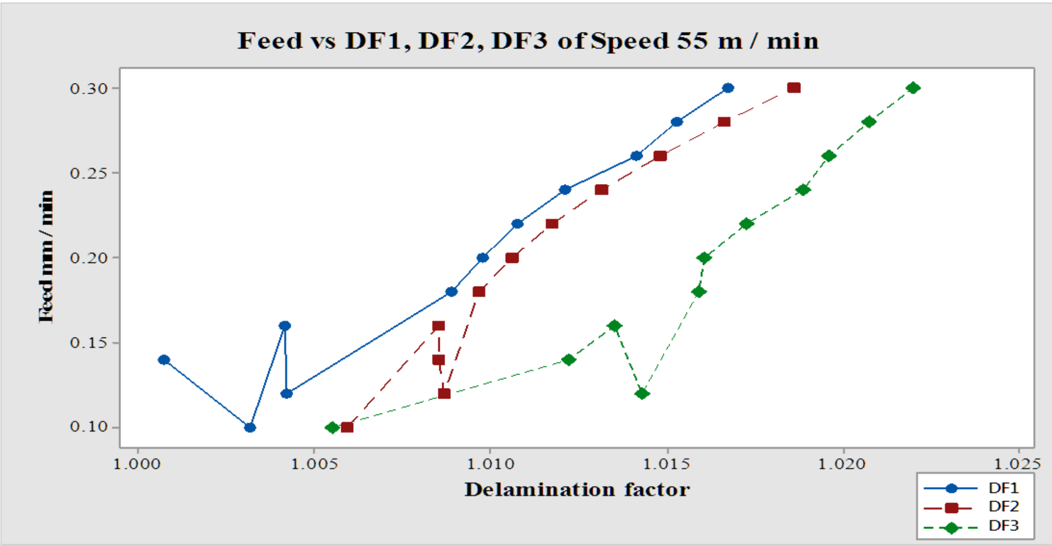

Figure 5.5 DF$_1$, DF$_2$, DF$_3$ Vs F for Speed 55 m /min

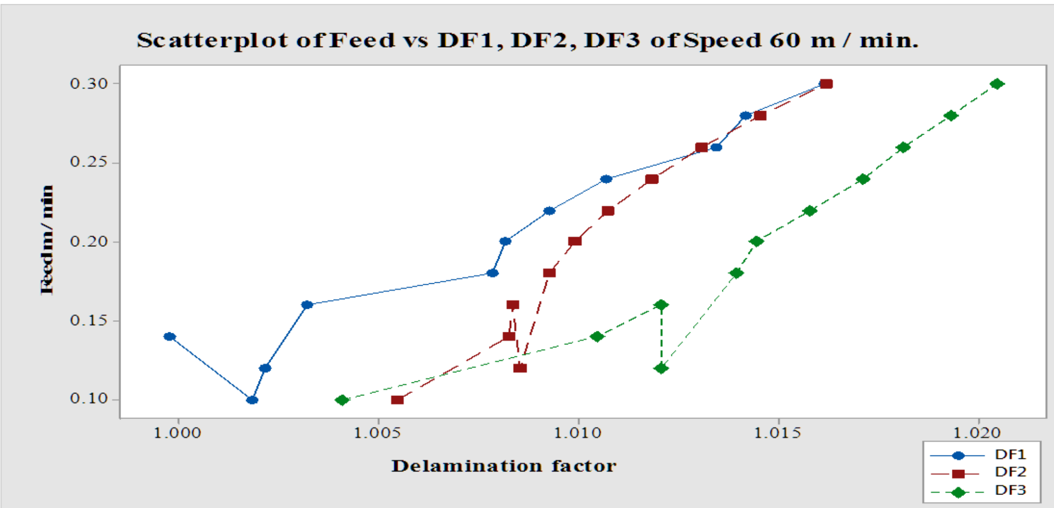

Figure 5.6 DF$_1$, DF$_2$, DF$_3$ Vs F for Speed 60 m /min

IJARSE
ISSN (O) 2319 - 8354
ISSN (P) 2319 - 8346

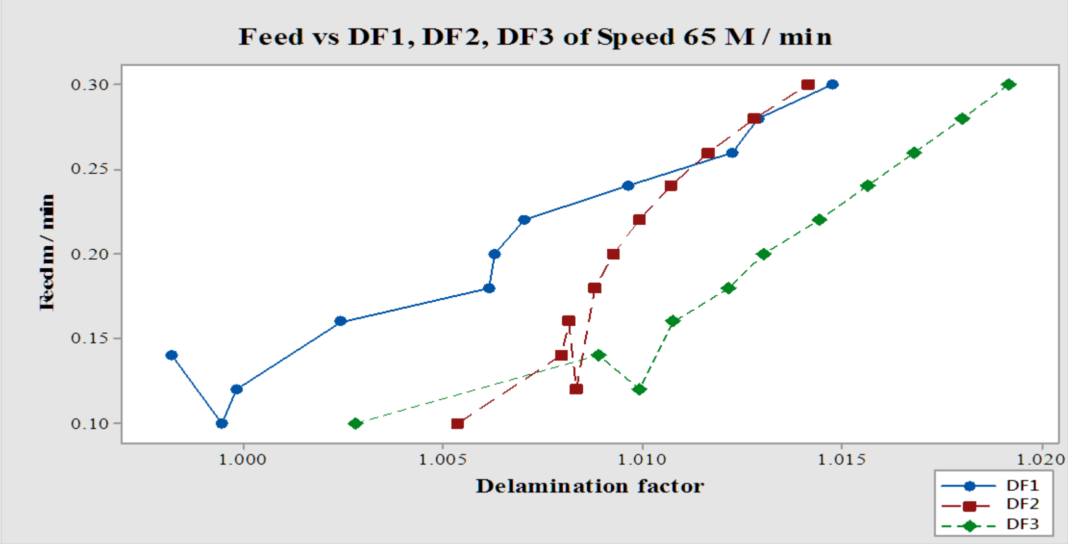

Figure 5.7 DF_1, DF_2, DF_3 Vs F for Speed 65 m /min

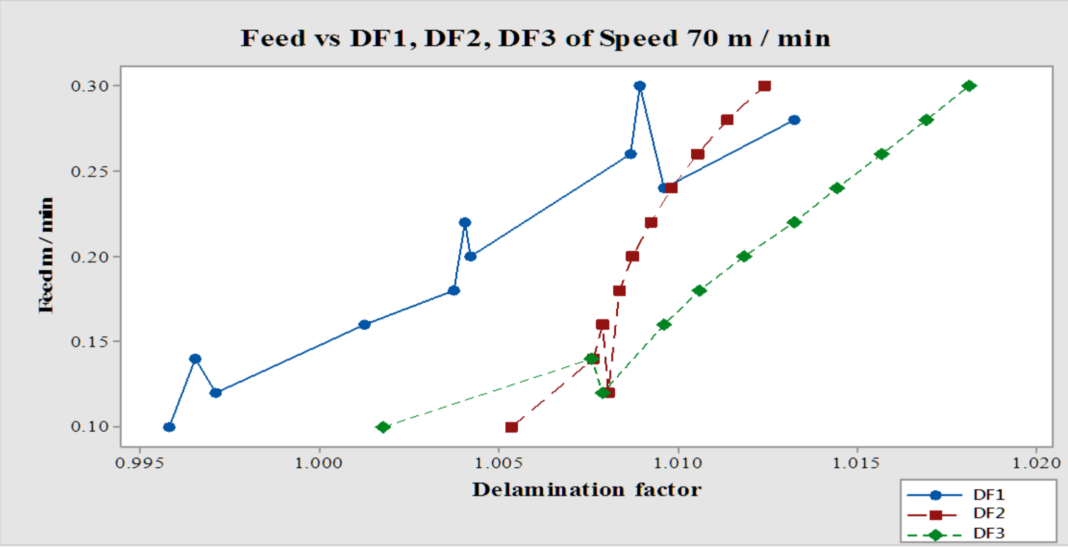

Figure 5.8 DF_1, DF_2, DF_3 Vs F for Speed 70 m /min

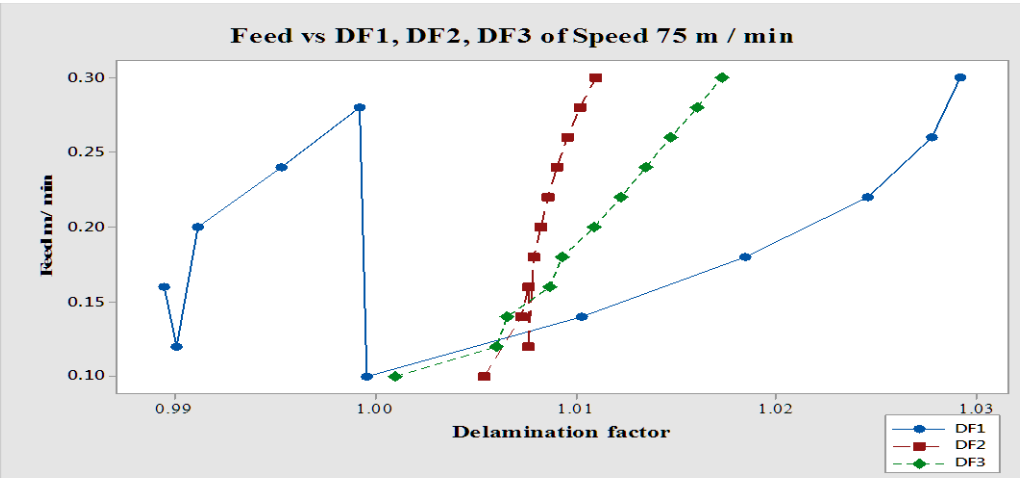

Figure 5.9 DF_1, DF_2, DF_3 Vs F for Speed 75 m /min

IJARSE
ISSN (O) 2319 - 8354
ISSN (P) 2319 - 8346

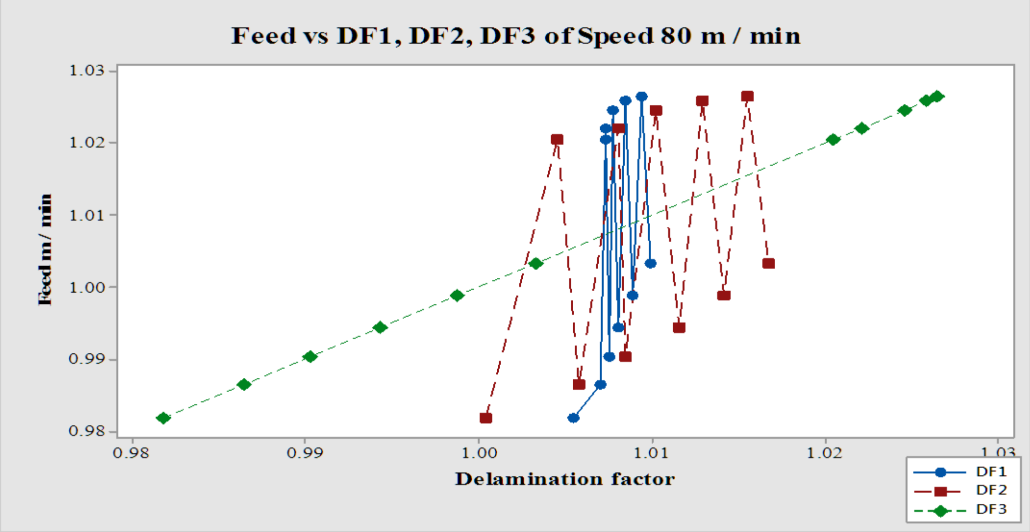

Figure 5.10 DF_1, DF_2, DF_3 Vs F for Speed 80 m /min

The optimal value of the hole diameter damage factor for each clause of fibre volume fraction is shown in the Table 5. 5.

Table 5.5 Optimal value of the hole diameter damage factor

Fibre Volume fraction	Speed	Feed	DF values
10 %	80	0.10	0.982
20 %	40	0.14	1.005
30 %	80	0.10	1.000

VI. RESULTS AND CONCLUSIONS

This attempt of optimizing the process parameters towards the minimum delamination (hole diameter damage factor) in drilling operations on the sandwich frp composite laminates is simulated by applying Simulated Annealing and Tabu Search Algorithm in the MATLAB programming. Based on the error rate in compiling the results the Tabu Search Algorithm shows better results than the Simulated Annealing Algorithm and the new method of Seeding technique is used and further enhanced results attained through Simulated Annealing Seed Tabu Search Algorithm. From the regression analysis it is evident that the feed parameter of the tool is showing high level influence on the hole diameter damage factor over the other parameter (speed). The optimum parameter selection within the set of values employed for minimum hole damage factor for the individual fiber volume fraction content of the frp is given through the Table 5.5 Graphical plots presented through the Minitab for various combinations of input machining parameter values would be the guidelines to the manufacturer concern in the selection of machining parameter combination with reference to the required product quality.

References

[1] H. Zhang, W. Chen.W, D. Chen and L. Zhang, Assessment of the exit defects in carbon fibre-reinforced plastic plates caused by drilling, Prec. Mach. Adv. Mater, 196, 2006, 43-52.

[2] W. Chen, Some experimental investigations in the drilling of carbon fibre-reinforced plastic (CFRP) composite laminates, Int. J. Mach.Tools Manuf, 37 (8), 1997, 1097-1108.

IJARSE
ISSN (O) 2319 - 8354
ISSN (P) 2319 - 8346
[3] G. Caprino and V. Tagliaferri, Damage development in drilling glass fibre reinforced plastics, Int. J. Mach. Tools Manuf, 35 (6), 1995, 817-829.

[4] Caprino, G.; Diterlizzi, A.; Tagliaferri, V. (1988). Damage in Drilling Glass Fiber Reinforced Plastics. Advancing with composites, Proceedings of International Conference on Composite Materials, Milan, Italy,493-503

[5] Tagliaferri, V.; Caprino, G.; Diterlizzi, A.(1990). Effect of Drilling Parameters on the Finish and Mechanical Properties of GFRP Composites, International Journal of Machine Tools and Manufacture, Vol. 30 (1), 77-84

[6] Tsao, C.C.; Chen Wen-Chou.(1997). Prediction of the Location of Delamination in the Drilling of Composite Laminates, Journal of Materials Processing Technology, Vol. 70,185-189

[7] Caprino, G.; Tagliaferri, V. (1995). Damage Development in Drilling Glass Fiber Reinforced Plastics, International Journal of Machine Tools and Manufacture, Vol. 35(6),817-829

[8] Mathew, J.; Ramakrishnan, N.; Naik, N.K. (1999). Investigations into the Effect of Geometry of Trepanning Tool on Thrust and Torque during Drilling of GFRP Composites, Journal of Materials Processing Technology Vol. 91, 1-11

[9] DiPaolo, G.; Kapoor, S.G.; DeVor, R.E. (1996). An Experimental Investigation of the Crack Growth Phenomenon for Drilling of Fiber Reinforced Composite Materials, Journal of Engineering for Industry-Transactions of the ASME, Vol. 118, 104-110

[10] Piquet, R.; Ferret, B.; Lachaud, F.; Swider, P.(2003). Experimental Analysis of Drilling Damage in Thin Carbon/Epoxy Plate using Special Drills, Composites Part A,Vol.31,1107-1115

[11] Capello, E.; Tagliaferri, V. (2001) Drilling damage of GFRP and residual mechanical behavior – Part I: Drilling damage generation, Journal of Composites Technology Res , Vol. 23(2),122– 130

[12] Capello, E.; Tagliaferri, V. (2001) Drilling Damage of GFRP and Residual Mechanical Behavior – Part II: Static and Cyclic Bearing Loads, Journal of Composites Technology Res, Vol.23(2),131-137.

[13] Naveen, P.N.E, Yasaswi, M,& Prasad.R.V, 2012, Experimental Investigation of Drilling Parameters on Composite Materials, IOSR Journal of Mechanical and Civil Engineering (IOSRJMCE), vol. 2, issue 3, pp 33-37.