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A Study on Micro Tig Tube Welding of Thin Extra Aisi 321 Austenitic Stainless Steel Sheets

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Abstract: Exhaust gas recirculation tubes were used for this study. To make bellows shape from TIG (Tungsten Inert Gas) welded extra thin tubes hydraulic forming method is used in industry. For this study, 0.2 mm thick AISI 321 austenitic sheets were combined by using micro TIG welding method and 11.80 mm in diameter pipes were produced. For the TIG welding process of thin sheet tubes shaped by liquid pressure precise welding parameter adjustment is required. With the micro TIG arc welding technique, healthy weld seams were obtained in three different power parameters. The effects of this differences on the mechanical properties and microstructure of the weld joints were experimentally investigated. The welding speed was kept constant and three different welding current and voltage values were selected. The images of the weld zone of the samples were taken by an optical microscope. The microstructures formed in the weld zone were examined. Micro hardness values of the base metal, HAZ (Heat Affected Zone) and weld zone were evaluated. Tensile tests of the samples were carried out for three different parameters. Strength of welding seams is very important in the hydroforming process. In order to evaluate the strength of the joint, the welded tube elastomer expansion test was applied. The effect of the expanding tube wall on the welded joint was evaluated by the expansion test. As a consequence of the study, the optimum power parameters of the welded joint was determined by destructive and non-destructive tests.

Keywords: TIG welding, EGR tubes, Elastomer expansion test

Introduction

TIG welding uses a non-consumable tungsten electrode and an inert gas for arc shielding, is an extremely important arc welding process (Juang & Tarng, 2002; Cary, 1981). In this process an electric arc is formed between a tungsten electrode and the base metal. The arc region is protected by an inert gas or mixture of different gases (Modenesi at all, 2000). Although TIG welding is usually applied with a single electrode, it may be sometimes done with several electrodes (Minnick, 1996). It is commonly used for welding of difficult-to-weld metals such as stainless steel, aluminium, magnesium, copper and many other nonferrous metals (Hicken, 1993; Althouse et al., 1992). The micro TIG welding, is an arc welding method that successfully generates weld seams in the tubes and joins metal sheets have ultra-thin wall thicknesses.

Some industries work with micro TIG welding nowadays are; Tools, mold and mold repair, metal bellows, valves, diaphragms, pressure transducers, sensors, implant devices, micro switches, batteries, motors, electronic devices, housings, airbag parts, air sealing elements, tube / fittings, vacuum tubes, thermocouples, tube closure, surgical instruments.

This study focuses on usage of exhaust gas circulation pipes/tubes. With the help of the micro TIG welding technique, welded tubes formed from stainless steel sheet and they are formed by using hydraulic forming method. The exhaust gas recirculation system (EGR) is one of the leading method to reduce emissions. For this study AISI 321 series austenitic stainless steel is preferred due to its good corrosion behavior at high temperatures in the design of metal pipes in EGR systems. In the designing of the system, the bellows are produced with the help of hydro forming technique in respect of the space and volume of pipes produced in various thicknesses and diameters of stainless steel in the motor region. The areas where the bellows are formed provide flexibility and allow the metal pipes to be placed around the engine block in the space reserved for them and more easily to be assembled to the mounting areas more compactly. TIG-welded and hydro-shaped pipes in EGR systems are shown Fig. 1.

Figure 1. A sample of TIG-welded and hydro-shaped EGR tube

In recent years, there has been significant increase in the production of hydro-shaped products. In the hydro-forming process of the pipes, generally thin-walled pipe is inflated by the internal pressure and it is shaped by the mold that surrounds it. (Hashemi, 2014; Korkolis & Kyriakides, 2008) Hydraulic forming is basically the formation of metal sheet or tube material in a closed container by means of a fluid medium (water, viscous polymeric material, etc.) (Wang, 1994). In this method, a completely liquid medium is used instead of the punch. The process can be summarized as the force applied by the pipe part to the shape of the mold cavity by the applied axial force and internal pressure or only the internal pressure (Şahin, 2004). It is ensured that the fluid pressure is distributed uniformly to each region and the part thickness is the same. Thus, the piece thickness is distributed uniformly. Therefore, more strength and smaller tolerant parts can be produced. In addition to their excellent corrosion resistance, stainless steels have the characteristics of having different mechanical properties, they can be used at low and high temperatures, they are easy to shape and they have aesthetic appearance.

AISI 321 weld joints resists to very severe corrosion conditions, are used in the production of aircraft exhaust manifolds, boiling pans, heat treatment equipment, cabin heaters, fireplaces designed for service at 427 ° C to 871 ° C (Yıldırım, 2010 ; Erdoğan, 2000).

Austenitic stainless steels are Fe-Cr-Ni alloys. Austenitic Cr-Ni stainless steels contain 12-25% Cr and 8-25% Ni in their compositions. Nickel is a strong austenite-forming element. The austenite occurs during solidification in these steels and remains unchanged even at room temperatures or below at room temperature.

Since there is no austenite - ferrite conversion during cooling, such stainless steels cannot be hardened by quenching (Yıldırım, 2010; Ceyhun, 1992; Kuştutan, 2003; Hasanbaşoğlu, 2005).

The total amount of Cr, Ni and Mn of such steels is 24% or more and the Cr content is usually 16% or more. While Cr provides oxidation and corrosion resistance, Ni and Mn ensure that the austenite phase remains stable at room temperature, even at high cooling rates. Depending on the composition of the steel, the permanent austenite structure completely contain austenite or austenite matrix in the form of ferrite grains (Yıldırım, 2010; Hasanbaşoğlu, 2005) The reasons of preference of stainless steels are corrosion resistance, resistance to high and low temperatures, ease of manufacturing, mechanical strength, appearance, hygienic properties and long life titles (Karcı, 2008).

The reason for the use of austenitic stainless steels in more than 90% of all welded stainless steel products is their good weldability. Chemical compositions and mechanical properties of bonding zone of austenitic stainless steels are often comparable to the base metal. Austenitic stainless steels can be easily combined with various welding methods (Kaluç & Tülbentçi, 1995; Kuştutan, 2003; Yıldırım, 2010).

The most important weldability features of such stainless steels are: Thermal conductivity coefficients are about one third of low alloy and carbon steel at room temperature. The coefficients of thermal expansion are approximately 1.5 times, ie, 50% higher than carbon and low alloy steels. The electrical conductivity of such steels is four to seven times larger than that of non-alloy steels. Due to these properties, welded joints of austenitic stainless steels produce more shrinkage than plain carbon steels's. During the cooling of the weld seam, the formation of large shrinkages and the internal stresses cause a cracking hazard are observed. Low heat and electrical conductivity of austenitic stainless steels are generally useful for welding. It is recommended to work with low heat input during welding. Because the heat generated does not move away from the welding zone as quickly as in carbon steels. Because of the high resistance of the material, the resistance welding can be operated with low current values (Woollin, 1994).

Method

In this study, AISI 321 austenitic stainless steel specimens with 0.2 mm thickness were welded by TIG welding method without using any filler material. Chemical composition of AISI 321 is given in Table 1. Welding was carried out with a 0.5 mm tungsten electrode. Welding speed were kept constant as 4 m/min. During the welding, the cylindrical trip sheet was fed manually into the welding area and welded pipes 11.80 mm in diameter were produced. Three different current and voltage parameters were chosen as shown on Table 2. After the completion of welding process, samples were cooled in the air.

Table 1. Chemical composition of base metal (wt.%)

AISI	**C**	**Si**	**Mn**	**P**	**S**	**Cr**	**Mo**	**Ni**	**Ti**	**Cu**	**N**
321	0.45	0.49	1.59	0.020	0.015	17.74	0.02	9.20	0.31	0.078	0.010

Table 2. Process parameters of micro TIG welded samples

	1	**2**	**3**
SPEED	4 m/min	4 m/min	4 m/min
CURRENT	38 A	44 A	33 A
VOLTAGE	8.4 V	8.3 V	8.1 V
GAS	%5L/min %100 Argon	%5L/min %100 Argon	%5L/min %100 Argon

In the system where the welding process is carried out, the strip-shaped stainless steel material is fed into the system. Firstly, the strip material applied from the reel to the forming gauges takes the tubular form. Then, the forehead is positioned at the forehead and driven to the area where the torch is located at a speed of 4 m / min. 5 L / min of pure argon shielding gas is given to the weld zone and the inside of the welded pipe. The welded pipe is finally go ahead to the device controls whether there is a discontinuity with the magnetic current. If there is any crack, the system stops itself and alarms.

Generally, for the mechanical test of the welded pipes, the mouth expansion test in accordance with TS EN ISO 8493 standard is used. However, it is not possible to apply in this test for the pipes with wall thickness of 0.2 mm. For the mechanical test of welded pipes with very thin wall thicknesses, an alternative method shown in Fig. 2 was developed.

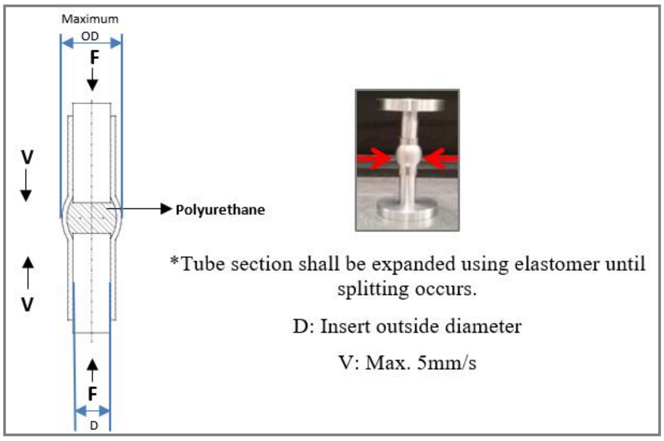


Figure 2. Elastomer expanding test

In the elastomer expanding test, the cylindrical elastomer placed in the welded sample tube is applied in both directions independently of the velocity (max. 5mm / sec). The compressive region of the compressed elastomer are undergone deformation and expansion. The applied force is maintained until the weld seam is deformed. When evaluating the test results, it is expected that there will not be any error in the welded area which is expanded by at least 55% compared to the pipe diameter. Polyurethane is used as the elastomer material.

Mechanical properties and microstructural properties of the samples bonded under different current intensity were examined. Expanding test samples were prepared according to Figure 2. Tensile test samples were prepared from welded tubes as 0.20 X 500 mm. Standard metallographic grinding was applied and then grinded samples were polished by using 3 μm diamond paste. Polished samples were etched in a solution of 4 g $CuSO_4$, 20 ml HCl and 20 ml distilled water. Microphotographs were taken with a OLYMPUS optical microscope. Hardness measurements were performed on the samples used for microstructural examinations. For hardness measurement, an NAVAS SMHT-2010S device was used by applying 200 g load.

Results and Discussion

The effect of the change in power parameter on the width of the weld seam is shown in Fig. 3. When the weld seam width is examined in macro size, it is seen that change in current density affects the weld seam width.

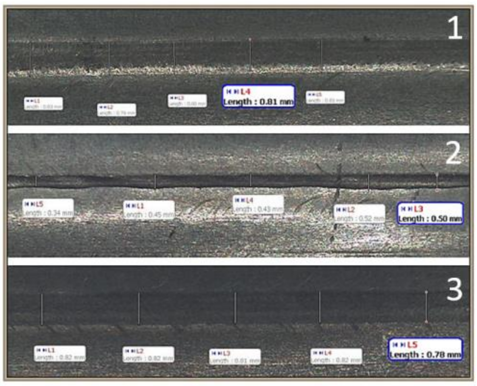


Figure 3. Effect of the parameter change on the width of the weld seam.

Photomicrographs of the transition zone of the samples which were welded under three different current intensity are given in Fig. 4.

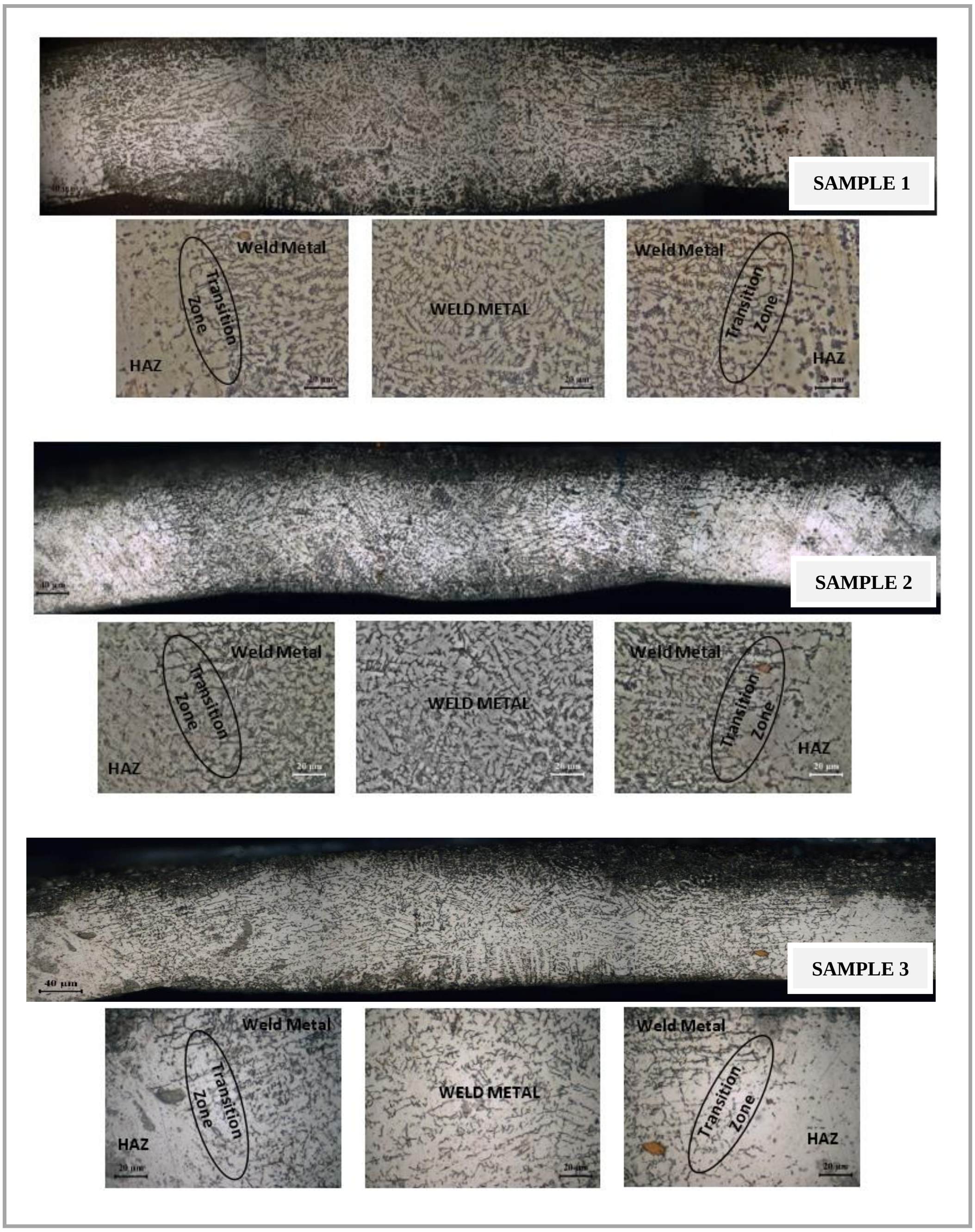


Figure 4. Optical photomicrographs of welding zone of Samples.

A significant HAZ situation was observed in all Samples 1, 2 and 3. Grains in the weld metal oriented parallel to the heat flow. As many other researchers (Durgutlu at all, 2000.), it has been determined that solidified weld metal is composed of homogeneously distributed dendritic structures. Depending on the cooling rate, it can be interpreted that these structures occur in different sizes. In terms of corrosion resistance, as it can be seen from Fig. 4 the narrow area of HAZ decreases corrosion defects and thus increases corrosion resistance.

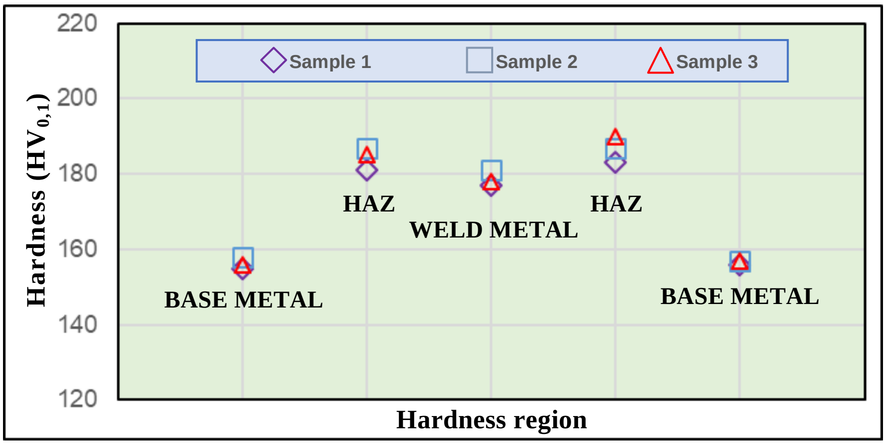


Figure 5. Hardness values of regions

Figure 6. Optical photomicrographs of hardness points on welding region of Sample 1

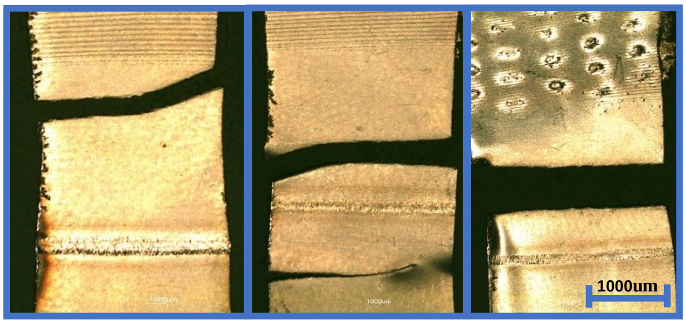


Figure 7. Optical macro photos of samples after tensile testing

As seen in the Fig. 7, in all three samples, the rupture occurred in the base material rather than in the weld zone. For the result of the tensile tests, 597 N/mm^2, 589 N/mm^2 and 592 N/mm^2 tensile strength were measured for Sample 1, Sample 2 and Sample 3 respectively. The highest tensile strength (597 N/mm^2) was obtained from the Sample 1. Samples with damaged or undamaged welded seams after expansion test shown in Fig. 8.

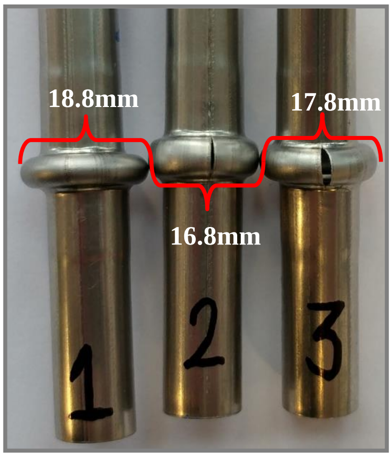
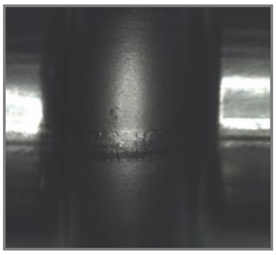
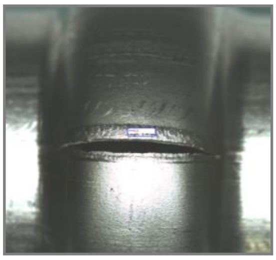
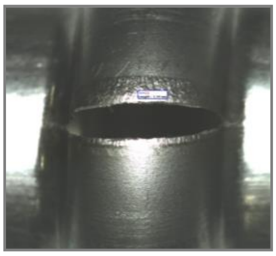
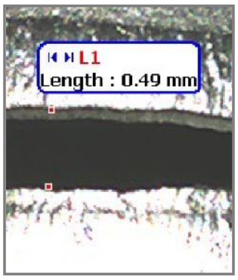
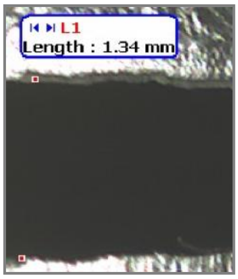


Figure 8. Samples with damaged or undamaged welded seams after expansion test

The diameter of the existing tube samples is 11.8 mm. The success criterion of the test is that there is no damage to the tube diameter with a minimum expansion of 55%. There should not be any welding defect of 18.3 mm diameter in the welding area. Expansion test results of the samples welded under different current intensity, are given in Table 3.

Table 3. Expansion test results

	SAMPLES		
	1	**2**	**3**
Maximum diameter in the expanding region	18.7 mm (%58 Expanding)	16.8 mm (%42 Expanding)	17.8 mm (%51 Expanding)
Tear / Defect status (Visual Inspection)	**No Tear**	Tear seen	Tear seen
			
			

Conclusion

On the basis of the mechanical and microstructural experimental studies accomplished and the results obtained on the effect of current intensity on the TIG welding processes of 321 austenitic stainless steel, the following conclusions may be drawn:

1. All the samples show a distinct HAZ. In addition, it is determined that the solidified metal is composed of homogeneously distributed dendritic structures.

2. From the microstructure photos, in point of corrosion resistance, the narrow area of HAZ decreases corrosion defects and thus increases corrosion resistance. AISI 321 series austenitic stainless steels are preferred due to Their excellent corrosion behavior at high temperatures in the designing of metal tubes for (EGR) systems.
3. For all current intensities, hardness of weld metal is lower than that of the HAZ. The ruptures occurred in the base metal for all samples after tensile test. However, the effects of the hydroforming process on the tube welding seam were seen by the expansion test. From the expansion test, tear was occurred in Sample 2 and 3 despite not in Sample 1.

4. For the expansion test, the best result was obtained from Sample 1 as 38 A current intensity. Cracks, tearing and surface defects were observed with naked eye after expanding tests. Sample 1 was expanded by more than 55% and it was not seen tearing. 42% and 51% expansion of the diameter caused tearing on the weld seam of Sample 1 and 2.

References

Althouse, AD., Turnquist, CH., Bowditch, WA., & Bowditch, KE. (1992) Gas tungsten arc welding, Modern Welding, *The Goodheart–Willcox Company Inc,* (pp. 327–328)
Cary, HB., (1981) 2nd ed. Modern welding technology. (2nd ed). AWS. (pp. 82 – 85).
Ceyhun, V., (1992) The Effect of welding parameters on the tensile-shear strength and the formation of intercrystalline corrosion in the spot welding of ferritic and austenitic stainless steels with carbon steel,

(Master dissertation) Istanbul Technical University, Institute of Science and Technology of Natural and Applied Sciences.

Durgutlu, A., Gulenc, B., & Tulbentci, K., (1999) The effect of welding speed on the microstructure and penetration in arc welding. Turk J Eng Environ Sci. 23, (pp. 251–259)

Erdoğan, M., (2000) Structure and Properties of Engineering Alloys, Nobel Academic Publishing Training Consultancy. Ltd. Sti, Ankara

Hasanbaşoğlu, A., (2005) The determination of resistance spot weldability of austenitic stainless steel and interstitial free steel, (Master dissertation), Zonguldak Karaelmas University, Karabük Technical Education Faculty.

Hicken, GK. (1993) Gas-tungsten arc welding, vol. 6. *ASM Handbook.* (pp. 190 –193).

Hashemi, R. (2014) Analysis of necking in tube hydroforming by means of extended forming limit stress diagram Engineering *Solid Mechanics, 2 (*pp.73-82)

Juang, SC., & Tarng, YS., (2002) Process parameter selection for optimising the weld pool geometry in the tungsten inert gas welding of stainless steel. *J Mater Process Technol* 122(1), (pp. 33 –37).

Korkolis, Y. P., & Kyriakides, S. (2008) Inflation and burst of anisotropic aluminum tubes for hydroforming applications. *International Journal of Plasticity*, 24(3), (pp.509-543).

Kuştutan, G., (2003) An Investigation of effect of cooling rate on the mechanical properties of resistance welded sheets, (Master dissertation) Gazi University, Institute of Science and Technology of Natural and Applied Sciences.

Karcı, F., (2008) An effect of cold deformation and heat input in the resistance spot weld quality of aisi 304 stainless steel, (Master dissertation), (Master dissertation), Zonguldak Karaelmas University, Karabük Technical Education Faculty.

Modenesi, PJ., Apolinario, ER., & Pereira, IM., (2000) TIG welding withsingle-component fluxes. J Mater Process Technol (pp. 99:260 –265).

Minnick, WH., (1996) Gas tungsten arc welding handbook. *The Goodheart-Willcox Company.*

Wang, Q., (1994) Hydromechanical Deep Drawing, *New Technol. New Process.* (pp. 23-24)

Woollin, P., (1994) Development in fusion welding of stainless steels, Welding & Metal Fabrication.

Yıldırım, G., (2010) The effect of welding consumable and shielding gas on the TIG arc welding of AISI 321 stainless steel. (Master dissertation) Karabuk University, Institute of Science and Technology of Natural and Applied Sciences.

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