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Experimental Investigation and Parameter Optimization of Low Power CO_2 Laser Cutting of a Carbon/Kevlar Fibre-reinforced Hybrid Composite

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To overcome the limitations of a singular fibre-reinforcement composite, a number of hybrid composites have been developed consisting of two or more different types of fibres in a common matrix. With the correct combination of dissimilar fibres, a variation of hybrid composite can be obtained possessing improved physical and thermal properties which is previously not possible with a single kind of reinforcement. The use of powerful lasers (several kW) in the cutting of composites is fairly widespread so as to overcome challenges regarding the anisotropic properties of these materials, but at the expense of a large heat affected zone (HAZ), kerf width, and fibre pull-out. The primary aim of this paper is to investigate low-power CO_2 laser cutting of a carbon/Kevlar fibre-reinforced hybrid composite. Response surface methodology (RSM) along with Box-Behnken design (BBD) was employed to understand the interactions between the process parameters, such as laser power, cutting speed and standoff distance (SOD), and their effects on the cut quality characteristics including size of the HAZ and kerf characteristics. Following this, process parameter optimization was successfully carried out using ANOVA to minimize the HAZ and kerf width. Qualitative measurement using a scanning electron microscope (SEM) was performed to evaluate the effects of process parameters and fibre orientation on fibre pull-out, HAZ and material decomposition. Difference between the thermal properties of carbon fibres, Kevlar fibres and polymer matrix (epoxy) was found to influence HAZ and kerf width. High thermal conductivity of carbon fibres particularly led to large extent of matrix recession and burning of Kevlar fibres around the cut path.

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1 INTRODUCTION

The increase use of products made of different composites is growing dramatically in many industries such as aerospace, shipbuilding, automotive parts, pollution control accessories, building materials and electrical components. In comparison to metals, fibre reinforced composites have excellent corrosion resistance and relatively high specific strength and stiffness. Major constituents in a fibre reinforced composite material are the reinforcing fibres and a matrix in which the latter acts as a binder for the fibres. Fibres are usually lightweight, stiff, and strong which provide most of the stiffness and strength of the composites. The polymer matrix binds the fibres together and transfers the load to reinforced fibres [1]. In general, composites are highly anisotropic depending on reinforcing fibre, matrix (binder) and fibre orientation. Figure 1 shows general classification of composites based on types of reinforcement and matrix. Well-known type of fibre composites include carbon fibre-reinforced polymer (CFRP), glass fibre reinforced polymer (GFRP) and Kevlar fibre-reinforced polymer (KFRP). Each composite is formed through combination of a specific fibre (carbon or glass or Kevlar) and a thermoset/thermoplastic matrix.

Among the advantages of CFRP are high tensile strength-to-weight ratio, high tensile modulus-to-weight ratio, very low coefficient of linear thermal expansion, high fatigue strength, and high thermal conductivity. Due to inherent brittleness of carbon fibres, CFRP is vulnerable to impact damage [2]. On the other hand, low elongation and fragility of carbon fibres can be compensated by Kevlar fibres [3]. Scientifically known as crystalline aromatic polyamide fibres, Kevlar fibre is five times better than steel in terms of strength per unit weight basis with reasonably high temperature resistance and corrosion resistance [4]. For this reason, KFRP is widely utilized as lightweight armour structures in applications ranging from personal body armours to

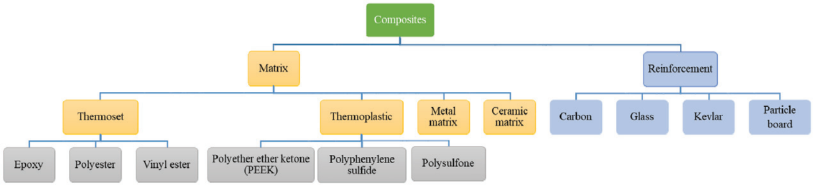

FIGURE 1
Classification of composites based on matrix and fibres.