

Impact of Dry Drilling CFRP with Ti-AlN Nano-coated Bits: Considerations for Machine Parameters and Hole Quality

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ABSTRACT

CFRP (Carbon fiber-reinforced polymers) has a high strength-to-weight ratio, resists corrosion, and is durable. High strength and hardness make machining difficult. Also consider the cutting tool. This experimental analysis the influence of machining on Hand-laid CFRP plates. In this case, the parameters Speed, Feed, and Cutting Tool were used to monitor a CNC drilling machine. Both a TiAlN nano coating and an uncoated 14mm High-Speed Steel (HSS) drill bit are used. Titanium-aluminum-nitride-coated HSS tools enhanced hole quality. Six various thicknesses of CFRP plates are drilled to observe hole entry and exit quality. There is no pushout delamination, when a double-coated HSS tool is used, ensuring the same hole quality at both entry and exit. DOE optimizes observations (DOE). Taguchi Analysis for six different thicknesses show a drill bit with a titanium-aluminum-nitride double coating produces the perfect drill hole quality on CFRP metal. This research looks into what happens when you dry drill Carbon Fibre Reinforced Polymer (CFRP) with Ti-AlN Nano-coated bits. It looks at how it changes the machine and the quality of the holes you make. Through careful testing and analysis, the study shows the most important things that need to be thought about when setting up a machine for dry drilling. The study also looks at the effect on hole quality, focusing on factors that affect surface finish, delamination, and the strength of the structure as a whole. The study's findings help us learn more about how Ti-AlN Nano-coated bits, machine parameters, and the quality of the hole made during CFRP dry drilling all work together. These findings can be used to improve the way machines are used for machining.

Keywords: *Taguchi Analysis, Design of experiments (DOE), Nano coated HSS tool, (TiAlN), Dry Drilling, HSS drill bit.*

1.0 Introduction

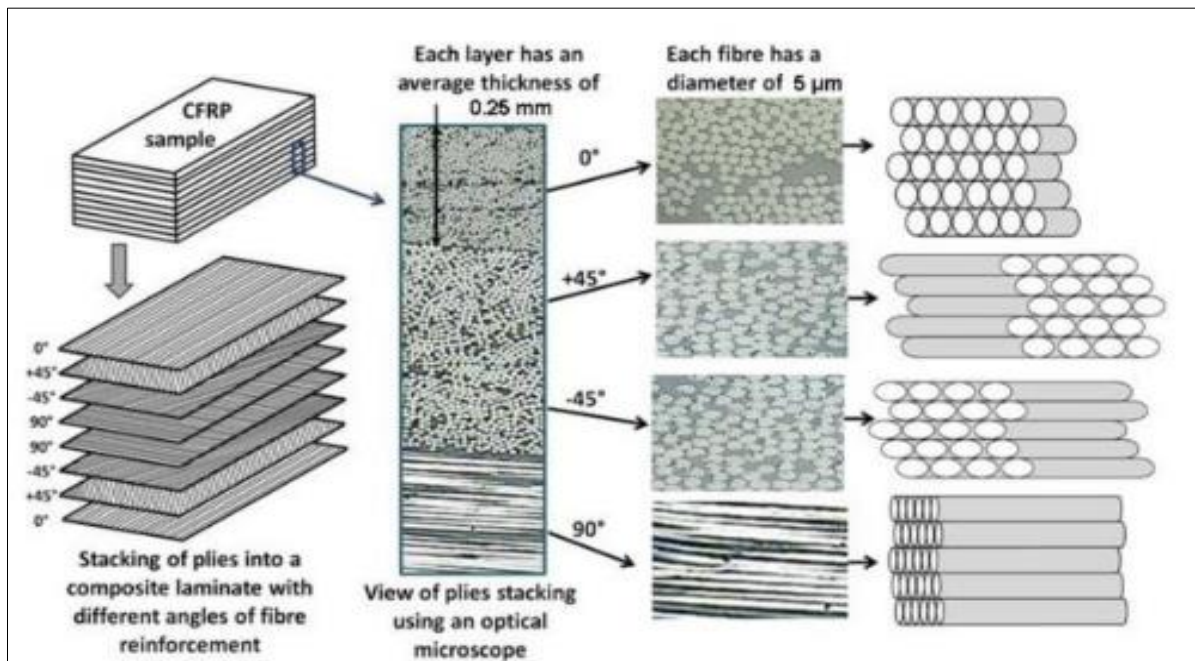
Nowadays, (CFRP) has been able to compete with due of its mechanical qualities, it is a viable alternative to currently utilised materials for vehicle bodies, aviation turbines, and high-end sporting goods. Although it is thought to be lighter, it has the highest quality, highest hardness, and most resistance to betrayal, consumption, weakness, vibration, and wear. It also has a low warm extension. CFRP can be used in a variety of industries, but the proper machining procedures must be in place first. [1-2] But because it has a very uneven structure and is constructed of two very dissimilar materials, conventional mechanical machining cannot be used to manufacture, such as drilling and processing and sawing and wire-cutting, encountered severe difficulty using ordinary cutting devices.

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Fiber delamination, pull-out, interior split, and real device wear are all caused by mechanically operated mechanical powers. Recently, lasers or grating water-planes have been used to monitor CFRP instead, which explains why. High-weight CFRP grating particles can be cut in harsh water-stream cutting without causing instrument wear or warming up. [3-5] Wet surfaces must be tolerated because saturated polymers soften and irritate fiber-framework grips, resulting in a decrease in mechanical properties. As a result of the CFRP composites' anisotropic and multi-scale normal structure, high-caliber CFRP machining was a particularly difficult challenge. [6-8] As a result, some superficial damage may occur, such as delamination, fibre pullout, and framework split. It is possible that damage to CFRPs during machining will reduce the heap bearing capacity of the segments and shorten their expected lifespan. In order to improve CFRP machining innovation, one of the most important considerations is to reduce cutting damages. Table 1.1 shows the synthesis of CFRP. [10].

Common weave styles of woven fabrics are depicted in Figure 1.1. These weave styles involve the interlacing of warp threads in Wet fibres in the longitudinal (0°) and transverse (90°) directions interlock regularly. Fabrics with two or more warp yarns intertwined with two or more filler yarns can be draped in a variety of shapes, greater ease than the plain weave CFRP, which produces the highest possible level of yarn slippage stability. Due to the limited scope of this thesis, other carbon fibre reinforced plastic (CFRP) manufacturing methods such as winding or Pultrusion for round CFRP pieces or specialized profiles will not be examined. There are a few distinct processing options available for curing the component after the fibres have been impregnated with the matrix (resin) material. The component size, matrix material, geometrical limitations, and other factors all have a role in the method that is chosen as the most suitable option. [11-13]. The application of the resin can be done in the technique that has the cheapest tool costs by spraying it on.

Figure 1: CFRP Lay-up Process and Material Qualities



The use of CFRP in commercial planes, such as the AIRBUS A350, has increased from just 5% of the total mass twenty years ago [14] to around a considerable part now. A sophisticated cycle is

used before attaching parts with bolts or screws when complex calculations and varied materials prevent fabrication of a single component. Drilling of CFRP is thought to account for almost 66 percent of all non-metal expulsion [15].

In comparison to laser boring, mechanical and unconventional penetrating techniques, for instance, typically provide better apertures with higher efficiency [16-17], but they also necessitate indisputably more complicated and expensive offices [18]. Colombi and Poggi undertook to conduct an exploratory study on the bonding properties of CFRP steel in 2006 [19]. Surface damage such as lattice, fibre ripping out, and delimitation could occur. When CFRPs are machined, they can crack [20], indicate that De-overlay was far less eloquent. The stack's leave gap is much wider than the section opening. The final surface roughness was most significantly influenced by the axle speed and kind of cutting tool coating. [21]. The findings anticipate investigating the impact of cycle boundaries on drilling in carbon fibre reinforced polymer (CFRP) composite using a multi-layer TiAlN/TiN pvd-covered tungsten carbide drill. According to Aishah Najiah Dahnethair investigation' findings show that tungsten carbide drills are often used to pierce CFRP because they are more efficient and reasonably priced than HSS and PCD drills. [22–25].

2.0 Experimentation

The fabrication of CFRP specimens comes first, followed by the execution of dry drilling procedures as part of two stages are included in the experimental work.

2.1 Preparation of sample

A manual lay-up procedure with carbon fibre layers measuring 9x9 millimeters in area and varying in thickness is used to manufacture carbon fibre reinforced plastic (CFRP). Specimens with varying thicknesses are presented in the table that follows below. Table.1. shows the Material Characteristics of CFRP Composites, while the table 2 shows Table.2 samples dimensions and Table.3. Parameters of Hardener and Epoxy resin

Table 1: Material Characteristics of CFRP Composites

	Specific heat CP, (J/kg K)	Thermal conductivity K (W/mK)	Damage temperature e TD(K)	Evaporation temperature TV (K)	Density ρ (kg/m3)	Latent heat Lv (kJ/kg)
Polymer Matrix	860	0.4	521	725-833	1365	1100
CFRP	860	60/6	2863	3965	1920	39000

Table 2: Samples Dimensions

S.No	Numbers of layers of sample (CFRP)	Weight (gm)	Thickness (mm)
1	6	0.018	2.1
2	10	0.027	3.2
3	12	0.032	4.1
4	15	0.041	5.2
5	18	0.054	6.3
6	20	0.061	7.1

Figure 1 presents the steps involved in the preparation of the specimen. The fabrication of CFRP plates requires adhering to certain specifications for the epoxy resin and hardener that are shown in.

Table 3: Parameters of Hardener and Epoxy Resin

No. of layers	Hardener		Epoxy resin	
	In gms	In ml	In gms	In ml
6	0.003	3	0.018	15
10	0.004	5	0.026	25
12	0.005	6	0.030	29
15	0.006	7	0.042	35
18	0.007	8	0.048	42
20	0.007	9	0.054	45

Figure 2: Preparation of Samples for CFRP



2.2 Dry drilling operation

Minimum spindle speed of 1000 revolutions per minute is required to operate the CNC drilling machine, dry drilling experiments were performed using TiAlN-coated HSS tools. The results are given IN Fig lists the specifications of the CNC drilling machine in table.

Figure 3: Drilling Machine (CNC)



Table 4: Specifications of CNC Drilling Machine

Specifications	Limit of the CNC Machine
spindle speed that is programmed	150-4000 rpm
ATC –highest length of tool	40mm
column of Spindle	110mm
Spindle to table distance	70mm to 185mm
ATC	6 stations
dimensions of Machine (L*w*H) mm	1000*575*650mm
size of Table	360mm*132mm
ATC –highest length of tool	40mm
direction of ATC	Bi-direction
Spindle nose taper	ISO 30

2.3 Tool design

For the purpose of drilling the CFRP Laminates, a high-speed steel (HSS) drill bit with a diameter of 12 millimeters was utilized. On the CFRP laminated material, the drilling operation was carried out in three distinct variants. The CFRP Laminate was initially drilled prior to any coating being applied, as can be seen in fig 4 (a). Second-stage titanium-aluminum-nitride (TiAlN) drill bit coating is shown in Fig. 4 (b). CFRP drilling operations result in a drill bit with a TiAlN/TiN double coating, as shown in Fig 4 c. Varying thicknesses of laminates and work pieces drilled at different speeds and depths using coated and uncoated drills.

Figure 4: HSS Drill Bit (12mm)



Figure 5: (a) (Double coated) HSS Drill bit with TiAlN
(b) (Single Coated) HSS Drill bit with TiAlN

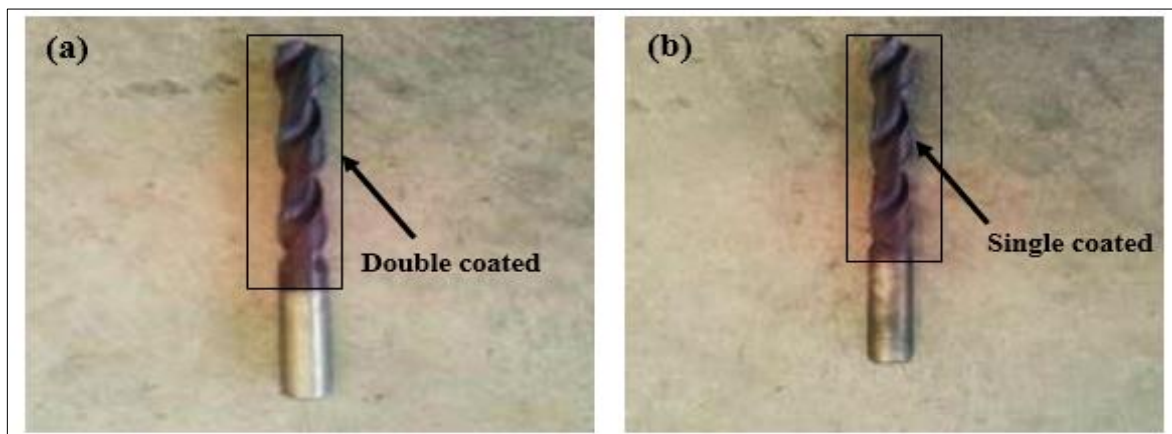
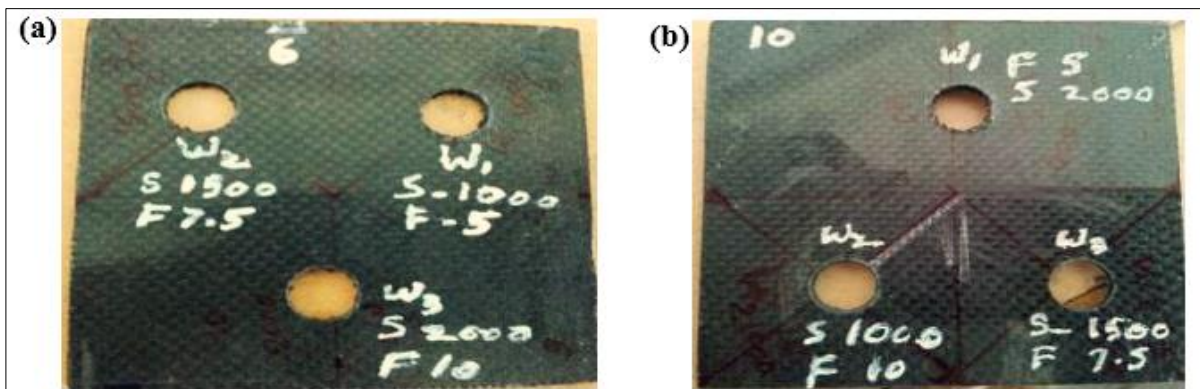


Figure 6: 6 layers, thickness 2.0

Figure 7: 10 layers, thickness



By employing a CNC drilling machine, a drilling program was input to the machine using G-codes and M-codes, and with the use of that program, CFRP was drilled using a variety of speeds,

feeds, axes, and drill bits that were both Nano coated and uncoated. The uncoated drill bit causes higher vibrations while drilling CFRP, whereas the drill bit that has been coated with nanoparticles causes less vibration fig 5 and 6 shows the 6 layer thickness and 10 layer thickness samples.

3.0 Results and Discussion

3.1 Taguchi analysis

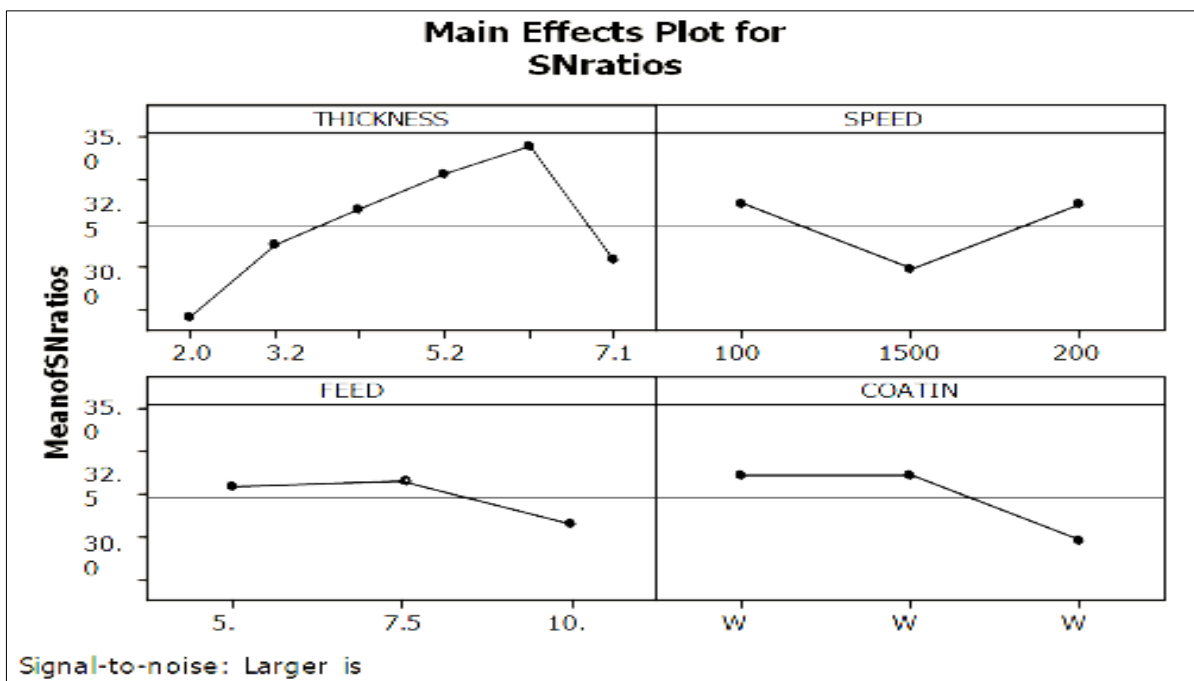
3.1.1 CYCLE TIME vs THICKNESS (M) and SPEED (RPM)

According to the findings that were derived from the taguchi plots, the two-layer nano coated drill bit produces holes with superior surface quality and identical entrance and exit holes after drilling the work piece. On the other hand, the entry hole and the exit hole with Despite having smaller thickness, the uncoated and single Nano coated drill bits are identical., but they vary as the thickness of the CFRP sheet increases, and drilling the CFRP sheet also causes more vibrations. However, when drilling into the CFRP sheet using a drill bit that has a double coating of nanoparticles, there are significantly fewer vibrations

Table 5: S/ N Ratio for Cycle Time vs Thickness (m) and Speed

1	25.39	30.65	29.23	32.21
2	27.69	26.24	31.68	30.25
3	29.66	32.31	29.28	26.32
4	31.79			
5	35.55			
6	28.68			
Delta	10.05	3.65	2.52	3.75
Rank	1	2	4	3

Figure 8: Graph Mean of S/N Ratio for Entry Hole



3.1.2 ENTRY HOLE vs THICKNESS (MM), SPEED (RPM)

Solution to signal-noise ratio would be Larger would be optimal

Table 6: S/N Ratio for Entry Hole vs Thickness (mm), Speed (rpm)

Level	Thickness (MM)	Speed (RPM)	Feed (MM/MIN)	Coating
1	20.55	20.58	20.65	20.59
2	20.65	20.59	20.68	20.65
3	20.55	20.59	20.70	20.62
4	20.24			
5	20.42			
6	20.60			
Delta	0.06	0.11	0.10	0.10
Rank	4	2	1	3

Figure 9: Mean of the Signal-to-noise Ratio for the Existing Hole

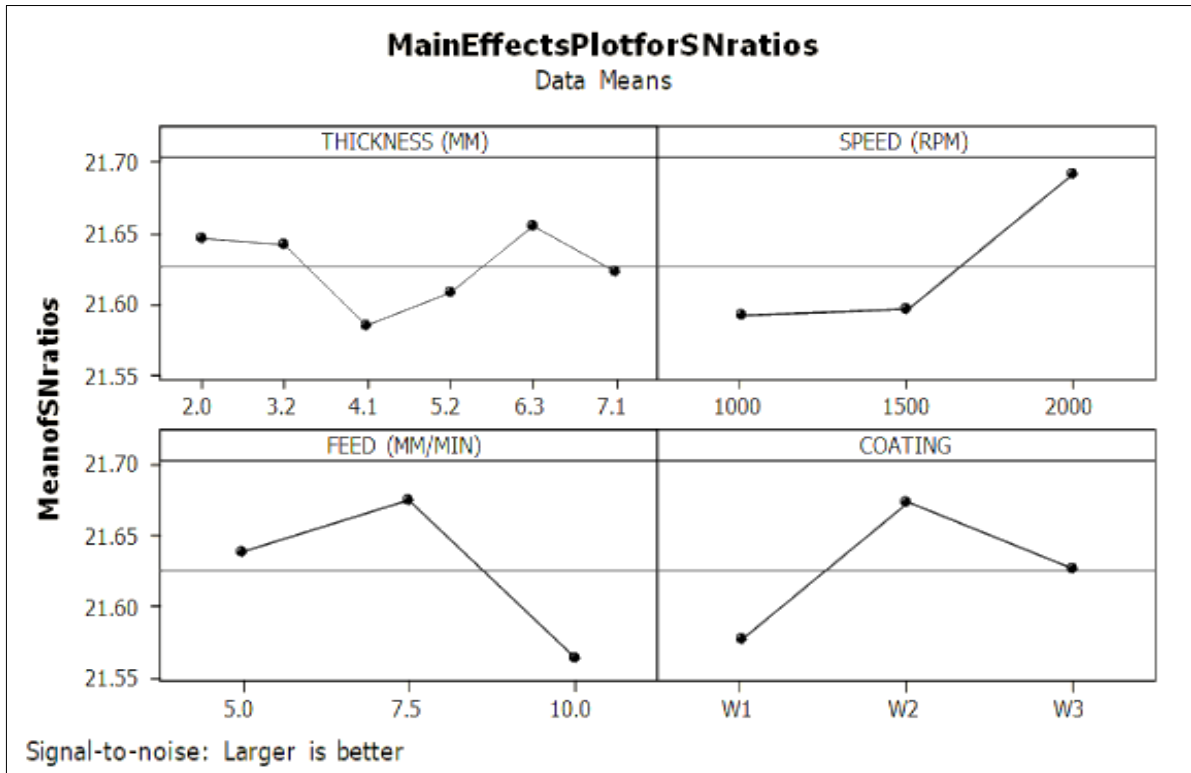
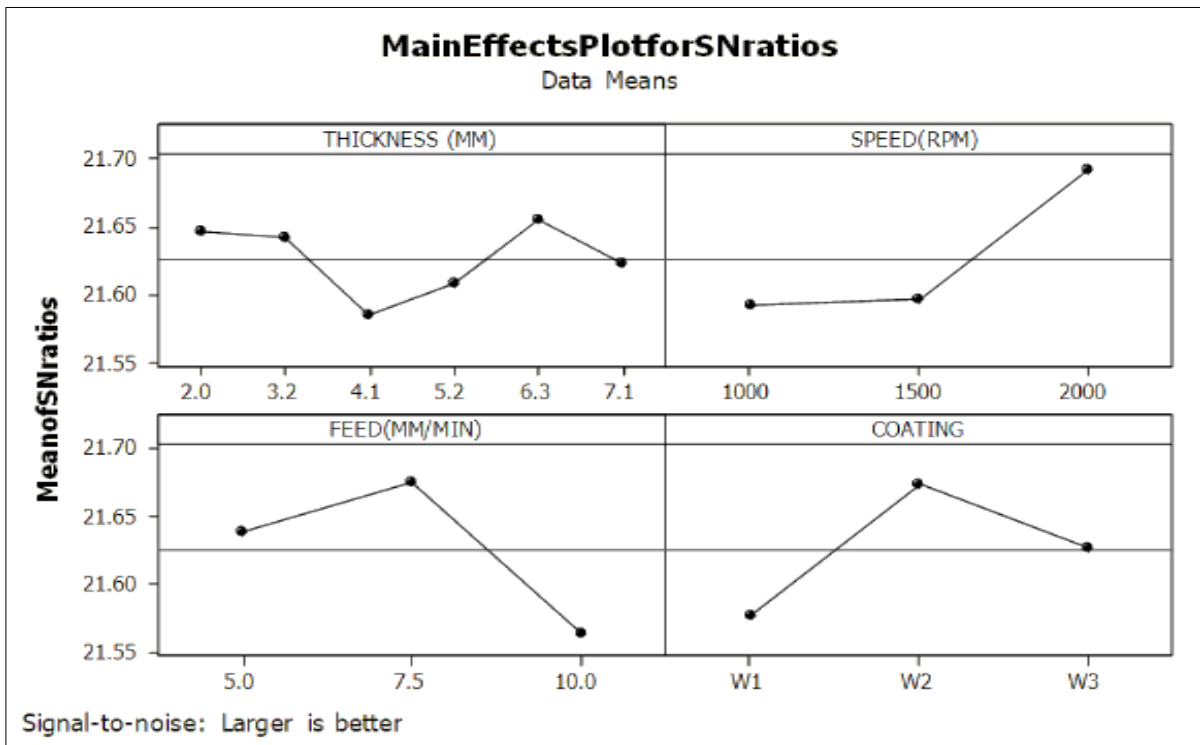


Table 7: Parameters for Taguchi Analysis based Solution

Level	Thickness	Speed	Feed (mm/min)	Coating
1	21.68	21.57	21.58	21.56
2	21.62	21.59	21.65	21.60
3	21.57	21.63	21.56	21.63
4	21.57			
5	21.55			
6	21.62			
Delta	0.11	0.06	0.09	0.07
Rank	1	4	2	3

Figure 10: Mean Cycle Time S/N Ratio



4.0 Conclusions

In this day and age, the most important aspects of a piece of technology are its portability, light weight, ease of use, and cost effectiveness. Composite material has gained widespread acceptance in recent years, particularly in technological fields such as the aircraft industry, the marine industry, the automobile industry, and civil engineering. The recyclability of CFRP composite material is very straightforward to accomplish, which has led to its widespread application in structural and non-structural applications. The primary focus of the composite should be on its high level of performance. When compared to uncoated and double-coated drill bits, the entry hole produced by single-coating drill bits is noticeably superior based on the drill bit's diameter. When compared to a single and uncoated drill bit, the exit hole produced by a drill bit with a double coating is far superior, and the vibrations produced by this type of drill bit are significantly lower. When a drill bit is doubly coated with TiAlN, the quality of the hole produced is significantly increased. Using Ti-AlN Nano-coated bits for dry drilling of carbon fibre reinforced plastic (CFRP) has a significant impact on both the machine parameters and the hole quality. In addition to shedding light on key factors that influence hole quality, the study highlights the significance of carefully considering and optimising machine parameters. For the purpose of advancing CFRP machining practices that are both efficient and of high quality, these insights are essential.

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