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An investigation of Drilling characteristics of Carbon-Carbon composites by Acoustic emission process

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ABSTRACT

Titanium coated tungsten carbide (Ti-WC) drill bit was used for drilling on the carbon-carbon composites laminates. The drilling speed was varied between 1000 to 3000 rpm with different feed rate of the drill. With respect to the time, the thrust force exerted on the laminates and the torque induced were assessed through acoustic emission process. The delamination factor (Fd) has been determined from the top surface of the drill holes through scanning electron microscope (SEM) images. The results obtained from the test specimen depending on the variation of the feed rate and the speed of the drill were discussed in detail.

Keywords

Titanium coated tungsten carbide (Ti-WC), carbon-carbon composites, acoustic emission process, delamination factor, scanning electron microscope (SEM), torque

Academic Discipline And Sub-Disciplines

Mechanical Engineering, Chemical Engineering, Manufacturing Engineering

SUBJECT CLASSIFICATION

Manufacturing, Composites, Drilling, Delamination

TYPE (METHOD/APPROACH)

Acoustic emission process, microstructure analysis

1. INTRODUCTION

Carbon-carbon composites or simply called as C-C composites finds numerous applications such as domestic appliances and industrial and automobile spares. These composite materials face critical problems during component fabrication such as cutting, drilling and shaping to desired sizes. Drilling is necessary to assemble different parts of the components which lead to damages during the process. Standard drill like brad drill or twist like drills were generally used to drill the carbon-carbon laminates. The drilling process needs to be controlled to avoid the delamination during drilling or else it can lead to the damage of the components. Hence the production of the components can be affected due to these lower reliability [1-3].

In industrial sector, reduction of wastage and fabrication of defect free components can increase the productivity and thereby it can increase the profit to the industrial sector. The usage of different drills can produce different thrust force on the component during drilling (machining) and that the delamination factor can be controlled. Radiography techniques were widely used in determining the delamination. Apart from this the feed rate of the drill can considerably change the delamination factor [4,5].

The reduced thrust can be adjusted by varying the geometry of the drill and thus the risk of delamination can be reduced. There were several studies reported on the need for drilling with reduced or nill delamination. Several drilling strategies were adopted to minimize the delamination risk. Several authors reported on the effect of drilling parameters such as drilling speed and the feed rate and cutting parameters on the composite materials. They were able to conclude about the need for higher feed rate which influences the thrust force. There were also reports on the variation in the drill geometry through feed rate and thrust force variation for making pilot hole strategy for delamination reduction. [6-8] The risk of delamination can be reduced by reducing the drill thrust force. The assessments were done by several authors and reported on its surface analysis through radiographic and electron microscopic analysis.

To monitor the drilling environment there were several types of systems reported in the literature in the recent past. One of the potential and practical method is the acoustic emission sensor method which is an intelligent and active indicator to monitor the status of the process. Acoustic emission (AE) signal generated during the process of drilling of laminates can be assessed for its delamination factor, friction mechanism and also for tool wear applications. The size of the holes during drilling at the entry point and at the exit point of the composites were used in the acoustic emission process and that it can also be used to monitor the weakening of the drill or the breakage of twisted drills can be determined. There were reports on the capabilities of this acoustic emission process for evaluation and detection of damage in the carbon composite laminates. Non destructive testing on the test specimens can be analyzed with the use of signals from the acoustic emission process and that the results can be correlated with the damage induced or the fracture mechanism on the surface of the drilled holes over carbon composites [9-12].

In the present work titanium coated tungsten carbide (Ti-WC) drills were used to assess the hole features on the carbon carbon composites. The tool material and the geometry play an important role in determining the delamination factor. Hence considering these basic facts, the drilling speed and the feed rate of the rods were varied to assess the thrust force exerted on the composite laminates. The combination of above two parameters was systematically changed and the delaminations induced in the composites were also assessed.

2. EXPERIMENTAL PROCEDURE

2.1. Work piece

The experimental work was carried out on carbon carbon composites. As procured samples of dimensions 300 mm x 300 mm x 4 mm were cut into rectangular laminates of sizes 100 mm x 55 mm x 4 mm were used for investigating drilling characteristics by the use of titanium coated tungsten carbide (Ti-WC) drill bits.

2.2. Offline measurements

1. Sample drilling done using titanium coated tungsten carbide (Ti-WC) tool bit
2. Feed rate
3. RPM

Input variables adopted in the present investigation is listed in Table 1 and the layout of the experiment is depicted in Figure 1.

Table 1. Drilling speed and feed rate adopted in the present investigation

Independent variables	1st Level	2nd Level	3rd Level
Drilling speed (rpm)	1000	2000	3000
Feed rate (mm/min)	10	20	30

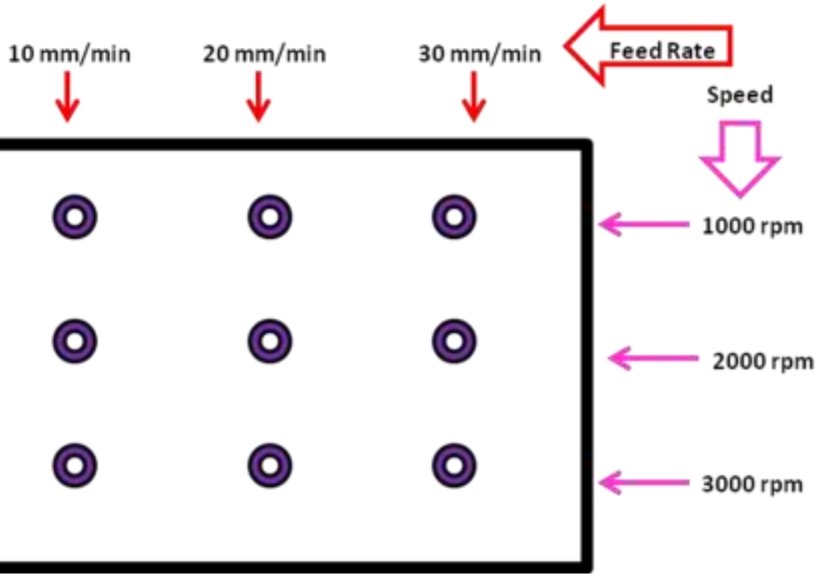

Fig 1: Test specimens and drilling parameters for Carbon-Carbon composites

2.3. Work piece

Acoustic emission (AE) uses a piezoelectric transducer based sensor with a frequency of 40 MHz was used in the present investigation. The optimum frequency was around 100 – 750 KHz with a resonance frequency of 513.28 KHz. A 2-4-6 AST pre-amplifier based signal detector was used which is having a gain sensor of 35 dB. The test was carried out in the frequency of 1 HMz with 16 bit of resolution and was observed in U-bend testing in which the two sensors were placed at a distance of 50 mm. The results of thrust force and torque were measured with respect to the time [13,14].

3. EXPERIMENTAL PROCEDURE

The drilling tests conducted uses titanium coated tungsten carbide drill in the dry atomospheric conditions to avoid foreign particles as contamination. The speed of the drill was varied between 1000 to 3000 rpm with simultaneous variation of the feed rate between 10 to 30 mm/min. The burr rotation and the feed rate induces a delamination factor (Fd) which is assessed from the experimental results. The plastic deformation is induced during drilling in the workpiece and hence while drilling a 6 mm hole, a back up plate can be used to avoid the higher breakage impact at the other end [15,16]. The variation of thrust force and torque with respect to the drilling time is shown in the below figure 2.

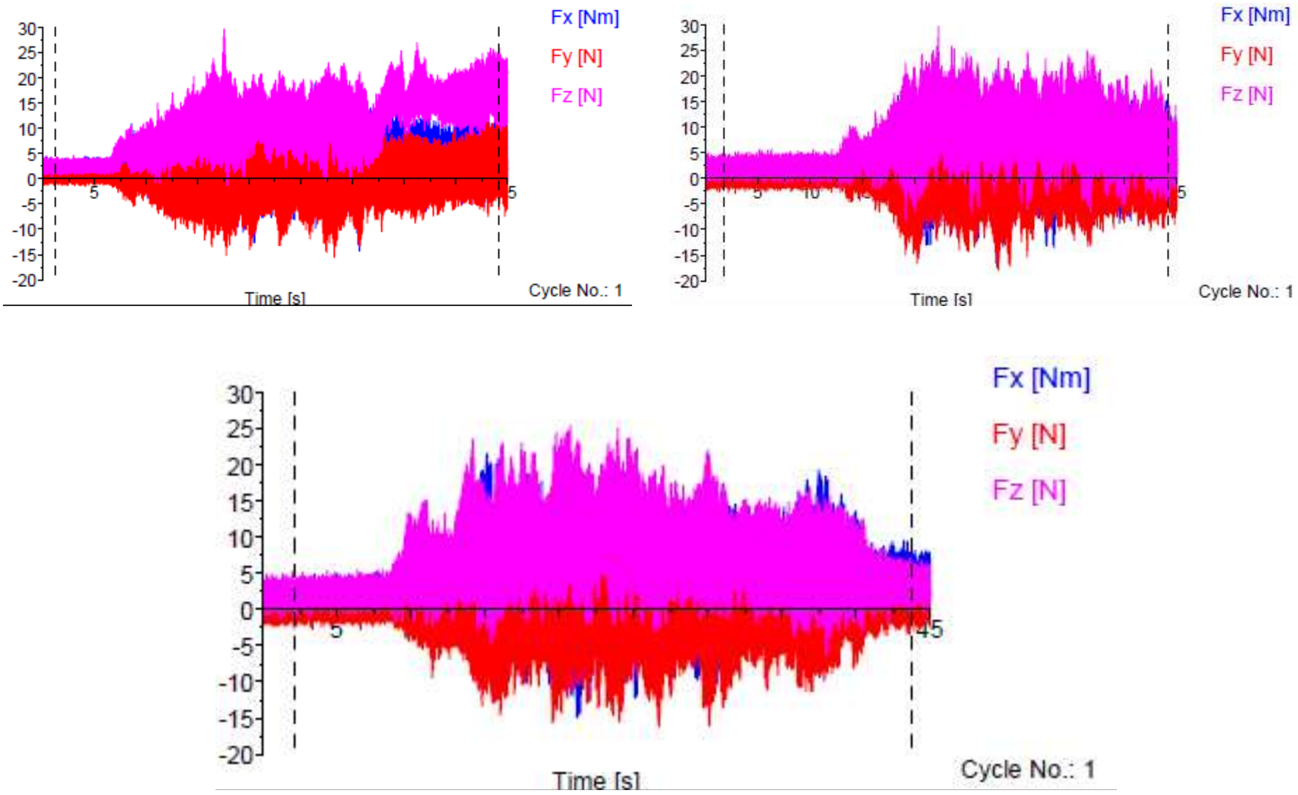

Fig 2: Torque and thrust force Vs time of drilling for (a) 1000 rpm (b) 2000 rpm and (c) 3000 rpm @ 10 mm/min

Figure 2(a) shows the thrust force and torque for a speed of 1000 rpm at a feed rate of 10 mm/min. The material offers the resistance during drilling and that this is reflected as the speed of the drill is increased to 2000 rpm which is shown in figure 2(b). Figure 2(c) represent the resultant thrust force due to the drilling speed of 3000 rpm. In all these measurements, the feed rate was maintained at 10 mm/min. The average thrust force was around 25 – 35 N, whereas the torque was found to be 30 – 35 Nm which is in comparable to that of the earlier reported values [17 – 20].

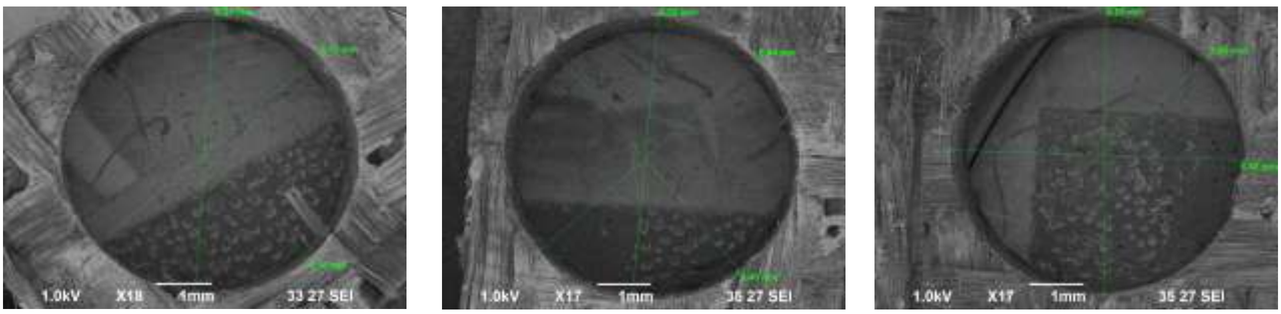

Fig 3: Microscopic picture of the composites for various drill speed of 1000, 2000 and 3000 rpm with constant feed rate of about 10 mm/min.

The hole edge damage is assessed by the extent of delamination factor (Fd or simply DF). The delamination damage occurs maximum at the entry point on the top surface of the holes. The calculations were also carried out using the same values. The scanning electron microscope (SEM) image was obtained on the top surface of the test specimen after drilling was carried out for various drill bit speeds of 1000, 2000 and 3000 rpm for a feed rate of 10 mm/min and it is shown in Figure 3. The delamination factor increases for the increase in speed from 1000 to 2000 rpm and then increases marginally when the speed is increased to 3000 rpm. For the drill speed of 3000 rpm and a feed rate of 10 mm/min, the test specimens of carbon-carbon composite laminates shows an increased delamination factor. Figure 4 shows the SEM image of the sample for the speed of 3000 rpm at a feed rate of 30 mm/min for which the maximum diameter of the delaminated hole and the nominal hole is represented by the scale markings. This kind of trend is followed for all the experimental conditions for the feed rate of 10 and 20 mm/min.

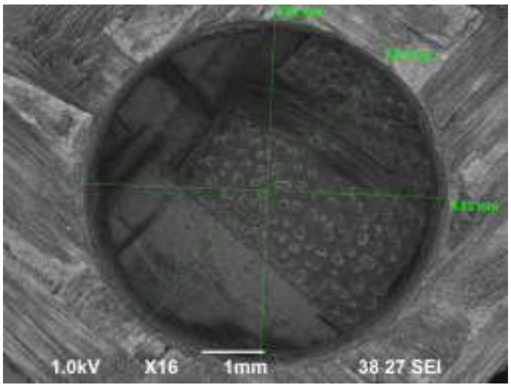

Fig 4: Microscopic picture on the surface of the carbon-carbon composites with a drill speed of 3000 rpm at the feed rate of 10 mm/min.

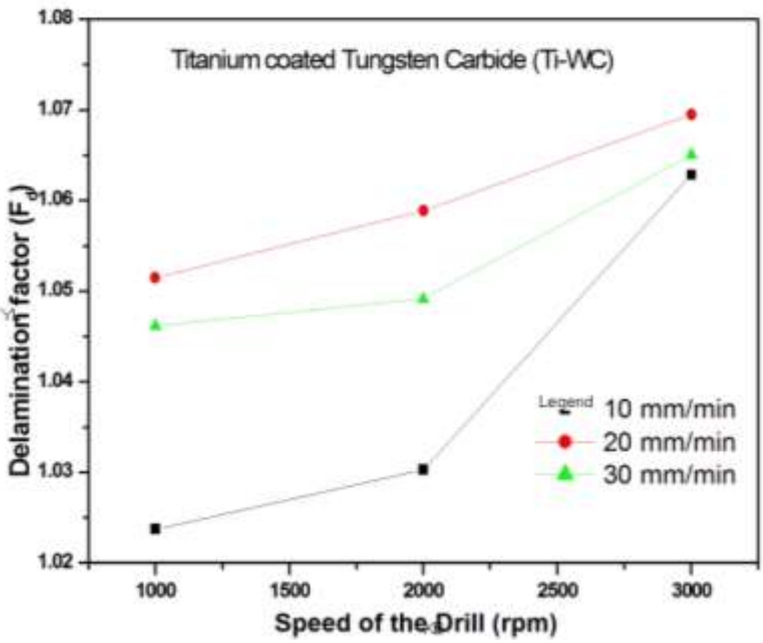

Fig 5: Delamination factor (F_d) for Ti-WC drill for various feed rate and drill speeds.

The variation of delamination for the measured is given in figure 5. It can be seen that for a speed rate of 1000 rpm and at 10 mm/min of feed rate the delamination factor remains minimum. Thereafter, the increase in delamination factor increases the error factor in the hole. For the feed rate of 20 mm/min and for all the drill speeds of 1000 to 3000 rpm the delamination factor (Fd) increases whereas, for the speed of 3000 rpm it is reduces marginally. This can be seen clearly from the SEM micrograph. Hence this can be considered as the optimized condition for handling the WC drill bit. Selection of drilling tool for the drilling conditions has to be optimized and that the thrust force exerted by the WC drill bit can be reduced and thereby the delamination factor can be considerably reduced by optimizing the tool geometry.

4. CONCLUSIONS

Samples of Carbon-Carbon composite matrix have been chosen for the present investigation. Acoustic emission (AE) characteristics were carried out on the test specimens and the obtained results were summarized as follows.

i. Carbon-Carbon composite rectangular laminates were used as test specimen for analyzing the drilling characteristics.

ii. Titanium coated tungsten carbide (Ti-WC) drill bit was used to drill the holes of 6 mm diameter on the test specimen by varying both the feed rate and the speed of the drill.

iii. The feed rate is varied in steps of 10 mm/min to 30 mm/min with the dril speed of 1000, 2000 and 3000 rpm.

iv. The time dependent factors were assessed through the measurement of torque and the thrust force on the rectangular laminates.

v. The delamination factor (Fd) is determined from the nature of the hole and the these preliminary results suggests that the delamination factor increase with increase in feed rate and drill speed.

vi. Optimimum value of delamination factor is obtained at the lower feed rate of 10 mm/min and at the drill speed of 1000 rpm.

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Author' biography with Photo

Mr.P.Saravana Kumar is an Assistant Professor in the Department of Mechanical Engineering, University College of Engineering Arni. He has put in 9 years of service in the teaching profession in various capacities. He is actively involved in research and currently he has been doing his Doctoral degree in Mechanical Engineering in Anna University Chennai in the field of "Manufacturing Engineering". The additional responsibilities held by him at his present position are NSS program officer, Deputy Warden, Cultural coordinator of UCEA. Besides, he has held various administrative and academic posts at University College of Engineering Arni. He has always been proactive in providing the best learning environment to the student community. Mr. P.Saravana kumar is one of the most distinguished and very active teacher in our College.

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