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EFFECT OF WELDING SPEED ON TENSILE STRENGTH OF PRESSURE VESSEL STEEL SUBMERGED WELDED JOINTS

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Abstract: In order to ensure the quality of welded pressure vessels joints and optimise the submerged arc welding process it is necessary to have an appropriate welding speed that can guarantee a strong welded pressure vessel product. The main parameter that can be manipulated in order to optimize the welding process, in this case, is the welding speed. Increasing the welding speed results in increasing productivity but the quality of the welding joints can be affected. This study presents how the welding speed influences the tensile strength of the welded joints from pressure vessel steel. There are treated aspects such as the dimensions, geometry of the welded seam and breaking stress occurred in stretching of the welded joints. The test specimens were created by using the submerged arc welding technology, and the welding process was realized by using a semiautomatic industrial submerged arc welding machine. The pressure vessel steel used as a base material is P355 N.
Keywords: welding, speed, parameter, stress, strain, strenght

1. INTRODUCTION

Pressure vessel products are made from semi–finished products of steel sheets. The main components of pressure vessels that make up the body of the tank are: in the middle, the rolled sheet cover and the embossed caps from the ends, on which can be located inspection, supply, exhaust holes and devices for measuring and controlling the flow pressure and temperature inside the tank. The components which form the body of the pressure vessel are joined in the production industry through submerged arc welding processes.[1]

Submerged arc welding technology is used for industrial welding of medium and large pressure vessels because offers high productivity and the protection of the weld bath is much more efficient than in the case of other welding technologies, which leads to the execution of homogeneous and compact welded seams, without porosity and welding defects that could be the priming base for cracks during exploitation. A main condition for the welding of pressure vessels is the realization of a welded seam completely penetrated in the welding joint in a single pass, a fact that can ensure optimal productivity in conditions of complete penetration of the weld. In order to achieve a good quality fully penetrated seam from a single pass, from only one side of the base material it is necessary to use a high intensity of the electric welding arc, also, the greater the thickness of the base material, the more intensity of the welding current is required to get the seam completely penetrated.[2][3]

Welding speed plays a very important role in optimizing and obtaining favourable productivity, but its increase reduces the deposition rate of the base material, the degree of penetration of the filler material both in the welding joint and in the base material. These consequences of increasing the welding speed in order to obtain a greater productivity can lead to the decreasing of the welded joint strength due to the previous mentioned technological factors that are directly affected.[4]

In order to see the influence of the welding speed on the decrease in the resistance of the welded seam, a series of welded samples with different welding speeds were executed in the industry, from which 4 specimens were taken for tensile strength testing for each welding speed separately.

The submerged arc welding technology consist of using an electrode wire in combination with a flux powder which is deposited on the surface intended for welding. In figure 1 is presented the principle of the submerged arc welding technology where it can be seen that the layer of flux powder is deposited in advance of the welding arc area. The electric arc formed between the tip of the electrode and the base material is melting the electrode and fills the joint of the base material this whole welding process takes place without the emission of light and gases into the atmosphere, creating a much safer working

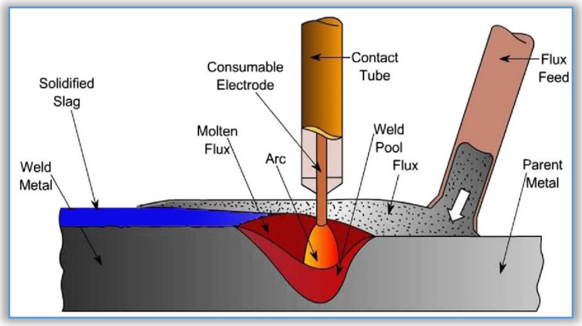

Figure 1. The principle of submerged arc welding [6]

environment than in the case of other electric arc welding technologies.[5] In the case of pressure vessel welding, the equipment used consists of the support on which the semi–finished product is placed, this being composed of two supports provided with rollers to be able to rotate the cylindrical–shaped semi–finished product around its central axis. The other main equipment that is used has the role of supporting the welding torch and the flux material management system, this equipment is made up of a mobile beam that can perform a linear advance movement also having the possibility to be adjusted vertically at different heights. [1][5]

Figure 2 presents the two main equipment's about which it can be mentioned that for execution of longitudinal welds, the support equipment of the semi–finished product must have the rollers locked, keeping the semi–finished product fixed and the support beam of the torch executes an advance movement. To realize the circular seams on the generator of the semi–finished product, the torch is positioned in a fixed position and the semi–finished product is rotated to in order to obtain the welded joint.

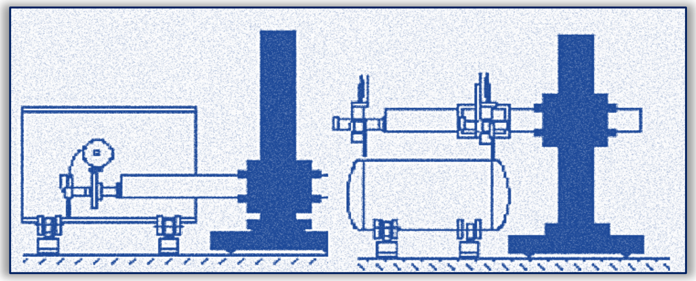

Figure 2. Submerged arc welding of pressure vessels [5]

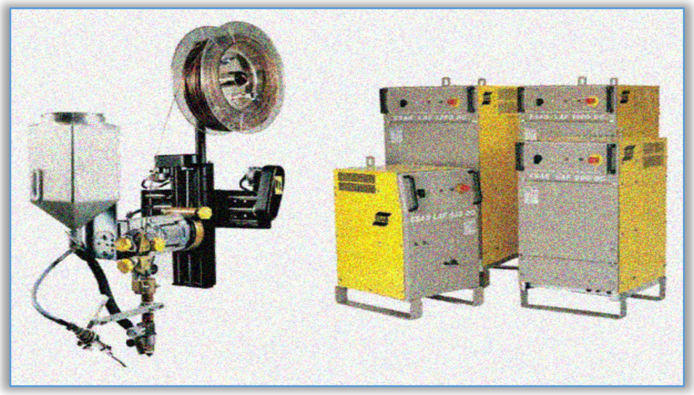

Figure 3. Equipment used for submerged arc welding [5]

The components that make up the welding machine are shown in figure 3 and they can be divided into three main components: the power source, the control panel and the welding terminal.

The welding terminal is composed of the following elements:

- the electrode wire drum,
- the electrode wire feeding system,
- the torch,
- the flux management system.

2. RESEARCH METHODOLOGY

To determine the effect of welding speed on the tensile strength of the joint, a set of welded specimens was carried out being made up of 6mm thick sheets but welded. Each specimen was welded with a different welding speed, the constant characteristics of the welding process being shown in table 1.

Table 1. Constant characteristics of the submerged arc welding process [7–11]

Welding process characteristics	Description	Codification	Norm
Base Material	Carbon steel for pressure vesels	P355 N	SR EN 10216–3:2003
Filler material	Circular section wire 3.2 mm from molybdenum–alloyed copper for welding non–alloy and low–alloy steels under a flux layer.	OK Autrod 12.24	–
Protective environment of the electric arc	Flux the layer deposited in a layer with a thickness of 25 mm	OK flux 10.47	–
Welding process feature	Welding under flux with wire electrode	121	EN ISO 4063
	Butt welding with full penetration	BW	SR EN 287–1
	Welding with root support	mb	
	One–pass welding	sl	
	Horizontal	PA	SR EN ISO 6947

Figure 4 shows images from the process of welding the 3 specimens with a welding speed of 25 cm/min, 50 cm/min and 75 cm/min. Here you can see the layer of material deposited during welding, the seam covered with slag left after the removal of the flux layer and the final seam after removing the slag film from the welded area.

The welded plate was divided into two regions, each specific to a different welding regime, from each region 4 samples were taken for tensile testing (Figure 4). The samples were taken according to the standard. The geometric aspects of the sample are shown in figure 5, where it can be seen that they have a length of 250mm and a width of the area where the break occurs of 25mm, the welded seam being

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located in the middle of the sample. The transition from the test specimen breaking area to its clamping area is made by me radius connection of R26mm. [12]

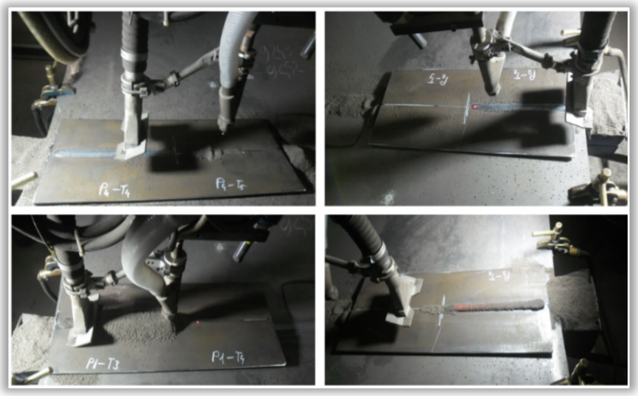

Figure 4. Submerged arc welding process of specimens

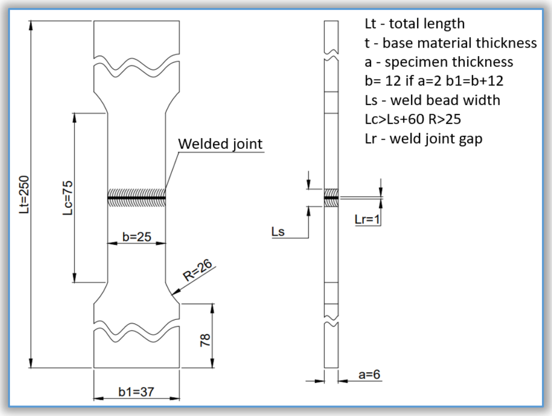

Figure 5. Tensile test specimen characteristics [12]

The processing of the samples consisted of cutting by guillotine followed by milling to obtain the breaking zone. All mechanical processing were carried out in such a way to prevent thermally affected areas from appearing.

Figure 6 shows the tensile test machine and a test piece mounted in the machine's clamping device before testing. The device mounted on the breaking area of the specimen is an extensometer that measures the displacements that occur in the material of the specimen during testing, with the help of the data collected by this device the modulus of elasticity of the specimens was determined.

The data collected after testing consisted of the displacement of the mobile beam of the machine and the instantaneous stretching force, after processing those, stress–strain curves were obtained. The tensile test speed used was 50 MPa/s.

Figure 6. Strain test equipment

3. EXPERIMENTAL RESULTS

Analyzing the stress–strain curves obtained it can be observed a clear tendency to decrease the tensile strength due to the increase in the welding speed can be observed resulting a conclusion that the welding speed is inversely proportional to the tensile strength of the welded joint.

Regarding the breakage of the samples, the one welded with a welding speed of 25 cm/min broke through the base material and the other two suffered breaks through the welded seam. Figure 7 shows a comparative situation of the 3 curves obtained, each of the 3 curves was chosen as representative of the 4 set curves from which it resulted.

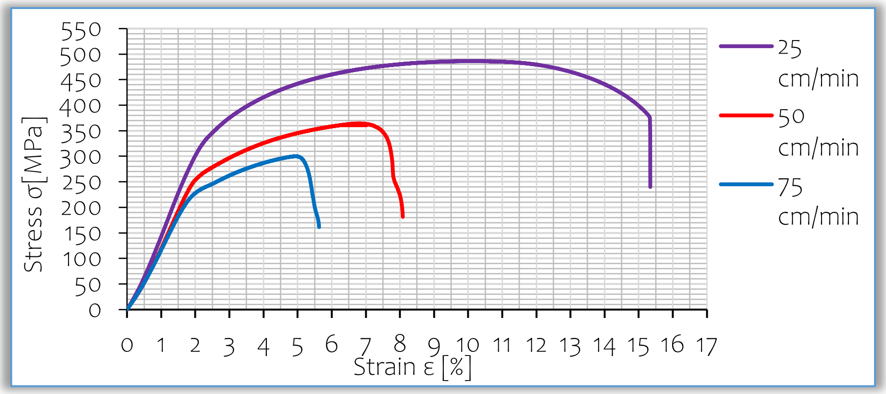

Figure 7. Stress–strain curves

The larger the area under the curve, the better the ductility of the welded joint due to the very good ductility of the weld made at a speed of 25 cm/min, practically, the break not occurring through welding, the deduced ductility is that of the base material.

An important mechanical characteristic of the base material is the modulus of elasticity, which is found in the material standards as 212000 MPa for the base material used P355N. Looking only at the graph of the stress–strain curve, a series of characteristic parameters of the welded joint can be determined, they can be found in comparative form in table 2.

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Table 2. The characteristics resulting from the interpretation of the stress–strain curves

Average strain test results	Welding speed			
	25 [cm/min]	50 [cm/min]	75 [cm/min]	U.M.
Maximum stretching force	87.35	73.00	73.34	kN
Maximum stress	486.24	318.91	299.94	MPa
The strain corresponding to the maximum stress	10.11	4.29	4.95	%
Breaking stress	239.93	152.64	161.38	MPa
The strain corresponding to the breaking stress	15.34	4.91	5.63	%
Yield tensile stress	291.34	242.06	221.09	MPa
The strain corresponding to the yield tensile stress	1.91	1.87	1.88	%
Modulus of elasticity	266040	143190	134470	MPa
Strain energy	6275.46	1088.41	1209.21	KJ

A main mechanical characteristic is the yield strength being determined by using the 0.2% offset method for yield stress, this parameter having a clear tendency to decrease with the increase of the welding speed.[13]

Practically, if we analyze the data from table 2, we can see a clear trend of decrease of all the parameters determined with the help of the stress–strain curves. It can be said that the welding speed is inversely proportional to the mechanical characteristics of the welded joints.

4. CONCLUSIONS

After the experiments it can be concluded that by increasing the speed of the submerged electric arc welding regime results in a decrease in the mechanical properties of the welded joints. The main indicators obtained after analyzing the stress–strain curves are: the maximum the stretching force, maximum stress, the yield tensile stress, the modulus of elasticity and the strain energy, for which increasing the welding speed has an obvious diminishing effect.

The nature of the breaks clearly indicates the decrease in the mechanical properties of the welded seams, for low welding speeds the break occurs in the base material of the specimen and for high welding speeds the break occurs through the welded seam, which is due to poor penetration.

Also, the ductility of the welded assembly decreases as the welding speed increases, poor ductility denotes rapid failure to fatigue and low plastic properties. It can be said that for the use of an increased welding speed, it is necessary to increase the parameters that contribute to the melting of the weld pool.

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