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ORIGINAL ARTICLE

Optimizing the delamination failure in bamboo fiber reinforced polyester composite

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Abstract Delamination is represented to be the most prevalent failure in composite structures. The use of composites in the manufacturing sector plays a very important role in the industry in general. Moreover these materials have unique characteristics when analyzed separately from constituents which are a part of them. In this paper, a partially ecological composite was made, using natural fibers as reinforcement (bamboo fiber), in the polyester resin matrix to form a composite, seeking to improve the mechanical behavior among its class of materials. The characteristics of a composite material are determined by how it behaves while machining, Drilling is the most predominant machining process because of its cost effectiveness when compared with other processes. Obviously delamination is the major problem that is focused by many researchers while selecting drilling as the machining process in polymeric composites. This research mainly emphasizes on the critical parameters by varying its speed, feed, and diameter of the cutting tool, their contribution to delamination was analyzed. Reduced delaminations were identified by varying the speed and feed rate.

1. Introduction

Composite materials have been dominant among all emerging materials because of its greater mechanical properties. The utilization of composite materials proved that it conquered new markets relentlessly. The mechanical properties of polymers have shortcomings in fulfilling many structural functions. Generally the mechanical strength of polymers is less compared with metals. However such limitations can be overcome by using treated natural fiber reinforced polymeric composites. While focusing on composite materials, the main points to be considered are cost effectiveness and environmental friendliness. The two main phases of composites are, a discontinuous phase called as "reinforcement" and a continuous phase called as "matrix" which is the major constituent of the product. The matrix separately shows less properties than when combined with reinforcement. It bears the load acting over it and distributes it evenly to the reinforcement. It helps in increasing the overall mechanical properties of the composites. Moreover factors like constituents, concentration, and geometry of the reinforcement determine the properties of the composite to a

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greater extent. Orientation of the reinforcement also has a major role in determining the mechanical properties. Volume fraction or concentration influences the contribution of individual constituents to the overall properties of the composites. Hocheng et al. (1992) concluded that a range of cutting parameters both feed rate and cutting speed should be conservative, since an increase in the feed rate can cause delamination, while an increase in the cutting speed raises the torque and consequently reduces the tool life. Won et al. (2002) observed that an increase in feed rate has an important influence on the chisel edge effect, while an increase of tool diameter decreases this effect. Delamination is mainly caused by the thrust force acting on the chisel edge. Mohan et al. (2007) have studied the influence of cutting parameters, drill diameter and thickness while machining GFRP composites and analyzing the delamination. Paulo Davim et al. (2004) have studied the influence of cutting parameters (cutting velocity and feed) while machining GFRP with two different matrices in order to study its influence along with those parameters on delamination.

Tsao et al. (2004) have studied the drilling of CFRP composite, the approach was carried out based on Taguchi techniques and analysis of variance. From the above literature, it has been identified that the delamination due to the thrust force and torque produced in drilling are important and is to be modeled. For modeling thrust force and torque in drilling a second order polynomial regression modeling is used. Various researchers developed several mathematical and predictive models to suit a particular situation but still there is a need for good predictive model persists in order to save time and labor. Therefore the present research initiative is to develop a predictive model using regression modeling to predict delamination factor for a particular cutting speed and feed rate in drilling of bamboo based polyester composite. Additionally, the results of delamination are compared with the oscilloscopic images obtained during drilling. To predict the delamination factor at the entry and exit of the hole, empirical models are developed. Production of high quality holes with minimal damage in composite materials is a key challenge. In this paper, delamination caused in bamboo fiber reinforced polyester laminate plates by drilling is evaluated.

2. Natural fiber reinforced composites

Natural Fiber-Reinforced Polymeric (NFRP) composites are quickly springing up in terms of research and industrial applications. Natural fiber serves as an important alternative to man-made fibers because they are abundantly available, economical, recyclable, biodegradable and possess a high mechanical strength. Lingo cellulosic plant fibers like bamboo, sisal, kenaf, cotton, jute, pineapple, banana, etc., are mainly used as reinforcement for NFRP composites. Nowadays they are used in various applications like transportation, defense, civil engineering applications, packaging, consumer products, etc. Natural fibers have many significant advantages over synthetic fibers. Currently, bamboo has been proved to be excellent in mechanical properties with strength and modulus (Navin chand et al., 2007). Evolution of next generation materials is only possible with polymeric composites with biodegradability. Biodegradable plastics take up the part of giving eco-friendly products that can compete with products made of petroleum feedstock and capture the changing markets. Natural or bio fiber composites are emerging as a feasible alternative to synthetic fiber reinforced composites especially in the field of automotive and civil engineering applications. Combining bio fibers such as bamboo with polymer matrices produce composite materials that are competitive with synthetic composite materials which require special attention; however bamboo fiber polyester composites are not fully eco-friendly because of the non biodegradable nature of the polymer matrix. But the utilization of natural fibers with such polymers will allow many environmental consequences to be solved. Natural fibers with unsaturated polyester matrix is highly beneficial than those of the unreinforced plastics because of the resulting strength and toughness of the composites. Moreover, cellulosic natural fibers are strong enough, light in weight, cheap, abundant, and renewable (Abdalla Rashdi et al., 2010).

3. Compression molding

Bamboo fiber reinforced polymeric composite is prepared using hand layup and compression molding. Initially NaOH is treated with bamboo fabric mesh with 10% concentration, then it is washed using distilled water till the entire chemical concentration was eliminated, it is then dried in hot air oven for 30 s and samples were weighed based on the requirement (Dhakal et al., 2006). Treating the fibers with NaOH helps in mending the interfacial bonding between the resin and fiber ensuing better mechanical properties. Several authors state that mechanical properties of composites can be improved by chemically treating the fibers (Yuhazri et al., 2011). Here the mesh is weaved with 0/90° orientation. Knitted bamboo fabric after fiber treatment is washed in water to remove the alkalinity and is dried at around 100 °C to remove completely the moisture content present in the fabric using hot air oven (Valadez-Gonzalez et al., 1999). Known amount of unsaturated polyester resin mixed with Kerox ME-50 (MEKP) catalyst and Kerox C-20 accelerator at a concentration of 0.01 w/w for rapid curing was coated on a pre-weighed bamboo fiber mat after applying resin, it was uniformly leveled with minor pressure using roller to remove the air packets within the layers. The bamboo fiber and polyester resin were left free for 2 min to allow air bubbles to escape from the surface of the resin, and then the coated layers were placed in a mold which was sealed with Teflon sheet coated with polymer release agents like silicone spray and grease all around. The mold was then closed and made compact using a hydraulic press at a temperature of 35 °C and at a pressure of 10 bar for about 3 min. After being taken out from the hydraulic press, it is kept in a vaccum furnace where high fiber bonding happens with the matrix thereby the delaminating tendency tends to reduce and then it is allowed for cooling at room temperature for few hours. After that the specimens of required dimensions were cut using a diamond tool cutter.

In compression molding the preheated polymeric composite is kept in a mold cavity with heating coils inbuilt to provide uniform heat as per the requirement. The upper cover plate of the mold is closed when the plunger of hydraulic press gets lowered and pressure is applied to act evenly on all surfaces. Uniform heat and pressure are maintained to create a homogeneous layer, and then the polymeric composite is held in a vaccum furnace which reduces the nature of debonding, it is followed by curing at room temperature for some time. Most