

Chapter 45

Predicting Drilling Forces and Delamination in GFRP Laminates using Fuzzy Logic

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ABSTRACT

Drilling of fiber reinforced plastics is necessary in order to assemble complex/intricate composite products. Drilling induced damage leads to high percentage of part rejection and reduced product efficiency and life. The thrust force and torque have been found to be the important factors influencing damage. In the present research endeavor, an attempt has been made to develop a fuzzy rule based model for predicting thrust force, torque and drilling induced delamination during drilling of glass fiber reinforced epoxy plastics (GFREP). The work piece material, drill geometry, drill diameter, feed and cutting speed have been considered as the five input parameters. Four types of solid carbide drills namely 8 facet, 4 facet, parabolic and jodrill of 4 mm and 8 mm size were used to make holes in UD-GFREP and { (0/90)/0 } s GFREP laminates at three different levels of speed and feed. The results of the predictive model have been found to be in good agreement with experimental values.

INTRODUCTION

Modern day applications especially in aerospace, automobile and chemical industries require materials with peculiar and unusual properties which are not met by ceramics, metals and polymer materials alone. Hence the usage of fiber-reinforced plastics

(FRP) is increasing more and more in production houses in-order to meet the ever increasing demands of performance and cost reduction. Some of the benefits in using FRP are that they are light in weight, have excellent strength to weight ratio, greater design flexibility, good toughness, excellent corrosion resistance, low tooling cost,

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electrical insulation, excellent acoustic performance, easy to handle and process and have potential to integrate electrical parts. The list is endless but it is important to note that it is very difficult for any composite to have all the properties and advantages. It is for design engineers to develop a particular composite for a particular use using two or more different ingredients that have distinct properties. Manufacturing of FRP is broadly classified as: primary manufacturing and secondary manufacturing. Few Primary manufacturing processes are wet/hand lay-up, spray lay-up, filament winding, vacuum bagging, pultrusion, resin transfer moulding etc.. Although primary processes result in near-net shapes but certain intricacy in product design necessitates the composite products to be made in parts. Hence drilling becomes necessary to ensure assembly of parts, but delamination associated with drilling leads to major rejections. Delamination leads to poor assembly tolerance, reduced structural integrity and performance of parts.

Various researchers worldwide have studied with different drill geometries, cutting speeds and feed rates in-order to reduce delamination. Their work has been successfully reviewed by Hocheng and Tsao (2003) and Abrao et al. (2007). In past, various researchers have tried to model different parameters involved in drilling. An analytical approach for predicting the position of the onset of delamination based on linear elastic fracture mechanics was developed by Tsao and Chen (1997). C.K.H Dharan et al. (2000) proposed an intelligent control strategy for minimizing the drilling induced damage. Lachaud (2001) proposed a model linking the axial penetration of the drill bit to the conditions of delamination of the last few plies in drilling thin carbon/epoxy plates without backing plate. Zhang et al. (2001) proposed a model for the critical thrust force at which delamination is initiated at different ply locations. An approach based on a combination of Taguchi's experimental analysis technique and a multi-objective optimization criterion to select

the cutting parameters for damage free drilling carbon fibre reinforced epoxy was suggested by Enemuoh et al. (2001). Semi-empirical relationships between drilling forces and cutting parameters were developed by Won and Dharan (2002).

Langella et al. (2005) suggested a mechanistic model for predicting thrust and torque during drilling of GFRPs using traditional twist drills. Fernandes and Cook (2006) developed a mathematical model of the maximum thrust force and torque during drilling of carbon fibre using a 'one shot' drill bit. Two mutually conflicting objectives were optimized: material removal rate and delamination factor. Comprehensive delamination models for the delamination induced by an eccentric twist drill and an eccentric candle stick drill in the drilling of composite materials have been proposed by Tsao and Hocheng (2005). Sardinas et al (2006) proposed a multi-objective optimization of the drilling process. Predictive models for thrust force and torque were proposed. Singh and Bhatnagar (2006) used a FE model to establish that the thrust force is not the only cause for drilling-induced damage; torque also contributes to the damage. Singh and Bhatnagar (2006) proposed a mathematical damage model for four drill geometries correlating the damage area ratio with the operating variables viz. cutting speed and the feed speed. An experimental and Finite Element approach has been proposed to study the drilling characteristics of UD-GFRP composite laminates by Singh et al. (2008). Gaitonde et al. (2008) did an investigative analysis of parametric influence on delamination factor in high-speed drilling of Carbon Fiber Reinforced Plastic (CFRP) composites. Mohan et al. (2007) evaluated parameters of cutting speed, feed rate, drill size and specimen with main objective of determining factors that influence the delamination using Taguchi and Response Surface Methodology.

Hence a number of mathematical and analytical models were developed to suite a particular situation but as such, the need of a good predictive model to predict delamination, thrust force and

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