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Water jet guided laser cutting of carbon fibre reinforced polymer

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Abstract

Across the last few years there has been a growing interest in the exploitation of carbon fibre reinforced polymer (CFRP). This composite material consists of a resin matrix and carbon fibre reinforcement. The differences present between the thermal and physical properties of the matrix and fibre, and the materials high melting temperature, can cause difficulties when laser machining. Laser machining is also typically associated with thermal damage, as it relies on a thermal based process to remove material, and taper, due to the convergent-divergent nature of the laser beam. These limitations can be overcome through utilisation of a water jet guided laser.
This paper investigates the basic characteristics of water jet guided laser cutting of CFRP, using a high-power laser with an average power of 400 W. Experimental trials were performed to understand the effect of different process parameters on the cut quality and overall cutting speed.

Keywords: Water jet guided laser; CFRP; cutting

1. Introduction

Carbon fibre reinforced polymer (CFRP) composite consists of a resin matrix with carbon fibre reinforcement. It is widely used across the aerospace and automotive industries for structural components. It has a high strength-to-weight ratio, resulting in improvements in fuel economy and reductions in emissions compared to using metal-based materials.

Milling and abrasive water jet cutting (Faraz et al., 2009; Folkes, 2009) are the current state-of-the-art methods used to process CFRP. Milling has a quicker material removal rate compared to abrasive water jet

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cutting, however, tool wear and heat generation are common during CFRP milling, resulting in defects such as delamination and de-bonding. Tool wear and heat generation can be eliminated via abrasive water jet cutting. However, delamination still occurs using this process.

The water jet guided laser (WJGL) offers an alternative method for processing CFRP. Fig.1 shows a schematic of the WJGL. A pressurised water jet guides a laser beam through total internal reflection to the workpiece. This technique offers many benefits over traditional laser processing. The water jet creates a cylindrical beam, which produces parallel kerfs, eliminating taper. It also extends the laser beam working distance, allowing the WJGL head to remain at a constant distance to the material surface during processing. The continuous application of water cools the material during processing, reducing thermal damage.

This research uses a WJGL to cut through 6 mm thick CFRP to investigate the overall cutting speed and quality that can be obtained.

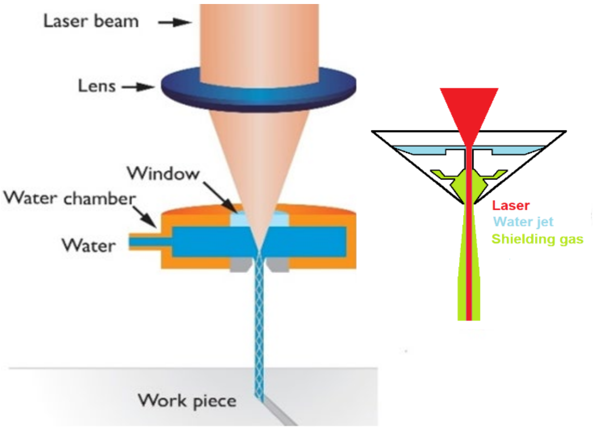

Fig. 1. Schematic of the water jet guided laser.

2. Methods and Materials

A Synova LCS305 system, fitted with a 532 nm Q-switched diode pumped solid state laser with maximum average power of 400 W was used for this work. The effect of water jet pressure and average power on the cutting speed and process-affected-zone (PAZ) were investigated in this study through performing linear cuts through the material. This was done using a bi-directional scan strategy with multiple passes. To obtain the cutting speed the time to achieve total material breakthrough was recorded for each cut.

3. Results

Both cutting speed and PAZ are increased when increasing water jet pressure (Fig.2). The increase in cutting speed is due to a higher water jet pressure improving the efficiency of molten material removal. The increase in PAZ occurs as the greater force induced by the water jet pressure causes a greater volume of the fibres which are aligned parallel to the cut length to be fractured and removed.

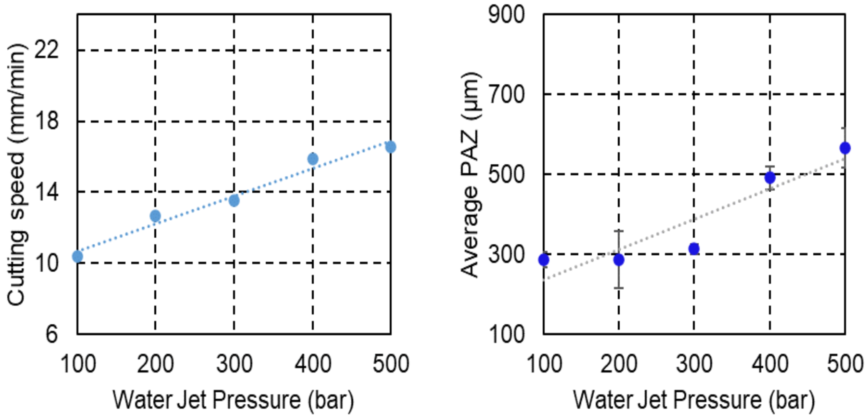

Fig. 2. Effect of water jet pressure on cutting performance.

Increasing average power resulted in increased to both the cutting speed and the PAZ (Fig.3). This is attributed to the increased peak power that occurs when average power is increased through changing the pulse energy, whilst maintaining a constant frequency. Material melting and ejection are promoted by the increase in peak power, thus increasing the cutting speed. This also increases the thermal input into the material, which in turn increases the volume of thermally affected material which is susceptible to removal via the pressure of the water jet, increasing the PAZ.

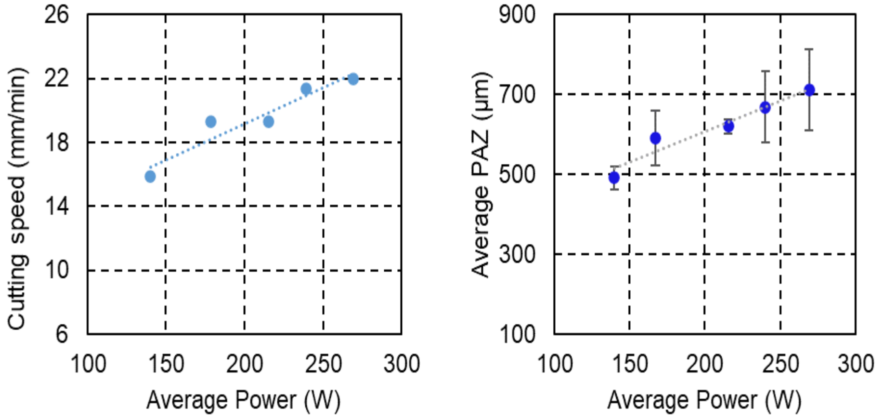

Fig. 3. Effect of water jet pressure on cutting performance.

4. Summary

In this paper, a systemic investigation was performed to understand the characteristics of WJGL cutting of 6 mm thick CFRP. The WJGL is beneficial for reducing the thermal damage typically associated with conventional laser processing. For the ranges used within this work, water jet pressure and average power were key in determining the overall cutting speed and PAZ for WJGL cutting of 6 mm thick CFRP.

Acknowledgements

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