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DRILLING ON FIBRE REINFORCED POLYMER/NON-POLYMER COMPOSITES LAMINATES: A REVIEW

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Abstract:
The use of polymeric composite material has increased considerably, and as a result, focus on machinability of such material has also increased. Drilling is the most frequently practised machining process for fibre reinforced polymeric composites in industry. Reinforced composites discovered for reaching applications rather than others because of their ease of manufacture. The various parameters during the drilling operation that might influence the drilling factors and material damage have been identified while working with composites. It is aimed to cover drilling operations, drill bit geometry and materials, delamination in drilling and its remedies, thrust force and tool wear.

Keywords: Reinforced composites, delamination in drilling, thrust force, tool wear.

Introduction:

Composite materials are turned out to be the successful useful materials for present day industry due to their phenomenal properties. The developed fiber composites are used in many engineering applications such as aircraft industry, space research, automobile fields, naval, sports goods, structural applications, household application etc. The most recent commercial aircraft designs have proposed a reduction in weight about 50% by replacing the primary structural components with fabricated nanopolymer composites. In order to achieve the reduced fuel consumption and better passenger comfort goals of these future commercial aircraft design innovations the use of light weight and elevated strength composites are required (GPRF)&(CPRF).

Drilling is one of the most important, frequently practiced, and unavoidable machining operation for components used in FRP composite structures. During drilling, the fibers take a high proportion of the load, which prevents uniform plastic deformation as normally observed during chip formation in metal cutting. While working, It is found to be much significant or severe at the bottom side of a work piece or at the hole exit periphery, called "push-out" delamination (hole exit delamination). With that reason, about 60% of the drilled holes on composites are rejected at the initial stage only. Also, the drilling of FRP composites have several undesirable effects such as edge chipping, macroscopic pitting, fiber breakage, fiber pullout, crack formation, thermal damage, stress concentration, matrix crazing along with delamination. Therefore, in order to improve the product performance and structural integrity of machined holes, the various material defects have to be trim-down by proper selection of cutting parameters, tool geometries, tool types and cutting conditions.

Literature Review:

Drilling of Glass Fiber Reinforced Polymer Composite:

Drilling of GFRP & Effect of Drill Material- Drilling induced delamination influenced by input parameters such as cutting speed, feed rate, drill point angle, drill diameter etc. The hardness of the glass fibers results in a high level of tool wear in drilling operations so material of drill dominates the selection of drill for drilling of GFRP. Carbide tools, coated carbide tools and PCD tools have better results in case of tool wear and tool life while the drilling of GFRP. The comparison of solid carbide and HSS drill for drilling of general purpose resin reinforced with glass fiber. Result confirmed that quality of drilled hole is also assisted by drill. It was also reported that the delamination and thrust force in case of solid carbide drill is lower than for HSS drill. Use three different drills (HSS, TiN coated HSS, Carbide) for investigating drilling characteristic of high performance PPA (polyphthalamide) matrix composite reinforced with 30% glass fiber.

Influential Parameters in Drilling Delamination on Fiber Reinforced Polymer Composites:

On drilling of fiber composites, the top & bottom of layers are de-aliened from the composites because of fiber matrix bonding damaged. In practically it is not possible to avoid entirely, but these defects are minimized by improving (adhesive) interfacial strength between the fiber and matrix. The nano clay materials are used to improving adhesive strength between the materials on fiber composites. Hence, the clay content having nucleating effect due to this, crystallization characteristic improved. In addition of above it is used to reduce melt flow rate of polymer, because delamination induced on fiber pullout during drilling operation. On decreasing melt, flow of polymer improves the bonding strength. A correct propagation of clay content needed to achieve good adhesive strength. It may vary means polymer-degassing defects induced due to increasing viscosity. The 7.5 % of nano clay content improves good strength of composites. Poor bonding and stress concentration produced due to excessive clay content on composites.

Drilling of Composite Laminates:

Drilling operations on composite laminates is essential for fastening with other materials to have useful outcomes. The fastening efficiency and excellence is relied on the quality of drilled hole. Producing error free precised holes is desired to ensure high joint strength during assembling of materials by riveting or bolting. However, the peculiarity (non homogeneous, anisotropic and highly abrasive and hard reinforced fibers) of composite laminate constituents poses hurdles during machining. Several undesirable damages (such as delamination and fiber pull-out) induced by drilling drastically reduce strength against fatigue, thus degrading the long-term performance of composite laminates. Among the various forms of material damage, delamination due to drilling is one of the major concerns in machining a composite laminate. It was reported that, in aircraft industry, the rejection of parts consist of composite laminates due to drilling-induced delamination damages during final assembly was as high as 60%. The thrust force has been cited as the primary cause of the delamination. The delamination may arise at the entry or exit of the drill bit during process.

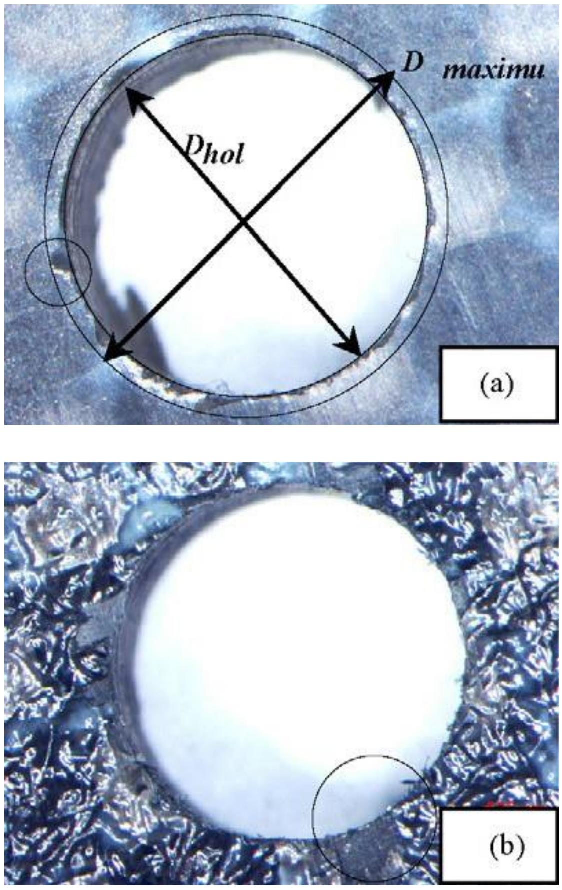


Figure: (a) Entry Delamination (b) Exit Delamination

The effect of mechanical drilling on polymer nano composites:

Nano particle release due to drilling - Due to the use of nano-sized particles, nano composites introduce a potential toxicological and eco-toxicological hazard. Research is comprehensively investigating the potential nanoparticles release and exposure to humans and the environment. Drilling on nano composites has the ability of unintentionally releasing these nanoparticles into the environment. Studies in toxicology have shown that particles within the nano scale are potentially hazardous to humans. The advantages of the nanoparticle physiochemical properties employed for the use within materials also render potential unique toxic effects within biological systems. Due to their small size, nanoparticles have the ability of penetrating the bloodstream and translocation throughout the body at which larger particles could not. Studies show that nanoparticles within the body can cross biological barriers such as the blood-brain and the blood-testis barrier and therefore treacherously reach highly protected organs. Published data from in vitro studies, suggests that nanoparticles have the aptitude to induce cell growth inhibition, cell death, inflammatory response, DNA damage and the generation of free radicals and reactive oxygen species. The toxicological effect is different for each type of nanoparticle, although the specific relationship between the chemical structure of every particle and the toxic implementations are still unknown. It is also important to note that some nanoparticles appear to be non-toxic, and others are may even possess health benefits.

Drilling on fiber reinforced polymer/nano polymer composite laminates:

Effect of tool types and tool materials on thrust force, torque and delamination-

Different types of drills and drill materials have greater influence on the thrust force, torque and delamination. Drilling of GFRP composite laminates with distinct and conventional uncoated cemented carbide drills exhibits a complete analysis of push-out delamination and drilling load profiles. Based on the experimental and analytical results, it was concluded that specialized drill tools reduced the drilling thrusts for the whole range of machining parameters compared to the conventional drills and also the magnitudes of push-out delamination damage were noticeable. Adjacent to the twist drill, the effects of different types of drills such as core drill, step drill, saw drill and candle stick drill have exhibit a major impact on the critical thrust force and delamination. In case of a saw drill, the size of the delamination zone is dependent on the thrust force applied on the FRP composite laminate. At high thrust forces, the size of the delamination
zone is equal to the drill diameter, which is the minimum possible delamination in case of a composite material. Also, when the diameter of the saw drill is considered to be zero, its behavior is analogous to twist drill with zero drill diameters or with infinite delamination zone. In case of a candle stick drill with zero circular load, i.e. no torsional load on the drill bit, the working is the same as that of a twist drill with a point load at the centerline of the drill. Also in cases where the drill centerline load is zero, this drill is analogous to saw drill. This is as the geometry of a saw drill does not accommodate for centerline loads illustrates the thrust force variation related to the feed rate for different drill tools.

In addition to the standard drill tools, the newly micro coated tools such as PCD tools, CBN coated tools, diamond like coated tools coated tools, etc. were also used to acquire good surface finish of the drilled holes with less damage. Author have selected three different types of drills; namely, HSS drill, carbide tipped drill and solid carbide drill for the purpose of drilling on CNF reinforced CFRP nanocomposite laminates.

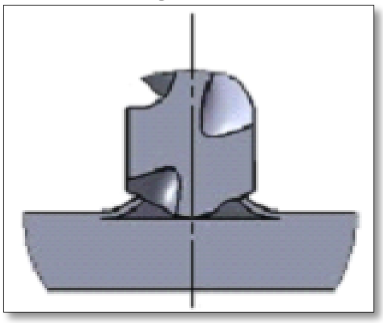
Drilling Damage in Composite Material:

Delamination is a damage that is likely to occur in the interlaminar region, along the contact plan between the adjacent layers in laminate parts. It therefore depends not only on fibre nature but also on resin type and respective properties such as the interlaminar fracture toughness, the elastic modulus or the Poisson ratio. The delamination mechanisms are divided into push-down and peel-up, according to on which laminate side it occurs: drill exit or entrance, respectively.

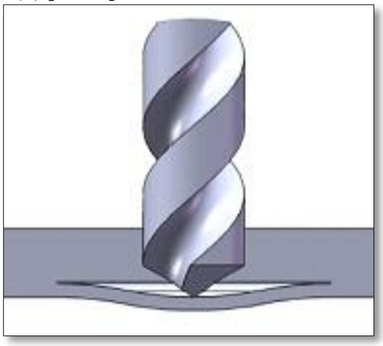
Peel-up is caused by the cutting force pushing the abraded and cut materials to the flute surface. Initially, the cutting edge of the drill will abrade the laminate. As the drill moves forward, it tends to pull the abraded material along the flute, and the material spirals up before being effectively cut. This action creates a peeling force upwards that tends to separate the upper laminas of the plate (Figure). This peeling force is a function of tool geometry and friction between tool and work piece.

Push-down is a consequence of the compressive thrust force that the chisel edge of the drill always exerts on the work piece. The laminate under the drill tends to be drawn away from the upper plies, breaking the interlaminar bond in the region around the hole. As the drill approaches the end of the laminate, the uncut thickness becomes smaller and the resistance to deformation decreases. At some point before the laminate is totally penetrated by the drill, the loading exceeds the interlaminar bond strength and delamination occurs (Figure). A suitable tool geometry that lowers the thrust force can reduce the delamination damage.

A recent advance on machining strategy was given by Schulze, minimizing the damage by directing the process forces towards the center of the work piece. This is achieved through a combined process of circular and spiral milling on a three-axial machining center.



(**a**) peel-up delamination at entrance.



(**b**) push-down delamination at exit.

Conclusion:

An overview of mechanical drilling on composite laminates is presented. Best results can be obtained from PCD tools but due to cost factor some other drill materials like TiN and TiAN coated drill may be proved alternative. The delamination effect on FRP composites can be reduced by proper selection of parameters and its level. Drilling of composite laminates differs significantly in many aspects from drilling of conventional metal and their alloys. The hole quality can be improved by using special drill bits, support plate, pre-drilled pilot hole, vibration-assisted twist drilling and high speed drilling. Studies have demonstrated that drilling can structurally damage conventional composite materials, no work has investigated the effects on nano composites. Along with assessing the damage drilling can cause on various polymer nano composites, it is crucial that any potential health or environmental risks associated with the materials are fully understood and characterized.

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