ISSN: 0974-2115
www.jchps.com Journal of Chemical and Pharmaceutical Sciences

AN OVERVIEW OF DELAMINATION IN CONVENTIONAL AND VIBRATION ASSISTED DRILLING ON GLASS FIBER REINFORCED POLYMER COMPOSITES

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ABSTRACT

The use of polymer composite material in commercial applications has increased considerably over the last decade, where there exist a myriad of paper and focus on the machinability of materials .The imperative objective of this paper work is to present a literature survey on the drilling of Glass fiber reinforced polymer composite materials, that vertically narrows on identifying empirically factors on quality of holes produced during drilling process, that are highly prone due to the delamination damage. The delamination is occurrence associated with shearing of GFRP require high scope on surveying the empirical occurrence of delamination. Delamination is a paramount problem in drilling of composite material. That impression practically 60% of aerospace application. The myriad review on literatures reveals the main reason for delamination occurrence is due to performing of drilling in inefficient way, the various technique adopted for performing for assembling components drilling are conventional drilling, laser machining, water jet machining, wire cut electrical discharge machining, High speed drilling, vibration assisted drilling, The analysis of survey it is proven that Vibration assisted drilling on composite materials possible to reduce delamination and increase tool life. Avoid the environmental problems doing in drilling new technique important. Because vibration assisted drilling intermittent contact between tool and work piece.

Keywords: Delamination, Thrust Force, Vibration assisted drilling, high speed drilling, ordinary drilling, Environmental effects.

INTRODUCTION

A composite is a structural material that consist of two or more constituents that are combined at a macroscopic level and are in soluble with each other. The constituents are the reinforcing phase and the other being matrix were both is embedded (Kaw, 2006). Basic definition of GFRP and its properties GFRP was widely used in airliner, marine industry, automotive, and home appliance (Zitoune, 2012; Soutis C, 2005). Due to their excellent properties such as high physical strength, high shock absorption property, low temperature respond, resist to degradation in chemicals, nuclear radiation and good dimensional stability (El-Sonbaty, 2004; Velayudham, 2005). During Assembling of GFRP composite the secondary machining process is inevitable that to secondary machining process that requires drilling is salient commercial aviation application. That requires drilling of hole which applications the GFRP was widely used in possess 60% of rejection in GFRP during assembling with aircraft component causes delamination (Stone R, 1996).

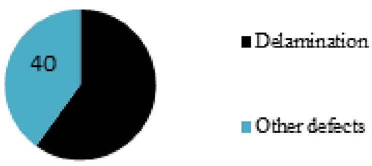

Fig:1 Rejection reason in aircraft industry

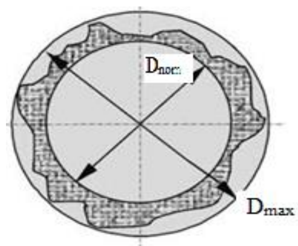

Fig :2 Scheme of delamination

During conventional drilling of composites material are proned to various types of damages such as fiber separated from composite, peel-up delamination, push-out delamination (Bhatnagar, 20047; Taylor, 2015; Taylor, 2008; Taylor, 2015). Due to composite materials anisotropy and inhomogeneity (Liu D, 2012; Tagliaferri, 1990).

1.1 Delamination: Delamination is a failure due to bonding material, often a composite separation of the layers of reinforcement or plies. Delamination reduce the life time and structural behaviour of composite materials (Konig, 1989).

1.2 Delamination Analysis: The delamination factor F_d, which can be defined as the ratio of the maximum diameter D_{max} of observed delamination zone to the nominal diameter D_{nom} of the drilled hole (Chen, 1997).

$$F_d = \frac{D_{max}}{D_{nom}}$$

D_{max} = maximum diameter in mm
D_{nom} = nominal diameter in mm

However, the criterion based on F_d may generally have an inherent incoherence due to the extent of delamination caused by just a few fibers peeled up or pushed down to a distinct significant width would not depict truly the real delamination zone of the drilled hole periphery.

1.3 Adjusted delamination factor: An adjusted delamination factor F_{da} based on digital image analysis to evaluate the delamination after drilling composite laminates, namely calculated by describing below Formula (Davim, 2007).

$$F_{da} = \alpha \frac{D_{max}}{D_{nom}} + \beta \frac{A_{max}}{A_{nom}} \text{-------------------} \qquad (2)$$

α parts represents the size of the crack Contribution.

β part represents the damage area Contribution.

Where A_{max} maximum area in mm^2

Nevertheless, F_d was used more frequently than F_a and F_{da} due to its high more practical usage.

1.4 Peel-up delamination: Peel -up delamination occurs around the drilled holes entry periphery:

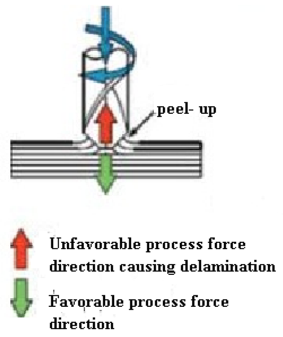

Fig: 3 Peel up delamination

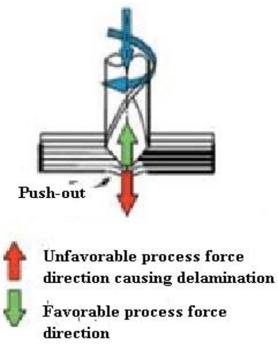

Fig. 4 Push-up delamination

When the cutting lip of drill bit make close contact with the composite laminate, a peeling force through the slope of the drill bit flutes, that results in the separation of plies from each other forming a delamination zone around the drilled holes and entry periphery.

1.5 Push-out delamination: Push-out delamination occurs around the drilled holes exit periphery. When the drill bit approaches the hole exit side, the uncut plies beneath the drill bit becomes more proned to deformation due to decrease of its thickness. Eventually, push-out delamination appears at the drilled holes exit periphery, if the thrust force applied to the uncut plies exceeds the inter-ply bonding strength. In practice, it has been found that the delamination associated with push-out is more severe than that associated with peel-up delamination.

2. Conventional Drilling: Delamination depends upon the thickness of fiber bundle. The damage is larger when the angle between the cutting edge and fiber direction is 45^0(Aoyama, 2001). Damage of composite material mainly depends up on the feed rate. Feed rate increases occurrence damages in composites [(18)] .The damages of drilling polymeric composite materials into are classified four categories.

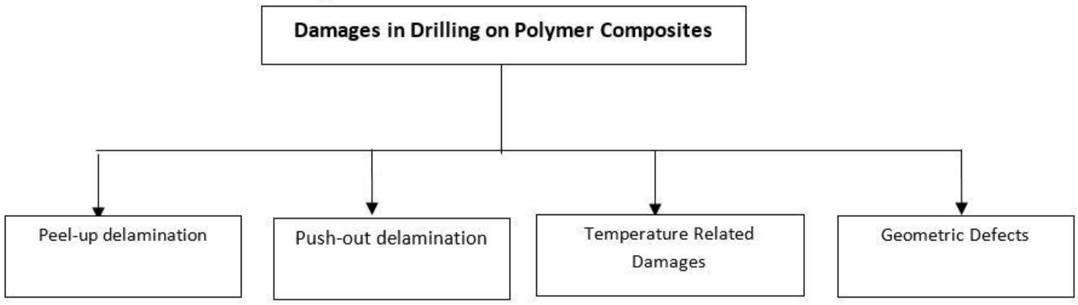

Fig:5 Classification of damages in polymer composites

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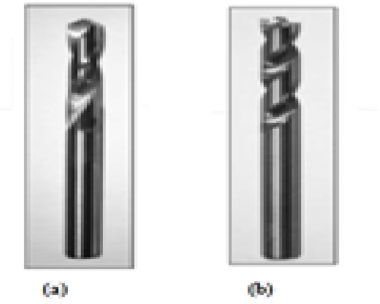
The delamination at drill entry is not sporadic as the tool geometry related damages are associated the angle between fibers orientation and cutting edge as the Temperature related damage occur with increase in friction between tool and work piece. Metal cutting drilling is not suitable for drilling of the composite material because the damages absorbed are frequently in aircraft used in HSS tool (Piquet, 2001). Delamination occur mainly due to anisotropy property of composite materials. That is the Ratio between drills bit radius and width of yarn playing an imperative role in tool life. Push out delamination proves to be a dominant factor than peel-up delamination. The cemented carbide tool in GFRP with its Pre hole diameter above or equal to 0.4 mm reduced thrust force. Thus Compares the tool performance drilling in GFRP with ‘‘Brad & Spur’’ tool and ‘‘Stub Length’’ tool.



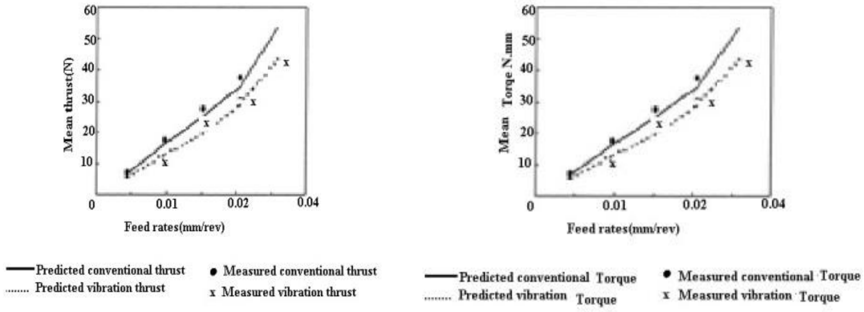


Fig:6 (a)brad and spur tool (b) stub length tool

Fig. 7. (a) Feed rate vs. mean thrust (b) Feed rate vs. mean torque

The ‘‘Brad & Spur’’ tool provides better performance than ‘‘Stub Length’’ tool because ‘‘Stub Length’ tool produce less damage than ‘‘Brad & Spur’’ tool (Davim, 2004). Adopting different unconventional machining such as EDM, W-jet, laser machining these technique almost provides same hole quality compared with ordinary drilling (Konig, 1985). Rejection rate proves to very high during drilling around the hole (Kishore, 2010). So these urges to use an alternative for reducing damages in composite materials during drilling. Another focal technique is said to be vibration assisted drilling which reduce delamination.

Vibration Assisted Drilling (VAD): The next one is VAD that uses piezoelectric transducer to induce the vibration on tool or work piece (Toews, 1998)**.** In conventional drilling, thrust force is the empirical reason for delamination (Hocheng, 2003; Ã AF, Biermann D, 2009; Mehbudi, 2013)**.** But vibration assisted drilling pulsed intermittent cutting process, makes discrete contact between tool and work piece, the VAD method developed less thrust force compare to the conventional drilling. VAD controls the various input parameters machining than the composite materials and making holes with high quality (Wang, 1995). Exceeding the critical thrust force delamination occurrence develops thrust force below the critical thrust force where is no delamination occur.

Vibration assisted drilling with some operating condition reduces 20 to 30% of less delamination compared to the conventional drilling (Zhang, 2001). Where the VAD Produces burr less in steel (Takeyama, 1991). The same approach is method followed for drilling of carbon-fiber reinforced polymer composite. In delamination were free holes are produced because of a developing thrust force which is less than critical thrust force (Zhang, 1994). Ultrasonic assisted drilling delamination reduced up to 50 % compare to the conventional drilling.

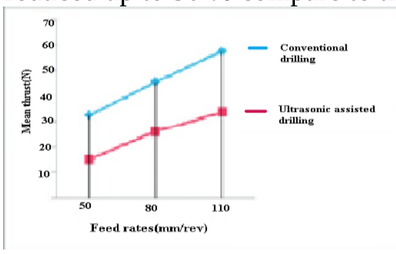


Fig : 8 Feed rate Vs. Thrust force in conventional and ultrasonic assisted drilling

Drilling of GFRP uses HSS drill bit developed thrust force and delamination which minimum compared to the conventional drilling with same tool used (Mehbudi, 2013). By applying low frequency vibration that are with assisted drilling cutting temperature and tool wear decreased with subsequence increase in tool life and reduce delamination (Tialv, 2014).

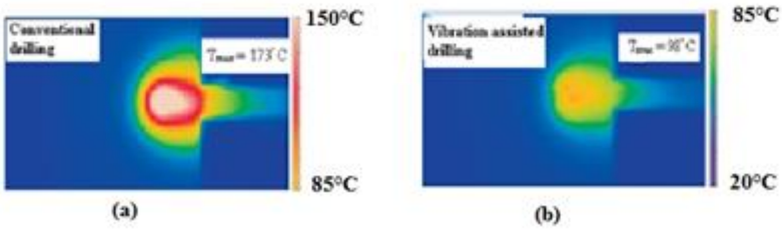


Fig : 9 Thermo graphical images for(a) Conventional drilling and (b) vibration Assisted drilling

VAD reduces thrust force required for drilling fiber reinforced polymer compare with conventional drilling (Wang, 2003). Same drilling condition of modulation assisted drilling reduces delamination factor up to 49% compare to the conventional drilling.

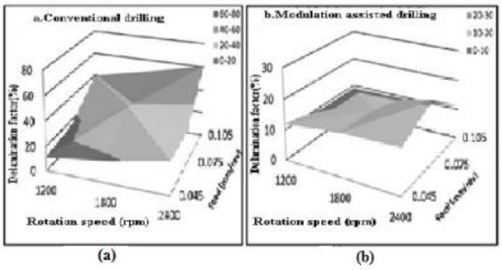


Fig : 10 (a)Delamination in Conventional (b) delamination in vibration assisted drilling

In modulation assisted drilling the instantaneous force becomes zero, during each modulation cycle thus reducing average thrust force (Taylor, 2014). Comparison of other type of vibratory motions (longitudinal, transverse) are studied for monitoring thrust force in that circular type of vibration is most effective for reduce delamination. By using vibratory drilling machine in circular type motion the frayed bores is reduce from 54% to 27% when compared to the conventional drilling machine.

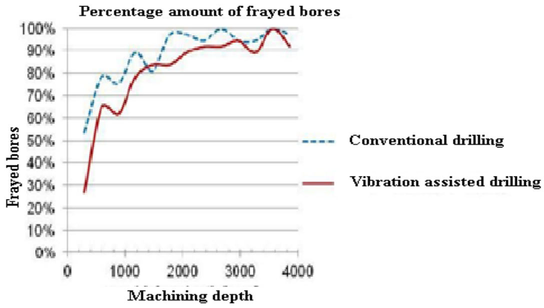


Fig. 11.frayed bores in conventional and vibration assisted drilling

The tool life has been increased while using uncoated solid carbide in vibration assisted drilling. Drilling is most effective in circular vibration frequency of 100 Hz and amplitude of 2 µm (Zemann, 2014). Three types of drills tipped WC, 2-flute solid carbide and 3 flute solid carbide and thickness of GFRP 4mm are used conduct for the experiment by varying speed at 630 and 1200 rpm with frequency from 0-280Hz , amplitude 10 - 15µm with feed rate feed rate 0.03, 0.04, 0.04 mm/rev. the analysis of experiment trials opts the optimal range condition are frequency 220Hz, feed rate 0.04mm/rev, speed 630 rpm and 3 flute solid carbide drill that are effective one with increase tool life (Ramkumar, 2004). Ultrasonic vibration Drilling in GFRP uses high speed steel with 5mm diameter that induces thrust force less than the conventional drilling. Machining quality with hybrid variation parameters vibration drilling method is better than that of constant vibration drilling because of unique characteristics of vibration drilling such as variation of cutting angles and uncut chip thickness in the whole drilling process. Moreover, the drilling efficiency of hybrid variation parameters vibration drilling method could be increased 52.1% with comparison to constant vibration drilling on the optimal conditions (Linbo, 2003). vibration assisted drilling promising technique reduce environmental effects so we adopt vibration assisted drilling best drilling in polymer composites.

CONCLUSION

The manufacturing of GFRP is mainly for an application of in transportation industry and component in electronic industry. So in this field the drilling used for secondary machining process for assembly purpose. While drilling GFRP delamination was the major defects. Due to this rejection of components more. Minimizing this vibration assisted drilling most suitable method compared to conventional drilling process .Because thrust force developed less the critical thrust force due to intermittent contact between tool and work piece at the same time tool life also increased. These vibrations of tool or work piece minimize damages through vibration assisted drilling.

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