Chapter 5
Advanced Machining Techniques for Fiber–Reinforced Polymer Composites

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ABSTRACT

This chapter addresses the issues and challenges associated with the conventional drilling of Fiber-Reinforced Plastics (FRPs). The status of the work reported in the area of conventional drilling of FRPs has also been reviewed. Further, the opportunities with the advanced machining techniques have been reported. A state-of-the-art research review has been presented in light of the capability of advanced machining techniques for machining of FRPs. Advanced machining techniques, such as Electric Discharge Machining (EDM), Electrochemical Machining (ECM), Abrasive Water Jet Machining (AWJM), laser beam drilling, vibration-assisted drilling, and Ultrasonic Machining (USM) for FRPs has been discussed. The limitations associated with the advanced machining of FRPs have also been highlighted.

1. INTRODUCTION

The application spectrum of the advanced materials such as FRP's has increased at an unprecedented pace in the last few years. The superior physical as well as the mechanical properties of FRP makes them a viable alternative to the conventional engineering materials. Though, FRP's have excellent combination of properties, but their machining performance is relatively poor. The inhomogeneous and anisotropic nature of FRP's, low thermal conductivity of the fibers and polymer, and highly abrasive nature of the fibers renders the conventional machining techniques inefficient for machining of FRP's. Most of the FRP parts are made to a near-net shape and size during primary manufacturing because of their ease-of-processing characteristics. But, the complexity in the product design makes the machining operations necessary in order to ascertain the structural integrity. Machining operations such as drilling, milling,

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turning, grinding, and boring are the most common machining operations performed on FRP parts. Among all the machining operations, drilling is the most repeatedly and extensively used machining operation. Drilling is performed in FRPs in order to fulfil the purpose of joining through mechanical fastening, such as bolting, riveting etc. It is well understood that the efficiency of the mechanical fastening is highly dependent on the precision and accuracy of the drilled hole. Drilling of FRP's by means of conventional methods is a challenging task, because the damage generated due to the generation of thrust force cannot be avoided. The damage formed in and around the machining zone creates an uneven surface which subsequently results in poor surface quality (Debnath, Singh, Dvivedi, & Kumar, 2013; Singh, Debnath, & Dvivedi, 2013; Bajpai & Singh, 2013). Furthermore, the heterogeneous nature of the FRP's subjects the drill bit to experience variable forces due to the difference in the properties of the constituents (matrix and reinforcement). The resultant forces result in damage of work material in the form of delamination, fiber pull out, and poor surface quality. The major thrust all around the world for minimization of machining induced damage has been in the direction of optimization of the process parameters, development of newer tool geometries specifically dedicated to machining of FRP's, and developing theoretical models for predicting critical forces (Singh & Bhatnagar, 2006; Singh, Bhatnagar, & Viswanath, 2008; Bhatnagar, Singh, & Nayak, 2004). In the last few decades, researchers have tried to conceptualize un-conventional routes of processing with an aim of reducing the damage during machining of FRP's. To overcome the limitations of conventional machining process, alternative techniques that utilize non-conventional sources of energy for material removal have been conceptualized, developed and commercialized. Advancements in the non-traditional machining processes offer an opportunity to process these materials economically, thus realizing the full potential of the FRP's. Electric discharge machining (EDM), electrochemical machining (ECM), ultrasonic machining (USM), water jet machining (WJM), abrasive water jet machining (AWJM) and laser drilling are examples of non-conventional/advanced machining processes which have drawn considerable research interest. The research and development work in the area of advanced machining processes may lead to conceptualization of an optimal process that is suitable for damage-free machining of a wide variety of FRP parts. This chapter provides an overview of the material removal mechanism observed in the various advanced machining techniques, feasibility of these techniques for machining of FRP's, and the effect of various process parameters on the machining performance. The major objective of the chapter is to present an overview of advanced machining of FRP's in general and drilling of FRP's in particular (as a secondary processing technique).

2. STATUS OF RESEARCH WORK REPORTED IN THE AREA OF CONVENTIONAL DRILLING OF FRP'S

The research interest in the area of drilling of various types of fiber reinforced composites has gained widespread attention in the last few decades. The major emphasis is on the minimization of drilling induced damage. Number of techniques have been proposed that can control the drilling induced-damage but, no particular technique is universal in nature. The solution methodologies are dependent on the tool point geometry and the tool material, operating conditions and variables, back-up support etc. The various methodologies applied to minimize the drilling induced damage have been discussed exhaustively in the following sections: