IJTRET
International Journal of Trendy Research in Engineering and Technology
Volume 5 Proceedings of FAME-2021
ISSN NO 2582-0958

Proceedings of 10th National Conference on Fascinating Advances in Mechanical Engineering
held at RMK college of Technology, Chennai on 5th April 2021

Determination of Delamination in Drilling Practice of GFRP Polyester Composites for Marine Structures

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ABSTRACT

Composite materials have been widely used in marine industries due to their superior mechanical properties. Drilling is a very common machining operation to install fasteners for assembly of laminates. The GRP composites in drilled holes to be affected by crack propagation and easily corroded the structures for spoil the entire composites. Delamination is a serious concern in the drilling of GFRP materials, suitable selection of drilling parameters is believed to mitigate damage. In this study focus on the effect of cutting parameters on drilling thrust force and torque during the machining process is analysed. The GFRP laminate is fabricated by hand layup process. In drilling have three different speeds, feed rates and by using two different cutting tools like HSS twist drill and multi facet drill. To decrease the damage factor of composite materials with different cutting tools, by varying drill parameters. To minimize the delamination factor of GRP composites mitigates the problem of fiber breakage, corrosion resistant for failure of hulls and related components.

Keywords: Glass Fibre reinforced plastic, HSS drill, multi facet drill, Delamination factor twist

I..INTRODUCTION

GFRP composite materials are acting an important role in growing engineering technologies for various applications. Glass Fibre Reinforced Plastics are light in weight with high strength, adequate stiffness with less brittleness and inexpensive. The main applications are in aerospace, marine and automobiles industries. Drilling process is very essential machining process for GFRP to make holes for assembly needs. The damage-free hole must need to maintain high strength and load carrying capacity in the assemblies. Delamination is one of the most important damages observed after drilling composite materials [1] and quality of hole is the effects of tool geometry and tool material [2, 3]. The two delamination mechanisms associated with drilling FRP are known as peel-up at drill entrance and push-up at the drill exit.

These holes surfaces are easily affected by delamination, fibre breakage and matrix cracking. Delamination lowers the strength of the hole and reduces durability of the components. Drilling fiber reinforced laminated composites requires special tools and techniques to control the delamination [4]. The degree of delamination defect is strongly dependent of the cutting parameters, especially feed rate during drilling of composite laminates [5].

Drilling of fibre reinforced plastics with conventional tools frequently results in defects like delamination, debonding, fibre pull-out, etc. Delamination belongs to the thrust force produces during drilling, when thrust force is reduced delamination also reduced. Trepanning tool is used to reduce the thrust force during drilling in FRP composites [6]. In FRP laminates surface analysis reveals the minimum peel up delamination at the low level of feed rate, at the high level of material thickness and medium level of cutting speed. Similarly, for the minimum push down delamination is observed at low level of feed rate, at high level of cutting speed and medium level of drill bit diameter and material thickness [7]. A comprehensive analyzed of delamination in various drills, the critical thrust force at the onset of delamination for various special drills is mathematically predicted and compared with the conventional twist drills [8].

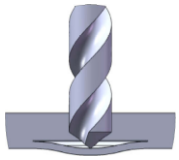

Fig.1. Delamination mechanism

Numerous research programs to be carried out for selection of drill bits diameters are 3 mm to 16 mm [9-26]. The present work is to minimize the delamination of drilling of GFRP composites when using 19 mm HSS twist drill and 19 mm multi facet drill. It has to analyze by microscope to measure the delamination.

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II. EXPERIMENTAL DETAILS

A. Work piece material

Glass fibers grade of 300 g/m^2 and woven roving grade of 600 g/m^2 were produced from Binani India products, Chennai. Polyester resin and hardener was obtained from Ciba Gugye Limited. This has a viscosity of 10 Poise at 250°C. The composites were developed by using hand layup technique.

B. Cutting tools

Two different types of drill bits with equal diameter of 19 mm, various shapes and geometries were utilised in this research in order to investigate and compare both types of tool wear as per objectives. These drills recommended for applications with wood, plywood, plastics materials and CFRPs.

C. Experimental setup and cutting conditions

All the drilling tests were carried out drilling capacity up to 40 mm, spindle speed in the range of 56-2800 rpm, spindle travel distance of up to 220 mm, vertical adjustment of spindle in the range of 0 to 178 mm, 525 × 400 mm table working surface and power of 6 kW. The tests were conducted at such constant cutting conditions as to avoid excessive thermal loads on the tool and work piece material. After performing some preliminary pilot-experiments on the laminates using two tools for this study, an optimal trade – off between the major results (delamination, etc.) was determined, and a set of suitable cutting conditions was chosen accordingly. It is here note worthy that the scope of this research is not to study the effect of process, tool and material – related parameters (drilling feed rates, cutting speeds, material type, tool designs, number of lips, etc) on the process loads and delamination results. Therefore, a cutting velocity of 16.71 m/min, 33.42 m/min, 42.38 m/min and a feed rate of 0.03 mm/rev, 0.05 mm/rev and 0.08 mm/rev were chosen for all the selected tools. No coolant was used during the drilling tests

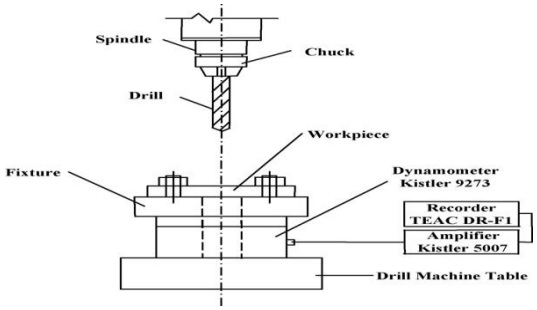

Fig.2. Schematic of the drilling setup

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TABLE.1. INPUT PARAMETERS OF DRILLING AND DRILL SPECIFICATION

Parameter	Level
Cutting speed	16.71 m/min, 33.42 m/min and 42.38 m/min
Feed rate	0.03 mm/rev, 0.05 mm/rev and 0.08 mm/rev.
Drill specification	(a) Diameter 19 mm HSS twist drill (b) Multi facet drill

D. Delamination measurement techniques

The delamination was mainly observed for Bi metal HSS hole saw cutter and Tungsten carbide tipped Hinge bit. Delamination was measured carefully using a modern 'Optical Mitotoyo Microscope, with 60x magnification. The workstation with built-in-camera and an integrated desktop PC, installed with commercial digital image processing software. Each reading was repeated three times and an average was calculated to ensure the precision and repeatability. This average value, then further, was compared as well with that taken using a conventional 'Mitotoyo Microscope' to ensure the reproducibility of the obtained results. The delamination factors are calculated by the following formulae. The figure given below shows the microscope to measure the delaminated diameter.

Formula of delamination factor (Fd)

$$Fd = \frac{Dmax}{Do}$$

Where, Dmax is maximum Delaminated diameter of the drilled hole D0 is drill diameter

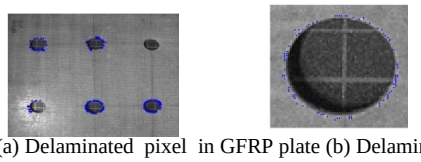

Figure. 3. (a) Delaminated pixel in GFRP plate (b) Delaminated pixel in close

III. EXPERIMENTAL RESULTS AND DISCUSSIONS

a. Drilling thrust and torque Thrust

The maximum values for the drilling thrust force and torque from the recorded data were chosen to represent the resulting mechanical loads. The twist drill showed a relatively higher thrust magnitude, compared to that of its counter parts. This is mainly due to its largest point angle. The slope of thrust progressions varies noticeably while moving from tools having greater point angles to those having smaller ones and vice versa. Drilling torque of a much smaller magnitude is observed due to the brittle matrix in the form of powdery chips. The higher drilling torque observed for twist drill, this particular type of tool may be due to its null angle of helix. The rising magnitudes of the drilling loads are indicative of the rising bluntness or wear of the tools. The multi facet drill removes the metal along the circumference of the cutting tool. Due to this the contact area between work piece and the tool is reduced. Hence the thrust force and torque produced in the work piece material is also reduced.

b. Hole entry and exit delamination

An interesting aspect regarding the observed very little relative difference in between the magnitudes of hole entry and exit delamination factors for most of the drill bits is also note worthy. For Hole saw cutter the thrust force increases with the increase in speed and feed rate during drilling process and it is very less than hinge bit. Torque also increases with the increase in speed and feed rate during drilling. But delamination factor at entrances and exit of drill decreases at high speed and low feed rate.

For the hinge bit, the thrust force decreases at high speed and low feed rate during drilling. Torque decreases at high speed and low feed rate during drilling. At low speed and low feed rate, the delamination factor at exit of drill decreases. But delamination factor at entrance of drill decreases at high speed and high feed rate.

c. Delamination measurement

The delamination factor at the tool entry and exit is measured by using Optical microscope. The delamination factor of hole entrance and exit of drill decreases in low feed rate is 0.03 mm/rev and high cutting speed 42.38 m/min from the selected cutting parameters.

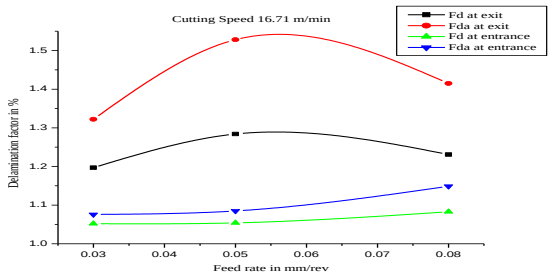

Fig.4. Delamination factors obtained by Hinge bit at cutting speed 16.71 m/min

For hinge bit, delamination factor at exit of drill decreases at low cutting speed and low feed rate also delamination factor at entrance of drill decreases at high cutting speed and high feed rate 0.08 mm/rev. Hinge bit gives better delamination rate at the entrance of drill as 1.049 in high spindle speed and low feed rate. Hole saw cutter gives better delamination rate at the exit of tool as 1.112 in high cutting speed and low feed rate. Hole saw cutter gives better performance than Hinge bit.

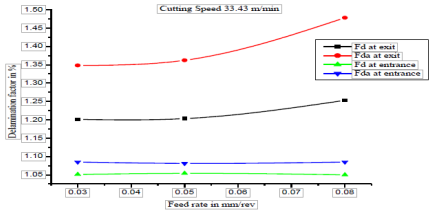

Fig.5 Delamination factors obtained by Hinge bit at cutting speed 33.43 m/min

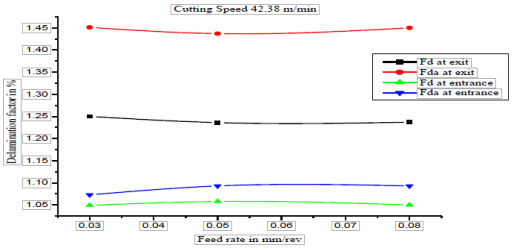

Fig.6 Delamination factors obtained by Hinge bit at cutting speed 42.38 m/min

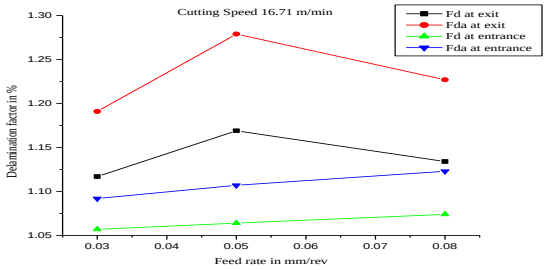

Fig.7 Delamination factors obtained by Hole saw cutter at cutting speed 16.71 m/min

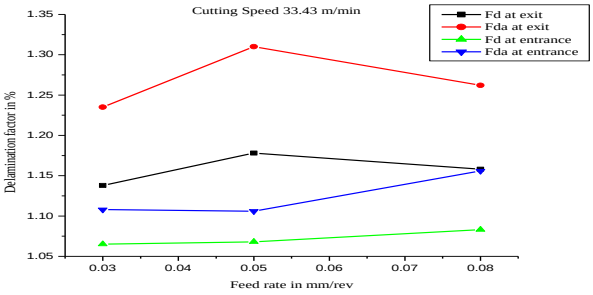

Fig.8 Delamination factors obtained by Hole saw cutter at cutting speed 33.43 m/min

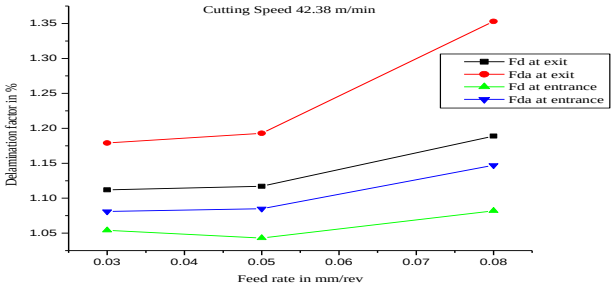

Fig.9 Delamination factors obtained by Hole saw cutter at cutting speed 42.38 m/min

IV. CONCLUSION

The study reveals the fact that the delamination factors of marine composite by using twist drill and multi facet drill for the application of marine vessels, was found that high feed rate affects the delamination rate.

The result was found that the better delamination in the multi facet drill is due the tool feature like raised lip. It makes fine surface at the entrance of the tool and the tools gives better hole geometry than normal drill bits. It is used for the application of marine craft for reduce the breakage of fiber failures and increases the life of the structures.

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