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Review on Defects in GFRP Composites

K.S.Vaghosi [1],Dr.G.D.Acharya [2]

[1]*Department of Mechanical Engineering, Government Engineering College, Rajkot, Gujarat, India.*
[2]*Atmiya Institute of Technology & Science, Rajkot, Gujarat, India.*

Abstract — *GFRP (Glass Fiber Reinforced Plastic) are the advanced materials for modern high technology products. The combination of different materials in manufacturing of GFRP composites like Glass fiber and Polymer matrix having different mechanical properties causes a problem in processing or cutting or making a hole due to their heterogeneous structures which are not common in metal components. Due to these varying properties, different defects are generated during processing of these materials. In this paper, various defects produced during cutting operations of GFRP composites are discussed.*

Keywords *- GFRP, Defects, Spalling, Matrix burnout, Uncut fibers, Delamination.*

INTRODUCTION

Fiber Reinforced Plastics (FRPs) consist of fibers of high strength and modulus embedded in or bonded to a matrix. In this form, both fibers and matrix retain their distinct physical and chemical identities; still they produce a combination of properties that cannot be achieved alone. In general, fibers are the principal load-carrying members, while the surrounding matrix keeps them in the desired location and orientation, acts as a load transfer medium between them, and protects them from environmental damages due to elevated temperatures and humidity [1]. In present days engineering products, development and application of Fiber Reinforced Plastics (FRPs) increased at fast speed. The idea of composite is not new; its application was found in ancient time also. Fiber Reinforced Plastics are basically composites which are the materials composed of two or more distinctly identifiable material constituents. Fiber Reinforced Plastic (FRP) have been widely used in engineering application such as power generation equipment, automotive, aircraft and manufacture of spaceships and sea vehicles' industries due to their significant advantages over other materials. These are an economical alternative to stainless steel and other materials in highly corrosive industrial applications. They provide high specific strength/stiffness, superior corrosion resistance, light weight construction, low thermal conductivity, and high fatigue strength, ability to char and resistance to chemical and microbiological attacks. As a result of the widening range of applications of these materials, its study has become a very important subject for research [2, 3].

Glass Fiber Reinforced Plastics (GFRPs)

The fibers used as reinforcements are glass fibers, carbon fibers, and aramid fibers. In GFRP, glass fibers are used as reinforcements. Glass fibers has advantages as low cost, easy manufacturing, comparatively good stiffness and strength value in addition to low density, better chemically resistance and electrically insulation properties. One of the limitations of GFRP is that when it is subjected to high tensile load, they are prone to break. However, they remain break resistant when subjected to high tensile load in short time frame. For different application requirement various forms of glass fibers are used such as chopped-strand mat, continuous mat, fiber glass roving, woven roving and yarns, surface mat [4]. GFRP composites are used in fairings, passenger compartments, storage room doors, pipes, tanks, pressure vessels, door and elevators of aircraft due to their high mechanical properties [4, 5].

Defects in Glass Fiber Reinforced Plastics

The general defects that occur in Glass Fiber Reinforced Plastics are as: Fiber-matrix debonding, Fiber pullout, Matrix cracking, Fiber misalignment, Density variation, broken fibers, Improper curing of matrix, delamination, Inclusions, Machining problems, spalling and thermal degradation.

Out of many known sources, there are two main sources which can describes these defects. (1) Processing or fabrication defects, and (2) In-field or service defects.

The defects that can occur during processing or fabrication are as: Abrasions, scratches, dents, cut fibers, improper joining of layers, voids, low quality materials usage, improper curing of resin, resin rich or resin lean areas due to improper distribution of resin, inclusion or contamination, manufacturing problems.

The defects that can occur during service or in-field are as: Environmental effects of temperature and humidity, exposure to hazardous chemical/radiation, biological degradation, improper handling and storage, corrosion, erosion.

They can also be classified as Micro level, Macro level or both combined micro-macro defects.

The Micro level defects are as: Fiber fracture/breaking, fiber buckling, fiber bending, fiber splitting, fiber cracking, matrix cracking, fiber pullout, fiber debonding.

The Macro level defects are as: Delamination [6, 7, 8]

Delamination

Among the defects caused by drilling, delamination around the drill hole site appears to be the most critical, delamination can often become a limiting factor in the use of GFRP for structural applications [9].

Delamination is a major problem associated while machining GFRPs and, in addition it reducing

- The structural integrity of the material,
- It also leads to poor assembly tolerances and
- It has the potential for long-term performance deterioration.

Two delamination mechanisms associated while machining GFRP are known as peel-up at the drill entrance and push-out at the drill exit. Peel-up delamination occurs as the drill enters the laminate while Push-out delamination occurs as the drill reaches the exit side of the material.

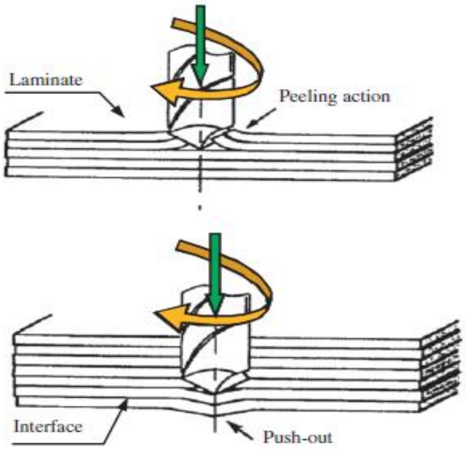

Fig. 1 Peel-up delamination at entrance and Push-out delamination at exit.

The conventional delamination measure for assessment and comparison of the delamination damage due to drilling of composite laminates is the one proposed by Chen [12]. It is a ratio called delamination factor (F_d) and he defines it as the ratio of the maximum diameter of delamination (D_{max}) to the nominal diameter of drilled hole (D) [9, 12].

$F_d = D_{max}/ D$

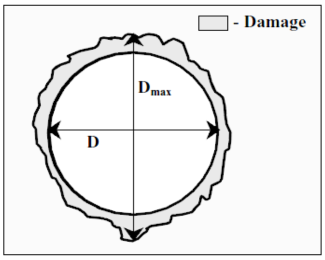

Fig. 2 Delamination damage [10].

Matrix burnout

It is a damage that occurs due to extent heat generated during machining process. This happens when GFRP is processed with drilling machine, laser machining, high speed machining.

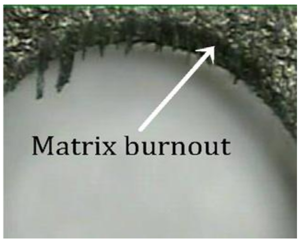

Fig. 3 Matrix burnout [11]

Uncut Fibers

GFRPs are made of individual lamina which is a layer of parallel fibers set in the polymer matrix. GFRP laminates are characterized by the order of orientation of the reinforcing fibers of the individual layers, which also largely determines the strength and application of the laminate. A commonly observed defect in drilling is uncut fibers which include incomplete fiber cutting [15].

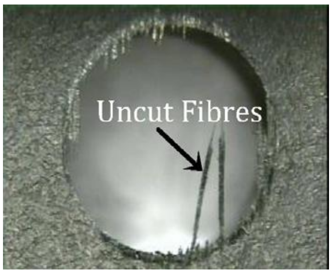

Fig. 4 Uncut Fibers [11]

Spalling

The lifting of bonded sheet can simulate the interface defects that can be induced during bonding construction is classified as spalling defect [13]. When spalling takes place definite shear crack appears in flexural structures, the spalling part and the unspalling part lie in different curved surfaces [14].

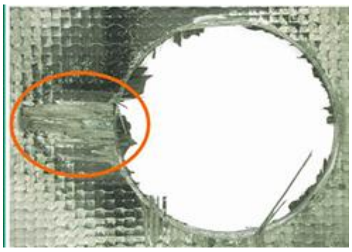

Fig. 5 Spalling

Fuzzing/Thermal degradation

The temperature-induced damage including fuzzing and matrix degradation is commonly produced by the thermal effects of drilling heat on the hole wall surface [16]. This defect is directly connected to feed rate, speed and thrust force in drilling process.

Fig. 6 Fuzzing/Thermal degradation

CONCLUSIONS

Glass fiber reinforced plastics contain two phases of materials with totally different mechanical and thermal properties which creates complicated intersections between the matrix and reinforcements during processing/machining. The structural anisotropy resulting from reinforcement from fibers influences quality during machining. In above review, the common problems that occur are discussed. Delamination is the major concern during machining of GFRP, because it also results in poor assembly tolerance and has the potential for long term performance in addition to the structural integrity of GFRPs.

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