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Effect of Sea Water on Drilling Processes of Glass Fibre Reinforced Epoxy Composite Materials to Analysis of Delamination Factor and Thrust Force

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Abstract
Fiber reinforced polymer composites have gained substantial attention as engineering structural materials in automotive, marine and aircraft industry as well as in civil engineering applications. This is due to their outstanding mechanical properties, impact resistance, high durability and flexibility in design capabilities and light weight
The present work describes the development and mechanical characterization of new polymer composites consisting of glass fiber reinforcement, epoxy resin and filler materials such as TiO2 and ZnS. The newly developed composites are characterized for their mechanical properties.
The tests result have shown that higher the filler material volume percentage greater the strength for both TiO_2 and ZnS filled glass epoxy composites, ZnS filled composite show more sustaining values than TiO_2.
The present work also describes the machining (drilling) of GFRP composites with the help of Step drill of three sets, with three different speeds. The work has been carried out by immersion of GFRP composites in sea water for 8hrs, 16hrs and 24hrs duration and performed drilling operation. Results revealed that 8-4 mm step drill showed better machining characteristic than the other two 12-8mm and 10-6 mm step drills. GFRP composite, with ZnS filler material soaked in sea water for 16hrs duration had better machining capability. The ZnS Filled GFRP composites had better performance than TiO2 filled GFRP Composites.
Keywords:Drilling; Polymer-matrix composites; Thrust force; Delamination.

I. INTRODUCTION

Composites are one of the most advanced and adaptable engineering materials known to men. Progresses in the field of materials science and technology have given birth to these fascinating and wonderful materials. Composites are heterogeneous in nature, created by the assembly of two or more components with fillers or reinforcing fibers and acompactable matrix.

A composite material can provide superior and unique mechanical and physical properties because it combines the most desirable properties of its constituents while suppressing their least desirable properties. At present composite materials play a key role in aerospace industry, automobile industry and other engineering applications as they exhibit outstanding strength to weight and modulus to weight ratio. High performance rigid composites made from and space vehicle technology.

Drilling of these composite materials irrespective of the application area, can be considered as a critical operation owing to their tendency to delaminate when subjected to mechanical stresses. With regard to the quality of machined component, the principal drawbacks are related to surface delamination, fiber/resin pullout and inadequate surface smoothness of the hole wall. Among the defects caused by drilling, delamination appears to be the most critical [1]

Drilling is usually the final operationduring the assembly of the structures in these applications. Any defect that leads to the rejection of the parts represents an expensive loss. For example in the aircraft industry, drilling associated damage factor accounts 60% of all part rejections during final assembly of an aircraft. More over the variation of volume fraction of the fibers makes the drilling process more complex, as proper feed; speed should be given particular volume fraction to produce a good hole. The quality of the drilled hole such as waviness/roughness of its wall surface, axial straightness and roundness of the hole cross-section can cause high stresses on the rivet, leading to its failure. Stress concentration, damage factor and micro cracking associated with machined holes significantly reduce the composites. Several hole production processes, including conventional drilling, ultrasonic drilling, laser beam drilling, water jet drilling etc., have been proposed for a variety of economic and quality reasons. Conventional drilling is still the most widely used technique in industry today. A major concern that has received considerable attention in drilling the holes in FRCM is damage

Figure 1 shows that the factors such as cutting parameters and tool geometry/material must be carefully selected aiming to obtain best performance on the drilling operation, i.e., to obtain best hole quality, which represents minimal damage to the machined component and satisfactory machined surface.

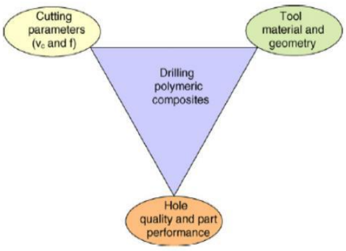


Figure:-1. Principal aspects to be considered when drilling fiber reinforced plastics.

II. Objective of the Work

It is observed that the addition of filler material will improve the strength and stiffness of composite and furthermore it is also noted that the environmental degradation under the sea water plays a greater role on the performance of the composite. In the view of this, the following objective has been set for present study.

- The basic aim of the present work is to develop and characterize new classic composite having different volume fraction of E- glass Fiber with epoxy resin, and filler materials such asTiO2 or ZnS.
- Experimental setup has to be developed for incorporating various sensors to capture online data such as thrust force while machining-drilling.
- To study the behavior for marine application of filled GFRP composites against drilling with seawater treatment.

III. Specimen Preparation

The method that is used in the present work for manufacturing the laminated composite plates is hand lay-up as shown in Figure.2 which is the oldest method that was used to get the composite materials. The type of Glass Fiber mat selected to make specimens was, Mat–330GSM. The matrix material used was a medium viscosity epoxy resin (LAPOX L-12) and a room temperature curing polyamine hardener (K-6), both manufactured by ATUL India Ltd, Gujarat, India. This matrix was chosen since it provides good resistance to alkalis and has good adhesive properties. Based on volume fraction the calculations were made for 60-40 (60% Glass Fiber – 40% Epoxy Resin) combination showed a better result. Two filler materials TiO_2 and ZnS were added to Mat 60-40 combination by keeping Epoxy percentage constant (40%). Based on literature survey the amount of filler added was 1, 2, & 3 % of Tio_2 and 1, 2, & 3% of ZnS, the details are as shown in Table 1&2. After preparation of the specimen the specimens were tested in tensile test, three point bending test, impact test to obtain the strength of materials.

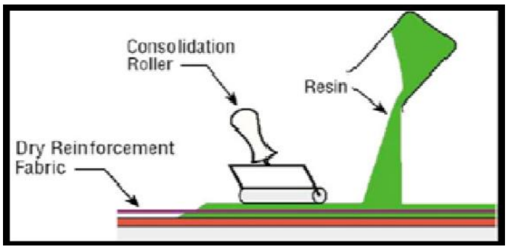


Figure:-2.*Hand lay-up Technique*

Table 1.*Filler Material Specimen Detail*

Mat -330GSM				
Sl. No	*Glass fibre content %*	*Epoxy*	*Filler content in %*	
			TiO_2	*ZnS*
01	*60*	*40*	*--*	*--*
02	*59*	*40*	*1*	*1*
03	*58*	*40*	*2*	*2*
04	*57*	*40*	*3*	*3*

Table 2.*Test specimen detail*

Test specimens	*ASTM*	*Size*
Tensile test specimens	*D-3039*	*250x25x4 mm.*
Impact Test Specimens	*D-256*	*55x10x10 mm.*
Bending test specimens	*D-790*	*110x25x6 mm.*

IV. Experimental Setup

The high speed steel twist drill has an 118^0 point angle. Three diameters (step drill) 12/8mm, 10/6mm and 8/4mm were selected to work on radial drilling machine which has a maximum spindle speed of 2650 rpm. There details are shown in Table 3. A piezoelectric dynamometer was used to acquire the thrust force as shown in Figure 3. The damage around the holes was measured using a tool maker's microscope

Table 3. Drill tool diameter and corresponding speed

Tool twist drill diameter mm (step drill)	*Cutting speed (rpm)*
12/8	*625*
	1256
	2560
10/6	*625*
	1256
	2560
8/4	*625*
	1256
	2560

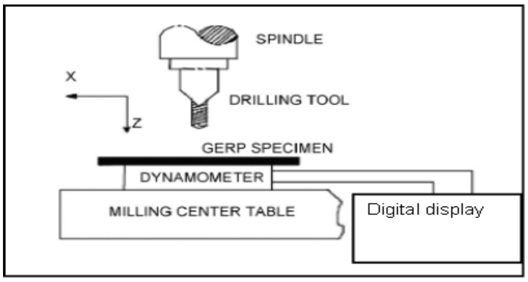


Figure:-3.Schematic diagram of experimental set-up

V. RESULTS AND DISCUSSIONS

Thrust force

Cutting forces are very useful for drill-wear monitoring, because these forces generally increase with tool wear. Thus, within the tool wear region, cutting forces provide good assessment of the tool condition. If the tool cannot withstand the increased cutting forces, catastrophic tool failure becomes inevitable. Consequently, tool life, which is a direct function of tool wear, is best determined by monitoring thrust force. Due to the thrust developed during drilling, many common problems exist. Some of the problem causes in drilling are fiber breakage, matrix cracking, fiber/matrix debonding, fiber pull-out, fuzzing, thermal degradation, spalling and delamination. The thrust force and torque developed in drilling operation is an important concern. Monitoring of thrust force in drilling is needed for the industry.

In Figure 4 a qualitative trend of thrust force as a function of the drilling is shown. As can be seen, a pushing action is exerted by the drill on the work piece.

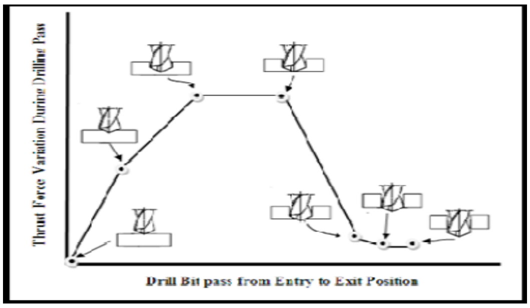
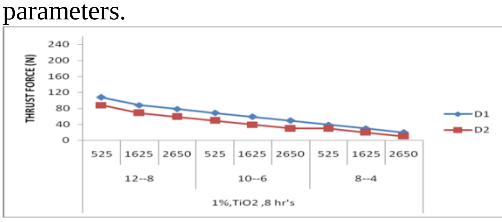
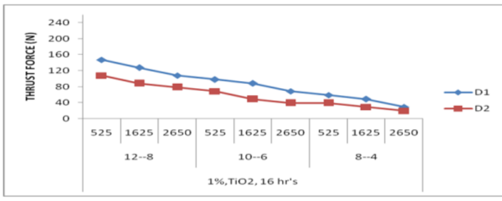
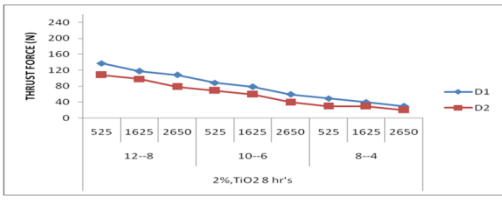


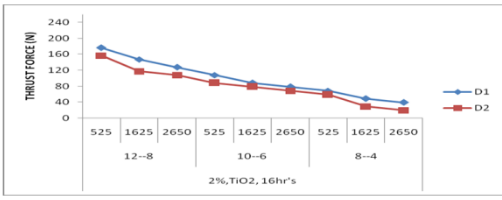
Figure:-4. Responses of cutting forces during drilling showing key process points

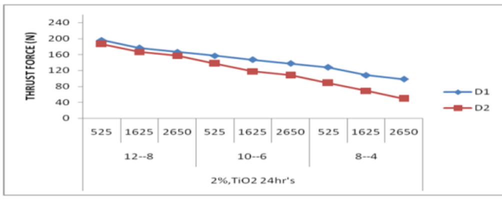
The value of thrust force was measured using a piezoelectric dynamometer. Figures 5and 6show the results of the thrust force for the three sets of drilling tests, as a function of the cutting parameters.











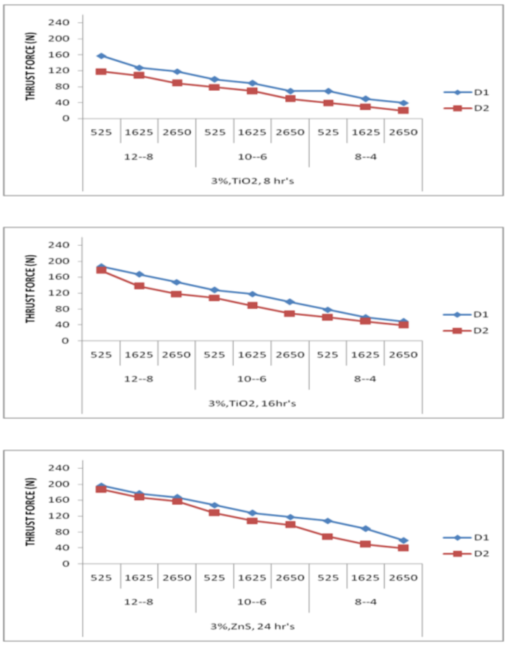


Figure:-5: Comparison of thrust force against drilling speed, feed and drill size for TiO_2&ZnS filled GFRP composite

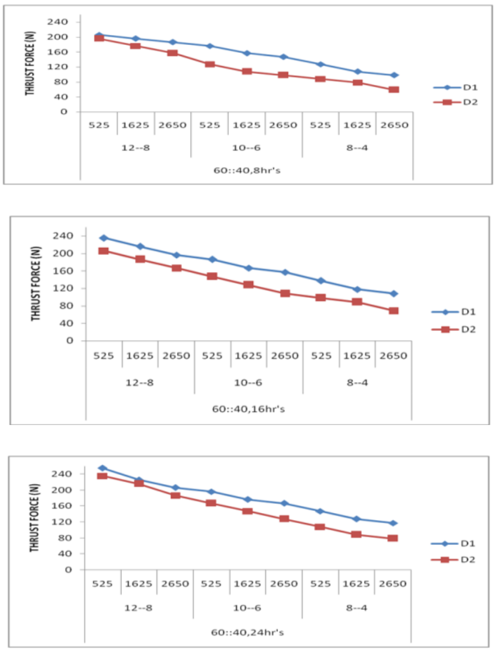


Figure:-6. Comparison of thrust force against drilling speed, feed and drill size for Unfilled (60:40) GFRP composite.

After drilling glass fiber reinforced epoxy composite laminates manufactured by hand lay-up; usingthreedifferent HSS twist drill and various cutting speeds, the cutting speed is the cutting parameter that has the highest physical as well as statistical influence on the thrust force and surface roughness inGFRPmaterial, the following conclusions can be drawn:

From the Figure 5, Figure 6 we are concludes that;

- As speed increases the thrust force decreases
- Smaller diameter has got greater thrust force than larger diameter in each step drill.
- When compared among all step drills 8-4mm step drill has shown less thrust force than 10-6mm and 12-8mm.
- As immersion time increases from 8hr, 16hr and 24hrs the thrust force also increases.
- If the immersion time is kept constant then both for TiO_2 and ZnS as % volume fraction increases the thrust force decreases.
- Unfilled composite has shown less thrust force values than Filled composite.
- ZnS has got significantly better values than TiO_2.

Delamination factor (F_d)

Delamination is caused by different drilling parameters. Several ratios were established for damage evaluation. One of them is delamination Factor (F_d), a ratio between the maximum delaminated diameter (D_{max}) and drill diameter (D_0). $\mathbf{F_d = D_{max}/D_0}$. Figure 7 shows Tool Maker's microscope with which delamination was measured.

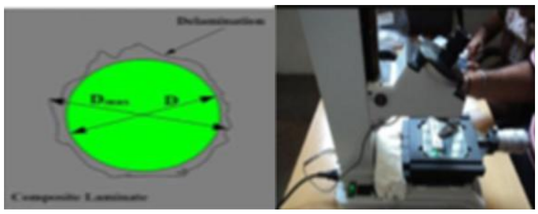


Figure:-7. Schematic view of delamination factor and a view of tool makers' microscope

Delamination is commonly classified as peel-up delamination at the twist drill entrance and pushdowndelamination at the twist drill exit as shown in Figure 8.

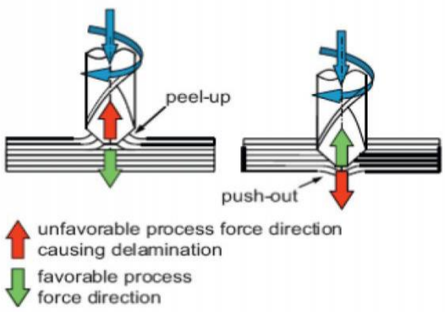
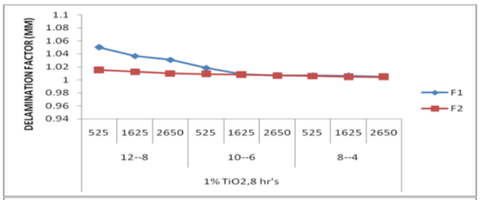


Figure:-8. Delamination at the twist drill entrance (left) and exit (right) when drilling laminates


DELAMINATION FACTOR (MM)
1.1
1.08
1.06
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1.02
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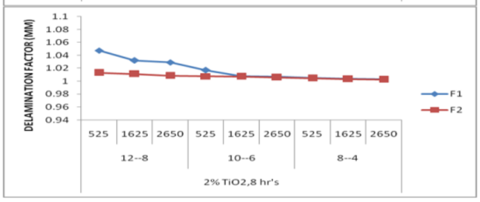
12--8 10--6 8--4
F1
F2
1% TiO2,8 hr's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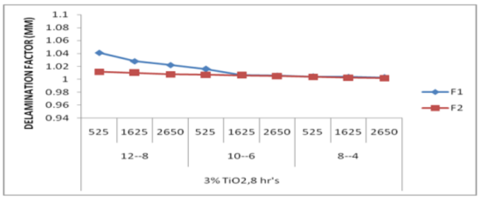
F1
F2
2% TiO2,8 hr's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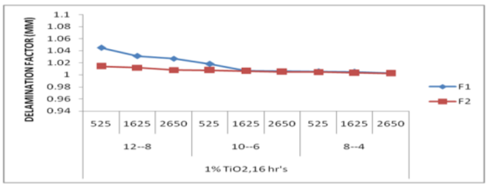
F1
F2
3% TiO2,8 hr's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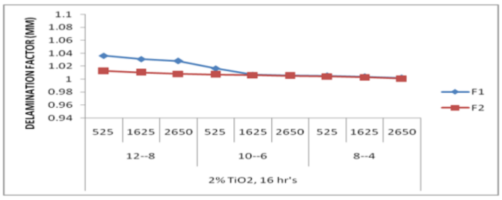
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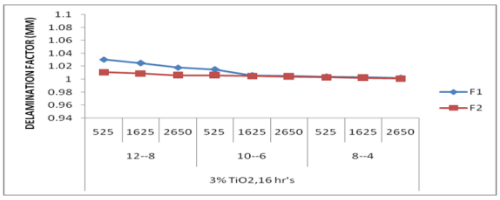
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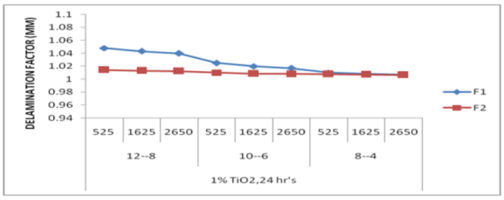
3% TiO2,16 hr's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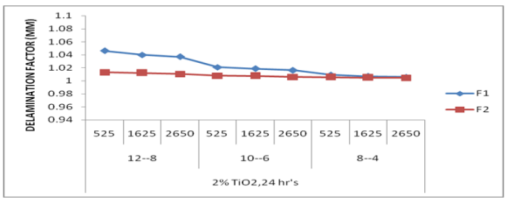
1% TiO2,24 hr's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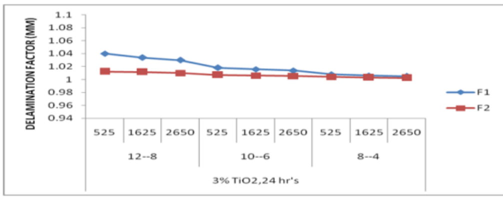
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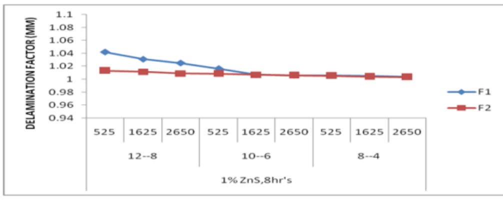
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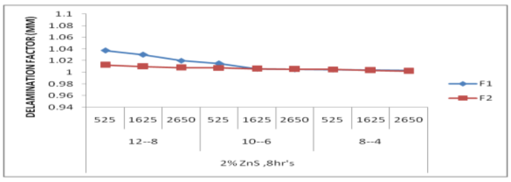
F1
F2
1% ZnS,8hr's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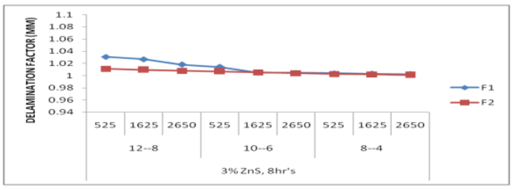
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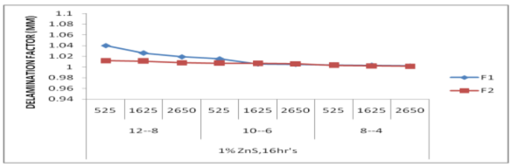
F2
3% ZnS, 8hr's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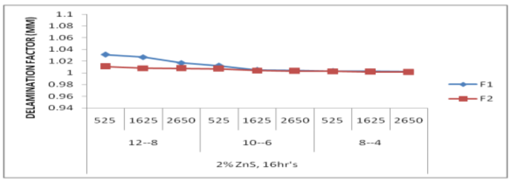
F1
F2
1% ZnS,16hr's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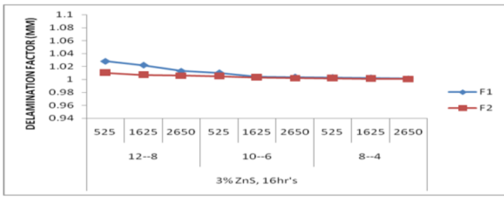
2% ZnS, 16hr's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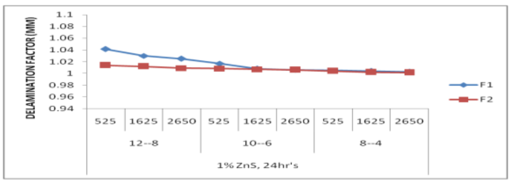
3% ZnS, 16hr's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12--8 10--6 8--4
F1
F2
1% ZnS, 24hr's

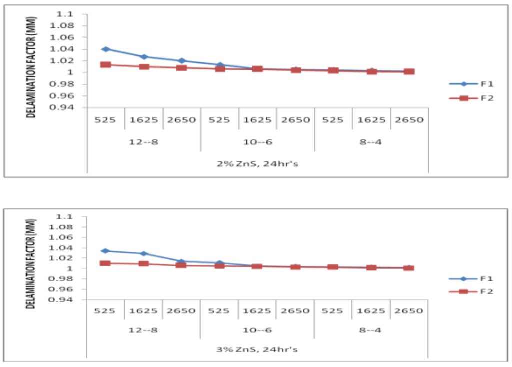

Figure:-9.Comparison of delamination factor against drilling speed, feed and drill geometry for Tio2 and Znsfilled GFRP Composite.

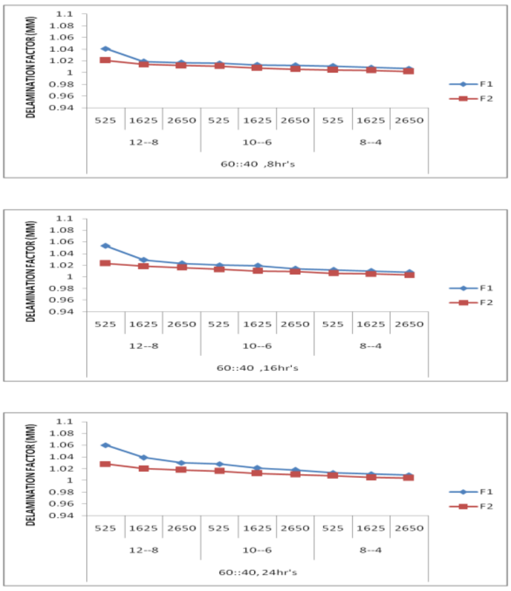

Figure:-10. Comparison of delamination factor against drilling speed, feed and drill geometry for Unfiled filled GFRP.

From Figure 9, Figure 10 we conclude that:

- Delamination factor decrease as speed increases for all the drill diameter.
- 12-8mm step drill shows higher damage factor fallowed by 10-6mm and 8-4mm step drill.
- Keeping immersion time constant, 1% has got larger values than 2% but for 3% it has decreased both for TiO_2 and ZnS.
- Observation was made towards immersion time, it has decreased from 8hr to 16hr but it has increased for 24hrs.
- Unfilled composite has shown more damage factor when compared to filled composites (TiO_2 and ZnS).
- ZnS Filled composite has shown less damage factor than TiO_2 filled composite.

VI. CONCLUSIONS

Based on the experimental results presented, the following conclusions can be drawn:

Thrust force

- As speed increases the thrust force decreases
- When compared among all step drills 8-4mm step drill has shown less thrust force than 10-6mm and 12-8mm.
- As immersion time increases from 8hr, 16hr and 24hrs the thrust force also increases.
- If the immersion time is kept constant then both for TiO_2 and ZnS as % volume fraction increases the thrust force decreases.
- Unfilled composite has shown less thrust force values than Filled composite.
- ZnS has got significantly better values than TiO_2.

Delamination factor

- Delamination factor decrease as speed increases for all the drill dia.
- 12-8mm step drill shows higher damage factor fallowed by 10-6mm and 8-4mm step drill.
- Keeping immersion time constant, 1% has got larger values than 2% but for 3% it has decreased both for TiO_2 and ZnS.
- Observation was made towards immersion time, it has decreased from 8hr to 16hr but it has increased for 24hrs.
- Unfilled composite has shown more damage factor when compared to filled composites (TiO_2 and ZnS).
- ZnS Filled composite has shown less damage factor than TiO_2 filled composite.

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