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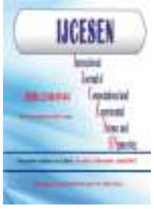

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Research Article

Tensile properties and microstructure of AISI 430 ferritic stainless steel welded TIG method

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Abstract:

In this study, AISI 430 ferritic stainless steel sheets with dimensions of 200x50x2.5 mm were joined by TIG (Tungsten Inert Gas) methods and the tensile properties and microstructure properties of the joined materials were investigated. Microstructure analyses and tensile tests of specimens joined by TIG welding were performed with SEM and TS 287 EN 895 standard, respectively. In microstructural studies, it was determined that a significant grain coarsening occurred in the heat affected zone (HAZ) AISI 430 ferritic stainless steel. Tensile strength, yield strength and elongation of the specimens decreased after TIG welding process.

1. Introduction

AISI 430 steel, which is included in the ferritic group among stainless steels, is a stainless steel material that is low in carbon and contains chromium [1-3]. This steel is frequently utilized in the automotive, white goods and nuclear energy areas due of its high ductility, thermal conductivity and corrosion resistance [4,5].

Welding is one of the methods frequently used in the industrial field to join pieces of material when continuity is desired between these pieces. Mechanical properties in welded materials vary depending on metallurgical changes such as microsegregation, precipitation of phases, solidification cracking, presence of pores, precipitation of phases, grain growth in the heat-affected zone and material loss by evaporation [6,7]. Therefore, the microstructure and mechanical properties of the welded materials must be determined during use. Corresponding to this, Yan et al. [8] showed that AISI 304 stainless steels have a low tensile strength and a high dendrite size after joining by TIG welding. In addition, Kumar and Shahi [9] concluded that precipitation occurs rapidly due to the effect of heat generated during welding and grain coarsening occurs in the HAZ region. This formation negatively affects the impact resistance.

When we look at the studies on AISI 430 ferritic stainless steel, Sun et al. [4] obtained higher microhardness values in the fusion zone (FZ) and HAZ of the welded joints using with interrupted pulsed argon arc welding (IPAW) compared to the base metal due to carbide precipitation and martensite transformation. On the other hand, Mohandas et al. [10] compared the ductility and strength of AISI 430 ferritic stainless steel joints joined by gas tungsten arc welding (GTA) and shielded metal arc (SMA) welds. They showed that GTA gave better values than SMA. On the other hand, microstructure studies on AISI 430 ferritic stainless steel welded with tungsten inert gas (TIG) showed the presence of ferrite, Widmanstätten austenite and low carbon martensite clusters in the fusion zone for two different fluxes SiO_2 and Fe_2O_3. Also, it has been observed that in welds obtained without and with SiO_2 flux, tensile failures are formed in the parent metal, while in Fe_2O_3 welding, tensile failures are formed in the fusion zone due to more amount of oxygen [11,12].

It is stated in the literature that; AISI 430 stainless steel is known for its magnetic properties, good corrosion resistance and formability [13]. However, it is stated in the literature that this steel is not suitable for welding and is not recommended for welding [14]. Therefore, the aim of the present study is to investigate microstructure and the weldability of this steel with TIG welding and to compare its mechanical properties before and after welding.

2. Materials and Methods

In order to achieve good results in welding work, the welding wire and electrode must have approximately the same composition as the material to be welded. In the present study, the chemical composition of AISI 430 ferritic stainless steel and welding wire is given in table 1.

Table 1. *Chemical composition of AISI 430 ferritic stainless steel welding wire (in wt.%)*

	C	**Mn**	**P**	**S**	**Si**	**Cr**	**Ni**
AISI 430	0.11	1.02	0.04	0.01	0.09	16.92	0.68
Welding wire	0.02	0.40	0.03	0.04	0.40	16.25	4.70

TIG welding, also known as tungsten inert gas (TIG), joins metal parts by passing an electric arc over a tungsten electrode. It uses an inert gas between the electrode and the joining parts. This method is preferred in many application areas because it provides high controllability and reliable results. In this study, TIG welding was carried out using INV DC TIG 200 A welding machine and argon gas was used as the shielding gas. The welding parameters were set as follows; current of 125 A, voltage of 30 V, welding speed of 5 mm/s, gas flow rate of 9 l/min and heat input of 0.90 kJ/mm. Microstructure studies of the welded samples were carried out by SEM. On the other hand, the tensile tests of welded samples were performed with an Autograph-Shimadzu AG-IS type device at a feed rate of 2 mm/min according to the TS 287 EN 895 standard.

3. Results and Discussion

AISI 430 stainless steel is a low carbon, approximately 17% chromium stainless steel that falls into the ferritic stainless class. Before the welding process, it was seen that the structure of AISI 430 stainless steel consisted of ferrite phase (Figure 1). In addition, the ferrite grains contain a small amount of scattered carbides. Figure 2 shows the microstructure of the weld zone and HAZ region of AISI 430 stainless steel welded with the TIG method.

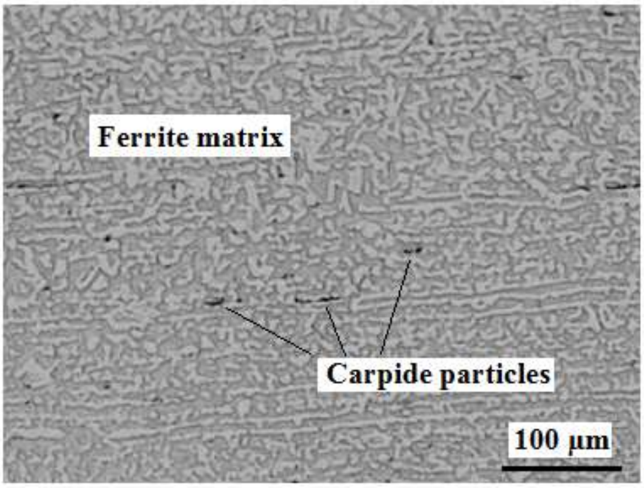

Figure 1. *Typical microstructure of AISI 430 ferritic stainless steel before welding.*

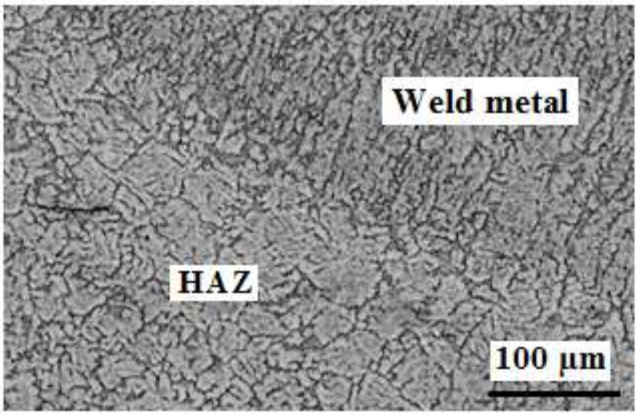

Figure 2. *SEM micrograph of AISI 430 ferritic stainless stainless steel after welded by TIG method.*

Figure 2 shows that the grains of AISI 430 ferritic stainless steels are coarser than the base metal grain structure in the HAZ of AISI 430 ferritic stainless steels. It can be said that the reason for this is that the increased heat input during welding slows down the cooling rate and solidification. The coarse-grained structure was also seen in a study by Tong et al. [15]. In that study, the coarse-grained structure seen in the fusion zone (FZ) has been explained by the stresses occurring under high temperatures. Additionally, Pichumani et al. [16] showed that lower cooling rate produces the coarse grain microstructure in the weld and HAZ zone. To summarize, the heat input during welding was effective in the HAZ, resulting in grain coarsening due to the increased heat input in this location. Coarse-grained structures are known to have lower strength than fine-grained structures. Tensile (σ_T), yield strength (σ_Y) and elongation values obtained from tensile tests of welded and unwelded AISI 430 ferritic stainless steel are given in table 2. The values given in table 2 were created by taking the average of 5 different test samples. When we look at table 2, we see that the welded samples have lower tensile, yield strength and also elongation values due to the microstructure that occurs after welding. In other words, the reason for amount of low tensile values in welded joints is presence of regions that do not deform due to increased hardness during welding. In literature 17, it was stated that chromium carbides formed in AISI 430 stainless steel joints reduce the tensile strength. Figure 3 shows that the failure point occurs without a large cross-sectional reduction. This finding indicates that the TIG-welded AISI 430 ferritic stainless steel has a brittle structure.

Table 2. *Tensile test results of AISI 430 ferritic stainless steel*

Mechanical properties	Before welding	After welding
Yield strength (σ_Y, MPa)	420.4	325.3
Tensile strength (σ_T , MPa)	522.8	323.7
Elongation (%)	22.6	6.3

Figure 3. *A photograph of the failure point in AISI 430 ferritic stainless steel welded using the TIG process.*

In summary, AISI 430 stainless steels can be welded appropriately with the TIG method. However, according to the results obtained from the tensile test, it is seen that the welded samples reach lower stress values and lower elongation values. In addition, the welded structures obtained have a very brittle structure. Steel is an interesting material and thus it has been used for different application and reported in the literature [16-24].

Author Statements:

- **Ethical approval:** The conducted research is not related to either human or animal use.
- **Conflict of interest:** The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper
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- **Data availability statement:** The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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