EVALUATION OF MACHINING PARAMETERS FOR CFRP UTILIZING A VERTICAL MACHINING CENTER (VMC)

Patel KrunalArvindbhai
Research Scholar
Gujarat Technological University,
Ahmedabad, Gujarat

Dr. Utpal V. Shah
Professor
Department of Mechanical Engineering
Government Engineering Collage, Modasa

Abstract—

The optimisation of different Method parameters using a variety of optimisation tools is thoroughly examined in this paper. When compared to other pieces of machinery, the moving vehicle performs exceptionally well in terms of accuracy and particular performance results. Every manufacturing sector aims to quickly and efficiently produce high-quality goods. It is difficult to meet the established quality standards for moving machinery when it comes to critical operational parameters like drive geometry, feed rate, depth of coolant application, and arbour race. As a result, choosing these parameters carefully is essential to guaranteeing the quality of the final product. To get the intended high-quality outcomes, the ideal parameters do not always function at their best. Enhancing these Method parameters in accordance with quality requirements is therefore essential. Although the Taguchi method is commonly employed for single-goal optimisation, alternative strategies like principal component analysis (PCA), grey relational analysis, and the substitute construct are used for multi-goal quality parameters. ANOVA analysis is also used to determine which parameters have the biggest effects on the designated quality standards.

Keywords—VMC (Vertical Milling Center), Different Optimization, Technique Parameter, Cutting Strength

I. INTRODUCTION

In order to create parts with precise dimensions and configurations, CNC milling is widely used in contemporary industries and machine shops. Out of all the drive methods, end drives are crucial for efficiently cutting metal, which advances the production of high-quality parts while lowering expenses. With this technique, a milling cutter can be used to create a variety of shapes. Prices have decreased as a result of the use of CNC machines, which have improved the quality of manufactured parts and expedited production processes [1-2].

In modern manufacturing, the CNC end milling technique has many benefits. But having sophisticated engineering skills alone is insufficient; improving real-world circumstances is essential to meeting character requirements. Method parameters like spindle speed, feed rate, depth of cut, coolant usage, and tool layout must be improved in tandem with critical elements like surface roughness, material removal rate, machining duration, power consumption, and tool longevity [3]. For overall objectives, principal component analysis and grey relational analysis are crucial optimization techniques, as are Taguchi methods, response surface methodology (RSM), and genetic algorithms.

II. REVIEWOF LITERATURE

In his study "Experimental Investigation into Tool Wear of Drilling CFRP," Andrew Hrechuk evaluates the performance of PCD and uncoated CVD-diamond coated drill bits when drilling CFRP samples of the Saab PAN type. Finding a correlation between tool wear and the calibre of the drilled holes was the aim. All drill bits showed comparable amounts of delamination and uncut fibres in the drilled holes when the cutting parameters were kept constant and the tool wear measurement was around 30 µm.Both the uncoated and CVD-diamond coated Seco 290A practice bits showed a significant reduction in cutting productivity and an increase in tool wear. On the other hand, the PCD Seco CX-1 drill bit displayed a clear pattern in which flank wear was equivalent to CER and edge wear was mainly indicated by an increase in cutting edge radius (CER) [4].

A new laser-mechanical hybrid drilling method that improves drilling quality in thick carbon fibre reinforced plastic (CFRP) laminates is presented in Hironori Sasai's paper "Improvement of Boring Quality of CFRP." Emerging features and hole formation during the laser pre-drilling phase were the main subjects of the study. To further clarify the material removal procedure during the reaming operation, a theoretical model was developed. In contrast to conventional drilling techniques, experiments using the laser-mechanical hybrid drilling apparatus were carried out to examine the effects on drilling characteristics and feed rate [5].

According to the prestigious study "Study Along Drive Bear During Moving CFRP Low Plain and Line Cold Machining" by M.K. Nor Khairusshima, scanning electron microscopy (SEM) images showed that attrition bear arsenic was present because of the sharp and quick increase in the drive bear region. This phenomenon was attributed to the frictional interactions between the cutting edge and tiny chips made from fractured carbon fibres, which had a major impact on the wear mechanics during the machining process. Furthermore, it was discovered that under low plain machining conditions, drive bear intensity rose as cut rates increased, specifically from 160 to 200 m/min, with feed rates ranging from 0.125 to 0.25 mm/tooth and from 0.5 to x millimetres. Although the results varied, the cut was especially noticeable during cold line machining. Remarkably, a decrease in drive bear was associated with an increase in cut rates from 160 to 200 m/min in the context of cold line machining [6].

According to Yanli's clause, "the cut effect and desert psychoanalysis inch moving of c character strong plastics," it is well known that, within certain ranges, some cut forces show an amp lean gain with arbour race, especially when they come into contact with fast check heaviness. Additionally, when race conditions are being constructed, damage is frequently caused by adhering to the eat-per-tooth principle [7].

Carbon fibre reinforced plastics (CFRPs) can be milled at higher cutting speeds to increase productivity and reduce costs, according to EckartUhlmann's study on high-speed cutting of CFRP. This method improves the quality of the workpiece and calls for the use of more sophisticated machining techniques. But attaining high-speed cutting (HSC) requires more than just speed increases; it necessitates a comprehensive strategy that takes into account machine conditions, tool design, and method settings. The use of instruments with the right geometries made especially for CFRP, as well as effective equipment and a dependable chip removal system, are essential to the success of HSC. Even though HSC machining of metals is well understood, more research is necessary to fully understand the complexities of CFRP materials. This analysis highlights how the use of HSC techniques alters the cutting mechanisms in CFRP machining, establishing a connection between cutting forces and improved cutting speeds as well as workpiece integrity. Notable results show that increased feed rates combined with higher speeds greatly increase productivity without sacrificing tool durability [8].

The research findings of EckartUhlmann, Sebastian Richarz, Fiona Sammler, and Ralph Hufschmied are presented in the paper "HIGH SPEED CUTTING OF CFRP." Several conclusions are drawn from the study: The application of interlayers for machining CFRPs with diamond-coated tools shows promise, and the use of innovatively designed CVD diamond-coated cutting tools for CFRP greatly improves method reliability and productivity. It is also possible to operate at temperatures lower than those currently used in secure practices. At the PTZ, a quantitative framework for evaluating CFRP's machined edges has been developed and is considered crucial. - Higher material removal rates can be attained by optimising the effects of peak cutting techniques, which will boost output without sacrificing workpiece quality. For CFRP machining, the CO_2 jet cutting and belt grinding methods exhibit significant promise for producing machined edges with high productivity and superior quality, respectively [9].

The study "High Quality Machining of CFRP with High Helix End Mill," by Akira Hosokawa, reports on side milling tests conducted on CFRP plates using two types of DLC-coated carbide end mills, each with a different helix angle. The following are the study's conclusions: When compared to the geometry of the conventional grind, the DLC end mill's performance seems subpar and inferior. - Using an end mill with a higher helix angle results in a significant decrease in both tangential and normal forces. The helix angle has a major impact on the cut width; the cut widths of the standard grind with a 60° helix angle are less than half of those measured in other configurations [10].

Teri examines the difficulties in machining complex materials in the area of "making of Complicated materials." He highlights that these materials display a range of behaviours that are influenced by a number of variables, such as the relative amounts of the intercellular material and the support's orientation and structure, as well as the characteristics of the support and the intercellular material. Additionally, he emphasises the significance of logical drive mechanisms in machining techniques, especially for elastic intercellular material composites (PMC) and robust plastics (FRP), which are essential for choosing the right cutting tools [11–12].

According to statistical evidence presented in D. Rajkumar's study "Optimisation of Machining Parameters for Little Boring of CFRP Composites Using Taguchi Method," the roundness of holes drilled in CFRP composites is significantly influenced by the feed rate, arbour speed, and cutting force, which contribute 39.21%, 49.32%, and 8.58% to the overall force, respectively [13]. According to a related study by Reddy Sreenivasulu, "Improving Indentation and Delamination Damage of GFRP Composites Under Close Moving Conditions Using Taguchi Method and Artificial Neural Networks," the main factor influencing delamination damage is cutting speed. Moreover, the depth of cut is the second most important factor influencing surface roughness, according to the analysis of variance (ANOVA) [14].

III. PRESENT A SUMMARY OF THE MATERIAL-RELATED PAPER

Three separate factors make up the experimental setup, and each is evaluated at three different levels. Important stimulus controls from a thorough review of recent research are used in this study. The following describes the rationale behind the selection of these factors and their corresponding levels:
(a) Speed: This refers to the arbor's and the workpiece's rotational speed, which is measured in revolutions per minute (rpm) and poses optimisation challenges.
(b) Feed rate: This is the speed, expressed in millimetres per rotation, at which the cutting tool moves along its assigned path.
(c) Depth of cut: This shows the distance, in millimetres, between the workpiece's rough and finished surfaces.
The impact of CFRP materials on the outcomes is then shown in Table 1.

Table 1 The sizes of CFRP materials and their outcome on performance outcomes[15-18]

Sr.no.	parameter of Composite Material (MM)	Arrangingof Fiber and Layer	Performance outcome	Citation
1	50.8 x 50.8x 8.4	60 - 0 -120°	As the fibre orientation gets closer to 90 degrees, the force variations and their intensity dramatically increase.	D., Sheikh-Ahmad, Kalla, J., &Twomey, J.-2010.
2	230 X 90 X 6	0-45-90-135°	As the fibre orientation angle changes from 0 to 180 degrees, the cutting forces first rise, then fall, and finally rise again.	He, Y., Qing, H., Zhang, S., Wang, D., & Zhu, S.- 2017.

3	260 x 240 x 9.36	0-45-90-135°	The maximum cutting force and tool temperature are noted at 0 and 45 degrees, while the lowest temperature is noted at 135 degrees.	R. Fredj, S. Gara,S. Naîmi, and O. Tsoumarev - 2017.
4	200 X 110 X 5	0-45-90-135°	Superior surface quality and increased tool durability can be achieved by choosing the right milling path and making sure the surface fibers are in a reversed cutting state.	D. Wang,T. Chen, F. Gao, and X. Liu – 2017.

The effect of CFRP material cutting on performance is sawn in Table 2.

Table 2PerformanceCutting ParameterConclusion[19-20]

Sr. No.	Detail in Cutting Force	Surface (Roughness)	Reference
1	As the feed rate rose, the cutting force for both end mills showed an upward trend, but it stayed mostly constant as the cutting speed increased.	In the realm of end milling, it was observed that for both three-flute and four-flute end mills, the axial surface roughness rose as the feed rate increased and decreased as the cutting speed increased.	E. Uhlmann et.al-(2015).
2	As the feed rate increases, the cutting force increases as well.		Wu, Xian et.al- (2016).

The effect of CFRP material tool performance coating is shown in Table 3.

Table 3 Tool Performance Coating's Effect[21-23]

Sr. No.	Effect of Cutting Force	Surface of Roughness	Reference
1	Compared to AlTiN-coated tools, diamond-coated tools produce less cutting force. The diamond tip's high rigidity and low friction coefficient, which successfully reduce the basic frictional interaction between the tool and the chip, are responsible for this phenomenon.	It is clear from comparing the indentation results from these two tools that the diamond-coated drive yields better results, as evidenced by a lower rise in indentation.	M. Haddad, R. Zitoune, F. Eyma, and B. Castanie(2014).
2	The data clearly shows that the amp-clad bur drive's forces are more efficient than those of similar geometries without a finish. Higher eat speeds and an increase in the subsequent drive effect may have played a major role in the earlier loss of the adamant take, which was	Diamond-coated tools are especially well-suited for the finishing cuts of CFRP, according to the information regarding rise indentation and its effects.	D. Kalla, J. Sheikh-Ahmad, and J. Twomey, (2010)

	attributed to chip and delamination. In the case of the light take drive D10, which exhibits less force than thicker films, this phenomenon is especially apparent.		
3	Compared to similar geometries without a finish, the amp-clad bur drive's applied forces are obviously greater. One possible and important factor causing the earlier loss of the adamant take, which leads to chip formation and delamination, is the increase in the subsequent drive effect, which is linked to higher speeds. When compared to thicker films, the light take drive D10 exhibits a lower force, making this problem especially noticeable.		O. Bílek, S. Rusnáková, and M. Žaludek, (2016)

Table 4 shows how tool geometry affects CFRP material performance.

Table 4 Tool Coating's Impact on Performance[24-26]

Sr. No.	Number of Flute	Parameter of Cutting Force	References
1	Astonished Mill and Rhombic	When compared to the staggered helical milling cutter, the rhombic milling cutter exhibits a significant decrease in both feed cutting force and radial cutting force.	T. Chen, F. Gao, S. Li, and X. Liu(2018)
2	flute (3 & 4)	As the feed rate increases, the cutting force for both end mills increases as well, but it stays mostly constant as the cutting speed increases.	E. Kiliçkap, A. Yardimeden, and Y. H. Çelik,(2015)
3	flute 2 (2no.s)	The influence of the helix angle b leads to a significant reduction in both the tangential force Fy and the normal force Fx when using an end mill that has a greater helix angle.	A.Hosokawa, N. Hirose, T. Ueda, and T. Furumoto(2014)

IV. Experimental Setup and Process Parameter

The CFRP composite plates employed in this experimental study were produced using the sheet compression molding method. These plates consist of essential layers of carbon fiber mats arranged in a specific orientation. The mechanical characteristics of the CFRP composite include a shank diameter of 20 mm, a collision angle of 0.6 degrees, a neck diameter of 18 mm, an overall length of 60 mm, a corner radius of 0.5 mm, a cutting diameter of 6 mm, and a total of 6 flutes. The dimensions of the CFRP Workpiece block were 100×100×30 mm, and the experimental setup is illustrated in Figure 1.

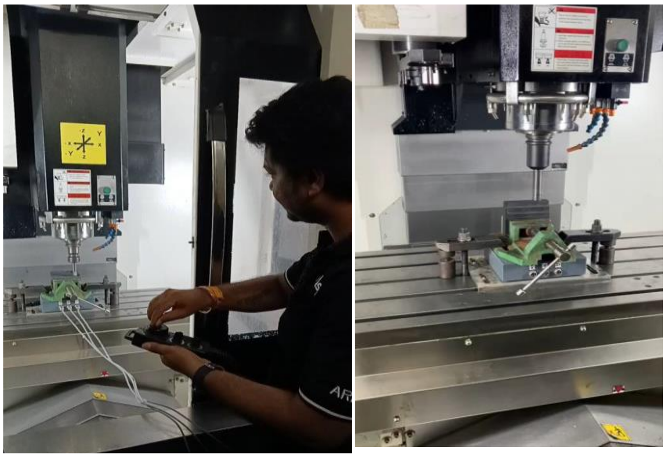

Figure 1: Excremental Performance

As shown in figure 2, the COSMOS CVM-1160 VMC was used to perform the tests on the VMC machine.

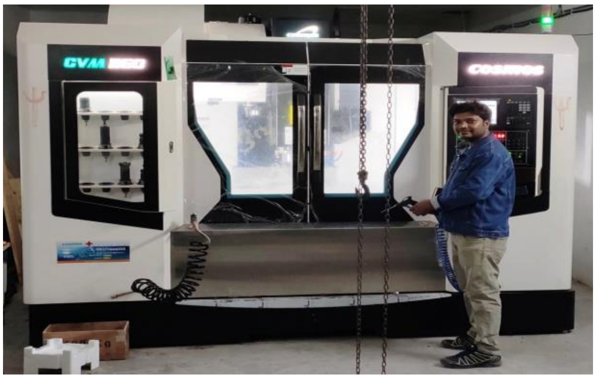

Figure 2: Machine Model (COSMOS CVM-1160)

V. OUTCOME

The impact of feed rate, cutting speed, and flute count on end mills in relation to machining quality:

The delamination factor is significantly impacted by feed rate, according to the analysis shown in Figure 3. In particular, the delamination factor rises in proportion to an increase in feed rate. The feed rate of 100 mm/min had the lowest delamination factor, while the feed rate of 200 mm/min had the highest. Furthermore, it was found that the delamination factor varied with cutting speed, with higher cutting speeds across a range of feed rate settings resulting in an increase in the average delamination factor. Several researchers [28,29] have confirmed this observation, showing that lower feed rates yield the best delamination results.Additionally, Erkan et al. [29] proposed that delamination is facilitated by the increase in plastic deformation rate at higher cutting speeds. Furthermore, it was discovered that, under constant cutting conditions, the delamination factor drops as the number of flutes is decreased. The end mill's multiple cutting edges engaging during each rotation is the cause of this decrease [28].

A difficult machinability parameter that has drawn a lot of attention is surface roughness [29]. It is intrinsically related to the tolerance or accuracy of automotive parts [26]. The metallurgical changes and geometric irregularities present on machined surfaces are important factors that require definition and control. Outlining the rise and hold of the end and the rise of unity is therefore crucial.The mechanical characteristics of the workpiece material, run-out errors, tool geometry, tool material, and machining parameters like speed, feed, depth of cut, and cutting fluid all influence how a machined surface looks in the end. Furthermore, work variance is linked to the rise end [29]. Surface roughness (Ra) is significantly impacted by the number of end mill flutes and cutting parameters.

The effect of feed rate, cutting speed, and end mill flute count on cutting force:

A force is required in the machining method to cause plastic deformation and to cut the material. This effect is known as the cut effect factor for arsenic. It is affected by a number of variables and shows a high sensitivity to elements like the machine's stability, heat generation, cutting tool machining parameters, material composition, hardness, and microstructure geometry. Because it fluctuates with changes in machining parameters, drive materials, geometry, drive bearings, and other factors, the cut effect factor is significant for arsenic. A number of experiments were carried out to look into this. According to the results of these experiments, the machining effect rate was determined by averaging the cardinal subsequent parts of the cut effect that played along the workpiece. the relationship between the machining effect and the list of flutes along the close grind and the various cut parameters.

VI. CONCLUSION

The impact of several parameters, such as the number of flutes on end mills and the cutting speed feed rate, on the end milling of CFRP composite materials using cemented carbide end mills has been investigated experimentally in this paper.

The impact of several parameters, such as the number of flutes on end mills and the cutting speed feed rate, on the end milling of CFRP composite materials using cemented carbide end mills has been investigated experimentally in this paper. When machining CFRP with a carbide end mill, research shows that a higher spindle speed reduces the cutting force. The depth of down get run to clearly drive bear astatine less speeds is also increased by nursing associates.

Changes to parameters like arsenic cut race, eat order profundity of down drive geometry, and drive matter are crucial because they affect cut forces, matter remotion rates, and end quality.It is beneficial to acquire the list of flutes along the close grind in order to achieve the amp-less cut effect astatine amp down eat order exploitation amp four-flute close grind. This modification contributes to reduced cutting forces and aids in lowering tool tip temperatures.

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