DEVELOPMENT OF A ZIGZAG WELDING SYSTEM THAT WILL INCREASE PENETRATION AND EFFICIENCY IN WELDING TECHNOLOGY

Anıl ŞEKER
anilseker@hotmail.com, https://orcid.org/0000-0002-7460-0151,
Demircioğlu Group, R&D Center, Bursa, Türkiye

Merve HATİPOĞLU
merve.hatipoglu28@gmail.com, https://orcid.org/0000-0003-3424-1489
Demircioğlu Group, R&D Center, Bursa, Türkiye

İbrahim BACANAK
ibrahimbacanak4@gmail.com, https://orcid.org/0009-0002-2355-6987
Demircioğlu Group, R&D Center, Bursa, Türkiye

ABSTRACT: *There are many methods used for the part joining process in the manufacturing industry. Among these methods, welding is the most widely used one. Products with more than one component are assembled by welding. Welding increases the durability and reliability of products by creating strong and durable connections between the joined parts. At the same time, welding simplifies the assembly process by reducing the number of parts and increases production efficiency. For these reasons, choosing the right welding method and applying it correctly is of great importance in industrial production processes. The MIG/MAG gas metal arc welding method is more widely used than other methods due to its mechanization, ease of welding in any position, etc. The quality control of joints made with this welding method is characterized by high penetration, low cost and high reliability at every stage of the welding process. Penetration refers to how deep the weld penetrates into the material and is a critical factor in the strength and durability of the weld joint. Sealing and durability of weld points are of great importance, especially in systems operating under high pressure or in sensitive parts. In this study, a zigzag welding apparatus was developed to eliminate the lack of penetration in gas welding technology. Cracks caused by lack of penetration at the welding point are prevented from preventing the part from fulfilling its purpose. When the results were examined; it was observed that there was insufficient melting and insufficient penetration in the visual controls of the products joined by the old welding method. The melting and penetration tests of the products joined with the developed zigzag welding apparatus were appropriate. In this project, it is aimed to produce higher strength products by preventing these problems caused by lack of penetration.*

KEYWORDS: *Weld Penetration, Weld, Zigzag Weld*

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1. INTRODUCTION

The process of joining metal materials, which is widely used in industrial applications, has made significant progress over time. Among the methods used in this process, welding, which is done by using heat, pressure or both in order to combine metals with different or the same properties, has an important place. The welding process allows the metals in question to be permanently joined or strengthened by a filling process. In this process, an additional metal may be used, or sometimes the use of additional metal may not be necessary.

Depending on the type of material on which the welding will be applied, it is considered as metal welding and plastic material welding. Metal welding: Combining metallic material using heat or pressure or both and with or without adding a material of the same type and melting range is called "metal welding". If an additional material is used to join two parts, this material is called "filler metal". Plastic material welding: Combining the same or different types of thermoplastic (non-hardening plastic) materials using heat and pressure and with or without adding an additional plastic material of the same type is called "plastic material welding" (Denislav, 2011).

Depending on the type of process, welding is divided into melt welding and pressure welding. Melting welding is the act of melting the material locally under the influence of heat alone and combining it with or without adding additional metal. Pressure welding involves locally heating and joining the material under pressure, usually without adding additional metal (Denislav, 2011). Figure 1 shows the schematic representation of melting and pressure welding.

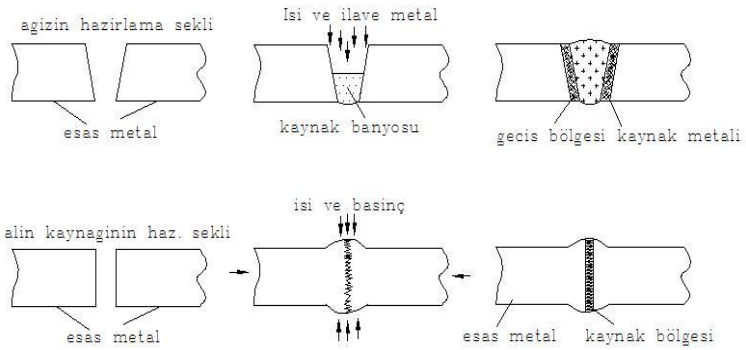

Figure 1: *Schematic representation of melting and pressure welding (Denislav, 2011)*

Especially in the automotive sector, the use of MIG-MAG welding has become widespread due to its high efficiency and ease of processing. MIG-MAG welding method is used for welding ferrous and non-ferrous metals or alloys of any thickness except very thin plates (Ekici, 2009). The applicability of the MIG welding method is quite simple. The arc is created by connecting the ground cable to the workpiece or welding table and bringing the wire electrode at the tip of the blower into contact with the welding nozzle. The machine automatically ensures the progress of the wire and the appropriate arc length. Gas welding stands out with its suitability for automation. With the development of the robot and by integrating appropriate automation into the robot, this process can be performed by robot (Köse and Tatlı, 2015). For this method, welding wires with different chemical compositions are used in various welding types such as electrode welding, argon welding, gas metal arc welding in the industry.

In the welding process, the quality of the weld seam is a critical parameter. Ideally, a weld seam should be free of defects or, if present, should be minimal. Errors occurring during welding can disrupt the uniformity of the seam and reduce its strength. These errors usually occur as a result of not choosing the correct electrode and welding wire. In addition, failure to prepare a proper weld bead, failure to choose the correct welding method, and inexperience of the welder may also cause errors.

Poor penetration occurs as a result of incomplete melting throughout the entire thickness of the material, which leads to the formation of cavities and notches in the lower regions of the joint, increasing the risk of breakage. The lack of penetration significantly reduces the fatigue strength of the seam. If the seam is subjected to warping, gouges and nicks on the underside can cause breakage.

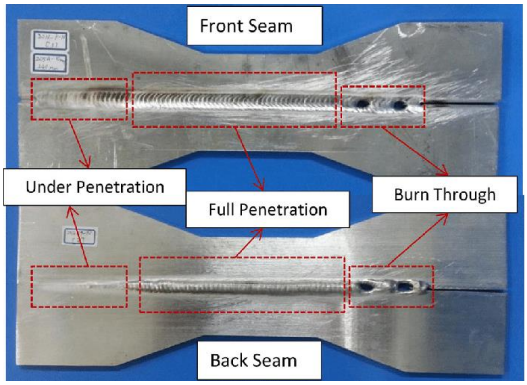

Figure 2: *Penetration errors (Zhang, 2014)*

In this study, studies have been carried out to prevent lack of penetration in welding technology, to increase the strength of the part with increasing penetration, and to produce products with higher strength by preventing problems caused by lack of penetration with the development of zigzag welding system.

2. METHODOLOGY

During the welding process, the most sensitive point between the parts to be joined is usually the weld points. The absence of air leakage from these points depends on the weld penetration being very good. Insufficient penetration at the weld points may cause possible cracks to appear and therefore the part to lose its functionality. In this study, it was aimed to produce higher strength products by overcoming these problems that may arise from lack of penetration.

2.1. Product Design

In line with the project objective, the study started from the design phase of the products to be subjected to the zigzag welding process and the mold of these products. The design of the product and mold was carried out in CAD environment.

In the design phase, firstly, the product to be subjected to zigzag welding process was designed. The technical drawing of the product is given in Figure 3 and the 3D visualization of the product is given in Figure 4.

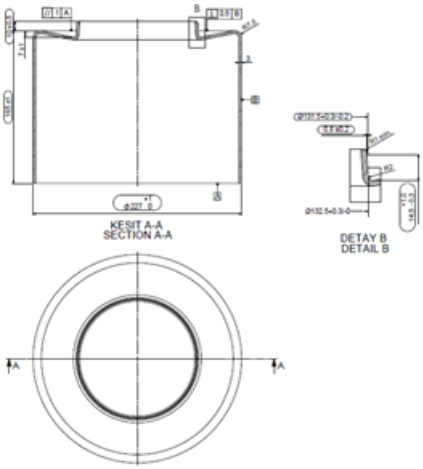

Figure 3. *Technical drawing of the product*

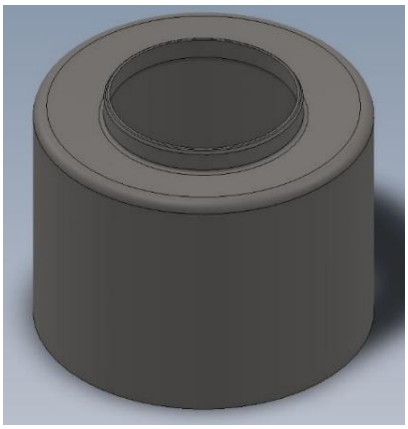

Figure 4*. Three-dimensional image of the product*

2.2. Zigzag Welding Apparatus Design and Welding Parameters

Lack of penetration in the parts to be welded is an important problem. Increasing penetration also leads to increased strength. It is a critical requirement that air should not leak from the welding points, especially in parts such as air suspension pistons that operate under high pressure. Therefore, weld penetration must be extremely good. To meet this need, the design of the apparatus to perform zigzag

welding using the MIG/MAG welding method was made in CAD environment. The two-dimensional view of the design is shown in Figure 5.

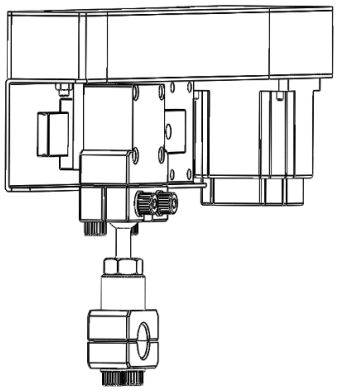

Figure 5. *2D image of the zigzag welding apparatus*

The apparatus shown in Figure 5 provides zigzag welding by moving the torches mounted on it along the axis, driven by the motor. The welding torches to be connected to the apparatus can be adjusted to the desired region to make 360 degree angle along the axis. The parameters of the welding process are given in Table 1.

Table 1. *The welding process*

Amperage	**Voltage (V)**	**Wire Speed (mm/min)**
260	25	14,22

Penetration tests of the welded products are carried out based on quality level D of EN ISO 5817 standard. The penetration test was concluded as suitable or rejected based on the parameters in Figure 6 according to the critical values of these parameters.

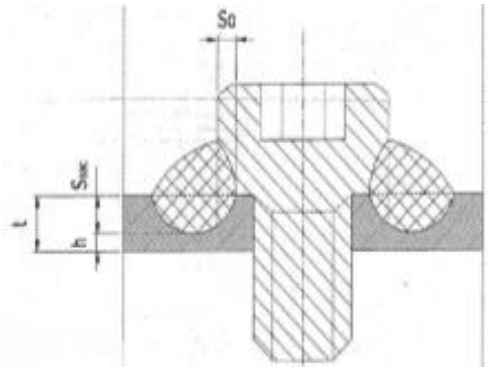

Figure 6. *Penetration test parameters*

3. DISCUSSION

In this research, an apparatus that can perform zigzag welding process using gas metal arc welding method has been developed. The apparatus is designed in such a way that the welding torches can be adjusted to 360 degrees along the axis to the desired areas. In the experiments, the effects of the zigzag welding apparatus on the welding zones were discussed.

4. FINDINGS

6224 (DD13) quality sheets were used in the experiments. The mechanical properties and chemical composition of the sheets used in the experiments are given in Table 2 and Table 3, respectively. The visuals of the specimens welded in zigzag form by MIG welding method are given in Figure 7.

Table 2. *Mechanical properties of the sheets*

Material	Tensile Strength (N/mm2)	Yield Strength (N/mm2)	Elongation at Break A80 (%)
6224 (DD13)	342	226	34

Table 3. *Chemical properties of the sheets*

Material	%									
	C	**Si**	**Mn**	**P**	**S**	**Cr**	**Mo**	**Ni**	**Cu**	**Al**
6224	0,052	0,024	0,249	0,014	0,0048	0,03	0,0028	0,033	0,03	0,042

Table 4. *Chemical composition of welding wires*

Welding Wire	C	Mn	Si	S	P	Cu	Cr	Ni
G1	0,066	1,515	0,881	0,012	0,008	0,089	0,04	0,044

Figure 7*. Images of specimens MIG welded with zigzag system*

The visual of the system apparatus that performs welding in zigzag form with the MIG/MAG welding method is given in Figure 8, and the visuals of the samples welded with the apparatus are given in Figure 9.

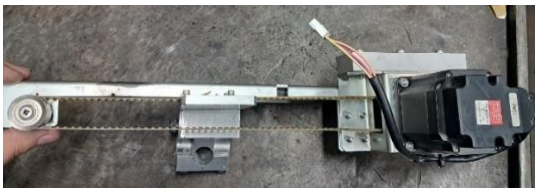

Figure 8*. Zigzag welding system apparatus image*

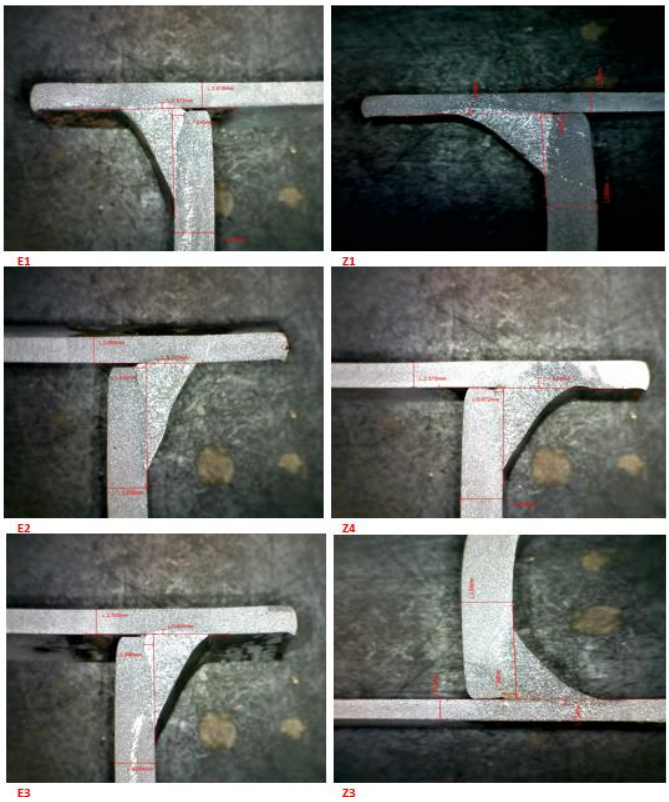

Figure 9. *Cross sections of specimens welded with zigzag apparatus*

The values measured as a result of the penetration test are given in Table 5.

Table 5. *Penetration Test Measurement Results of Welding Process with Old Technique and Welding Process with Zigzag Apparatus*

Welding with Old Technique				
Specimen	Support Sheet		Body	Conclusion
E1	t1	3,885	2,59	OK
	Ssac/Ssac	0,922	0,946	
	h1	2,963	1,644	
E2	t1	3,934	2,615	NOT OK
	Ssac/Ssac	1,046	0,749	
	h1	2,888	1,866	
E3	t1	4,034	2,565	NOT OK
	Ssac/Ssac	0,946	0,498	
	h1	3,088	2,067	

Welding with Zigzag Apparatus				
Specimen	Support Sheet		Body	Conclusion
Z1	t1	4,009	2,515	OK
	Ssac/Ssac	0,872	1,021	
	h1	3,137	1,494	
Z2	t1	4,009	2,615	OK
	Ssac/Ssac	1,245	0,573	
	h1	2,764	2,042	
Z3	t1	3,959	2,665	OK
	Ssac/Ssac	1,32	0,373	
	h1	2,639	2,292	

5. CONCLUSION

Considering the findings, the h_{max} value of Specimen 2 (E2), which was welded with the old welding technique, should be 2.4 mm, but it was measured as 3.934 mm as a result of the penetration test and as a result, the penetration test was rejected. Specimen 3 (E3) h value was measured as 2.565 mm and the penetration test was rejected because it exceeded the h_{max} value. When the specimens in the welding process using the zigzag apparatus were evaluated according to the same test criteria, the penetration tests of all specimens were appropriate as a result of the results given in Table 1. It was observed that seam welding with the zigzag apparatus gave better results in terms of penetration. In the light of these findings, the necessity and advantages of using zigzag apparatus in the welding process are discussed in detail.

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