Influence of Workpiece Thickness and Cutting Speed to Kerf Shape and Stria Formation in Laser Cutting of Acrylic Resin Plate

K. Saifullah M.R. Sofian M Tasyrif A.S. Fathinul-Syahir I. Ishak
School of Mechatronic Engineering, Universiti Malaysia Perlis,01000 Kangar, Perlis, Malaysia
Email: saifullah@unimap.edu.my

Abstract- **In laser cutting process, the main factor to decide a maximum cutting speed and maximum thickness of a material is the laser power itself. Besides that, various factors such as process parameter, optical effect on a material and the material thermal characteristic also complicates the problem to decide maximum cutting speed and maximum thickness of a plate. In this experiment, formation process of a kerf by laser cutting was examined from the viewpoint of the heat input based on observing the laser cutting part of acrylic resin plate.**

Keywords: **Laser cutting, Shape of kerf, Acrylic resin plate, Focal length, Cutting speed**

I. INTRODUCTION

Laser cutting is one of the important applications of laser machining process. For metal cutting process, gas is used to assist cutting operation; assisting gas can be reactive or inert depending on the process requirements. For acrylic resin, it is not necessary to use assisting gas during cutting process. Through laser cutting, acrylic is cut by evaporative removal. High energy laser beam pointed to the workpiece surface will cause the temperature of the material increase rapidly, resulting the material to convert from solid to gaseous state.

In laser cutting, the end product quality matters. The to oscillation in laser output power, material impurities and workpiece cutting speed result in instabilities associated with molten layer in kerf. This, in turn, causes striation formation and out of flatness at the cutting edges. The striation can be characterized geometrically by dross height and stria frequency [1]. Investigation into stria characteristics is necessary for improved laser cutting process.

Considerable research studies have been carried out to examine laser cutting process. The influence of surface plasma on laser cutting was studied earlier [2], [3], [4], [5], [6] and [7] and penetration time during laser cutting process was examined by Yilbas et al. [8]. The quality improvements for laser machining operation were considered by Pietro et al. [9]. They indicated that the process manipulation could lead to significant quality improvements. Laser cutting of fibre reinforced plastic composite materials was considered by Cenna [10]. He compared the predictions with experimental results and indicated that they were in good agreement.

In laser cutting process, there are other factors that affect the end product quality. Some of these factors include the focus setting of focusing lens and the workpiece thickness. The focus setting modifies the power distribution across the focused spot while thickness alters the energy required for full-depth penetration cutting. In the present study laser cutting of acrylic resin at different focal length of lens and different workpiece thicknesses are considered. The different kerf sizes and striation patterns are identified and repeated.

II.EXPERIMENT METHOD

Acrylic board of 2, 4 and 6 mm thickness were cut using carbon dioxide laser (CW) set at constant power of 1kW. Acrylic board being very efficient in absorbing carbon dioxide laser power and its thermal conductivity is being smaller. The energy loss during cutting process by the laser beam reflection and the heat transmission etc. is assumed to be very small. Laser power was set constant 1kW. The maximum cutting speed able to cut acrylic board (critical cutting speed) was quantified. When the cutting speed is faster than critical cutting speed, then a kerf shape is formed. This kerf forming physical process was investigated. ZnSe made condenser lens of focal length 127, 245 and 508mm was used in the experiment.

III. RESULT AND DISSCUSSION

3.1 Critical Cutting Speed

Fig.1(a) shows the influence of acrylic board thickness on the critical cutting speed. The critical cutting speed decreases as acrylic board thickness increases. Moreover, the use of the lens decreases the cutting speed at all board thickness increases. Since the laser power output was set constant, the reciprocal of the cutting speed is the energy necessitated in cut one unit of length. This minimum necessary energy (critical heat input) is shown in Fig.1 (b). The critical heat input increases as board thickness and the focal length of the lens increases.

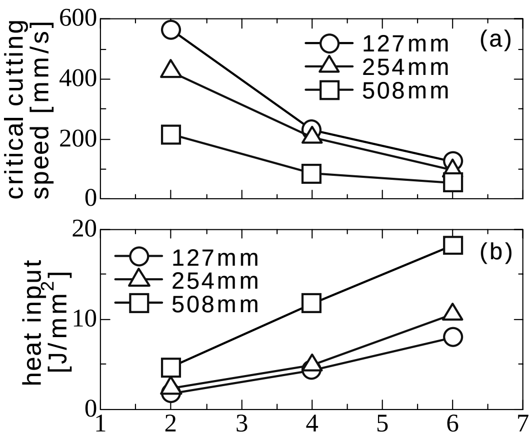


Fig.1 Influence of the critical cuttingspeed and heat input on plate thickness

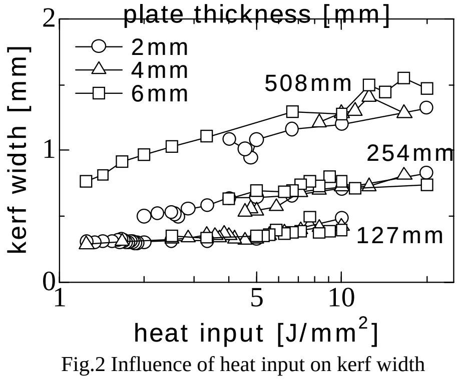


Fig.2 Influence of heat input on kerf width

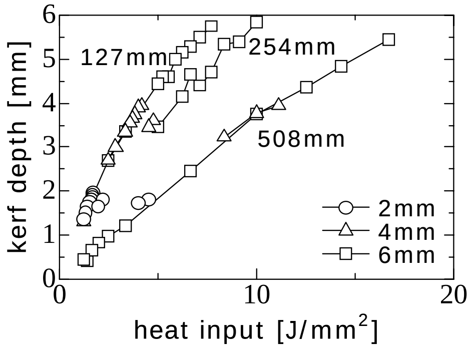


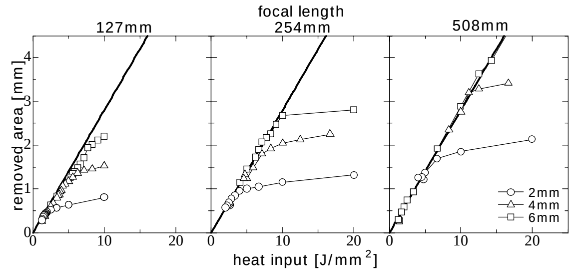
Fig.3 Influence of heat input on kerf depth

3.2 Cross Section of Kerf Shape

If only the irradiated laser energy increases the depth of the kerf, the ciritical heat input is increases directly in proportion to the board thickness. Or, if the kerfs cross section grows by the similar figure, the critical heat input must be proportional to the square of board thickness. It is understood that actual measurements are in between these two above cases as shown in Fig.1 (b). It's believed that the influence of board thickness that causes it for the critical heat input is controlled by the shape of kerf cross section.

Fig.2 shows the change in the width of the kerf entrance when the heat input or the cutting rate is changed. The width of the kerf entrance doesn't depend on board thickness and remains almost constant for the same lens. As the heat input increases, some of kerf entrance width also increases. The width of the entrance increases almost in proportion to the focal length when the focal distance of the lens increases. However, the depth of the kerf increases as the heat input increases but the increase is far larger compared with the case of the width of the kerf entrance as shown in Fig.3. Size of kerf cross section increases when the heat input and the focal length increase.

Next, the results of the measurement of cross sectional areas in the kerf cross section are shown in Fig.4. This sectional area shows the amount of the acrylic material removed through evaporation process caused by the laser irradiation. This area increased in proportion to an increment of the heat input. The constant of proportion almost remains unvarying at 0.28mm^3/J although there are variations of the focal length of the lens and board thickness. In other words, energy required to remove the acrylic material per unit volume was3.6J/mm^3. After the depth of the kerf reaching board thickness, the efficiency of the laser energy to remove acrylic material decreases, so that cross sectional area comes off the proportion limit substantially as shown by thick line in the figure.



CONCLUSIONS

Some of the advantages in laser cutting of acrylic resin plate are that the cutting process has small laser reflection and there is little heat loss in heat transfer. From the experiment results, the following conclusions may be brawn:

a. Even though the groove geometry (kerf shape) was different due to the significant changes of focal length for lens, to remove the material per unit volume would require same amount of energy.
b. The influence of the focal length on the kerf entrance width is noticeable whereas the influence of heat input on it was very small.
c. For larger focal length of the lens, the depth of the kerf is almost directly proportional to the heat input, but for the shorter focal length there have gap from the proportional to heat input. The gap is caused from the proportion in a focal length and short lens.

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