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A Review Study on Non - Traditional Machining of Composite Materials

Hussein Mohammed Ali

Ph. D in Mechanical Engineering; Department of Power Mechanic Techniques Engineering, Technical Engineering College of Mosul, North Technical University, Mosul, Iraq
Email: *alabadi. hussein[at]ntu.edu*
iq.hrlha[at]yahoo.com
Tel: +9647708372370

Abstract: ***Recently, composite materials have replaced metals as the material of choice in many industrial industries due to their advantages of higher strength at lower weights. In comparison to metals, they exhibit better impact qualities, and they also have good damping capabilities, which help to lessen noise and vibration. These characteristics make composite materials ideal for a variety of industrial applications, including tennis rackets, golf clubs, airplanes, and vehicles. Because these materials have anisotropic and non - homogeneous structures, machining them is challenging. The current work comprises a review that focuses on atypical processing of composite materials, such as metallic matrix and ceramic matrix composites, as well as unconventional processing of glass - and carbon - fiber reinforced polymers, to lessen or eliminate the separation problem.***

Keywords: Composite Material, Abrasive Water Jet, Laser, Machining

1. Introduction

Comparing composite materials' industrial processing to those of other traditional metals and their alloys reveals differences. In addition to being non - homogeneous and anisotropic, the material behavior in the operation of composites also depends on the properties of different reinforcement, matrix, and the volume proportion of reinforcement and matrix [1]. Non - traditional operations are any of a multitude of methods for removing material without utilizing sharp cutting instruments, as is required in typical manufacturing processes, such as mechanical, thermal, electrical, chemical, or mixtures of these energies [2]. By using conventional machining techniques like turning, drilling, shaping, and milling, hard and brittle materials are challenging to work with. Nontraditional machining techniques, also known as advanced manufacturing techniques, are used when traditional machining techniques are not practical, satisfactory, or cost - effective due to the difficulty of clamping very hard, fragile materials for traditional machining and the complexity of the part's shape [3]. In order to meet the necessary operating conditions, numerous non - traditional operation types have been devised. When used properly, these methods have significant advantages over conventional machining processes. The issues with some non - traditional machining of composite materials were reviewed in this research.

2. Non - Traditional Composite Material Machining

An innovative method called Non - Traditional Operation Processes is used to get around the problems of Traditional Operation Processes. Some of these machining techniques include abrasive water jet machining, electron beam machining, laser machining, ultrasonic processing, and water jet machining [4]. Two primary categories of non - traditional machining were given in detail in this article.

2.1 The ultrasonic machining process (USM)

One millimeter - sized circular and noncircular holes can be produced using this unorthodox machining method. The tool vibrates at a very high frequency when high frequency vibrations are applied to it. Impact loads will be created by this instrument on the abrasive particles, which will then create impact loads on the work piece [5].

2.2 Process for Electrical Discharge Machining (EDM):

The procedure is often referred to as spark machining or spark eroding. To remove material off the surface of the workpiece by local melting or vaporization, electrical energy is employed in this method to create the spark between the tool and the workpiece that is immersed beneath the dielectric medium. Normal dielectric fluid works as an insulator, but at the right voltage or with a rise in voltage, the fluid becomes ionized [6].

2.3 Process of Electro Chemical Machining (ECM):

In this procedure, the removal of material from a workpiece's surface is made possible by the coupling of electrical energy and chemical energy. It operates according to Faraday's law of electrolysis. According to the basic tenet of Faraday's law, a material's chemical equivalent weight is directly related to the mass of the substance that is deposition or liberation at any electrode when a particular amount of charge is passed through it. NaCl, a conducting electrolyte, was utilized, and there was no tool wear, hence the wear ratio was infinite [7].

2.4 Process for Electron Beam Machining (EBM):

One of such non - traditional machining techniques that maintains extreme accuracy is electron beam machining. Below is a full explanation of the quick explanation of EBM. The electron gun produces extremely high - velocity electrons traveling in all directions when it receives a very high voltage power supply. All of these high - speed electrons are gathered and shaped into an electron beam with a cross - sectional area less than 0.05 - millimeter square using a magnetic lens or a deflector [7].

2.5 Process of Water Jet Machining (WJM):

The pressure energy in the extremely high - pressure water is changed into velocity energy or kinetic energy as it travels through the convergent nozzle. Due to this, water is shot out of the nozzle at a speed that is thought to be between 200 and 400 meters per second. The continuous impact load is acting on the workpiece as this high - velocity water jet strikes it. Therefore, plastic deformation and fracture will occur in highly soft materials. As can be seen from the foregoing, the mechanism of material removal is a process known as etching that results from plastic deformation and fracture.

2.6 Machining Composite Materials using an Abrasive Water Jet

It is interesting that the advanced water jet machining technique uses abrasives as a medium. Below is a thorough explanation of the abrasive water jet machine. The abrasive particles will be added to the water such that they also emerge from the nozzle at a very high velocity, so overcoming the second drawback of water jet machining. The ideal range for abrasives will therefore be between 40 and 60 percent. Surface roughness (Ra) and slit taper ratio (TR) of an aramid fiber reinforced polymer composite were examined as a function of abrasive water jetting (AWJM) process variables by M. An empirical study was undertaken by A. Azmir et al. The Taguchi method and analysis of variance were used to optimize the AWJM process parameters (ANOVA). They found that, in terms of impacting Ra quality standards, bypass rate was regarded as being more significant than hydraulic pressure. The standoff distance in the case of (TR) had the greatest influence on traversal rate. Additionally, it was confirmed that the chosen (AWJM) parameter combination meets the actual requirements for machining (AFRP) composites in practice. The efficiency of head - oscillating oscillation and regular cutting of (GFRP) composite materials was compared by E. Lemma et al. [9] in their comparative study. Comparing the findings reveals that the head oscillation approach significantly improves the quality of surfaces compared to traditional (AWJ) cutting up to 20% improvement in surface quality, in several of the samples, measured by Ra values, was seen. In their investigation into the AWJ polycrystalline diamond's cutting properties, D. A. Aluminum oxide (Al2O3), silicon carbide (Sic), and diamond were used by Accente et al (PCD). The feed speed (pump pressure, standoff distance, and abrasive volume) was modified to provide full jet penetration of each type of abrasive while maintaining specific operational parameters. It has been demonstrated that the use of various abrasives significantly impacts the rates of material removal and nozzle wear ratios, which affect the kerf quality (width, taper angle) of diamond cutting surfaces. We treated two separate composite materials: glassy epoxy and pre - impregnated graphite woven cloth. Shanmugam and others. [11] Research into the slit taper angle, a cutting performance parameter produced by abrasive water jet (AWJ) technology, for the processing of two different types of composite materials, epoxy pre - impregnated graphite woven fabric and epoxy glass. Increasing water pressure causes kerf taper angles to drop within the defined working range, whereas increasing standoff distance causes kerf taper angles to rise by (2 to 5 mm). When the abrasive mass flow rate increases, the kerf taper angle seems to hardly alter at all. When utilized as a practical guide, the model has been validated and proved to conform with the tests. An approach to determine the maximum depth of cut utilizing various process parameters for various kinds of materials was developed by A. E1 - Domiaty et al. [12]. Without the need of many empirical constants, the suggested model can determine the maximum cutting depth that can be obtained in a particular material with a given set of process parameters. The shape of the notch is the only presumption in this model. For this premise to be true, we must know the radius of the slit along which the abrasive water jet is projected. LM Hlava et al. [13] calculate the angle of divergence between the plan's tangent and the impinging abrasive water jet's axis and utilize that information to forecast a model. The declination angles on the cutting wall images are calculated using Corel Draw TM. The software algorithm for quality control during abrasive waterjet cutting can use the discovered pattern. J. Based on an experimental examination, Wang [14] investigated abrasive water jet cutting of polymer matrix composites. It has been demonstrated that abrasive waterjet cutting technology is an excellent and efficient substitute for processing polymer matrix composites, with good yield and top - notch quality.

2.7 Laser Machining of Composite Materials

When a laser beam provides power, it emits electromagnetic waves of extremely high intensity in the shape of a beam known as a laser beam, whose wavelength ranges from (0.1 to 70) micrometers. The electromagnetic wave energy is transformed into heat energy when this high - intensity electromagnetic wave beam strikes the workpiece based on the surface phenomena radiation heat transfer. A. Sina et almodel. 's [15] was developed to forecast the slit width at entry and exit, material removal rate, and energy transmitted via the cutting slit while laser cutting composite materials. To find out how cutting parameters affect cut quality and to compare the outcomes to predictions, experiments were conducted using various laser and material combinations. The facts gathered reveal astounding agreement. I used three polymeric materials: polypropylene (PP), polycarbonate (PC), and polymethyl methacrylate. Consideration was given to using carbon dioxide laser cutting by Chowdhury et al (PMMA). We investigated the heat affected zone (HAZ), surface roughness, and dimensional accuracy of the output quality. The response surface method was used to create predictive models (RSM). Utilizing analysis of variance, first - order response models for HAZ and surface roughness were presented (ANOVA). It was discovered that a linear function of the input parameters can adequately explain the response. Calculating the gap between the notional value and the real value allowed researchers to evaluate the dimensional accuracy of laser cutting on polymers. According to the study, PMMA, PC, and PP all had the least

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HAZ. PMMA has better cut edge surface quality than acrylic in terms of surface roughness (PP and PC). Z. L. Li and others. [17] examined the CFRP effectiveness of a solid - state, diode - pumped UV laser (DPSS). The outcomes demonstrate that the CFRP composite can be sliced with a short - pulse UV laser with a low HAZ (50 lm). F. Three thermoplastic polymers, polyethylene (PE), polypropylene (PP), and polycarbonate (PC), were sliced using a carbon dioxide laser by Caiazzo et al. [18] in a range of thicknesses from (2 to 10 mm). Sample thickness, cutting speed, focusing lens type, gas pressure, and flow were the process variables that were looked at. As a result, the authors gave the three polymers under investigation the following "scores": medium PP, low PE, and high PC. Ming - Fei Chen, et al. [19] studied the effects of a number of laser cutting parameters, including auxiliary gas flow rate, pulse repetition frequency, cutting speed, and focus position, in order to enhance the product's optical transmittance ratio and surface roughness. An orthogonal matrix was used as the foundation for nine tests. The results show that the auxiliary gas flow rate of 20 NL/min, pulse repetition frequency of 5 kHz, cutting speed of 2 mm/sec, and laser focus position of 0 mm are the best process parameters. Additionally, it was discovered that the auxiliary gas flow rate had the biggest impact of all the properties. Design of Experiments (DOE) methodology was used by H. A method for choosing process parameters for laser cutting MDF is provided by El - Touhani et al. [20]. MDF board of three different thicknesses was cut using an ACO_2 laser (4, 6 and 9 mm). Laser power, cutting speed, air pressure, and pivot point placement are taken into account as process variables. The upper notch width, lower notch width, upper notch width to lower notch width ratio, roughness of the cut portion, and operating cost were all measured to assess the cutting quality. D. K. uses abrasive water jet, regular water jet, and laser cutting. To examine the surface roughness and crack characteristics of various materials, including carbon composite and fiber reinforced polymers, Shanmugam et al. The findings demonstrate the potential value of various tactics. In spite of the fact that abrasive water jet cutting offers a better cut than the other two techniques, all three seem to be reasonably useful.

3. Conclusions

This study made it obvious that there are two types of machining that can be used on composite materials: conventional or traditional machining and non - conventional or non - traditional machining. However, some areas still require more clarification. There is still considerable work to be done in this field because glass - fibre - reinforced polyester composites have received less research attention than other fiber - reinforced composites. Surface distortion, fiber/resin withdrawal, lack of roundness, dimensional accuracy, and insufficient surface roughness of the hole wall are the main issues with the quality of machining holes.

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