Development of a New Drilling Tool for Drilling Hybrid Composites

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Abstract : Production of quality holes, with minimum damage by drilling of hybrid composites is one of the challenging task, as composites are highly abrasive, causing a high rate of tool wear. With the advent of technology in material science, hybrid composites have occupied a major part in engineering structures due to their high stiffness to weight ratio. This paper discusses the influence of drilling tool geometry on hole geometry in hybrid composites. A new tool design is proposed for improved hole quality. The obtained results are compared with the holes drilled with a conventional twist drill. Microstructural analysis performed indicates the type of failures in drilled holes.

Keywords – Tool Design, Hybrid composites, Hole geometry, Micro structural Analysis

I. INTRODUCTION

Fiber reinforced composites are certainly one of the oldest and most widely used composite materials. Their study and development is largely carried out due to their potential in structural applications. The concept and technology of Fiber Reinforced Plastics (FRP) composites have undergone a sea change with better understanding of the bonding mechanism between the matrix and fiber reinforcement, fiber orientation, fiber reinforcement size and distribution, morphological features, etc. FRP composites have steadily gained applications in the fields ranging from aerospace to sports equipments. This appeal is primarily due to their high strength-to-weight ratio, tailorable mechanical properties and fatigue resistance. Carbon fiber composites are becoming widely adopted in the transportation, sporting goods and wind energy sectors [1, 2]. This is because “carbon-fiber composites weigh about one-fifth as much as steel, but can be comparable or better in terms of stiffness and strength, depending on fiber grade and orientation [3-5]. ”In addition, carbon fiber show good creep resistance and good compatibility with epoxy matrix. The main drawbacks of carbon fiber composites for industrial use are rather susceptible to stress concentration and impact damage due to the brittleness of carbon fiber [4]. The other major factor that is prohibiting the use of carbon fiber in common use is the high price [5-7].

To overcome both of these problems and to make carbon fiber more adaptable, hybridization is done. In the process a more ductile and low priced fiber is introduced in certain proportions to improve the mechanical properties [8-10]. Hybrid composites normally contain a high modulus, high strength and costly fiber such as graphite or carbon fiber. The second fiber is usually a low modulus fiber and cheap fiber like Kevlar, Glass or Basalt fibers. The intrinsic mechanical properties of the different reinforcement material gives rise to unique structural materials in terms of toughness and strength. Glass fiber may also be a good candidate for the preparation of hybrid composites of this type. It has good toughness properties, low price and relatively good interfacial adhesion to the matrix [11]. Many researchers have analytically and experimentally investigated [7-12] the mechanical properties of FRP composites and others used finite element analysis [13-17] to predict the behavior of FRP and their mechanical properties. Micro-mechanical models developed to understand the behavior of fiber and particulate reinforced polymeric composites was used to simulate stress distribution and maximum stress concentrations locations [18, 19]. Finite element models could predict the interfacial tensile and shear stress with perfect bonding between fiber and matrix is available in literature [20, 21]. However a few efforts were made to relate the experimental results of mechanical properties of Hybrid composites with the FE analysis and theoretical results while considering the isotropic behavior of composites. The main advantage of using finite element analysis is to generate the quantitative data about the failure morphology of the composites and to understand the deviation of the predicted data with the experimental results. When composites parts are subjected to drilling operations, the defects that are likely to appear differ from metallic parts, making evaluation of hole quality more difficult. Besides process related problems in composites fabrication, drilling can cause several defects like, delamination, intralaminar cracks, fibre pull out and thermal damage. These problems can affect the mechanical properties of the produced parts, hence, lower reliability. Some of these defects are not visible in a visual inspection, and so the trend is very cautious when using FRPs in critical parts. This has caused a barrier to the widespread of composites usage in other applications, namely in primary structural components.

II. EXPERIMENTAL METHODS

A new tool is developed to drill holes using existing machines with minimum damage to the machined surface and to assess the Damage of Drilled Hybrid Composite laminates. Holes were drilled with optimum speed and feed using conventional twist drill and the newly designed drill bit. Point angle and Helix angle are changed to observe the influence of drill geometry on the hole geometry. The conventional twist drill specifications are 2 flutes, 30° Helix angle, 2 mm web thickness, 118° point angle. The design specifications of the newly designed tool are Solid carbide Twist drill with 2 flutes, 30°helix angle, 2 mm web thickness, 120° and 90° double point angle. The twist drill and the newly designed tool are shown in figure 1 and 2 respectively.

Figure 1. Twist Drill

Figure 2. New design

The workpiece specimen is made as per the standards as shown in Figure 3. Drilling tests are conducted under different drilling conditions on FANUC CNC machining center on the standard samples with different drilling bits are shown in Figure 4 and 5. The Coordinate Measuring Machine (CMM), model GX600 was used to measure the roundness and cylindricity of the drilled holes as depicted in Fig. 6(d). The surface finish tester, Surtronic 3+ model was used to measure the surface finish. The experimental plan, speed, feed, drilling conditions, hole geometry and the exerted force for the conventional tool and the newly designed tool are shown in Table 1 and 2 respectively. The delamination factor calculated for the different holes are shown in Table 3.

Figure 3. Workpiece

Figure 4. Drilling with Twist Drill

Figure 5. Drilling with new Tool

The microstructural analysis performed on the holes are shown in Figure 6 to 9.

Table.1 Conventional Tool: Experimental Plan and Hole geometry

Standard Trial order	Plan of experiments		Speed (rpm)	Feed (mm/rev)	Cylindricity	Roundnes	Thrust Force (Kgf)	Surface Finish (µm)	Average F_d F_d at entrance	Average F_d at exit
1	1	1	640	0.08	0.0068	0.0044	21	5.11	1.00165	1.00211
2	1	2	640	0.13	0.0080	0.0055	31	3.35	1.00425	1.00285
3	1	3	640	0.20	0.2061	0.0065	51	8.01	1.00248	1.00216
4	2	1	1120	0.08	0.0096	0.0071	19	2.54	1.000762	1.00201
5	2	2	1120	0.13	0.0067	0.0017	35	6.61	1.0024	1.00208
6	2	3	1120	0.20	0.0139	0.0047	45	4.93	1.00273	1.00286
7	3	1	1760	0.08	0.0051	0.0075	17	12.64	1.00341	1.0029
8	3	2	1760	0.13	0.0073	0.0065	22	7.15	1.00057	1.00226
9	3	3	1760	0.20	0.0063	0.0021	25	5.64	1.00243	1.00308

Table.2 Newly designed Tool: Experimental Plan and Hole geometry

Standard Trial order	Plan of experiments		Speed (rpm)	Feed (mm/rev)	Cylindricity	Roundness	Thrust Force (Kgf)	Surface Finish (µm)	Average F_d at entrance	Average F_d at exit
1	1	1	640	0.08	0.0270	0.0103	11	5.83	1.00151	1.00203
2	1	2	640	0.13	0.0289	0.0070	16	5.40	1.00252	1.00283
3	1	3	640	0.20	0.0334	0.0000	25	8.56	1.0024	1.002112
4	2	1	1120	0.08	0.0457	0.0000	09	11.34	1.000125	1.00193
5	2	2	1120	0.13	0.0218	0.0032	12	11.08	1.00223	1.00202
6	2	3	1120	0.20	0.0254	0.0050	18	10.26	1.00261	1.0028
7	3	1	1760	0.08	0.0473	0.0009	08	9.75	1.00326	1.00283
8	3	2	1760	0.13	0.0112	0.0030	12	8.27	1.00048	1.00221
9	3	3	1760	0.20	0.0070	0.0066	11	1.79	1.00238	1.00303

Table .3 Delamination factor

	Twist drill			New Designed Tool		
Feed rate [mm/rev]	0.08	0.13	0.20	0.08	0.13	0.20
Speed [rpm]	640	1120	1760	640	1120	1760
Delamination factor [F_d]	1.0060	1.0072	1.0052	1.0043	1.0020	1.0034

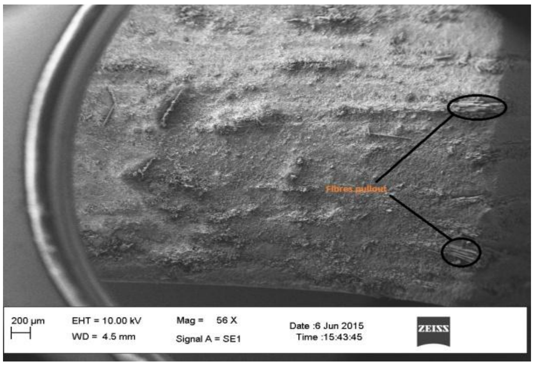

Figure 6. Fibre Pull Out

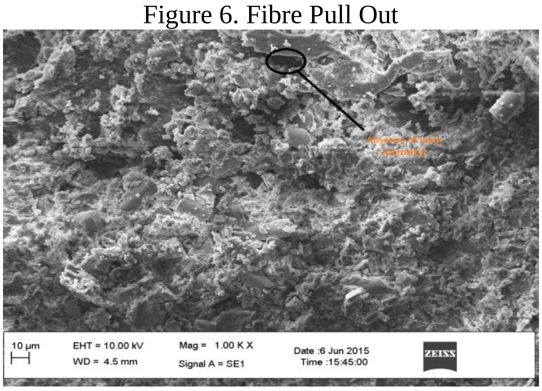

Figure 7. Porosity

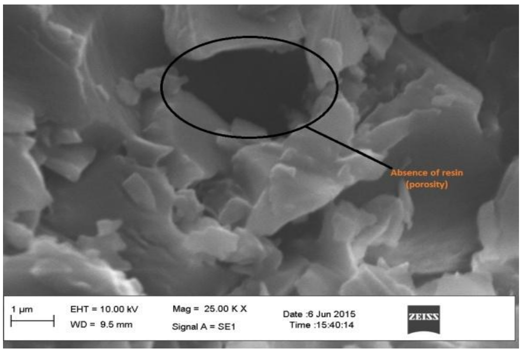

Figure 8. Absence of Resin

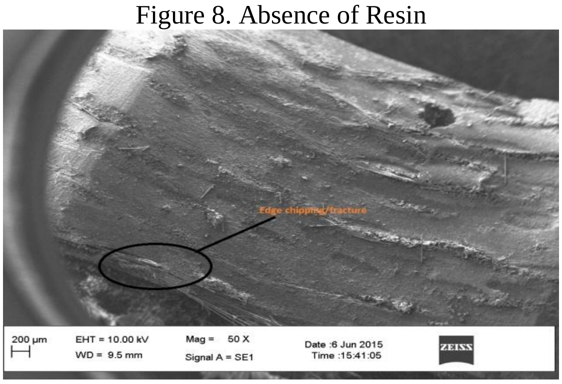

Figure 9. Edge Chipping Fracture

III. CONCLUSIONS

- From the results, it is clear that the new drill bit presents a better performance than the conventional drill bit under the same conditions (i.e., spindle speed and feed rate).
- The surface roughness obtained by new tool is less than obtained by conventional drill bit.
- Delamination can be reduced if proper cutting parameters are selected.
- Considering the parameters used in this work, a speed of 1120 rpm with a feed rate of 0.13 mm/rev produced better hole geometry.
- The drill geometry has an influence on the results used for evaluation: delamination around the hole.
- However, the results show that the newly designed tool require improvements in order to have good results regarding damage reduction.

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