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THE EFFECT OF CHANGE IN WELDING SPEED IN LASER WELDING OF STAINLESS STEEL PIEZO INJECTOR PARTS ON WELD BEAD GEOMETRIES

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Laser welding, one of the untraditional joining techniques in manufacturing has taken place in the automotive and automotive supply industry. This method used by most automotive companies, has become more attractive since it provides low heat input, small HAZ (heat affected zone), high penetration, low distortion and high strength. Piezo injectors in gasoline motors are one of the applications of laser welding. In this study, Nd-YAG laser welding has been applied to stainless steel piezo injector parts and the change in welding speed parameter has been examined in terms of weld bead geometry.

Keywords: Laser welding, Piezo injectors, Stainless steel, Welding speed.

Introduction

Laser is the abbreviation of "light amplification by stimulated emission of radiation" words. It means the enhancing the intensity of light. Laser includes principles of constituting beam with same phase, amplitude and high power. Laser beams, which differ from other beams in this respect, are used in different fields of manufacturing industry.

Laser beam consists of very powerful beam rays. Therefore, the most important superiority of laser is its high power. Power density of laser is 10^3 W/cm^2 approximately and when this is compared to power density of sun light on earth's surface, which is 0.1 W/cm^2, laser's power could be understood [1].

There are a lot of parameters which affect laser welding. These parameters are laser power, focus position, spot size, process gas, material thickness, material type and material surface condition as well as welding speed, which will be further discussed in this paper. Welding speed parameter must be chosen with regard to material and welding process.

Karaaslan has researched the effect of changes in laser power and welding speed on penetration in Nd-YAG laser welding. He realized that penetration was higher with P=2000 W compared with P=1400 W. In addition, he reported that increase in welding speed yielded shallower penetration in both laser powers [2]. Durgutlu [3] has reported that when welding speed was increased it resulted in less heat input and therefore, it caused a decrease in base metal molten metal amount. Benyounisvd [4], has realized that when welding speed increased, penetration and HAZ decreased. Uzun and Keles [5] has found in their study that weld bead width decreased, in addition to increase in difference between surface and root widths, with the increase in welding speed. Researchers also realized that decrease in transition zone width with increasing welding speed. Gery, Long ve Maropoulos [6], has concluded that welding speed had considerable effects on weld bead geometry, molten zone and HAZ limits.

In this study, stainless steel piezo injector parts cylindrical in shape were laser welded with different welding speed parameter and effect of this parameter on weld bead geometry was inspected.

Material and Method

Materials used are X5CrNi18-8 austenitic stainless steel with 2 mm thickness and X4CrNiMo16-5-1 martensitic-austenitic stainless steel with 4.9 mm thickness. Weld bead macrographs (weld metal left and right regions taken at 2X) for different welding speeds were acquired with optical measurement. EDX analysis of materials is given in table 1 and laser welding parameters are given in table 2.

Table 1. EDX analysis for X5CrNi18-8 and X4CrNiMo16-5-1 stainless steels

	Chemical composition (% wt.)						
Material	**C**	**Si**	**Mn**	**Cr**	**Ni**	**Mo**	**Fe**
X5CrNi18-8	0.05	0.28	1.60	18.74	7.87	0.00	71.52
X4CrNiMo16-5-1	0.04	0.50	1.05	15.86	5.46	0.90	76.21

Table 2. Laser welding parameters

Laser Welding Parameters	**Setting**
Laser power	1 kW
Focus position	300 mm
Shielding gas	Nitrogen
Flow rate	5 $L.min^{-1}$
Welding speed	0.815 $m.min^{-1}$

Piezo injector parts have been welded with Trumpf Trudisk 1000 Nd-YAG laser welding machine. Optical positions are given as;

Focus position; X=2.00 mm; Y=2.00 mm; Z=2.00 mm

Gauge Blocks; X=12.02 mm; Y=11.68 mm; Z=13.4 mm

Piezo injector parts of stainless steel are cylindrical in shape and laser spot pulses to three points (120° between spots) have been realized in order to prevent axial misalignment. In experiments, only welding speed parameter in table 2 was changed.

Distance between bead width and middle of the root (NLF), bead width (NB) and penetration (EF) are given in figure 1. Tolerance values for stainless steel materials for safe weldability under normal conditions are given in table 3.

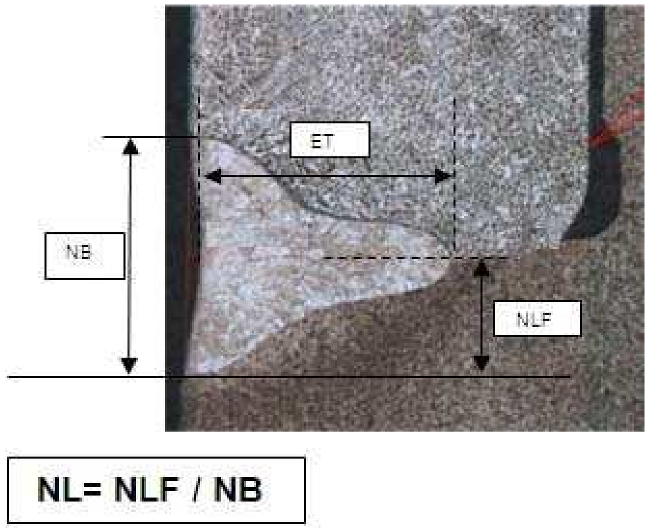

Figure 1. Notations shown in weld bead macrograph

Table 3. Laser welding tolerance values [7]

NOTATION	DEFINITION	TOLERANCE
NB	Bead width	0.75-1.05 [mm]
ET	Penetration	0.55-0.75 [mm]
NL	NLF / NB	0.40-0.60

In all experiments, it was shown that whether weld bead geometries were out of tolerance as a result of increasing weld speed.

Experimental Results

Welding speed under normal conditions was 0.815 $m.min^{-1}$ for laser welding of stainless steel piezo injector parts. Laser weld speed trials were realized with 10%, 20%, 30%, 40%, 50% and 100% increments to set welding speed. 100 specimens were welded for each trial condition.

Macrograph of weld bead obtained with 0.815 $m.min^{-1}$ welding speed is given in figure 2. When optical measurement values are compared with tolerance range, it can be seen safe welding was achieved.

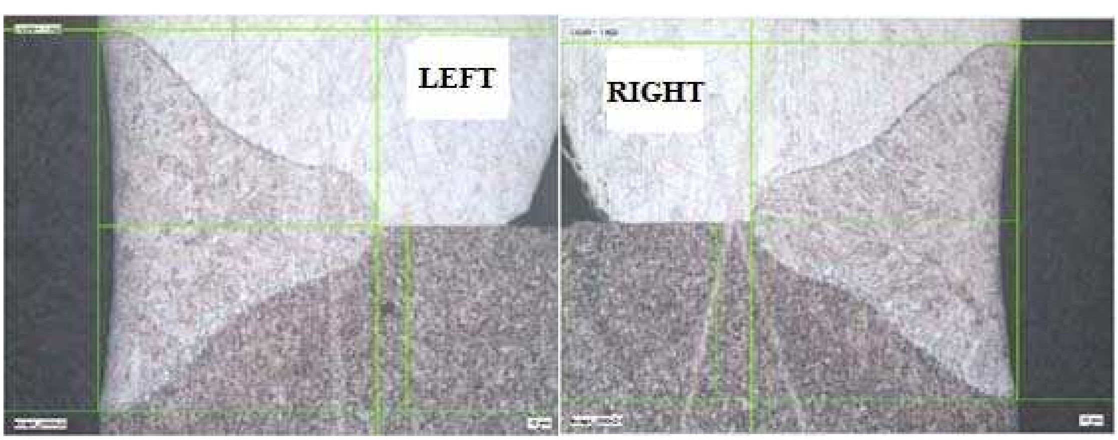

Figure 2. Left and right weld beads for 0.815 $m.min^{-1}$ welding speed

Welding speed was defined as 0.906 $m.min^{-1}$ after 10% increase in welding speed. It was observed 5 specimens deviated from tolerances with this speed. Penetration was out of tolerance for left and right weld beads. After welding with 20% increase in speed, 9 specimens were out of tolerances. Weld bead width in right weld bead was the only weld geometry parameter to be out of tolerances. 30% increase in speed, yielded 12 specimens to deviate from tolerances. Weld bead width in left and right weld beads was the weld geometry parameter to be out of tolerance. 23 specimens were noted to be out of tolerances with 40% increase in speed. Weld bead width in left and right weld beads was the weld geometry parameter to be out of tolerance. 50% increase in speed yielded 54 specimens to deviate from tolerances. Macrograph for left and right weld beads for one of the specimens welded with 50% increase in speed is shown in figure 3. Weld bead width in left and right weld beads was the weld geometry parameter to be out of tolerance.

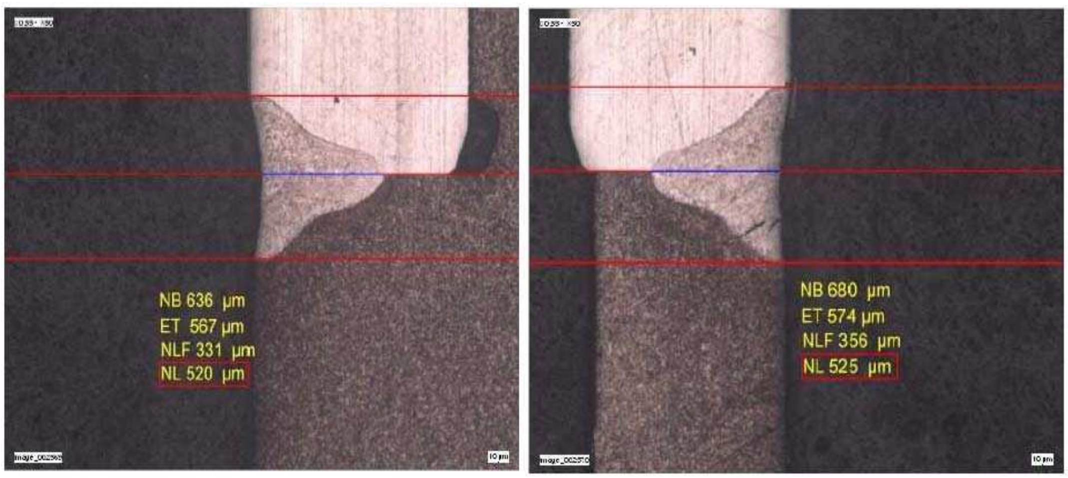

Figure 3. Left and right weld beads for 1.222 $m.min^{-1}$ welding speed

When welding speed doubled, it was observed 86 specimens deviated from tolerances. Macrograph for left and right weld beads for one of the specimens welded with 100% increase in speed is shown in figure 4. Penetration and weld bead width in left and right weld beads were the weld geometry parameters to be out of tolerance. Weld bead geometry measurement results are given in table 4 for each welding speed.

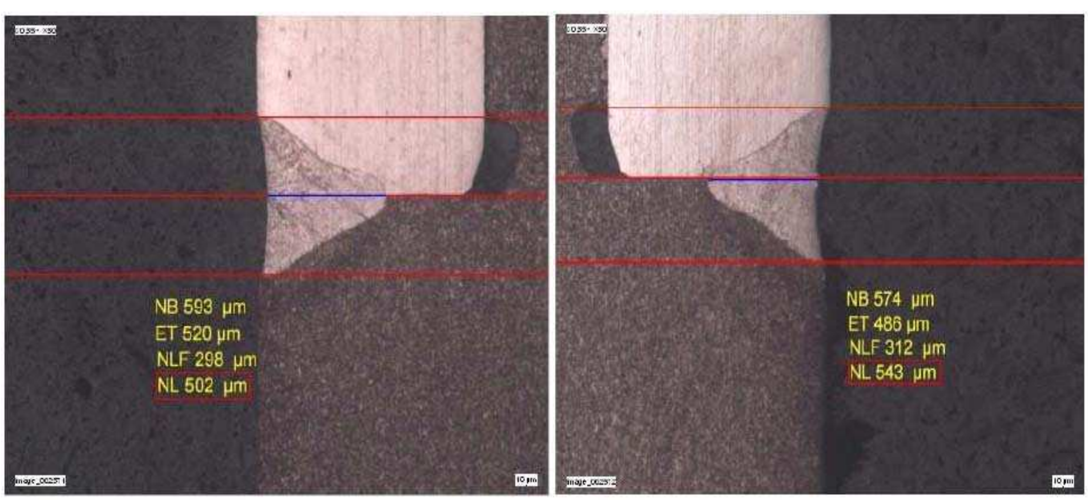

Figure 4. Left and right weld beads for 1.630 $m.min^{-1}$ welding speed

Table 4. Weld bead geometry measurement results with regard to welding speed

Welding speed (m .min^{-1})	ET (Left) (mm)	ET (Right) (mm)	NB (Left) (mm)	NB (Right) (mm)	NLF (Left) (mm)	NLF (Right) (mm)	NL (Left)	NL (Right)
0.815	0.722	0.722	0.800	0.800	0.394	0.394	0.492	0.492
0.906	0.466	0.616	0.770	0.750	0.396	0.397	0.514	0.529
0.978	0.636	0.576	0.762	0.744	0.365	0.363	0.479	0.487
1.059	0.590	0.582	0.701	0.691	0.357	0.349	0.509	0.505
1.141	0.554	0.595	0.682	0.684	0.338	0.338	0.495	0.494
1.222	0.567	0.574	0.636	0.680	0.331	0.356	0.520	0.523
1.630	0.520	0.456	0.593	0.574	0.298	0.312	0.502	0.543

Conclusion

Welding speed increased by 10%, 20%, 30%, 40%, 50% and 100% in laser welding of cylindrical piezo injector parts made of stainless steel with a 1 kW laser welding machine. Weld bead geometries of 100 specimens for each case measured optically and out of tolerance parts were counted. Results are summarized below.

1. It was observed that out of tolerance part numbers rose with increasing welding speed starting with 0.815 m.min^{-1}
2. It was noted that penetration began to drop with increasing welding speed. Heat input was lowered with increasing welding speed. Therefore, there was less penetration in weld bead. Penetration was 0.722 mm welding under safe conditions and this value was measured to be 0.541 mm, 0.606 mm, 0.586 mm, 0.574 mm, 0.570 mm and 0.403 mm for welding speed increase by 10%, 20%, 30%, 40%, 50% and 100%, respectively. This means 44% drop in penetration when welding speed was doubled.
3. Weld bead width was observed to be less with increasing welding speed. Weld bead width was 0.800 mm welding under safe conditions and this value was measured to be 0.765 mm, 0.753 mm, 0.696 mm, 0.683 mm and 0.658 mm and 0.583 mm for respective welding speeds. This means 27% drop in weld bead width when welding speed was doubled.
4. When welding speed was increased beyond optimal conditions, it caused both penetration and weld bead width to decrease and this instance led a negative result of increasing out of tolerance part numbers, which would be discarded.

It can be concluded with these results that in order to increase welding speed, i.e. manufacturing rate, laser welding machine with higher power must be employed.

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