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On the welding of austenitic/ferritic stainless steels by an High Power Diode Laser

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In technical literature there are few papers about the use of high power diode lasers in material processing, and particularly in metals welding. In this paper, two different stainless steels (AISI 304 and 430), according to specific and particular industrial needs and requests, have been tested with a welding process by an High Power Diode Laser (HPDL) emitting a 808 nm laser radiation. Beads on plate have been studied. The goal was to evaluate the maximum thickness to be welded and to define the best process parameters for each material. The experimental evaluation has been carried out considering the following parameters: power level, welding speed, shielding gas, gas nozzle and orientation of the focused elliptical spot as to the welding direction.

1. INTRODUCTION

Diode Lasers are widely used in different applications in which a milliwatt power range is required. With the coming of new technologies, diode lasers have reached power up to several watts and so they entered in industrial manufacturing sphere [1,2,3]. It has been noted that in comparison with other laser types, semiconductor lasers offer on of the best solutions available on the market as regards reduced sizes, lifetime and reliability [1,2,3,4]. The parameters that have the most impact on the performance and economics of every semiconductor laser application are output power, brightness and operating lifetime [2,3,4]. So that the key to the market growth has been a continuous improvement in all three ones. They have allowed a development of completely new applications, together with the increased performances (some hundreds of W as power output and 10,000 h at least of operating lifetime and maintenance [5,6]). So HPDL are assuming an interesting role in the industrial material processing [1,5].

2. EXPERIMENTAL SET-UP AND PARAMETERS

As laser source a FISBA DL 100 model, High Power Diode Laser (HPDL), with an high efficiency (about 50 %), an IBS (Individual Beam Shaping) system by Fisba Optik A G, emitting a 808 nm laser radiation and a 98W maximum output power level (16 to 98 W continuous range) has been employed. As focusing system, a 55 mm focal length borosilicate lens, located at a distance of 30mm from the work-piece (focus on the material surface), has been used. As workpiece moving system a X-Y-Z cruciform stepped motorized table, operating on a 0.14 to 2.5 m/min translating speed range, has been utilized. So, usually 12 different values from 0.14 to 2.5 m/min range of welding speeds and 7 different values from 16 to 98 W range (16, 33, 52, 67, 81 , 90 and 98 W) of laser power levels were adopted for the tests. Figure 1 shows a simple scheme of the experimental set-up. Every time, after each experimental welding test series, a visual inspection has followed and the best results have been then examined by a computerized imaging system. So that the most significant weld bead images and the relative magnification levels for each material tested have been stored. Finally, some cross–sections and metallographic tests have been carried out. The main scope of this experimental work was to test the possibility of welding different materials in very thin thickness, by operating with an HPDL laser source.

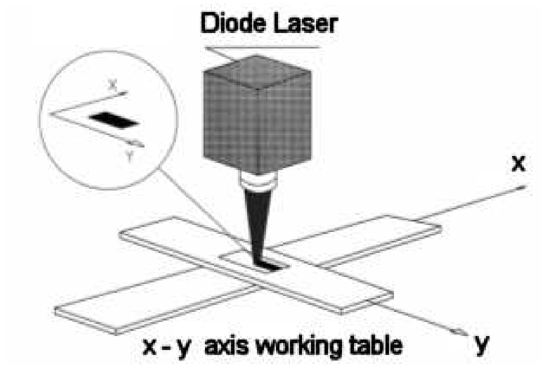

Fig. 1. Experimental set-up

2.1 Materials tested

The materials were selected according to specific and particular industrial needs and requests, so that the following ones were experimented:

- austenitic stainless steel sheets - AISI 304 - 0.40 mm thick
- ferritic stainless steel sheets - AISI 430 - 0.06 - 0.10 - 0.15 - 0.20 and 0.30 mm thick

3. RESULTS AND DISCUSSION

In the following paragraphs the most significant results and remarks together with the tables and the images, for each material, have been reported. For all the experiments, the orientation of the elliptical focused spot respect as to the welding direction has been fixed so that the short side of the spot “worked“ during the translation of the workpiece from left to right on Y moving table.

3 .1 AISI 430 : Ferritic Stainless Steel

This material doesn't present particular problems to be welded by this diode laser radiation (see Table 1). In figure 2 the welding speed versus laser power for different thicknesses is plotted. It has been possible to weld a 0.06 to 0.30 mm thickness range with a full penetration. The surface view of many bead crowns is very interesting and promising. It is interesting to underline that for the 0.06 mm thickness the melted width is only 0.6 mm large while for the 0.30 mm thickness the melted width is 1.6 mm large at 0.4 m/min and 98W power level. It has been possible to weld a 0.15 mm thickness with a full penetration. In figure 3, a macrograph of a 0.30 mm thick AISI 430 is represented, the melted width is 1.6 mm at 0.4 m/min and 98 W power level.

Table1.
AISI 430 – Process parameters for full penetration welds

Thickness	Current (A)	Power (W)	Welding Speed ($m \cdot min^{-1}$)	Melted Width (mm)	Lens-Workpiece Distance (mm)
0.06	13	81	2.50	0.65	30
0.06	11	67	1.50	0.54	30
0.06	9	52	1.25	0.75	30
0.06	7	33	0.62	0.60	30
0.10	15	98	1.50	0.96	30
0.10	13	81	1.25	0.97	30
0.10	9	52	0.62	0.90	30
0.15	15	98	1.00	1.03	30
0.15	15	98	0.87	1.15	30
0.15	11	67	0.50	1.08	30
0.15	11	67	0.50	1.22	30
0.20	15	98	0.62	0.96	30
0.20	13	81	0.40	1.87	30
0.20	12	72	0.37	1.36	30
0.30	15	98	0.40	1.60	30

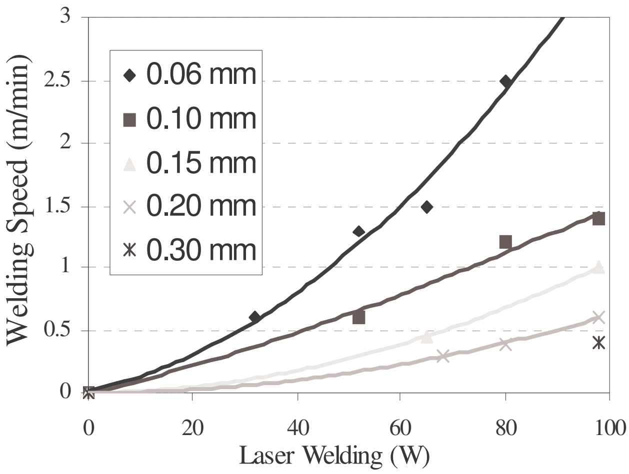

Figure 2. AISI 430 - Welding speed versus laser power for different thicknesses

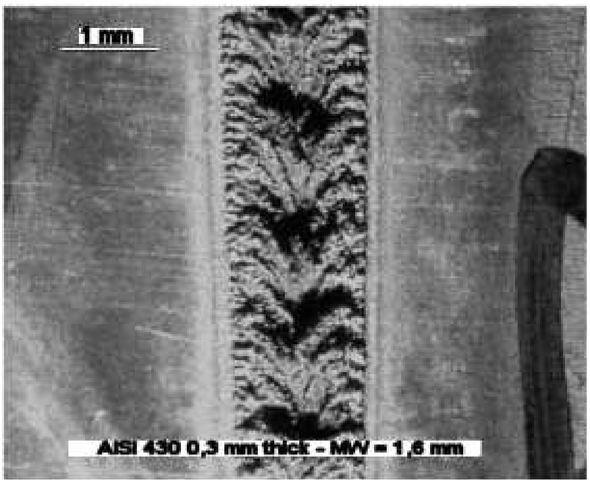

Figure 3. AISI 430 0.3 mm thick: macrograph at 0.4 m/min and 98 W power level

3.2 AISI 304 : Austenitic Stainless Steel

With different laser power levels, a speed range from 0.14 to 0.37 m/min has been tested, no melted zone has been produced and noted, even if the maximum power level (98W) and the minimum welding speed (0.14 m/min) have been used. It is possible to hypothesize that the problem is not the material and respective surface absorption but its "big" thickness (0.40 mm) compared with the available laser power levels. On the other hand, it hasn't been possible to have some thicknesses lower than 0.40 mm as normal supply.

4. CONCLUSIONS

For the AISI 304, an austenitic stainless steel, 0.40 mm thick, it hasn't been possible to weld by HPDL (98 w c.w. maximum power level); even if this last value of power was used and the minimum value of welding speed was imposed (0.14 m/ min). On the other hand the AISI 430, a ferritic material, doesn't present particular problems to be welded by this diode laser radiation. In fact, also the maximum thickness (0.30 mm) has been easily welded at 0.4 m/min and 98W. The above lets to think that the austenitic one is very difficult to be welded. In the light of their thermo-physical properties [7,8], as the AISI 304 has some lower conductivity and diffusivity properties compared with the AISI 430 and the laser welding process is clearly a typical conduction welding [7,8], it is evident that the limit is not the type of stainless steel but its thickness; that is, 0.40 mm for only 98W c.w. is an upper limit. So that, it should be useful to use an other HPDL with a 200 to 300 W c.w. laser power level but, keeping in mind that the welding process always remains a conduction one and the investment for HPDL source would be much more expensive in comparison with a CO_2 gas laser, in the end all this could be not economically correct. In conclusion it is possible to affirm that the HPDL welding process is convenient for restricted applications and thicknesses.

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