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FOCUS POSITION INFLUENCE ON THE MOLTEN ZONE FOR LASER BEAM IRRADIATION OF STEEL PIECES

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Abstract: *For laser welding focal plane position relative to the workpiece surface generate special effects on the material melted zone. Focus effects were analyzed in relation to the power and welding speed. Characterization of fusion lines obtained with laser beam on the thick steel plates was performed for sizes measured for cross section through the piece and piece surface. It has been shown that the defocus produce significant variations in relation to the welding speed and to low level of power*

Key-words: *laser welding, steel, response surface, laser beam defocusing, melting*

1. INTRODUCTION

Research molten zone sizes obtained from the laser beam irradiation is important for choosing parameters for laser welding. The issue addressed in this paper is similar to that discussed in the following studies [1], [2] and [3]. Particular interest for variations caused by defocus on the weld characteristics was presented in the works [4], [5], [6]. In this studies laser beam was focus within the piece. Focusing the laser beam above piece was used in the work [7]. To characterize the welds linear energy was used as a parameter in the works [8] , [9], [12]. Showing welds characteristics by measured sizes and weld depth and weld width is of central importance. Classical variations for width and depth of the welds are shown in the works [10], [11]. The ratio between weld width and weld depth has been shown to work [8]. Weld cross-section molten zone area was presented in the paper [13]. Studies using factorial experimental plans were presented in the paper [16]. Efficiency of obtaining melt for welding process was analyzed in the works [13], [14], [15].

The present investigation is proposed for steel melting area. Characterize this area is done by characterizing surface weld sizes and quantities characterizing weld cross section and weld sizes characterizing surface. This is considered two different aspects of the production of molten, material that is melting, and melts movement.

Figure 1 Plate with fusion lines made

Among the parameters that intervene in the control of laser beam irradiation occurs important role plays defocus distance between the focal spot of the laser beam and workpiece surface. Focus of laser beam below the surface of the piece provide a form of convergent laser beam in the interaction zone with material and inside keyhole (cavity formed by evaporating material) and laser beam spot size increases by increasing the workpiece surface during the interaction between laser radiation and material. These effects of defocus increase the effect of material melting. On the other hand, focus the laser beam on the workpiece surface decreases the intensity of the laser beam to the workpiece surface. In this context it becomes important to analyze defocus effects compared to those of power and speed.

2. EXPERIMENTAL PROCEDURE

The experiment consisted in made lines of fusion (welds), 110 mm long, on Dillimax 500 steel plates with thickness of 10 mm (carbon steel, carbon content ≤ 0.16 %). Was used a Nd: YAG Trumph Haas 3006D laser source with 3kW maximum power on a continuous wave regime CW. Laser beam was transmitted through a optical fiber with core diameter of 0.6 mm, figure 1.

The focus system made a focal spot with 0.6 mm diameter. Lens focal length was 200 mm. As protective gas argon was used with a flow rate of 20 l min. Were used sheets of material with dimensions of $100 \times 130 \times 10$ mm for which were made between 5 and 8 welds, with a distance of over 10 mm between welds.

In experiment were varied the laser power, welding speed and distance between focal plane and piece surface (defocusing or defocusing depth), figure 2. Welds were cut in the stable part of the weld near the place where welding process was stopped. Weld section was processed metallographic. Weld width, near the piece surface w, and weld depth h were examined using a microscope with precision of 0.01 mm. Melted area MA was measured directly by its footprint.**.** Defocusing values are considered negative if the laser beam was focus inside the piece**.**

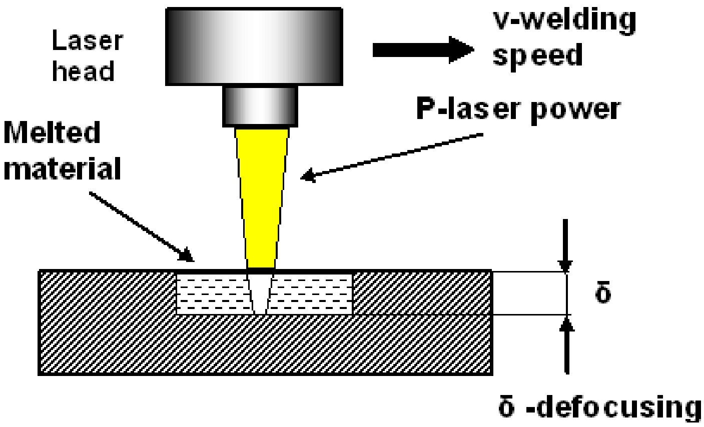

Figure 2 Experimental parameters for welding process

On the weld surface weld width l[mm] was measured as the average of several values for the beginning middle and end of the weld. For crater obtained at the end of the welding were measured crater area and deformation by relative variation obtained between crater axes.

Defocusing effects on diameter spot on the workpiece surface were determined experimentally.

3. ANALYZE OF VARIATIONS

Fusion lines (welds) were characterized by performed several sizes. These were measured on the weld surface and weld cross section.

Figure 3 shows the response surface for weld width w changes with defocus and power. It observes that defocusing produces variations only at low power values. In this case the laser beam focus inside the piece decreases the weld width. It is noted that on the experimental field weld width increases with power. At high power defocus increases the weld width is evidence of increasing laser radiation absorption in keyhole cavity.

Figure 4 shows the variation of weld width with welding speed and defocus. On the experimental field, weld width decreases with speed. For high welding speed weld width decreases with defocus. It looks like that the significant effect of defocusing weld width is decreasing intensity laser beam to the workpiece surface. This effect is emphasized by lowering the intensity of the laser beam on the workpiece surface by decreasing power or increasing speed.

Figure 5 shows the variation of weld depth with power and defocus. The experiment shows that the weld depth increases with power. Defocus does not produce variations.

Figure 6 shows the response surface for weld depth variation with welding speed and defocus. It is noted that on the experimental field weld depth decreases with defocus and welding speed. Defocus decrease is stronger at higher welding speed values. This variation shows that by focusing the laser beam inside the laser beam intensity decreases at workpiece surface. This decrease produces significant variation for speed increase.

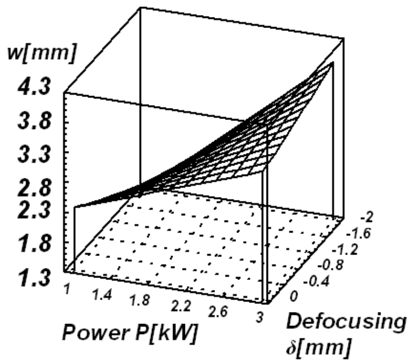

Figure 3 Response surface for weld width measured on weld cross-section with power and defocus

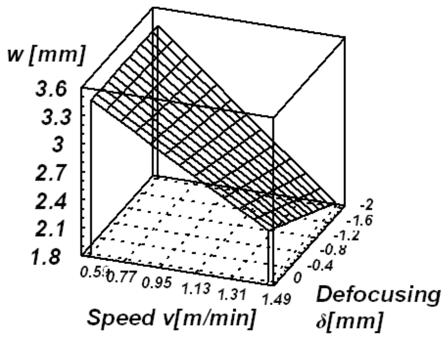

Figure 4 Response surface for weld width measured on weld cross-section with speed and defocus

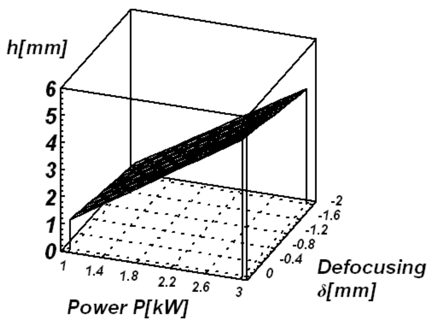

Figure 5 Response surface for weld depth with power and defocus

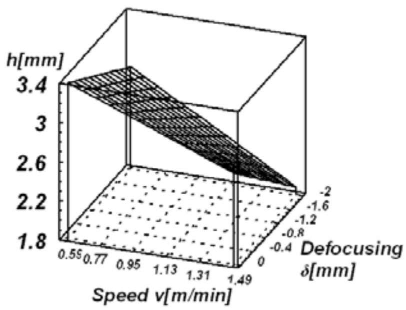

Figure 6 Response surface for weld depth, depending on the speed and defocus

F ratio (w/h) is defined as the ratio of the weld width and depth of the weld. Unit values for this ratio show the presence of keyhole welding regime. Figure 7 shows the variation of ratio F with power and defocus. It shows that on the experimental field F ratio decreases with power. There is a slight increase in the ratio F with defocus. This proves at least as a principle that by focusing the laser beam inside the piece achieve increased energy absorbed in keyhole cavity.

Figure 8 shows the variation of ratio F with defocus and speed. It is noted that at low welding speeds F ratio increases with defocus. It looks like that for laser beam defocusing within the piece increasing the laser beam spot on the workpiece surface and thus favors increasing the weld width against the weld depth. At high values of welding speed F ratio decreases with defocus. It looks like that in this situation where time interaction between laser radiation and the material is small by focusing the laser beam inside piece favoring the laser radiation absorption in the keyhole. On the experimental field welding speed increase ratio F for laser beam focus to the workpiece surface and decreases the ratio F for focus within the piece. This shows that the effect of high intensity is higher for melting the workpiece surface and the laser beam inside piece favors the keyhole welding regime.

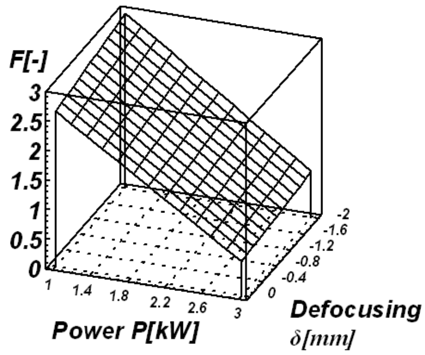

Figure 7 Response surface for ratio F, depending on power and defocus

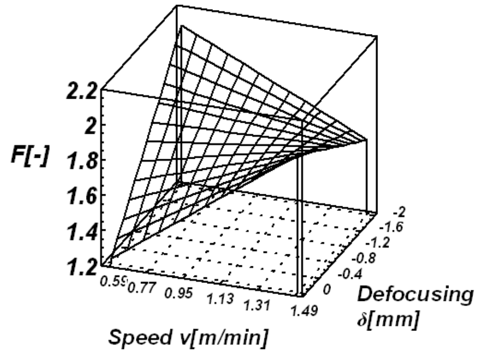

Figure 8 Response surface for ratio F, depending on speed and defocus

Figure 9 presents the variation of melted area with welding speed and defocus. It is noted that on the experimental field there is a increase for area melted area with power. Defocus does not cause significant variations on melted area. It shows the dependence of melt quantities by laser beam intensity obtained regardless of other other parameters.

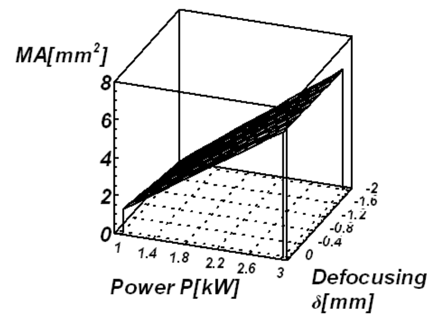

Figure 9 Response surface for melted area on weld cross-section with power and defocus

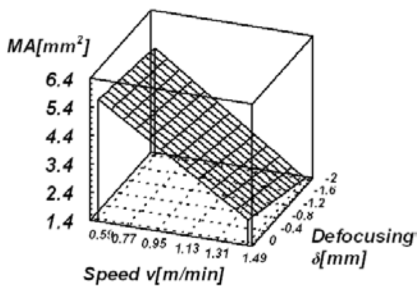

Figure 10 Response surface for melted area on weld cross-section with speed and defocus

Figure 10 shows the variation of the melted area depending on the welding speed and defocus. It is noted that lower level of welding speed produces high melted area. Defocus produces a weak effect. This is an effect of decreasing melt area. It looks like that defocus does not affect the expansion of the molten material area. This effect is emphasized increased absorption of radiation inside the keyhole.

Another set of quantities that characterize the melted material are obtained for the surface of the weld. Such the weld width L was measured for each weld for three points at the beginning, middle and final part of the weld and was considered the average. Crater at the end of the weld were measured dimensions and its area. Was calculated crater deformation.

Figure 11 shows the variation of weld width L with power and defocus. It is noted that on the experimental field weld width L increases with power. Defocus increases weld width at high power and decreases at low power .

Figure 12 shows the variation width L weld with welding speed and defocus. It is noted that on the experimental field weld width decreases with speed. Defocus produces little effect on the weld width. Small welding speed increases the defocus effect by increasing laser beam spot width on the workpiece surface. High welding speeds lowering defocus effect by decreasing the laser beam intensity for focusing piece inside.

Figure 13 shows the variation of crater area with power and defocus. It is noted that on the experimental field the crater area increases with power. Small variations are produce by defocused. At high powers is an increase of crater area with defocus. Crater area has a similar behavior with the weld width.

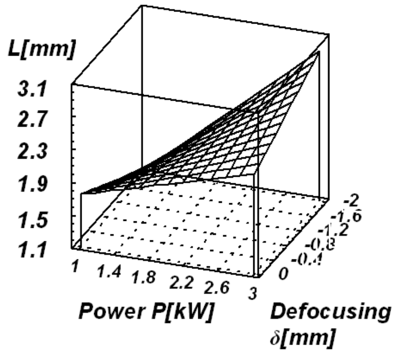

Figure 11 Response surface for average weld width L with power and defocus

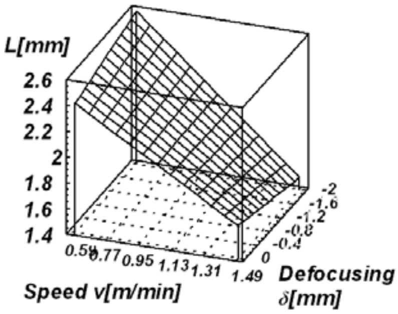

Figure 12 Response surface for average weld width L with speed and defocus

Figure 14 shows the variation of the crater area with welding speed and defocus. It is noted that in the experimental area of the crater increases welding speed. This variation is interpreted as a favor to obtaining melting material against vaporization. Defocus produces increase of crater area. This increase is stronger at low welding speeds. It looks like the effect of increasing the laser beam spot on the surface of the workpiece becomes important for crater area.

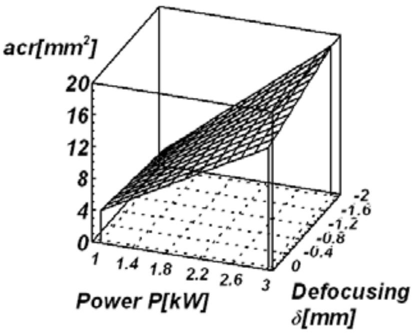

Figure 13 Response surface for crater with power and defocus

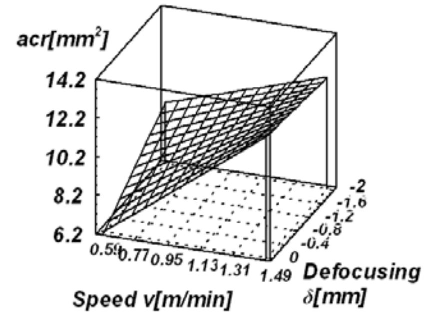

Figure 14 Response surface for crater area, with speed and defocus

Figure 15 shows the variation of crater deformation, depending on the power and defocus. It is noted that on the experimental field crater deformation increases with power. Defocus produces small variations of crater deformation. At high power is a decrease of crater deformation. This is due by a decrease in intensity laser beam to the workpiece surface.

Figure 16 is the variation of crater deformation with defocus and power. It is noted that on the experimental field crater deformation decreases with speed. Defocus produces a decrease for deformation at low welding speeds.

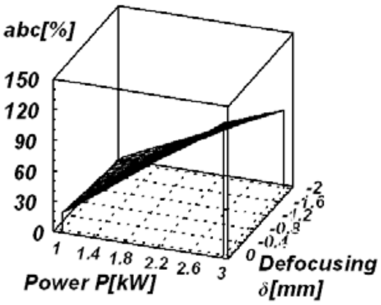

Figure 15 Response surface for crater deformation with power and defocus

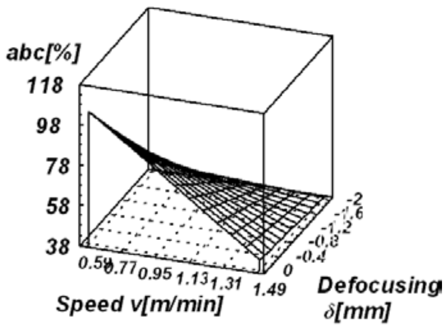

Figure 16 Response surface for crater deformation with speed and defocus

Through these variations shows that the deformation crater is depend by irradiation. This crater deformation increases with laser beam intensity and time of interaction between laser radiation and piece.

4. CONCLUSIONS

The paper analyzed defocusing effects for sizes characterizing weld surface and weld cross section. In relation to the work piece surface laser beam focus inside piece produce lower laser beam intensity and increases the interaction between laser and material. On the other hand, the focus in the interior of the piece increases the absorption of the laser beam by multiple reflections at the keyhole cavity walls. So, focus the laser beam produces different effects on weld characteristics. These effects were analyzed for a high number of quantities measured in different conditions. For sizes discussed were noted as follows:

- Defocusing effects are more powerful in relation to the welding speed than the power.
-Defocusing effects can be better highlighted the one dimensional sizes than those that came from the consideration of two dimensions (surface type).

- Variations presented showed that laser beam focus inside piece leading to the presence of keyhole welding regime.

The analysis is achieved as a result of the connection between varied parameters in laser welding and the steel melting due to laser beam irradiation.

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