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Influence on Ti-AIN Nano-coated drill bit on machinery parameters and quality of hole in dry drilling of CFRP

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Abstract: Many of the researchers attained concentration on CFRP (Carbon fiber reinforced polymers) and identified as maximum material for the implementing in the domains of engineering in former past years unsettled for their maximum robustness for less ratio weight, resistance of corrosion & resilience. However, process of machining is seen as the great challenge due to their high strength & high hardness. The selection of cutting tool is another aspect. The present contribution of experimental work deals with the impact of machining aspects on CFRP plates prepared by Hand lay-up procedure. Here, the simulation study has been conducted on a CNC Drilling machine by considering Speed, Feed and type of Cutting tool as parameters. A High-Speed Steel (HSS) Drill bit of size 12mm is used to drill the hole without coating and with titanium-aluminum-nitride (TiAlN) Nano coating. The drilling operation further enhanced once again by double coating of HSS tool with titanium-aluminum-nitride to describe the hole quality. The drilling operation is performed on six different thicknesses of CFRP plates to observe the quality of the hole at entry and exit. When the double coated HSS tool introduced it is observed that the quality of hole at entry and exist is same and without push-out delamination (POD). The observations are optimized by using Design of experiments (DOE). Finally, the outcomes exhibit the optimal drill hole quality surface on the CFRP metal through using double coating of titanium-aluminum-nitride on HSS drill bit is explained by using Taguchi Analysis for six different thickness.

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

1. Introduction

As of late (CFRP) has fit to trade current materials utilized for body of car, airplane turbine, building & maximum-grade sports products, due to its serious mechanical characteristics. It has been considered less weight; however, has maximum quality, high hardness, & great protection from betraying, consumption, weakness, vibration, and wear, with low warm extension. So as to utilize CFRP in different businesses, appropriate machining methods must be made sure about. In any case, because of its profoundly inhomogeneous structure, made out of two totally divergent materials, regular mechanical machining, for example, boring, processing, sawing, and wire cutting experience experienced significant difficulty on ordinary cutting instruments. Straightforwardly actuated mechanical powers cause fiber delaminating, pull-out, inside split, and genuine device wear. For this explanation, as of late, grating water-planes or lasers have been embraced to measure CFRP on the other hand. In rough water-stream cutting, water is utilized to quicken the grating particles with high weight and CFRP can be cut without instrument wear and warmth age. In any case, the dampness take-up in the cut surfaces can't be dodged, and it prompts the corruption of mechanical properties, on the grounds that saturated polymers become milder and irritate fiber-framework grips. CFRP machining with high caliber due to the anisotropic and multi-scale normal for the composites structure of CFRP turned into a major test [5, 6]. Consequently, a few surface harms may happen like delamination, pulling out of the fiber, and framework splitting. When CFRPs are machined these harms could bring down the heap bearing capacity of CFRP parts and decrease the life expectancy of the segments. Consequently, hindering the cutting harms is one of the most significant contemplations for advancement of CFRP machining innovation. The CFRP synthesis is appeared in the table 1.1. [3][4].

Table.1. CFRP Properties of Material

Material	**Density ρ (kg/m³)**	**Thermal conductivity K (W/mK)**	**Specific heat CP, (J/kg K)**	**Evaporation temperature TV (K)**	**Latent heat Lv (kJ/kg)**	**Damage temperature TD(K)**
CFRP	1850	50/5	1200	3573	43,000	2973
Polymer Matrix	1250	0.2	710	623–773	1000	443

The Figure 1.1 shows common weave styles of woven fabrics, where warp fibers in longitudinal direction (0°) and weft fibers in transverse direction (90°) interlace in a regular pattern to generate a mechanical interlock. The plain weave CFRP produces maximum yarn slippage stability, while other fabrics with two or more warp yarns interlocking two or more filling yarns are more pliable and can more easily be draped to simple contours. Other manufacturing methods of CFRP, e.g. winding or Pultrusion for round CFRP parts or certain profiles will not be discussed, since the focus of this thesis is on flat UD and woven CFRP laminates.
Different processing routes exist to impregnate the fibers with the matrix (resin) material and cure the component. The selection of the appropriate method depends on the component size, matrix material, geometrical constraints, etc. In the method with the lowest tool costs, the resin is applied either by spraying,

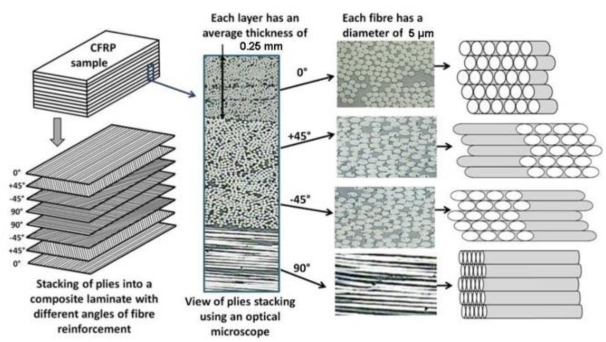


Figure 1.1: Lay- up process of CFRP and properties of CFRP.

2. Literature Survey

The utilization of CFRP in traveler airplane, for example, the AIRBUS A350 now makes up about a large portion of the all-out mass, up from just 5% twenty years ago[25].Drilling of CFRP, considered for very nearly 66% of all non-metal expulsion, is an intricate cycle applied before joining of parts with bolts or screws where complex calculation as well as various materials preclude creation as a solitary component[26]. Mechanical and unusual penetrating methods, for example, beat laser boring [7, 8] by and large furnish better quality openings with higher efficiency however require unquestionably more perplexing and costly offices [9]. An exploratory examination of the bond attributes between CFRP-steel individuals was led by Colombi and Poggi in 2006 [10]. surface harms may happen like delimitation, pulling out of the fiber, and lattice breaking when CFRPs are machined [11–14]. M.Simoncini, the aftereffects of their investigation shows that De-overlay was considerably less articulated. Leave gap breadth of the stack is a lot of lower than the section opening. K.Giasin, the consequence of their examination shows that the axle speed and sort of cutting device covering had the most critical impact on the accomplished surface harshness [15-19]. Ozden Lsbilir, the aftereffects of their examination expect to explore boring cycle in carbon fiber rein constrained polymer (CFRP) composite with multi-layer TiAlN/TiNpvd covered tungsten carbide drill the impact of cycle boundaries have been researched in boring. Aishah Najiah Dahne, the after impacts of their investigation shows the tungsten carbide drills are regularly utilized for penetrating CFRP as they are more functional contrasted with HSS and PCD drills as far as efficiency & cost [20-24].

Experimental setup

The Experimental work is carried out in two phases, first is preparation of CFRP specimen and next is performing Dry Drilling operation.

Specimen Preparation

The preparation of CFRP is prepared by hand lay-up process of carbon fiber layers of size 9X9 millimeters of area of six different thicknesses. Specimen with different thickness is shown in the following in table3.1.1.

S.No	**No. of Layers of Specimen(CFRP)**	**Total Thickness In (Mm)**	**Weight(gm)**
1	6	2.1	0.018
2	10	3.2	0.027
3	12	4.1	0.032
4	15	5.2	0.041
5	18	6.3	0.054
6	20	7.1	0.061

Table.1. The Preparation of specimen is shown in figure 1

The Specifications of Epoxy resign and Hardner is used in the preparation of CFRP plates shown in

Sl.no	**No. of layers**	**Epoxy resin**		**Hardner**	
		In ml	**In gms**	**In ml**	**In gms**
1	6	13	0.016	2	0.002
2	10	22	0.024	4	0.003
3	12	27	0.029	4	0.003
4	15	33	0.037	5	0.004
5	18	40	0.049	6	0.005
6	20	43	0.049	7	0.005

Table.2. Specifications of Epoxy resign and Hardner.

Figure.2. Preparation of CFRP Specimen

Dry Drilling operation

Dry drilling experiments were carried out using titanium-aluminum-nitride (TiAlN) coated HSS tool on a CNC drilling machine of minimum spindle speed of 1000 rpm is shown in the figure 3.2.1.The specification of the CNC drilling machine shown in Table 3.2.1.

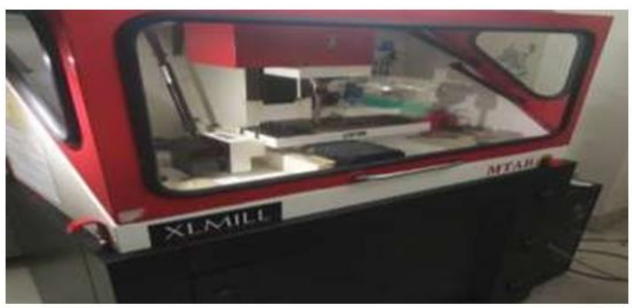


Figure.3. CNC drilling machine

Table.3. Specifications of CNC machine

SL.no	Specifications	Limit of the CNC Machine
1	size of Table	360mm*132mm
2	Spindle to table distance	70mm to 185mm
3	column of Spindle	110mm
4	Spindle nose taper	ISO 30
5	ATC	6 stations
6	ATC – highest dia of tool	16mm
7	ATC –highest length of tool	40mm
8	direction of ATC	Bi-direction
9	spindle speed that is programmed	150-4000 rpm
10	dimensions of Machine (L*w*H) mm	1000*575*650mm

Tool Design

A High-speed steel (HSS) drill bit of 12mm diameter was introduced to drill the CFRP Laminates. The drilling operation performed on CFRP laminated in three different variations. In the first stage the CFRP Laminate was drilled without any coating shown in figute 3.3.1. In the second stage the drill bit was nano coated with Titanium-Aluminum-Nitride (TiAlN) as single coated as shown in figure 3.3.2 later the drill bit was double coated with Titanium-Aluminum-Nitride (TiAlN) shown in figure 3.3.3 and the drilling operation for all different thickness CFRP Laminates.

Figure.4. High Speed Steel DrillBit(12mm)

Figure.5. HSS Drill bit with TiAlN (Single coated)

Figure.6. HSS Drill bit with TiAlN (Double coated)

work pieces drilled with the different speed, depth of cut with coated and un-coated drill bit

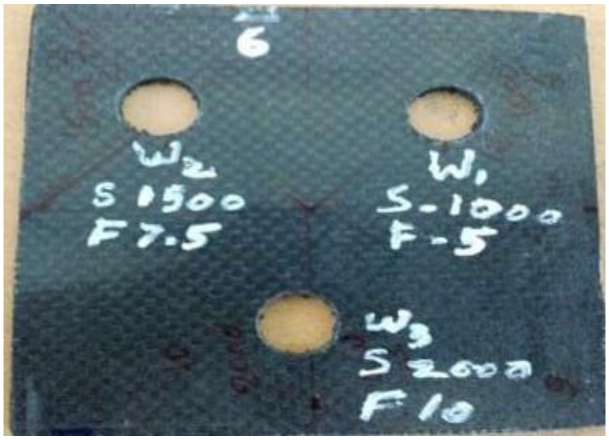


Fig.7. 6 layers, thickness 2.0

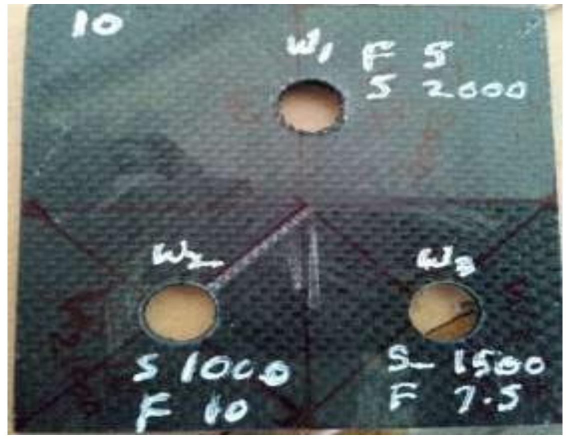


Fig.8. 10 layers, thickness

By using CNC drilling machine, with the help of the G-codes and M-codes drilling program was given as input to the machine, with the help of that program the drilling of CFRP is done by changing the different speed, feed, axis and also Nano coated and un-coated drill bit. While drilling the CFRP more vibrations are occurred with the un-coated drill bit and less vibration are occurred with the Nano coated drill bit.

3. Results and Discussion

Taguchi Analysis: CYCLE TIME vs THICKNESS (M), SPEED(RPM)
Solution of ratio of signal-noise
Larger would be optimal
THICKNESS SPEED FEED Level (MM) (RPM) (MM/MIN) COATING

1	24.42	31.12	30.43	31.12
2	28.71	27.25	30.75	31.10
3	30.77	31.13	28.32	27.28
4	32.85			
5	34.45			
6	27.78			
Delta	**10.03**	**3.88**	**2.43**	**3.84**
Rank	**1**	**2**	**4**	**3**

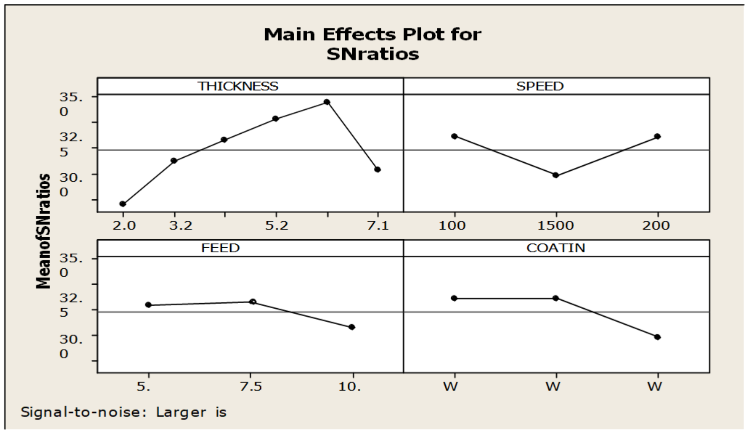


Figure.9. Graph mean of S/N Ration for entry hole

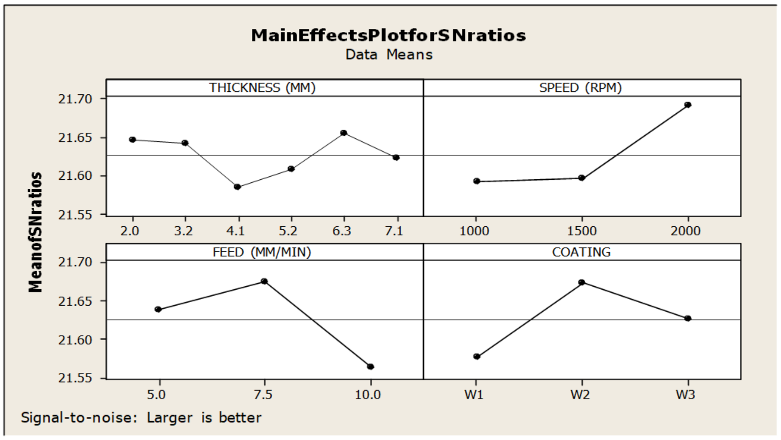
Taguchi Analysis

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

Solution to signal-noise

Larger would optimal

Level	THICKNESS (MM)	SPEED (RPM)	FEED (MM/MIN)	COATING
1	21.65	21.59	21.64	21.58
2	21.64	21.60	21.67	21.67
3	21.58	21.69	21.56	21.63
4	21.61			
5	21.65			
6	21.62			
Delta	**0.07**	**0.10**	**0.11**	**0.10**
Rank	**4**	**2**	**1**	**3**



Graph.10. Graph mean of S/N Ration for exist hole

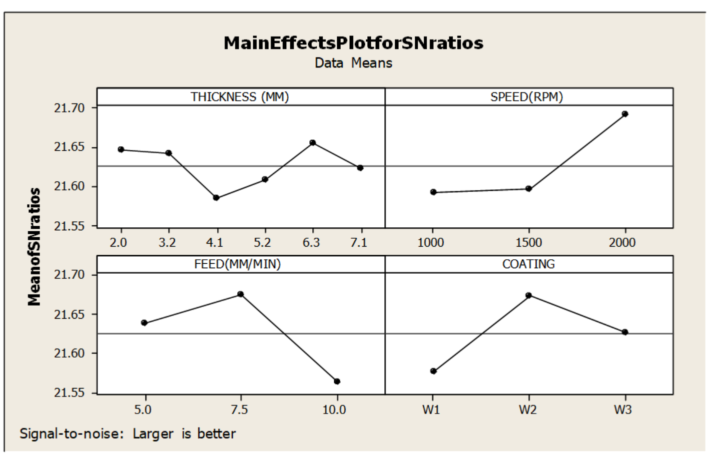
Taguchi Analysis

Solution table over signal-noise

Larger could be optimal

THICKNESS SPEEDFEED Level (MM) (RPM) (MM/MIN) COATING

1	21.67	21.57	21.58	21.56
2	21.61	21.59	21.65	21.60
3	21.58	21.63	21.56	21.63
4	21.56			
5	21.56			
6	21.61			
Delta	**0.11**	**0.06**	**0.09**	**0.07**
Rank	**1**	**4**	**2**	**3**



Graph.11. Graph mean of S/N Ration for cycle time

From the results obtained from the taguchi graphs, the entry and the exit hole after drilled the work piece is same with the double layer Nano coated drill bit and hole surface quality is also better, whereas un-coated and single Nano coated drill bit the entry and exit hole is same with the less thickness and varies when thickness of the CFRP sheet increases and vibrations also more while drilling the CFRP sheet. Whereas less vibrations are occurred while drilling the CFRP sheet with the double layer Nano coated drill bit.

4. Conclusions

In this modern era of technology where compactness, less weight, easy workability and economic is main factor. Composite material is widely accepted in the era of technology like- marine, automobile, civil work and aerospace technology. CFRP composite material is widely used for structural and non- structural and recyclability of the composite is very easy. High performance becomes the main key of thecomposite.
In single coating drill bit entry hole is much better according to size of the drill bit compare to uncoated and double coated.
In double coating drill bit exit hole is much better according to size of the drill bit and Vibrations are less compared to single and uncoated drillbit.
Hole quality is improved when drill bit is double coated with TIALN.

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