To Investigate the Effects of Various Micro Drilling Process Parameters on Fibre Reinforced Polymer Composites

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Abstract- In aerospace applications such as automobile, aircraft and the manufacture of space ships and sea vessels, fibre reinforced polymer composites outperform other materials. They have excellent basic strength stiffness, excellent corrosion resistance, a light weight structure, low thermal conductivity, high strength, and chemical and microbiological resistance. The main goal of this research was to use the hand layup process to produce GFRP-Glass Fiber Reinforced Plastic (a composite material) using glass fibre, epoxy and hardener, which is one of the most cost-effective ways to make fiber-based composites. Micro drill bits of Carbide and H.S.S. material with different diameters of 0.5 mm, 0.8 mm, and 1 mm were used to machine the GFRP composite using a CNC vertical machining centre and micro drill bits of Carbide and H.S.S. material. In the current experiment, drilling parameters such as feed and spindle rpm were varied. The values are tabulated and a graph is created after all of the information is gathered.

Keywords- Micro Drilling, Fibre Reinforced Polymer, GFRP-Glass Fiber Reinforced Plastic, Carbide material and H.S.S. material;

1. INTRODUCTION

A composite material is one that is made up of two or more component materials. It is also known as a composition material or composite. These constituent materials have significantly different chemical or physical properties, and when combined, they form a material with properties not present in any of the individual elements[1]. Separating composites from mixtures and solid solutions, individual parts remain separate and distinct in the finished structure. Masonry and reinforced concrete Engineered composite materials include composite wood, such as plywood, ceramic matrix composites (composite ceramic and metal matrices), metal matrix composites, and other advanced composite materials[2].

FRP (Fibre Reinforced Polymer) is a type of polymer that is made up of fibres (FRP) A polymer that has been reinforced with fibres is referred to as a composite [3]. It's a kind of material that belongs to the composite materials category. Composite materials are produced by dispersing particles of one or more materials in a continuous network formed by another. For a variety of purposes, new content can be selected. Materials that are less expensive, lighter or stronger than common materials are common examples[4].Robotic Materials are composites that systematically combine sensing, actuation, computation, and communication[5]. Composite materials are used in houses, bridges and structures for boat hulls, swimming pool panels, race car bodies, shower stalls, bathtubs, storage tanks, and imitation granite and cultured marble sinks and countertops, to name a few[6].The most sophisticated examples are regularly used in extreme environments on satellites and aircraft[7]. FRP (fibre-reinforced plastic) is a composite material made up of a polymer matrix and fibres[8]. Fiber-reinforced polymer or fiber-reinforced plastic are other names for it [9]. The most popular fibres are glass (in fibreglass), carbon (in carbon fibre reinforced polymer), aramid or basalt. In rare occasions, other fibres such as paper, wood, or asbestos have been used[10]. Although phenol formaldehyde resins are still used, the thermosetting polymer is usually an epoxy, vinyl ester or polyester. FRPs are used in the aerospace, automobile, marine and construction sectors. They are commonly used in ballistic armour and cylinders for self-contained breathing apparatuses. FRP composites are not the same as traditional construction materials like steel and aluminium. FRP composites are anisotropic, while steel and aluminium are isotropic[11]. As a consequence, their properties are spatial, with the best mechanical properties along the fibre placement path. These materials have an excellent strength-to-density ratio, excellent corrosion resistance, and useful electrical, magnetic, and thermal properties[12].They are, however, brittle, and their mechanical properties are affected by the rate of loading, temperature, and environmental conditions. The primary function of fibre reinforcement is to carry load along the length of the fibre while also providing strength and stiffness in one direction[13]. It replaces metallic materials in many structural applications where load-carrying capacity is crucial[14]. Engineers can achieve significant improvements in the functionality, safety and economy of construction by using FRP in engineering applications due to their mechanical properties[15].

2. LITERATURE REVIEW

C.C. Tsao, H. Hochengstudied evaluation of thrust force and surface roughness in drilling composite material using Taguchi analysis and neural network[16].This study proposed an experimental approach to evaluating the thrust force and surface roughness provided by candle stick drills using regression analysis of experiments and RBFN[6]. The authors discovered that the feed rate and drill diameter are the most important factors affecting thrust power, while the feed rate and spindle speed are the most important factors affecting surface roughness[6]. For the evaluation of drilling-induced thrust force and surface roughness in composite material drilling, RBFN has been shown to be more successful than multi-variable regression analysis in confirmation tests[13].Robert Voss & Marcel Henerichs1 & David Harsch& Friedrich Kuster &Konrad Wegener [14] proposed geometry parameters $A\alpha,w$, $A\gamma,w$, $l\alpha$, $l\gamma$, rpeak, rsg, rideal in the Cutting Edge Analyser (CEA) approach prove the applicability in an experimental drilling study under consideration of the physics of cutting (feed and velocity direction). Based on the extensive measurement data it is found that the shape of the cutting edge, described by $l\gamma$, rpeak, rsg is more important for the machining quality, than the amount of wear described by the areas $A\alpha,w$ and $A\gamma,w$[12]. The three characteristic values $l\gamma$, rpeak and rsg with a large significance on the machining results are combined to a comprehensive cutting edge quality criterion Qcrit. Drilling experiments with the related analyses of cutting edge micro-geometry show a good correlation between the proposed cutting edge quality criterion Qcrit and the machining quality Qd.ShujiUsui, Jon Wadell and Troy Marusichstudied damage as well as damage mechanisms in the machining process using FEM[17]. In the UD-CFRP orthogonal cutting, the proposed finite element model, which assumes the cutting energy is the sum of the surface energy and friction loss, captured various failure modes and damage types and accurately predicted the torque and thrust power[13]. The damage on the machined surfaces was predicted by the proposed FEM method and compare well with experiment results[11]. Future work entails the extension of this method to CFRP milling and other processes. Keiji Ogawa, Heisaburo Nakagawa, Toshiki Hirogaki & Eiichi Aoyama studied the effects of diamond coated tools in micro-drilling of CFRP plates using a high-speed spindle suggested novel method to improve tool life for micro-drilling CFRP was proposed and the effects were demonstrated by some experiments[15]. The tool life of a newly developed diamond-coated tool for micro-drilling CFRP was assessed[18]. The diamond-coated tool had a tool life of around three times that of a standard non-coated tool. In his analysis paper, K.M. John and S. Thirumalai Kumaran discovered that backup support is one of the most powerful strategies for suppressing exit burr, delamination and workpiece deflection [19].

The following conclusions were reached as a result of the thorough investigation:

- Even at higher critical thrust force and feed rate, a low level of active backup force is found to be adequate for delamination and burr-free machined material.
- Drilling with a passive backup support plate that has twice the workpiece's Young's modulus is found to increase machining efficiency as compared to other support materials.
- As compared to single material, there were fewer defects in multi-layer stack drilling, but burrs were found in unorthodox machining, including with stack support plates.
- The fabrication of a backing layer reduces burr and delamination due to matrix bonding between layers.

3. DRILLING OF HOLES IN RECTANGULAR PLATES OF GFRP

A vertical milling machining machine was used to drill the GFRP composite plate. Experiments with various spindle speeds, bit diameters, and feed rates were conducted[20]. In this analysis, carbide drill bits and H.S.S drill bits were used. Delamination factor was discovered to be affected by feed rate and spindle speed. The GFRP plated with dimensions of 233 x 28 x 5 mm is shown in Figure 4. The vertical milling machine with drill bit is shown in Figure 5. The results of the experiments are summarized in Tables 1-3. A Brinell microscope is used to calculate the delamination factor of a drilled hole.

Fig. 1. Glass Fibre Reinforced Polymer Plate

Fig. 2. Vertical Machining centre with tool

Fig. 3. Vertical Machining centre

Sr. No.	Material	Density (Kg/m^3)	Tensile Strength (MPa)	Modulus of Elasticity (MPa)
1	Glass Fibre	2550	2200	82
2	Epoxy	1180	55	3.8

Table 1. Properties of GFRP and Epoxy

Small drills, as well as a process for precise micro drill rotation and a unique drilling period, distinguish micro drilling. A micro drilled hole's walls are also among the smoothest surfaces created by conventional methods. This is due in large part to the peck period, a special drilling interval. The tiniest micro drills are spade micro drills. Chip removal from the hole is more difficult because the drills do not have helical flutes like conventional drills. Drills with a diameter of 50 micrometres or more may be fitted with twist drills. All drills smaller than this size are spade drills due to the complexity of fabricating a twist drill of this size. Spade-style micro drills have a number of distinct geometric features. For starters, the drill's point isn't even a point. Even regular twist drills do not have a fully targeted end. Instead, a cutting edge (dubbed the chisel edge) is created by two intersecting planes that also describe the drill's two primary cutting edges on the micro drill's end. Material is collected primarily by extrusion and cutting with a chisel tip at a high negative rake angle. The actual cutting energy along the chisel edge is relatively high as compared to the drill's main cutting edges. The lack of a point on the chisel edge makes drilling more difficult.

Sr. No	Spindle Speed(RPM)	Feed rate(mm/min)	Drill diameter(mm)	Delamination-factor
1	300	10	0.5	1.0003
2	300	10	0.8	1.0006
3	300	10	1	1.0008
4	300	20	0.5	1.0004
5	300	20	0.8	1.0006
6	300	20	1	1.0007
7	600	10	0.5	1.0005
8	600	10	0.8	1.0007
9	600	10	1	1.0009
10	600	20	0.5	1.0006
11	600	20	0.8	1.0007
12	600	20	1	1.0009
13	900	10	0.5	1.0004
14	900	10	0.8	1.0005
15	900	10	1	1.0008
16	900	20	0.5	1.0002
17	900	20	0.8	1.0007
18	900	20	1	1.0004

Table 2. Drilling of FRP laminate using HSS drill bit

Sr. No	Spindle Speed(RPM)	Feed rate(mm/min)	Drill diameter(mm)	Delamination-factor
1	300	10	0.5	1.0002
2	300	10	0.8	1.0005
3	300	10	1	1.0006
4	300	20	0.5	1.0003
5	300	20	0.8	1.0005
6	300	20	1	1.0008
7	600	10	0.5	1.0004
8	600	10	0.8	1.0005
9	600	10	1	1.0008
10	600	20	0.5	1.0004
11	600	20	0.8	1.0006
12	600	20	1	1.0008
13	900	10	0.5	1.0003
14	900	10	0.8	1.0004
15	900	10	1	1.0007
16	900	20	0.5	1.0001
17	900	20	0.8	1.0005
18	900	20	1	1.0003

Table 3. Drilling of FRP laminate using carbide drill bit

4. Results and discussions

FRP composites are now used in a number of applications. In this experiment, carbide drill bits and H.S.S. drill bits were used to drill FRP composites. Spindle speed, drill bit diameter, and feed rate were used as input parameters in the drilling process, and the delamination factor was used as an output response. The delamination factor improved as the feed rate and spindle speed increased, as seen in the tables. This was due to the fact that the cross-sectional area of the undeformed chips was greater. Drilled holes in GFRP sheets drilled with a carbide tool outperformed holes drilled with an HSS tool. Strong hole quality can be achieved by using a higher spindle speed and a slower feed rate. Drilled holes of 0.5 mm, 0.8 mm, and 1 mm in GFRP sheets made with a carbide tool (D.F 1.0001, 1.0004, and 1.0003 respectively) are clearly superior to holes of 0.5 mm, 0.8 mm, and 1 mm made with an HSS tool (D.F 1.0002, 1.0005 and 1.004 respectively). A good hole efficiency can be achieved with a higher spindle speed and a lower feed rate. When drilling GFRP composites, the Carbide or HSS drill bit can encounter two different materials: E Glass fibre (which is hard and brittle) and hardened Epoxy polymer matrix (which is soft and ductile). This is an out-of-the-ordinary case. An encounter is bound to impact the composite, unlike a uniform isotropic material like steel. As a result, drilling parameters like spindle speed, feed rate, and drill bit material must be carefully selected for optimum drilling with minimal injury.

5. Conclusion

In addition, composites are commonly used in a range of engineering fields. GFRP composites are gradually replacing traditional fabrics. Cutting speed and feed rate were discovered to be two important factors that influence drilled hole efficiency in GFRP composites. By selecting acceptable values for these parameters, the accuracy of holes can be improved. To achieve the least amount of delamination, the drilling machine's feed rate and cutting speed should be controlled. The wider the hole diameter, the lower the chance of delamination.

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