STUDY ON THE LASER CUTTING QUALITY OF ULTRA HIGH STRENGTH STEEL

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ABSTRACT

Ultra High Strength Steel (UHSS) has been used in vehicle as it able to improved durability of the vehicle while reducing the mass. Laser cutting process has been an alternative choice in trimming of the UHSS to regain the final shape. This study is intended to study the effect of input parameters of Carbon Dioxide (CO₂) laser cutting on the UHSS, focusing on the cutting quality and mechanical properties. CO₂ laser cutting machine was used to perform the cutting process. Kerf width, taper angle and Heat Affected Zone (HAZ) region were evaluated as the cutting quality with variation on laser power, cutting speed and assisted gas pressure. Result shows that power intensity at focusing point reflecting the outcome on cutting quality. Apparently, gas pressure does not greatly influence in determining the cutting quality.

Keywords: 22MnB5; Carbon Dioxide laser; kerf width; heat affected zone.

INTRODUCTION

Development of new material in automotive sector has been evolving rapidly especially on weight reduction. UHSS has been introduced to fulfill the requirements needed on current vehicle as its offer better mechanical properties. Formed by the hot press forming, the mechanical properties of the material itself have increased and common stamping process unable to trim the side edge of the material.

Laser cutting has been an alternative choice in trimming the parts into final shape. Among all type of laser, Nd:YAG and CO₂ are most widely used in laser beam machining application. CO₂ has a longer wavelength that is 10.6µm and produce better efficiency and good beam quality. It is suitable for fine cutting of sheet metal at high speed[1]. Laser cutting process and cut quality depend upon proper selection of laser parameters and workpiece parameter [2, 3]. Lamikiz et al. [4] has made the research on Advanced High Strength Steel (AHSS) and conclude that the kerf width size is resulted from selection of laser power and cutting speed.

Laser power is an essential parameter in cutting process. It requires sufficient amount of power to heat up the material before penetrate and cutting process completed.
Chen [5] reported that cutting quality and performance depend on the laser power. 80% of the researcher were using power as the main input parameters has shown the impact of laser power in determining the cutting quality [6]. Hasc [7] concluded that laser power contributes about 26% of the kerf taper compared to cutting speed. The kerf formation also increase as bigger laser power were used and this effecting the surface quality of the cutting materials [2, 8, 9].

Cutting speed is considered as a main input parameter in laser cutting process. It posses the effect of power intensity on laser beam. Radovanovic [6] reported that 86% of CO₂ laser cutting research has include cutting speed as the main input parameters. Decrement of cutting speed is needed a the thickness of material increased [10, 11]. Besides that, as the cutting speed increase, kerf width, hardness and HAZ region will decrease. [2, 4, 7–9].

Lack of research on type of assisted gas compared to other input parameters. Nitrogen gas is needed to expel the molten material without allowing it drops on the underside. Chen [5] reported that nitrogen gas was able to improve the cutting quality compared to oxygen. Therefore this project was conducted to evaluate the cutting performance of CO₂ with the aid of nitrogen gas.

**EXPERIMENTAL SET UP**

This study was conducted to evaluate the laser cutting quality of UHSS on two aspects namely dimensional accuracy and surface integrity. On dimensional accuracy, top kerf width, bottom kerf and taper angle were evaluated based on the parameters setting. Meanwhile, in terms of surface integrity, heat affected zone (HAZ) was evaluated.

Table 1 shows the selected process parameters to cut the 22MnB5 steel. Three input parameters were manipulated with three level for each parameters. In this experiment, the nozzle gap and laser focus distance were kept constant at 1 mm from the top of the workpiece surface. Table 2 shows the mechanical properties of 22MnB5.

<table>
<thead>
<tr>
<th>Factors</th>
<th>Material thickness = 1.7mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parameters</td>
<td>Units</td>
</tr>
<tr>
<td>Laser power, ( P_{\text{avg}} )</td>
<td>W</td>
</tr>
<tr>
<td>Cutting Speed, ( V_c )</td>
<td>mm/min</td>
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<tr>
<td>Gas pressure</td>
<td>MPa</td>
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</tbody>
</table>

| Table 2 : Mechanical properties of 22MnB5 [12]. |
|-------------------------|-----------------|-----------------|---------------------|-----------------|
| Martensite temperature  | Yield stress (MPa) | Tensile strength (MPa) | Elongation \( \% \) | Hardness Hv |
| (°C)                   | Original | Hot Pressed | Original | Hot Pressed |                       |                      |
| 410                    | 457      | 1010        | 608      | 1478        | 6                     | 520                  |

Figure 1 shows the set up of workpiece on the laser machine. The K-type thermocouple wires were attached at each cutting path to record the material surface temperature during cutting process. The thermocouples were connected to the data
logger to record the temperature data. To ensure the formation of kerf width is remains constant, the gap of 5 mm was set. The cutting process was conducted until it reaches the cutting distance of 20 mm.

The MITUTOYO TM 505 microscope was used to capture the top and bottom kerf as well as the taper angle. Detail of the measurement was illustrated in Figure 2. Furthermore, the region of HAZ was measured using OLYMPUS STM6 microscope. The samples were prepared and etched using 2% Nital for 5 seconds.

![Experimental setup](image1.png)

**Figure 1**: Experimental setup.

![Kerf width and taper angle](image2.png)

**Figure 2**: Kerf width and taper angle.

**RESULTS AND DISCUSSION**

**Kerf width**

Top kerf and bottom kerf were evaluated and early conclusion has found that assisted gas is crucial in determining the kerf width formation. It was found that the kerf was unable to form without assisted gas due to lack of cutting catalyst. Chen [5] also concluded that suitable gas is needed to determine the cutting quality. Figure 3 shows
the width of kerf formation with variation on gas pressure. Positive correlation was observed between laser power and kerf formation meanwhile negative correlation occurred against the cutting speed. The effect of gas pressure on kerf formation is insignificant. This finding is well agreed with [2],[8] and [13] where they concluded that wider kerf width can be observed at the higher laser power with slower cutting speed. Effect of laser power can be seen greatly as the increment of laser power resulting wider kerf formation. Interaction between laser power and kerf in this study shows that laser power is proportionally interact with kerf formation. Contradict to laser power, cutting speed is inversely proportional with the kerf formation. Higher cutting speed mean less heat concentrated at workpiece surface as the laser beam is moving faster along desired profile. This resulting less thermal effect applied to the working material thus producing narrower kerf formation.

Figure 3 : Kerf formation.

**Taper angle**

Figure 4 shows the result of taper angle when cutting 22MnB5 steel. High laser power has a capability to reduce the taper angle formation where the heat applied able to penetrate fully down through the thickness of the working material. Higher laser power penetrate the material better hence wider kerf with less taper were formed. As a consequence, greater material removal rate obtained by increasing the laser power hence reducing the taper formation. High cutting speed mean that laser beam movement is faster thus less time were spend at single point location. Consequence from that, bigger
taper angle were formed at high cutting speed due to less energy input time and not been fully transmitted toward the thickness of working material. Assisted gas pressure was found to be one of the significant factors influencing taper angle formation. High pressure of gas especially nitrogen help to cooled down the cutting area faster thus preventing the molten metal to be flushed away from the cutting region. Relationship between each input parameters is contradict to kerf formation where increment of power density helps to reduce the taper. The previous authors [14], [7] and [15] concluded that by increasing the laser power while reducing the cutting speed will produce smaller taper ratio.

![Figure 4: Taper angle formation.](image)

HAZ region

Figure 5 shows the result of the formation of HAZ when cutting 22MnB5 steel. Laser power interacts proportionally with HAZ region where increment of laser power will produce greater HAZ region. Faster cutting speed requires less time consuming at specific area. The absorption rate is reduces thus weaken the HAZ formation. Even though the effect of gas pressure is not too significant, interaction between gas pressure and HAZ region has shown that it is proportionally related. Increasing the gas pressure will slightly increase the HAZ region due to the dross creation. The result shows that the HAZ region at the top kerf is slightly thinner and thicker along the material thickness. It was reported that HAZ formation increases from top to bottom and HAZ
region were transformed back gradually in layers [16]. Laser power interacts proportionally to HAZ region while negative interaction on cutting speed. In addition lower cutting speed and higher laser power produced thicker HAZ region [4], [8], [17]. Figure 6 illustrated the cross sectional view for HAZ region for 0.25MPa at the magnifying of 100X. Different colour tones with dark boundaries shows the HAZ region along the cutting edges.

Figure 5: HAZ region along the material thickness.
### CONCLUSIONS

This study was attempted to identify the relationship between input parameters and cutting quality of 22MnB5 steel. It is found that laser power and cutting speed were greatly influence the cutting quality and mechanical properties whereas the gas pressure doesn’t significantly influencing the output. Higher power density produces poor cutting quality. Furthermore, incomplete cutting was observed due to insufficient heat. Laser power plays an important roles followed by cutting speed and gas pressure. Relationship between kerf width and taper angle is found inversely proportional where widest kerf width will produce less taper angle. Meanwhile the selection of suitable input parameters are crucial in determining the best cutting quality and mechanical properties.

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### REFERENCES