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EXPERIMENTAL INVESTIGATIONS OF MILLING ON FIBER COMPOSITES

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Abstract - *A composite material is made by combining two or more materials – often one of that have very different mechanical properties, Composites are one of the most widely used materials. Fiber-reinforced polymers consist of a combination of two separate phases within a single material microstructure, typically a fiber and resin. Machining of fiber reinforced composite materials is a complex task due to its heterogeneity in inner structure and attracts many researchers to undergo such work and analyze the machining parameters. Milling is used as a corrective operation for removing excess amount of materials after manufacturing the composite materials and Milling can be done with a wide range of machine tools. In this work the influence of speed, feed and depth of cut on the machining forces namely, thrust force and torque were studied. The focus of this thesis will remain on studying the fiber failure mechanisms occurring in the machining process and how these are affected by process parameters such as tool geometry and fiber orientation. The three machining responses used to validate the proposed fiber failure model were chip morphology, delamination, and cutting forces. The responses were analyzed using Materials of experiments to examine the most influencing factors aiming to reduce the cutting forces. The results showed that all three factors chosen have a significant effect on the responses. The experiments were conducted according to Materials. The four cutting parameters selected for this investigation are milling strategy, spindle speed, feed rate and depth of cut. Response table of grey relational grade for four process parameters is used for the analysis to produce the best output.*

Key Words: Fiber, Resin, Composite, Milling, Machining parameters, Failure mechanisms

1. INTRODUCTION

Composite materials are constructed from two materials; one material is called the reinforcement or discrete phase. The other is called a matrix or continuous phase. The fiber and the matrix have two different properties but When combined together they form a material with significantly different properties that are not found in either of the individual materials, such as high strength per weight ratio, high corrosion and thermal resistance and high stiffness, which are markedly superior to those of comparable metallic alloys. The duty of the matrix phase is to hold the reinforcement in order to form the desired shape; while the function of the reinforced is to carry the major external load thus improves the overall mechanical properties of the matrix. When the two phases are mixed properly, the new combined material present better strength than would each individual material. The simplest explanation of a composite material is shown in figure 1.

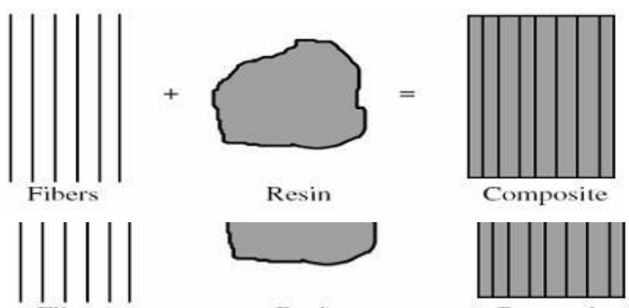

Figure 1: Formation of composite material using fibers and resins

Components and structures in various applications

1. Continuous Fiber
2. Chopped strands
3. Woven

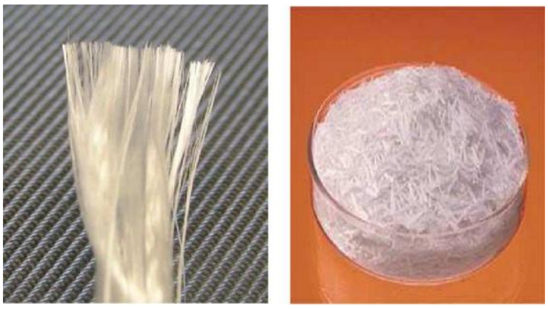

Figure 2: continuous fibers & chopped strands

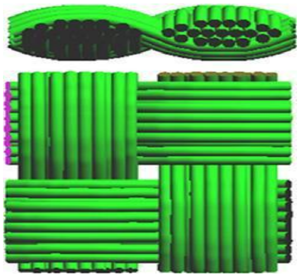

Figure 3: Forms of Glass Fiber

Aramid is the universal name for aromatic polyamide. It is presented in 1972 by du Pont under the trade name Kevlar. There are two commercial types: Kevlar-29 and Kevlar-49. The former has a low-density, high strength, low modulus fiber and it is designed for some applications like ropes, cables, armor shield, etc. while the second one has low density, high strength, and high modulus. It is used in aerospace, space shuttle, ships and boats, automotive, and other industrial applications.

LITERATURE REVIEW

The literature reported in this chapter contains investigations of the cutting process for fiber-reinforced polymers and highlights specific factors which affect their machining performance. The focus of this review will remain on studying the fiber failure mechanisms occurring in the machining process and how these are affected by process parameters such as tool geometry and fiber orientation. Section 2.1 outlines some mechanical properties of FRP composites and presents some issues occurring in the machining of these materials. Section 2.2 discusses various experimental studies in literature and covers topics including cutting mechanisms, cutting forces, and material damage and focuses on the unique orientation-based failure mechanisms encountered in the machining of FRPs. Section 2.3 covers experimental and theoretical modeling approaches used to predict machining forces while Section 2.4 outlines several finite element-based machining models. Section 2.5 discusses gaps in the current state of the literature.

Fiber Composites

Fiber-reinforced polymers consist of a combination of two separate phases within a single material microstructure, typically a fiber and matrix phase. The fibers in the microstructure typically carry the primary load and have a high strength and stiffness. The ductile matrix material provides several key functions including stabilizing the fibers in compression, distributing and transmitting loads between fibers, and providing off-axis properties.

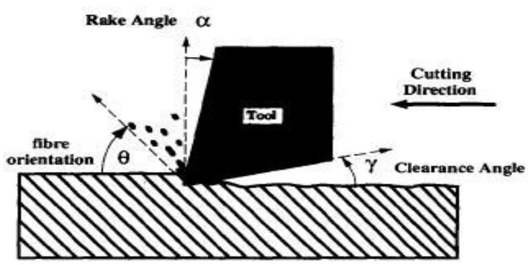

Figure 4: Fiber Orientation Definition

Methodology Experiments

A micro-milling experiment was employed to validate the proposed fiber failure mechanisms for. Three machining responses, viz., chip morphology, delamination, and cutting forces, are used to interpret failure mechanisms and validate the model.

Microstructure Characterization

The specimens used in this experiment were obtained from ACP Composites (www.acp-composites.com). They were in the form of plates of layered, resin-infused carbon fibers with a fiber volume percentage of 60 percent. Each lamina was approximately 180 μm thick. The machining samples were cut from a large 3 mm thick composite panel into 10 x 10 mm samples to fit on the machining test bed. Figure 3.2 shows a scanning electron microscope (SEM) image of the top view of a material sample indicating several fibers along with zones of epoxy. The carbon fibers in the samples were observed to be continuous over the entire length of the work piece and found to have a diameter between 5 and 8 μm. Note that many fibers in Fig. 3.2 have a generous coating of epoxy making them appear to have a larger diameter.

Experimental Test bed

Cutting Forces

The simulated machining forces are validated by comparing the simulated machining force trends across the four fiber orientations to their experimental counterparts. In the cutting force comparison, attention here is given to relative force trends across the four fiber orientations. Figure 5.11 shows a comparison of the simulated and experimental machining forces. The highest simulated cutting forces exist for the 45 and 90 degree orientations, where crushing-dominated failure is observed.Significantly lower cutting forces are seen for the 0 and 135.Degree orientations where bending failure is observed. This agrees well with the experimental cutting force magnitudes and cutting force trends, as the failure mode is seen to primarily dictate the cutting forces.

CONCLUSIONS

The objective of this research was to gain a better understanding for the fiber failure mechanisms occurring in the material machining process in milling machining process. In this connection a representative pattern was proposed for conducting various experiments on proposed failure mechanisms. Subsequently a pattern was developed to obtain a more fundamentals for better understanding the failure mechanisms which involves in material machining as a function of fiber orientation.

This research was focused on determining the effect of fiber orientation on the fiber failure mechanisms occurring in the micro-machining process. Specific attention was given to carbon fiber reinforced composites with fiber orientations of 0, 45, 90, and 135 degrees with respect to the direction of tool motion in an effort to cover the full range of fiber orientations encountered in the machining of composites.

The following is a set of conclusions that can be taken from this work:

1. The fiber failure mechanisms occurring in the Material machining process were found to be notably different Material counterparts. These differences exhibited themselves most significantly in the 45 and 90 degree orientations where the fibers were found to fail in crushing rather than bending as is typical at the macro-scale. For the 0 degree fiber orientation, the fibers were found to either fail in bending or buckling dominated failure, depending on the tool edge radius and DOC under

consideration. For the 135 degree orientation, the fibers were observed to fail in bending at the micro-scale, similar to the macro-scale failure mechanisms.

2. The chip morphology analyses agrees with the proposed Material failure mechanisms since the chips in the 45 and 90 degree orientations show small fragmented chips indicating crushing-dominated failure, while the chips collected for the 0 and 135 degree orientations had fiber significantly longer than the FPT or DOC of the process indicating bending or buckling dominated failure.
3. The delamination patterns observed support the failure modes proposed as the bending or buckling-dominated failure in the 0 degree orientation results in negligible delamination while the sub-surface bending failure in the 135 degree orientations results in the highest positive delamination. Both the 45 and 90 degree orientations showed low positive delamination because the fiber failed in crushing at the point of contact of the tool.
4. The cutting force trends correlate with the proposed fiber failure modes. The machining forces in the 45 and 90 degree orientations are significantly higher than the force in the 0 and 135 degree orientations, indicating that a crushing failure results in a higher force than a bending or buckling-dominated failure.

Future Work

New material and failure models would need to be developed. It would be beneficial to observe that the waste Materials can be used in reproduction for Fiber composite .The feed rate factor is seen to make the largest contribution fallowed by spindle speed and depth of cut to the overall performance in all the cases. The present work can be extended for further quality improvement like other machining parameters such as milling geometry and material parameters can also be taken into account for experimental analysis.

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