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MICROSTRUCTURE AND MECHANICAL PROPERTIES OF ASS (304)-FSS (430) DISSIMILAR JOINTS IN SMAW & GTAW PROCESS

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ABSTRACT

The current study presents some fundamental observations on the microstructure and mechanical properties in SMAW and GTAW process, formed by AISI 304 (ASS) and AISI 430 (FSS) with AWS E308L austenitic stainless steel covered electrode, being a dissimilar welding procedure. The welding processes carry out in this experiment are Shielded Metal Arc Welding (SMAW) and Gas Tungsten Arc Welding (GTAW). Samples of the weld metals are conventionally prepared for the micro structural characterization and mechanical properties.

KEYWORDS: SMAW, GTAW, 304-430 dissimilar welding.

INTRODUCTION

Welding is the joining of two crystalline workpieces usually of metal bringing their fitted surfaces into such intimate contact that crystal-to-crystal bonding occurs. Industrial welding usually entails local heat from a burning gas or an electric arc, or heat generated by electric resistance. The fitted surfaces may melt together, or a filler rod may melt between them to form a connecting bridge. Some welding involves further metal in addition to the workpiece, as in brazing and soldering [1].

Welding is a fabrication or sculptural process that joins materials, usually metals or thermoplastics. The interface of the two parts to be joined are brought to a temperature above the melting point and then allowed to solidify so that a permanent joining takes place. Welding is not only used for making structures but also for repair work such as the joining of broken castings. Products obtained by the process of welding are called as weldment [2].

MATERIALS AND METHODS

MATERIALS

This chapter studies about the types of stainless steels involved in this project such as duplex stainless steel, martensitic stainless steel, ferritic stainless steel and austenitic stainless steel.

StainlessSteels

When over 11% of chromium added to iron it imparts a considerable improvement in corrosion and oxidation resistance hence the term stainless steel. An important attribute of stainless steel in addition to their corrosion resistance is a result of the development of an impervious surface film of chromium oxide which self healing if scratched or damaged. Most of the stainless steels exhibit good strength, properties and resistance to scaling at elevated temperatures. Exposure to elevated temperatures increases the thickness if the oxide film and reduces the lusture of the stainless steel.

The common grade stainless steels are classified and assigned by the American Iron and Steel Institute (AISI) according to the chemical composition as shown in Table 1 .

Table 1 : Alloy Type Based on AISI Series

AISI Series	**Alloy Type**
2XX	Cr-NI-Mn
3XX	Cr-Ni
4XX	Cr

Stainless steels can be divided into five families. The first four are based on the characteristic crystallographic structure/microstructure of the alloy. They are listed below:

1. Martensitic
2. Ferritic
3. Austenitic
4. Duplex
5. Precipitation hardening stainless steels

The fifth family is based on the type of heat treatment rather than microstructure.

Ferritic Stainless Steel

Ferritic stainless steels are Fe-Cr alloys with body centered cubic (BCC) crystal structures with 11 to 27% chromium. These steels have low chromium – to – carbon ratio so that it doesn't allow the formation of austenite. They are non – hardenable by heat treatment. They are magnetic and have good ductility and good corrosion resistance.

The ferritic stainless steels can be classified as group I alloys, which are standard stainless steels. Group II alloys which contain low interstitial element (C, N, and O).

Group I alloys or first generation FSS includes 430, 442 and 446. They are standard grade of ferritic stainless steel. They are used primarily for their resistance to corrosion and scaling at elevated temperature. Because of grain coarsening there is the formation of martensite. It contains only chromium as a ferritic stabilizer and appreciable carbon. The application of the Group I alloys is not as extensive as compared with other types.

Group II alloys or second generation FSS includes 405 and 409. To overcome some of the difficulties and to improve weldability, several of standard grades FSS have been modified. They are called as Group II alloys. They contain lower level of carbon and chromium. Al, Nb, Ti, W, V etc are added as ferrite stabilizers. They are easy to fabricate than the first generation FSS.

Group III alloys or super FSS types includes S44726, S44635 and S44800. They have low interstitial elements (C, N and O). High chromium content which due to low 'C' and 'N' content results in good ductility and toughness.

Austenitic Stainless Steel

Austenitic stainless steels are Fe-Cr-Ni-C alloys that possess Face Centered Cubic (FCC) structure. ASS is usually the most corrosion resistant of all the stainless steels. They are non – magnetic in the annealed condition. They cannot be hardened by heat treatment. They can be hardened by cold working. They possess excellent cryogenic properties and good high temperature strength and oxidation resistance.

WELDING PROCESSES

This chapter deals with the types of welding used in this project such as Shielded Metal Arc Welding and Gas Tungsten Arc Welding.

Shielded Metal Arc Welding (SMAW)

Heat required for welding is obtained from the arc stuck between a coated electrode and the work piece. The arc temperature and thus the arc heat can be increased or decreased by employing higher or lower arc current. A high current arc with a smaller arc length produces a very intense heat.

Gas Tungsten Arc Welding (GTAW)

Gas Tungsten Arc Welding (GTAW) is an arc welding process wherein coalescence is produced by heating the job with an electric arc struck between a tungsten electrode and the job. A shielding gas (argon, helium, nitrogen, etc) is used to avoid atmospheric contamination of the molten pool. A filler metal may be added, if required.

WELDING PARAMETERS

The stainless steel specimens of dimensions 150X75X4 mm^3 were prepared and the edge to be bonded was chamfered at 35^0. Surfaces of machined samples were cleaned and then placed adjacent to each other by 2-mm distance.

MATERIAL SELECTION

In this study, 304 austenitic stainless steel and 430 ferritic stainless steel specimens 4mm thickness were welded to each other by GTAW and SMAW and the chemical composition of the base material and filler material are given in Table 2 .

Table 2: Chemical Composition of Base Metal and Filler Metal

ELEMENTS MATERIALS	C	Cr	Fe	Mn	Ni	P	S	Si	Mo
304	0.04	18.5	Bal	1.6	9.5	0.025	0.02	0.45	-
430	0.05	17	Bal	0.77	0.5	0.030	0.020	0.50	-
E308L	0.03	20	Bal	1.75	10	0.03	0.025	0.8	0.7

METHODOLOGY

The main objective of this project is to join austenitic stainless steel SS304 and ferritic stainless steel SS430 by various welding processes such as GTAW and SMAW. Conduct various mechanical tests such as tensile test and micro hardness test, then microstructure analysis on the weld metal to determine the effect of various process parameters such as welding current, welding voltage, welding speed and gas flow rate. The overall methodology in this project is shown in Figure 1.

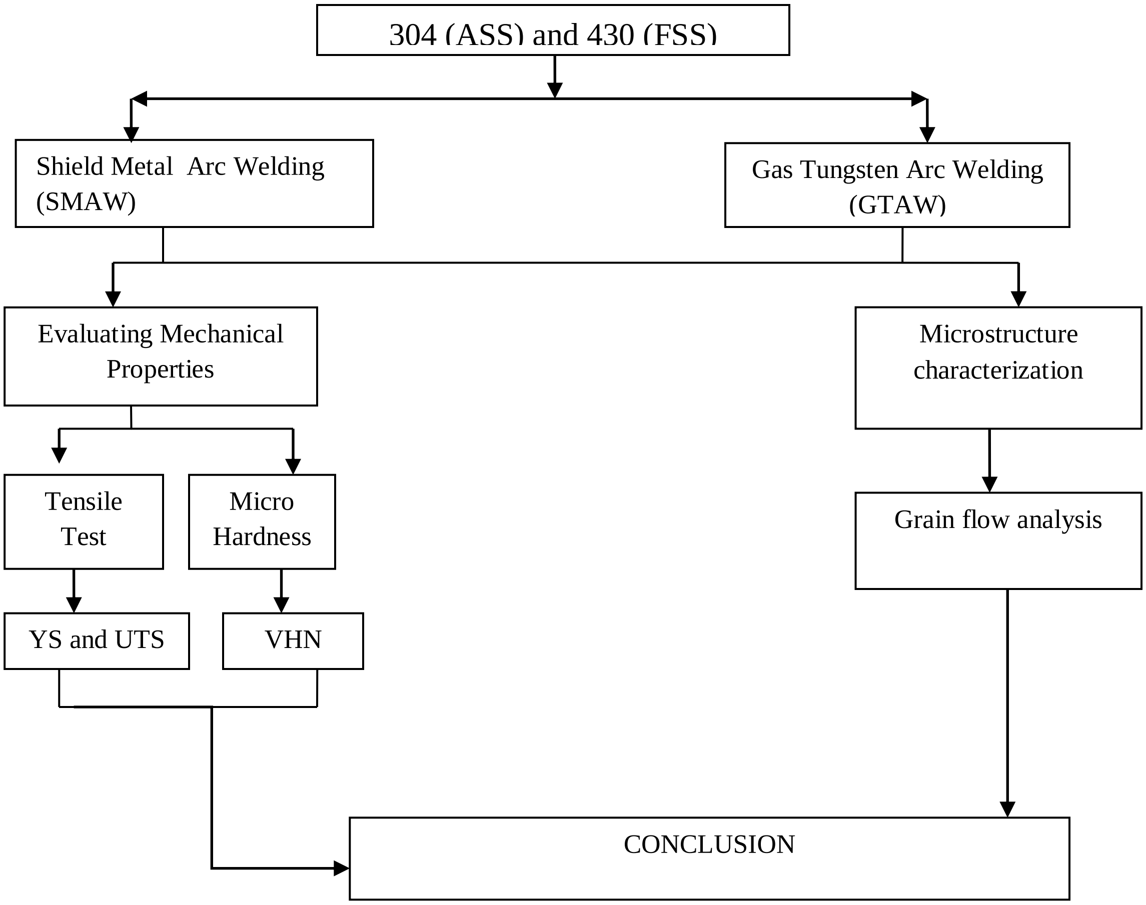


Figure 1: Methodology of Project Work

EXPERIMENTAL WORK

The two welding process are conducted to join ASS 304 and FSS 430 using the parameters stated above. After welding process, the mechanical properties of the specimens are evaluated by conducting tensile and micro hardness test. The tensile test is conducted in tensile testing machine to evaluate yield strength and ultimate tensile strength. The micro hardness conducted in micro Vickers hardness tester to evaluate VHN. The microstructure in the weld region is characterized using metallographic microscope and by calculating the weight loss the corrosion rate is evaluated. The welded samples are shown in the below Figure 2-3.

Figure 2: Welded Specimen by SMAW

Figure 3: Welded Specimen by GTAW

RESULTS AND DISCUSSION

TENSILE TEST

Tensile test was conducted on the base material and the samples welded by SMAW & GTAW welding methods. The testing samples were prepared according to the ASTM E8-04. From the welded samples 8 specimens are prepared for tensile test which are shown in Figure 4. Among 8 specimens, each 4 specimens are from GTAW and SMAW.

Figure 4: Tensile Test Specimens

The tensile test results for the samples welded by various welding methods are tabulated in the below Table 3 and the base material results are shown in Table 4.

Table 3: Tensile Test Results of Welded Specimens

PROPERTIES / PROCESS	Ultimate tensile strength (kN/mm^2)	Yield strength (kN/mm^2)	Elongation (%)
SMAW	0.452	0.412	16.500
GTAW	0.470	0.468	18.588

Table 4: Tensile Test Results of Base Materials

PROPERTIES / MATERIAL	Ultimate tensile strength (KN/mm^2)	Yield strength (KN/mm^2)	Elongation (%)
304	0.372	0.310	48.217
430	0.279	0.154	26.875

Proof stress used when yield stress hard to find. Proof stress required a permanent strain of 0.1% or 0.2% on a removal load. Method for determining proof stress is shown in Figure 5.

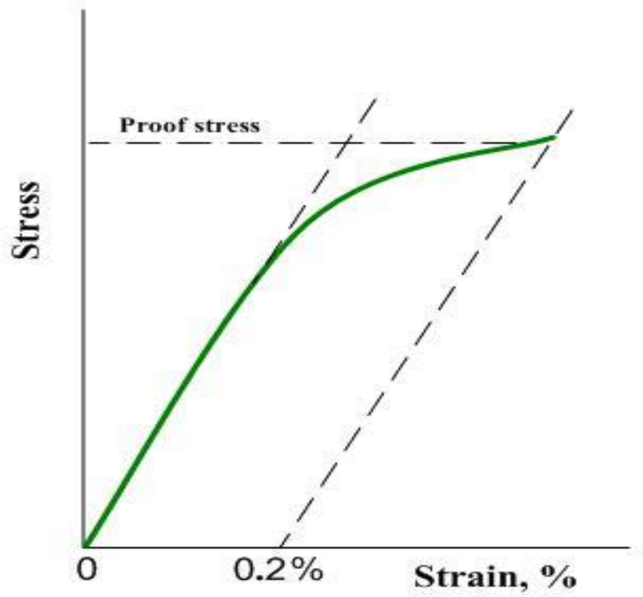


Figure 5. Proof stress

The stress strain curve for GTAW and SMAW is shown in Figure 6-7 respectively.

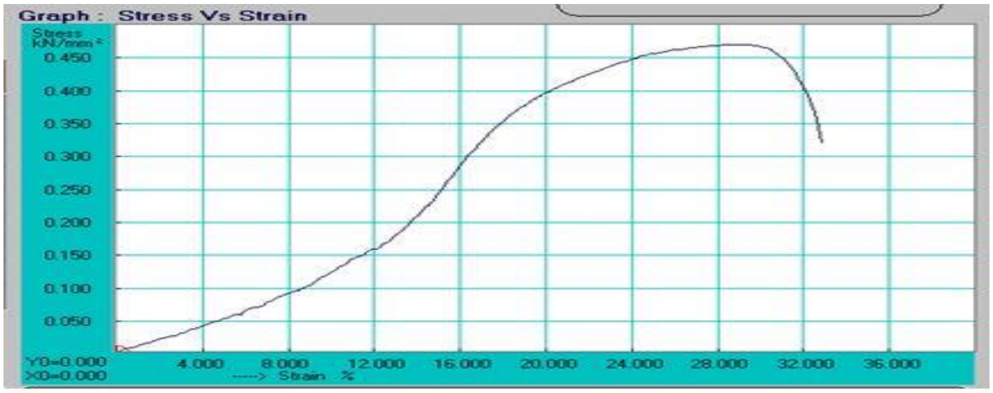


Figure 6: Stress-Strain Curve for GTAW

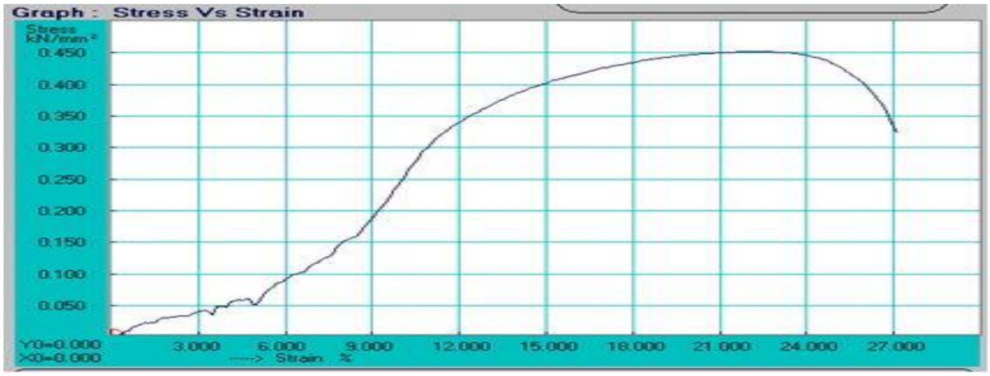


Figure 7: Stress-Strain Curve for SMAW

From the Table 3, highest tensile strength and yield strength is 0.470 KN/mm^2 and 0.468 KN/mm^2 respectively which were welded by GTAW process. And SMAW have tensile strength of 0.452 KN/mm^2 and yield strength of 0.412 KN/mm^2, respectively.

In GTAW and SMAW, the fracture occurred in the base material when welding FSS430. It concludes the weld region possesses good strength than that of base material. The high strength in the welded region is due to the presence of molybdenum, chromium and nickel content in the filler material. The fracture in the weld sample is shown in the Figure 8.

Figure 8: Fractured Sample in Tensile Test

MICRO HARDNESS TEST

The micro hardness (VHN) test was performed on the etched transverse cross-section of the weld zone using a load of 0.5 kg, which was applied for duration of 20 s. The micro hardness results were tabulated in Table 5. In each region, readings were taken in 9 different locations and the average value is tabulated. It concludes that the hardness of the weld region is higher when compared to the base material. The reason is the dissimilar combination in the weld pool possesses good strength against toughness than that of base material because of the fine grain size in the welded region.

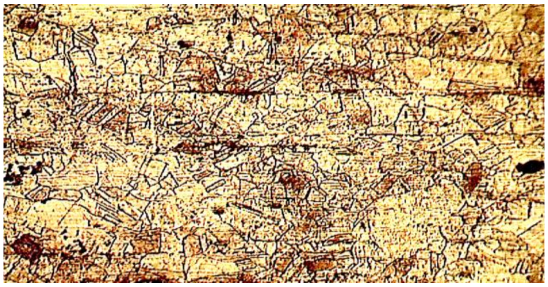
Table 5: Micro Hardness Results

Process	**Distance @1mm**	**VHN @0.5 kg load**
SMAW- 430	0-8	177.685
Weld region	9-17	227.345
304	18-25	209.40
GTAW- 430	0-8	187.76
Weld region	9-17	284.215
304	18-25	209.265

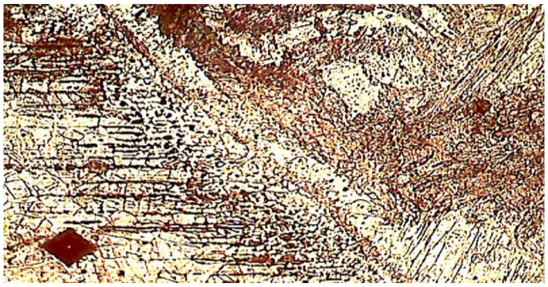
MICROSTRUCTURE CHARACTERIZATION

This chapter studies the microstructural characterization of the welded sample by various welding processes.

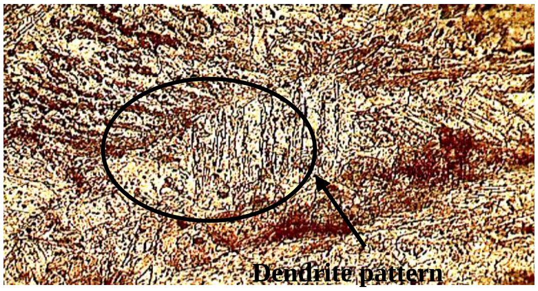
Microstructure of SMAW



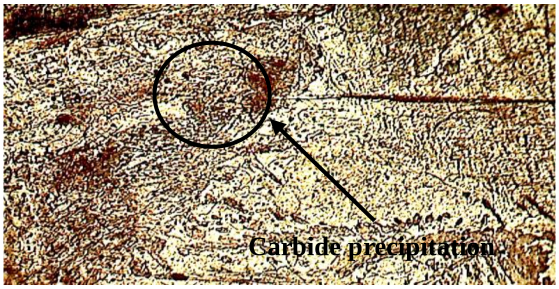
(a)



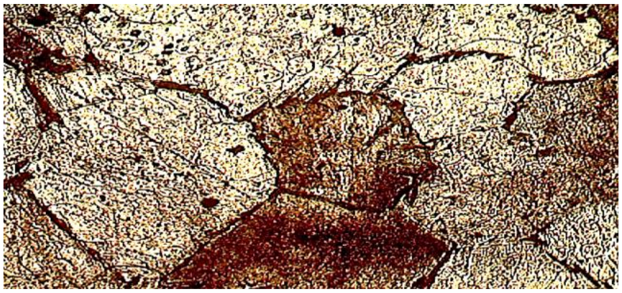
(b)



(c)



(d)



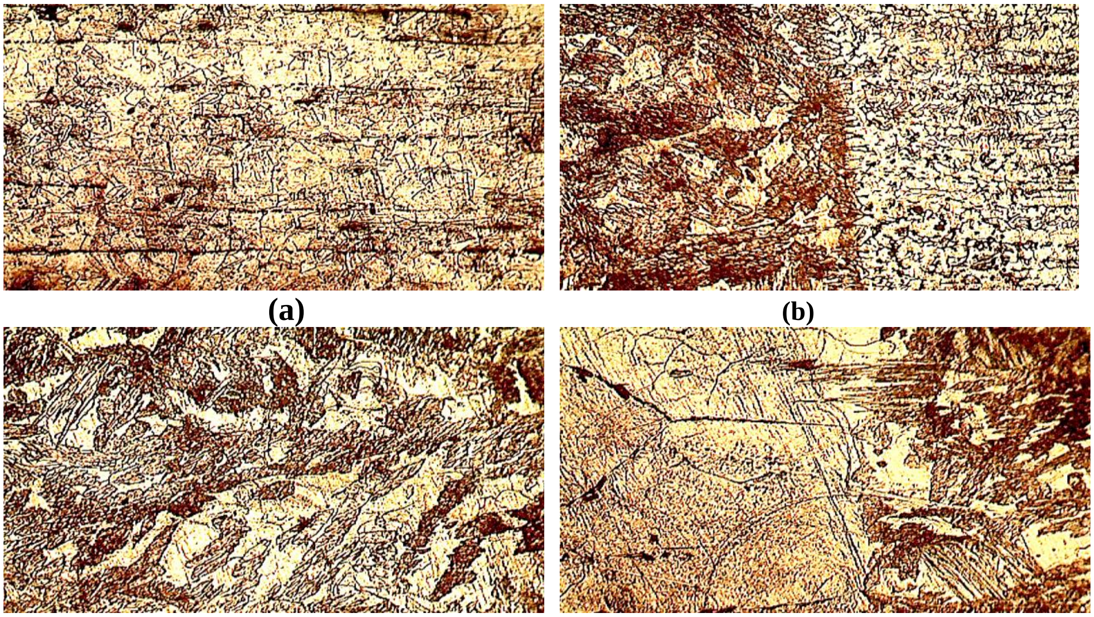
(e)

Figure 9: (a) Microstructure of 304, (b) HAZ between Weld and 304, (c) Microstructure of Weld, (d) HAZ between Weld and 430, (e) Microstructure of 430

The etchant used to clean the samples for microstructure examination is kroll's and aqua regia solution and the magnification is at 150X. Figure 9 (a) shows the microstructure of the SS304 matrix. The material as rolled sheet and the longitudinal rolling direction is shown by the austenite grains with stringers between the grains which are tapped during the rolling; (b) shows the interface zone of the SS and the weld metal. The heat affected zone is seen at the SS side and it is partially re-crystallized at the zone; (c) shows the weld metal matrix with the presence of fine dendrite pattern.; (d) shows the ferritic SS alloy re-crystallized due to heat and the grains are larger at the heat affected zone. The grains are completely ferritic with some carbide of chromium; (e) shows the microstructure of ferritic SS alloy with ferrite phase. The ferrite grain is white and the carbide grain is black.

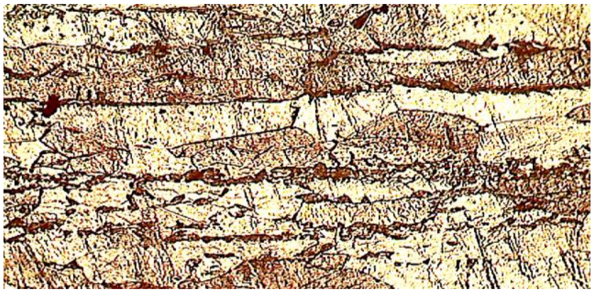
Microstructure of GTAW

The etchant used to clean the samples for microstructure examination is kroll's and aqua regia solution and the magnification is at 150X. Figure 10 (a) shows the microstructure of the SS304 matrix. The material as rolled sheet and the longitudinal rolling direction is shown by the austenite grains with stringers between the grains which are tapped during the rolling; (b) shows the interface zone of the SS and the weld metal. The heat affected zone is seen at the SS side and it is partially re-crystallized at the zone; (c) shows the weld metal matrix with the presence of fine dendrite pattern. The weld consists of austenite with some ferrite islands; (d) shows the weld metal microstructure have very large dendrites with coring along the parent metals. The ferritic SS alloy re-crystallized due to heat and the grains are larger at the heat affected zone. The grains are some ferrite and carbide; (e) shows the microstructure of ferritic SS alloy with ferrite and carbide grains. The ferrite grain is white and the carbide grain is black.



(a) **(b)**

(c) **(d)**



(e)

Figure 10: (a) Microstructure of 304, (b) HAZ between 304 and Weld, (c) Microstructure of Weld, (d) HAZ between Weld and 430, (e) Microstructure of 430

CONCLUSION

On the basis of the mechanical properties, micro structural characterization, macrostructure examination, and corrosion behaviour experimental studies accomplished and the results obtained on the effect of welding processes on dissimilar welded joints of stainless steel the following conclusion may be drawn:

1. For tensile strength, the best strength is obtained from GTAW process when compared to SMAW. The ultimate tensile strength is 0.470 KN/mm^2 and yield strength is 0.468 KN/mm^2.
2. In tensile test, the fracture occurred in base material, 430. Hence, the weld possesses good strength than that of base material.
3. The hardness in the weld metal is higher than that of base material. The reason is the dissimilar combination in the weld pool possesses good strength against toughness than that of base material because of the fine grain size in the welded region.
4. From the macrostructure, the flow lines are formed from base material towards the weld pool. The HAZ is very large in 430 and very small in 304. The fine crystal like structure can be viewed in the macrostructure shows the presence of carbides.
5. In the microstructure, the fine grain flow shows good formation of the weld in the joint. The elongation of grain size is due to high temperature. The direction of flow of grains is from base material towards the weld pool.

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