Optimization of machining parameters of Kevlar fibre reinforced composites

Article *in* AIP Conference Proceedings · October 2020

DOI: 10.1063/5.0025145

Vijayananth Suyamburajan
Vels University

Ajith Arul Daniel
Vels University

Optimization of machining parameters of Kevlar fibre reinforced composites

Cite as: AIP Conference Proceedings **2283**, 020117 (2020); https://doi.org/10.1063/5.0025145
Published Online: 29 October 2020

S. Vijay Ananth, A. Ramesh Udayakumar, Ajith Arul Daniel, and N. Poornachandiran

Optimization of Machining Parameters of Kevlar Fibre Reinforced Composites

S VijayAnanth[1, a)], A Ramesh Udayakumar[2, b)], Ajith Arul Daniel[1, c)] and N Poornachandiran. [3, d)]

[s1]*Department of Mechanical Engineering, VISTAS, Chennai, 600117, Tamilnadu, India.*
[2]*Department of Mechanical Engineering,* MisrimalNavajeeMunoth Jain Engineering College, Chennai– 600096, *Tamilnadu,* India.
[3]*Department of Mechanical Engineering, Bhaktavatsalam Polytechnic College, Kanchipuram 631552, Tamilnadu, India.*

[a)]Corresponding author: ssvijayananth@gmail.com
[b)]rameshudayakumar@hotmail.com
[c)]ajith_danny@yahoo.com
[d)]muzhunila1969@gmail.com

Abstract. Composite materials have the applications in the field of space and space vehicle in light of their less weight to high quality. Composite materials are as a rule progressively utilized in different applications like space, flying machine, marine, building and car division on account of their predominant physical and mechanical properties despite the fact that they are somewhat expensive. Composite materials have used for material framework in view of their remarkable execution in different specific applications. Fibre incorporation and the heterogeneous property of composites make it increasingly hard to machine with the customary machining process. Be that as it may, a few nonconventional strategies have been received for machining composites, in which Abrasive Water Jet Machining (AWJM) was demonstrated to be increasingly compelling and an ideal procedure in machining of fibre-strengthened composite material. This article is planned to feature and classify the machining execution of the fibre-strengthened composites on machining with AWJM process.

INTRODUCTION

The particular properties of composite materials have made them unrivalled in different applications. Composites have the applications utilize composite materials with consistent strands, which makes it hard to frame holes and openings without influencing the fibre fortification during the manufacturing process [1, 2]. In such case, machining is the main best answer for creating gaps and for different prerequisites. However, machining of fibre composites is complicated in light of the fact that the idea of composite cutting system varies from the traditional materials. The fibre support may cause more device wear in the customary machining process, which prompts serious harm in the material [3,4]. To remove these limitations different machining procedures were worked from the underlying phase of advancement of composite materials. During the beginning time of improvement of composite materials, customary techniques were received for machining. Afterward, expanded utilization of composites drives the advancement of new technolgies. Profoundly complex machining strategies were created to machine the composite materials, outstandingly any procedures like water jet machining, ultrasonic machining, laser machining, and electric discharge machining. Water jet machining is the most best strategy to machine polymer composites because of its better favorable position over other machining properties. Through Abrasive water jet machining (AWJM), composites can be prepared by cutting, drilling, and processing [5, 6].

In the course of recent decades, there has been a developing enthusiasm for the utilization of common fibres in composite applications. These sorts of composites present numerous focal points contrasted with engineered strands, for example, low apparatus wear, low thickness, less expensive cost, accessibility, and biodegradability [7]. The most well-known regular plant utilized in applications are bast strands, for example, hemp, jute, flax, kenaf, and

Proceedings of International Conference on Recent Trends in Mechanical and Materials Engineering
AIP Conf. Proc. 2283, 020117-1–020117-11; https://doi.org/10.1063/5.0025145
Published by AIP Publishing. 978-0-7354-4013-5/$30.00

sisal. One reason for developing this interest is that normal strands have a higher explicit quality than glass fibre and a comparative explicit modulus. With these properties and less expensive sources, these characteristic strands hypothetically offer attractive explicit quality sand modulus, at a lower cost [8, 9]. These regular strands, found in all life patterns of varying backgrounds, are appeared in Many normally happening filaments can be utilized as composites, however generally in applications that include low pressure. A portion of the filaments are obtained by preparing horticultural, modern, or buyer squander. These materials have just been grasped by car creators and this pattern has arrived at North America [10].

Regular strands are subdivided dependent on their roots, i.e., regardless of whether they are gotten from plants, creatures, or minerals, as demonstrated. As per study gatherings, plant strands are the most popular of the common filaments, utilized as reinforcement in fibre strengthened composites [11, 12]. Plant strands incorporate bast filaments, leaf or hard strands, seed, natural product, wood, oat straw, and different grass strands. The synthetic arrangement, just as the structure of plant filaments, is genuinely convoluted. Plant strands are composite materials planned ordinarily. The strands are essentially included an inflexible, crystalline cellulose small scale fibril rein-constrained formless lignin, and additionally hemicelluloses network. Most plant strands, aside from cotton, are made out of cellulose, hemicelluloses, lignin, waxes, and a few water dissolvable mixes; where cellulose, hemicelluloses, and lignin are the significant constituents [13, 14]. The primary constituent of any plant fibre is cellulose. Cellulose is the normal homopolymer (polysaccharides), where D-gluco-pyranose rings are associated with one another with bglycosidic linkages. Cellulose is frequently found as a generally high modulus, fibril segment, of numerous normally happening composites, for example, wood; where it is found in association with lignin. In a past reports the greater part of plant fibres contained 65–70% cellulose, which is made out of three elements, C, H, and O2, with a general recipe of C6H10O5, which are crystalline. The lignin and other non-cellulosic substances are associates with the cell dividers and their quality alters the last properties of the fibre [15].

A significant quality of plant filaments is their capacity to ingest dampness from the air incomparatively enormous quantities in light of the fact that cellulose is hygroscopic. Most polymeric filaments swell because of dampness absorption. This retention prompts changes in loads and dimensions as well as in qualities and solidness. Furthermore, plant fibre is expresented to natural rot. Most plant filaments obscure and debilitate with age and presentation to light. Plant strands are not as sturdy as engineered polymeric filaments. They are on the whole effectively assaulted by an assortment of living beings, at high stickiness and temperature, prompting decay and mold. In this manner, plant filaments are considered as inexhaustible re-sources and they don't worsen the CO2 outflows issue

MATERIAL PREPARATION

By hand laying method the Kevlar natural fibre composites were prepared and the weight is applied by a compression machine. To dismiss the dampness the prepared composite was dried in the sun for 48 hours. For the entire model, the ordinary strands and made fibres are stacked. While accumulating the layers of strands, a mix of epoxy tar and hardener is applied absolutely over the fibres [16, 17]. After the sap is applied, a roller is surrendered the fibres to pack and manufacture the bond between the Kevlar fibre and different strands. By turning the roller over the composites helps in clearing the air pockets or air pockets formed among strands and gives better results in machining or surface consummation for the produced composite material [18]. These strategies of laying up the fibres and applying hardener are done, then again until the cutoff of five layers of strands are stacked into the structure. Completely made composite overlay is appeared in Fig. 1., the whole strands get together is crushed at a temperature about 60°C and held under dead weight tension for 8 hours, and subsequently the composite gets cooled under room Fabric Resin Roller 44℃ temperature and average weight. By then the composite abundance tars are removed from the structure and the thickness of the prepared composite model was 5mm.

TESTING AND MORPHOLOGY ANALYSIS OF KEVLAR COMPOSITE

Tensile test

Flexible test was finished by ASTM standards, models are placed in the grips of an all inclusive test machine at a pre-characterized hold separation and pulled until disillusionment. For ASTM D638 the test speed can be directed by the material detail or time of disillusionment (1 to 10 minutes). A normal test speed for standard test models is 2 mm/min (0.05 in/min). An extensometer or strain gage is used to choose prolongation and tractable modulus. Dependent upon the help and sort, testing in more than one presentation may be basic.

A ductile pressure will in general draw a part separated; a compressive pressure will in general smash or breakdown a body; a shear pressure will in general divide an auxiliary part; a torsional stress will in general control a part; a twisting pressure will in general diverts a part. A material reaction to the three significant types of stress, strain, pressure, and shear can be estimated on a general testing machine.

FIGURE 1. Specimen before and after tensile test

The flexural test gauges the force that necessary blending a pole under three centers stacking conditions. That data is normally used to pick segments for parts that will supports the stores with no alteration in the shape in sound. Flexural modulus is used as an indication of materials robustness in the midst of pitch. Since the physical properties of various segments vary dependent upon the encompassing temperature, it is possible to test materials under explicit temperatures that reproduce the normal end using condition.

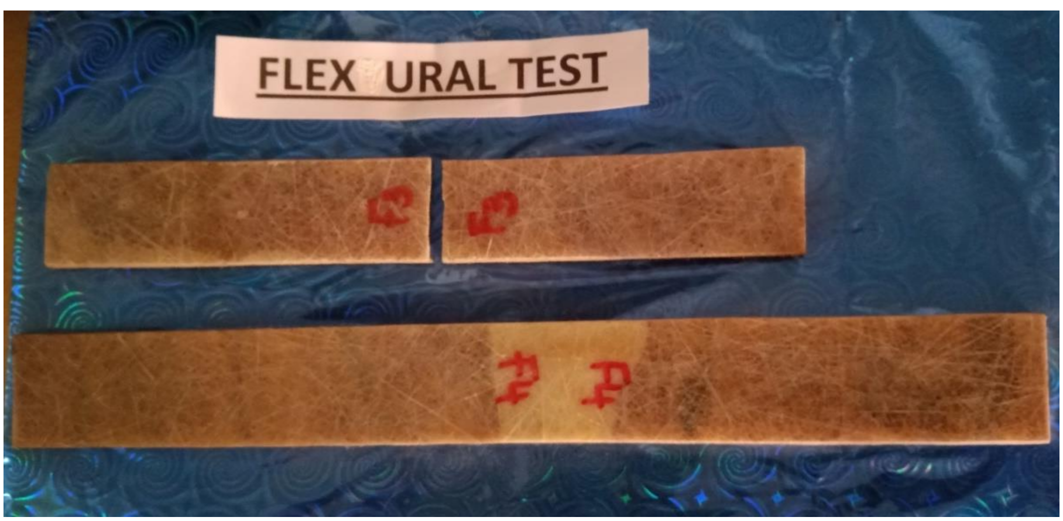

FIGURE 2. Specimen before flexural test

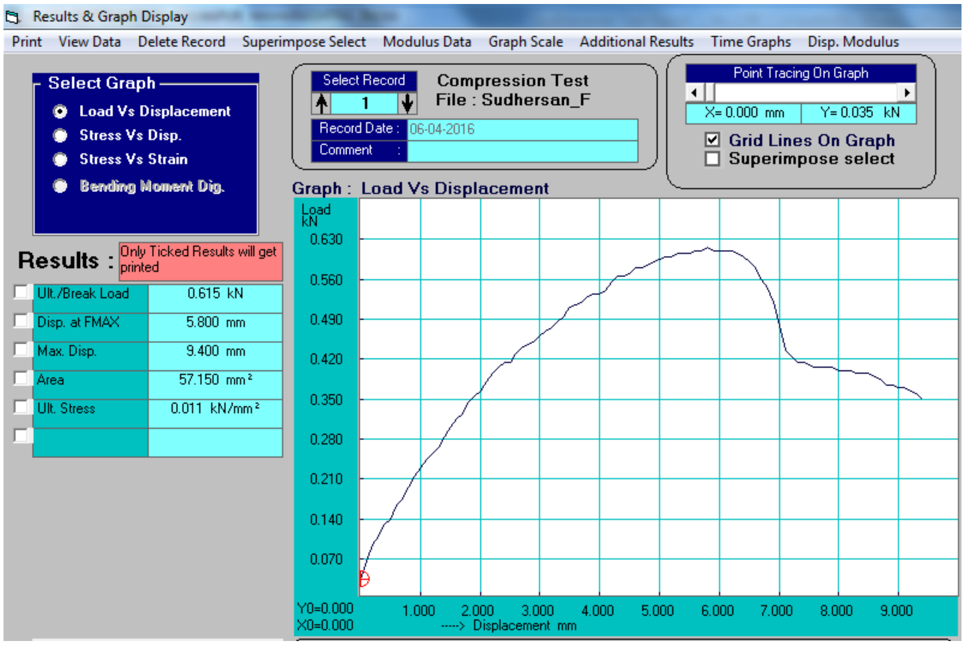

FIGURE 3. Flexural test graph load vs displacement

Double Shear test

Double shear test results when two equal powers act in inverse ways that will in general produce a sliding of one section as for the other piece of the body. Bolts and pins are some common items exposed to shear pressure, moreover cutting activities, for example, punches produce shear pressure. Shear testing results are to some degree not as exact as pressure and pressure testing because of the extra presentation of grinding and twisting powers in the testing procedure. Shear tests on level stock are frequently done in single or twofold shear though, round stock is for the most part tried in twofold shear, in double shear tests the applicable area is twice the area of the cross section

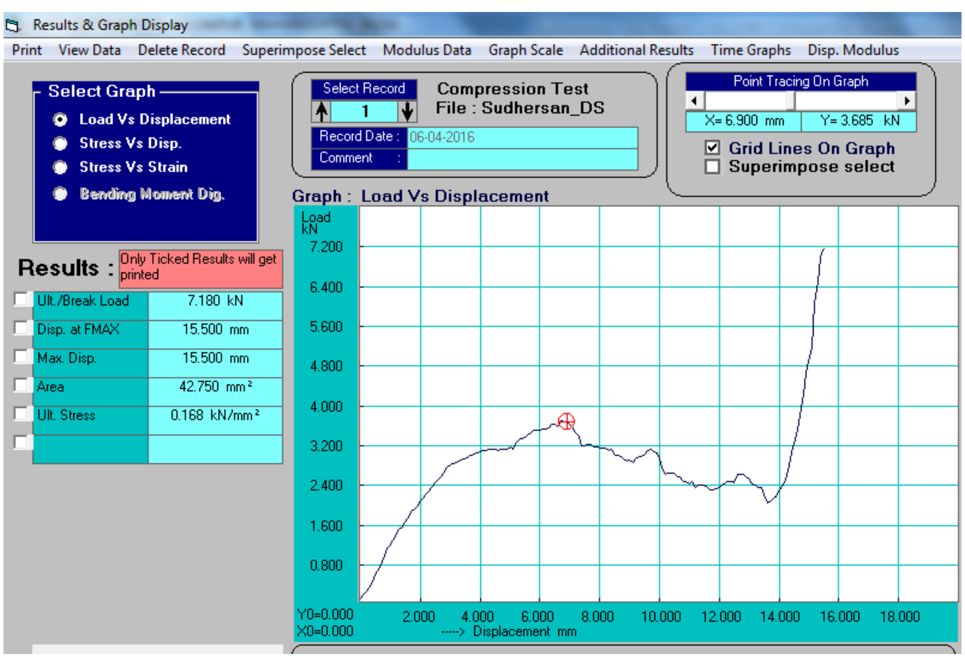

FIGURE 4. Double Shear test graph load vs displacement

Impact test

Impact test is utilized to decide durability, load-redirection bends and all out vitality ingestion of effect occasions. Since speed can be differed, it can mimic genuine effect esteems at high-speeds. This advanced effect test gives full power and vitality bends during the millisecond of the effect, utilizing the high energy which fuses an effect head and a heap cell. The information is regularly used to determine fitting materials for applications including sway. The test is additionally used to assess the impact of optional, completing activities or other ecological factors on plastic effect properties. Obtained Impact value = 12.8 Joules

FIGURE 5. Specimen before impact test with V-notch

To find the scanning electron microscope of the given kevlar composite specimen with their dimension is 1*1 to varying the micron meter level of the scanning electron microscope at this figure represent the various image and the cracks blow holes are formed in the kevlar composite specimen. The optical microscope images show the distribution fibre particles in the sample with varying percentages of different tested samples for to obtain a clear view of the fibre distribution and damages of the composite specimen by using a Scanning Electron Microscope.

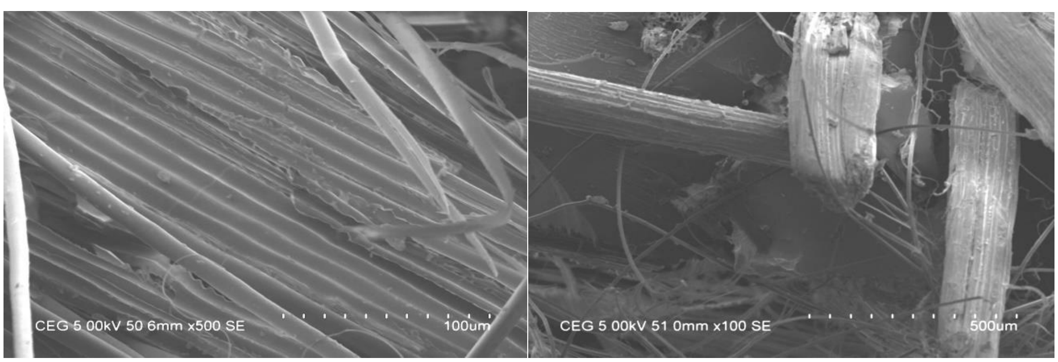

FIGURE 6. Tension Test

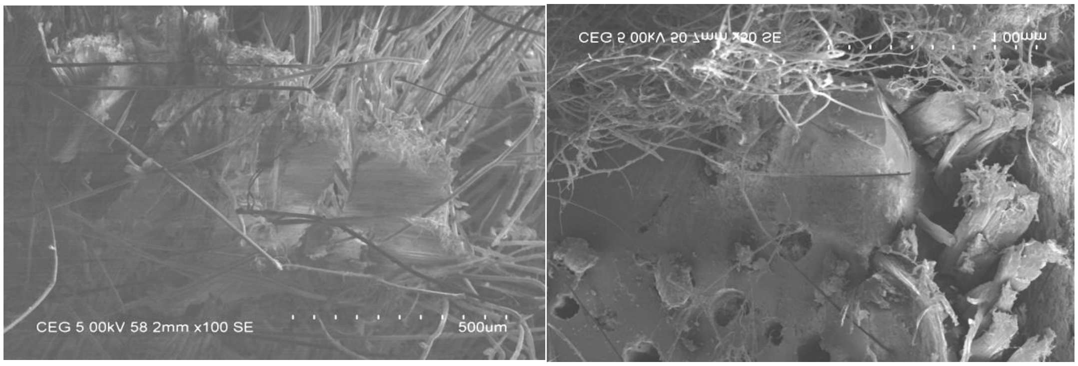

FIGURE7. Impact Test

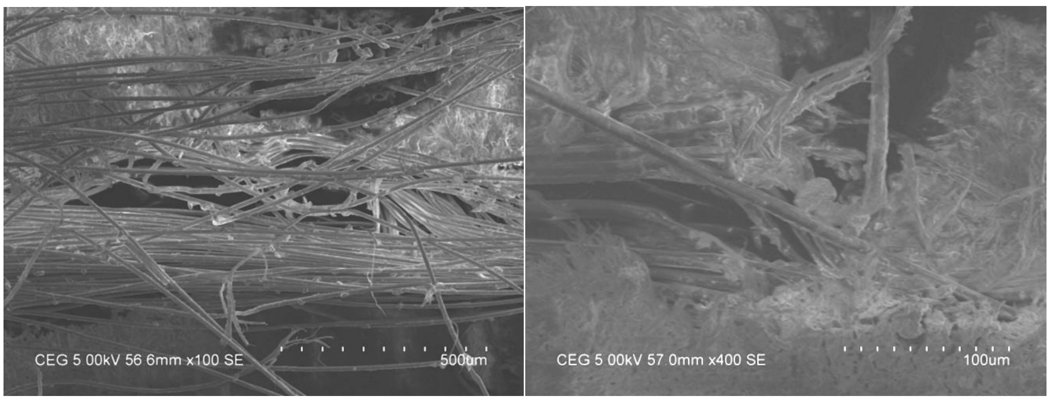

FIGURE 8. Flexural Test

Microstructural investigation of the elastic broke examples was examined utilizing checking SEM. Fibre and framework holding assumes an indispensable job in the mechanical properties of the composites. By and large, fibre or fortifications could bear the pressure or it go about as a load conveying part, while grid moves the load to the fibre. Additionally, sap bonds the fibre together. The figure shows plainly there are delamination's between the Kevlar textures and shows moderate fibre/grid grip. Despite the fact that solitary Kevlar texture had higher rigidity, the poor fibre grid grip and delamination influences the elastic properties of the Kevlar composites. The pulled out Kevlar and Cocosnucifera sheath after elastic testing as seen the figure and obviously looks at the fibre–grid grip of Kevlar texture and Cocosnucifera sheath and it shows that Cocosnucifera sheath have preferred attachment with the framework over Kevlar texture.

In any case, delamination happens in the middle of the Kevlar texture and Cocosnuciferasheath . From Figure it is gotten that however the Cocosnucifera sheath have better holding with the grid and it has a few voids which influences the mechanical properties of the composites. For the most part, the woven texture contains strands both in twist and in fill headings and they are entwined with one another. While applying the tractable burden the strands the transverse way will likewise will in general fix which makes pressure focus at the interface of the fibre and network. Subsequently, small scale splits has been started in the lattice which proliferates the transverse way causing fibre crack. These proceeds, until the example have been broken totally.

Machining of composite material

Abrasive water jet machining (AWJM) is a non-standard machining methodology that offers a beneficial choice rather than normal strategies. Material evacuation occurs through deterioration and results from the relationship between a grinding water stream and the work-piece materials. AWJM is seen as a promising machining instrument for hard to-machine materials. Instead of this, it is multifaceted in context on a couple of method parameters, for instance, water powered, rough, blending and cutting parameters influencing the show of the system. Generally, the methodology execution can be evaluated similarly to significance of cut, material expulsion rate, cutting capability, kerf geometry and cut surface completion. The cut geometry depends upon the sort of abrasives and cutting parameters like 45 harsh fly weight, standoff distance (SOD) of the spout from the goal, work feed rate, rough mass stream rate, etc. This machining procedure are done by utilizing grating water fly machine (AWJM) by changing its 3 parameters as 3*3*3 which is equivalent to 27 mixes. By utilizing these mixes 27 passes are been made in the composite material as appeared, these are be performed by changing the parameters in a compelling way. Here we utilized garnet as the rough material for machining process.

FIGURE 9. Water Jet Machine

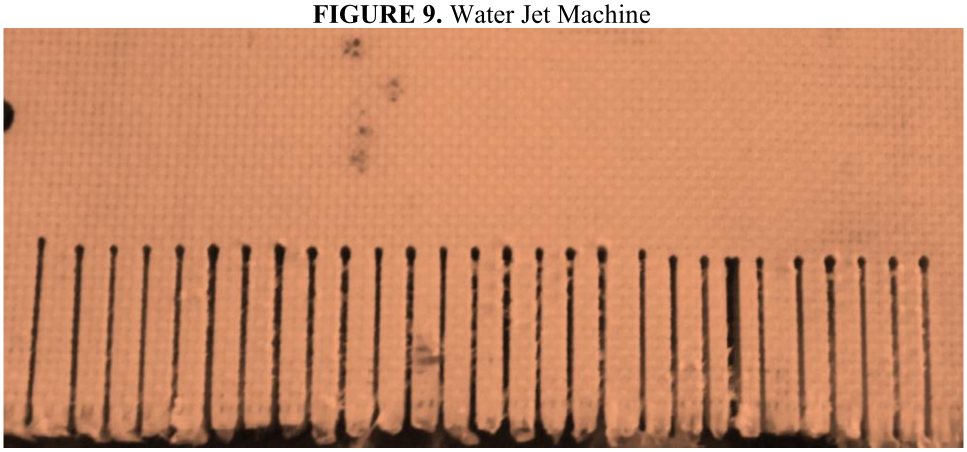

FIGURE 10. Machined composite material

The AWJ machining parameters and levels of the experiments were chosen based on the literature review followed by trial experiments. Table 1 shows the machining parameters that were chosen to study the performance of AWJ machining of tungsten carbide GFRP composite

TABLE 1. Parameter

S.No	Machining Parameters/ Input factors	Level		
		1	2	3
1	Standoff Distance (mm)	2	3	4
2	Pressure (psi)	17000	19000	21000
3	Traverse Speed (m/s)	620	440	345

OPTIMIZATION OF PARAMETERS

The above mentioned parameters are been taken for the machining optimization process. With the help of this table 9 combinations are been carried out to make the machining process in the effective manner.

TABLE 2. Machining Parameters

Exp. No	Standoff Distance (mm)	Pressure (psi)	Traverse Speed (mm/s)	MRR (g/min)	Surface Roughness (μm)
1	2	17000	440	108.3	4.125
2	2	19000	540	216.086	5.603
3	2	21000	640	324.129	5.853
4	3	17000	540	420.168	4.095
5	3	19000	640	552.220	5.517
6	3	21000	440	648.259	5.654
7	4	17000	640	816.326	4.237
8	4	19000	440	960.384	5.745
9	4	21000	540	1068.427	5.977

Here MRR is carried out by using the formula

MRR = actual weight – final weight

And the surface roughness is measured by using the surface pyrometer device. From this data the S/N ratio for MRR and surface roughness are been measured with the help of ANOVA table and Taguchi method.

TABLE 3. Machining Parameters table with S.N Ratio

S.No	Standoff Distance	Pressure (psi)	Transvesr Speed (mm/s)	MRR (g/min)	Surface Roughness	S/N ratio for MRR	S/N ratio for Ra
1	2	17000	440	108.043	4.125	40.67	-12.308
2	2	19000	540	216.086	5.603	46.69	-14.968
3	2	21000	640	324.129	5.853	50.21	-15.347
4	3	17000	540	420.168	4.095	52.46	-12.245
5	3	19000	640	552.220	5.517	54.844	-14.834
6	3	21000	440	648.259	5.654	56.23	-15.047
7	4	17000	640	816.326	4.327	58.23	-12.541
8	4	19000	440	960.384	5.745	59.64	-15.185
9	4	21000	540	1068.427	5.977	60.57	-15.529

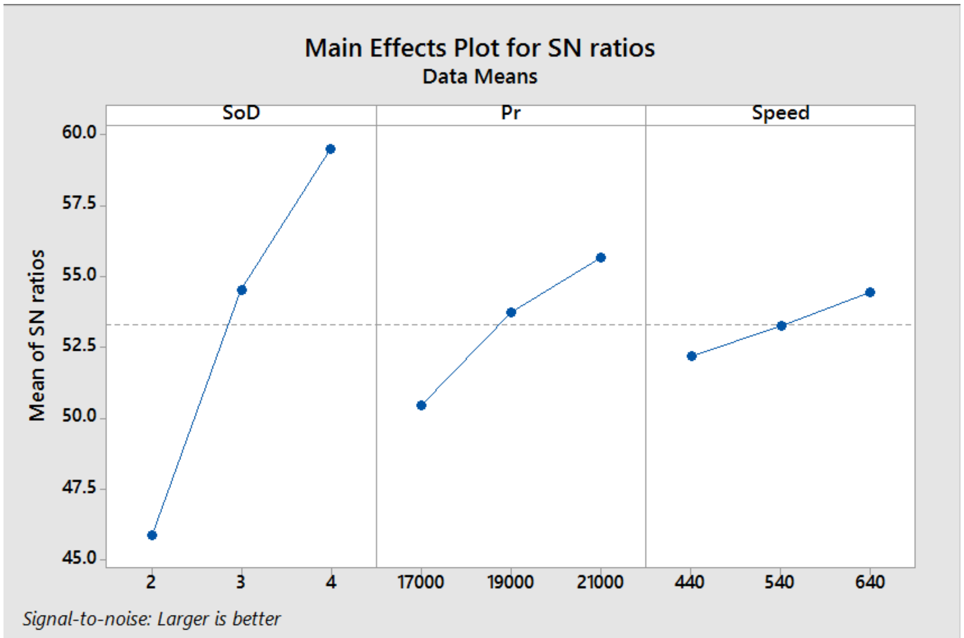

FIGURE 11. S/N ratio graph for MRR

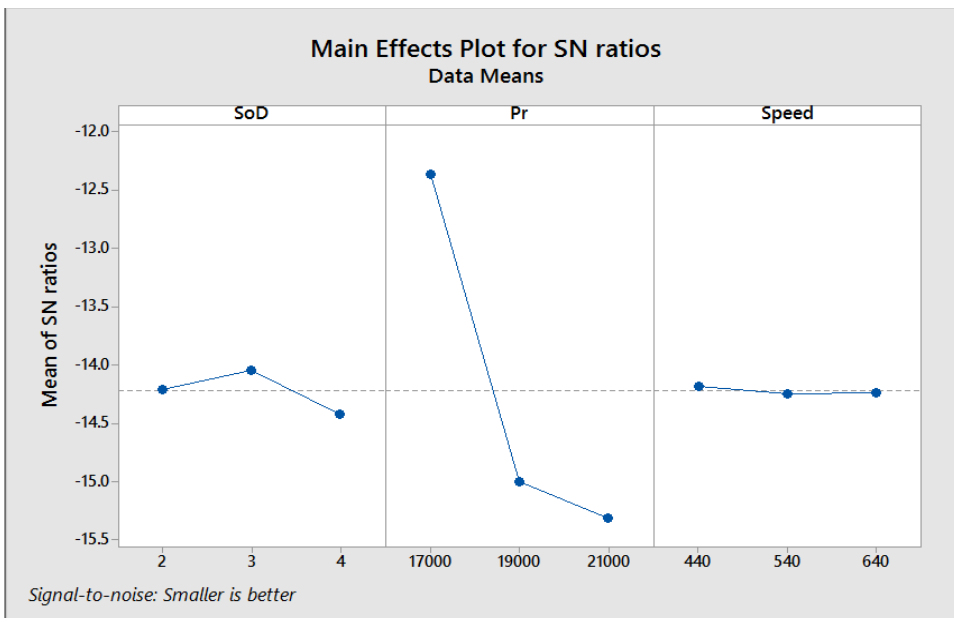

FIGURE 12. S/N ratio graph for Ra

TABLE 4. Reponses table for MRR

Level	Current(A)	Pulse on time (μs)	Pulse off time (μs)
1	23.4	20.03	19.71
2	20.12	19.65	19.85
3	15.84	19.66	19.79
Delta	7.56	0.38	0.15
Rank	1	2	3

TABLE 5. Anova Table for MRR

Parameters	Degree of freedom	Sum of Squares	Variance	F Values	P (%)
Current (A)	2	6.17	1.13	40.26	72.3
Pulse on Time ()	2	2.07	0.167	5.96	24.3
Pulse of Time ()	2	0.23	0.071	2.56	2.7
Error	2	0.06	0.028	-	0.7
Total	8	8.533	-	-	100

TABLE 6. Response table for Ra

Level	Stand of Distance	Pressure	Speed
1	-14.21	-12.36	-14.18
2	-14.04	-15.00	-14.25
3	-14.42	-15.31	-14.24
Delta	0.38	2.94	0.07
Rank	2	1	3

Delamination of the composite is for the most part caused because of the push power prompted during machining. Furthermore, the expansion in feed rate expands the heap which thusly expanded the push power. In this manner, delamination increments with the expansion in feed rate. On opposite, when the cutting pace expands, the actuated push power diminishes because of the conditioning of lattice material. The conditioning of the lattice is caused because of the expansion. Be that as it may, from the watched outcome, it is discovered that when the speed surpasses 540 the dark evaluation diminishes. This is on the grounds that, when speed passes 540 rpm, push power somewhat increments. The expansion in push causes nucleation of harm in the bored gap and prompts increment in stress focus. This pressure fixation decreases the rigidity of penetrated composite and causes cataclysmic separate of composite when burden is applied. Notwithstanding the production of stress fixation in the gap, legitimate burden move between the network and fibre is confined because of expanded delamination with the expansion in feed rate.

CONCLUSION

In this project presents a way of fabricating Kevlar composite and machining process with optimizing parameter, then different types of tests and analysis are made to predict the properties of fabricated Kevlar composite material. The ultimate strength of Kevlar composite is 110.36 N/mm2 which is suitable for automotive parts replacements. This fabricated Kevlar composite have a maximum break load of 6.60 KN thus withstanding more load before breaking also it has excellent wear properties which make them suitable for effective replacement of piles in tyres. The analysis of experimental results is carried out using Taguchi's analysis. The level of the best process parameters are been determined by using ANOVA. From the SEM images we can clearly see the cutting edges of the fibres, fibre pull-out due to the testing process induced damage area.

REFERENCE

1. Wang J. Machinability study of polymer matrix compo-sites using abrasive waterjet cutting technology. J Mater Process Technol; 94: 30–35,1999.
2. Xu W, Zhang L, Wu Y, et al. Effect of tool vibration on chip formation and cutting forces in the machining of fibre-reinforced polymer composites. Mach SciTechnol 2016; 20: 312–329.
3. Dandekar CR and Shin YC. Modeling of machining of composite materials: a review. Int J Mach Tools Manuf 57: 102–121, 2012.
4. Farah N, Abd H, Ascroft H, et al. Analysis of tool wear, cutting force, surface roughness and machining temperature during finishing operation of ultrasonic assisted milling (UAM) of carbon fibre reinforced plastic (CFRP). ProcediaEng, 184: 185–19, 2017.

5. Rao S, Sethi A, Das AK, et al. Fibre laser cutting of CFRP composites and optimization of process parameters through response surface methodology. Mater Manuf Process, 32: 1612–1621, 2017.
6. slam MM, Li CP and Won SJ. A deburring strategy in drilled hole of CFRP composites using EDM process. J Alloys Compd, 703: 477–485, 2017.
7. Ramulu M and Arola D, 24: 299–308, Water jet and abrasive water jet cutting of unidirectional graphite/epoxy composite. Composites 1993.
8. Uthayakumar M, Khan MA, Kumaran ST, et al. Machinability of nickel-based superalloy by abrasive water jet machining. Mater Manuf Process, 31: 1733–1739, 2016.
9. Kumaran ST, Uthayakumar M, Mathiyazhagan P, et al. Effect of abrasive grain size of the AWJM performance on AA(6351)-SiC-B4C hybrid composite. ApplMech Mater, 766: 324–329, 2015.
10. Kalirasu S, Rajini N, WinowlinJappes J, et al. Mechanical and machining performance of glass and coconut sheath fibre polyester composites using AWJM. J ReinfPlast Compos 2015; 34: 564–580.
11. Arun K, Santhosh G, Vivek N, et al. Process parameter effect on surface finish in abrasive waterjet machining: a review.Int J Emerg Trends Eng, 6: 20–27, 2016.
12. M.A. Azmir, A.K. Ahsan, Investigation on glass/epoxy composite surfaces machined by abrasive water jet machining, Journal of Materials Processing Technology, 198, 122–128 2008.
13. C. Ulasaydas¸ AhmetHascalik, A study on surface roughness in abrasive waterjet machining process using artificial neural networks and regression analysis method, Journal of Materials Processing Technology, 202, 574–582, 2008.
14. B. Deepanraj, V. Sivasubramanian, S. Jayaraj, Multi Response Optimization of Process Parameters in Biogas Production from Food Waste using Taguchi -Grey Relational Analysis, Energy Conversion and Management, 141, 429-428, 2017.
15. N. Senthilkumar, B. Deepanraj, K. Vasantharaj, V. Sivasubramanian, Optimization and Performance Analysis of Process Parameters during Anaerobic Digestion of Food Waste Using Hybrid GRA-PCA Technique, Journal of Renewable and Sustainable Energy, 8(6), 063107, 11, 2016.
16. D. Balamurali, K. Manigandan, V. Sridhar, Analysis of the Effect of Machining Parameters on Wire Electrical Discharge Turning of Stainless Steel, Journal of Advanced Engineering Research, 2(1), , 34-41, 2015.
17. R. Selvam, L. Karunamoorthy, N. Arunkumar, Investigation on performance of abrasive water jet in machining hybrid composites, Journal Of Materials and Manufacturing Processes, 32(6), 700-706, 2017.
18. Jino, R., R. Pugazhenthi, K. G. Ashok, T. Ilango, and P. R. Chakravarthy, "Enhancement of Mechanical Properties of Luffa Fiber/Epoxy Composite Using B4C", Journal of Advanced Microscopy Research, 12 (2), 89-91, (2017).