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A Review on Welding of AISI 316L Austenitic Stainless Steel

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Abstract*: AISI 316L is an austenitic chromium-nickel stainless steel that has highest corrosion and creep resistance properties because of molybdenum (Mo) contents in addition to other constituents of the austenitic stainless steels and is modified for welded construction (low carbon content modification). In this research paper, a thorough review on welding of AISI 316L austenitic stainless steel was made considering four different most commonly used welding processes. From the review, it is acquired that shielded metal arc welding (especially manual) is the most suitable choice of welding process for AISI 316L austenitic stainless steel because of possible reactions of chromium with carbon and oxygen at welding temperatures in other welding processes.*

Keywords— Austenitic Stainless Steels, AISI 316L, Welding Processes, Shielded Metal Arc Welding

1. INTRODUCTION

1.1. Stainless Steels:

In the beginning, the stainless steels were named according to the percentage composition of chromium and nickel. That is why one of the firstly developed stainless steel which contained 18% chromium and 8% nickel was named 18 – 8 stainless steel.
With the development of more stainless steel alloys, American Iron and Steel Institute (AISI) established a numbering system to classify the different alloys. In this system, the chromium stainless steels were designated with numbers in 400 series and the chromium – nickel steels with numbers in 300 series.
Variations from this numbering system were also accommodated in AISI nomenclature system. For example, low carbon modifications of AISI 304 and AISI 316 are designated as AISI 304L and AISI 316L respectively. Similarly free machining modifications of these alloys are designated by the letter F or the symbol of an element after the number; examples are AISI 430F and AISI 303Se.

1.2. Austenitic Stainless Steels:

Austenitic stainless steels are the highest tonnage of weld able steels that are produced every year. These steels as a family offer a combination of optimum mechanical, corrosion resistance and heat/temperature resistance properties that are unachievable by any other commercially available metal. These excellent set of properties make austenitic stainless steels suitable for most of the applications such as in fabrication of as small things as pots and pans in kitchen to as large and complex structures as in fabrication/manufacturing of aircrafts and nuclear reactor equipments.

1.3. Welding of Austenitic Stainless Steels:

Among AISI stainless steels, austenitic stainless steels are the most weld able grades. However, austenitic stainless steels too have few limitations, hence their welding require special attention. During welding of austenitic stainless steels, distortion and wrapping of welded parts is the prominent issue which arises due to the high coefficient of thermal expansion of austenitic stainless steels.
Austenitic stainless steels have over 50% higher coefficient of thermal expansion than carbon steels and other 400 series alloys of stainless steels.
The weldments of austenitic stainless steels sometimes show decrease in corrosion resistance especially in hot acid mediums due to carbide precipitation during welding in these grades.

2. REVIEW OF WELDING PROCESSES ON AISI 316L

A review on welding of AISI 316L austenitic stainless steel by four most commonly used welding processes that are shielded metal arc process, submerged arc process, gas metal arc process and gas tungsten arc process is depicted in the following sections.

2.1. Welding AISI 316L with the Shielded Metal Arc Process:

Shielded metal arc welding (SMAW), also known as conventional arc welding and industrially known as stick welding is a type of welding process that uses a consumable metal electrode. The weld circuit is completed between the electrode itself and the base material (work piece). In shielded metal arc welding process, the electrode is covered with a flux which melts together with the core of the electrode that forms the slag/gas that shields the weld pool and prevents it from the incoming dust or dirt and moisture etc.
The shielded metal arc welding is widely used in most industrial applications due to its versatility, simplicity and indoor/outdoor applicability.
The currently available literature on the shielded metal arc process of AISI 316L revealed that up to thickness of 10mm (0.4 inch), the manual shielded arc welding is the most suitable process for welding AISI 316L as the same results in superior mechanical properties of the weldments that are tensile properties including percent elongation, impact properties and hardness properties.

2.2. Welding AISI 316L with the Submerged Arc Process:

Submerged arc process is a type of welding that uses a continuously fed wire (bare electrode i.e., electrode not covered with flux). The arc circuit is completed between the continuously fed electrode and the base material (work piece). In submerged arc welding process, a shielding gas is not required as the blanket of powdered flux acts as a protective blanket/covering which protects the weld zone from incoming dust, dirt moisture etc.
The available literature reveals that the submerged arc welding process is economical for welding of AISI 316L austenitic stainless steel when the plate thickness becomes greater than 10mm (0.4inch).
In these cases, submerged arc welding process is economical for thicknesses greater than 10mm (0.4inch) as it would result in less number of passes of welding.
However, the shortcoming in submerged arc welding process is that the high heat input in submerged arc welding process normally results in the reduction of impact properties (toughness) and resistance to corrosion (anti corrosion properties).

2.3. Welding AISI 316L with the Gas Metal Arc Process:

Gas metal arc process is a type of welding process that uses a consumable metal wire electrode. The weld arc circuit is completed between a consumable wire electrode and the base material (work piece). Gas metal arc welding (GMAW) process utilizes an inert gas or a mixture of two or more inert gases as the shielding gas that prevents dust, dirt and moisture etc from entering into the weld zone.
The currently available literature reveals that the AISI 316L austenitic stainless steel weldments welded by gas metal arc process are susceptible to the entrance of air through the underside of the weld when the weld puddle is solidifying. As a result of air entrance, the nitrogen and oxygen present in the air weakens the molten and cooling weldment and hence the mechanical properties of the weldments that are tensile properties, impact properties and hardness properties are compromised.

2.4. Welding AISI 316L with the Gas Tungsten Arc Process:

Gas tungsten arc process is a type of welding process that uses a non consumable tungsten electrode, a filler material (bare wire) and an inert gas. In gas tungsten arc process, the electric arc is formed by completing the circuit between tungsten electrode and base material (work piece). The welding region is protected from dust, dirt and moisture by an inert gas or a mixture of two or more inert gases.
While investigating the currently available literature on gas tungsten arc welding of AISI 316L austenitic stainless steel, it is acquired that the mechanical properties of AISI 316L austenitic stainless steel weldments, that are tensile properties, impact properties and hardness properties are better than the submerged arc and gas metal arc processes but are lower than the shielded metal arc process.
Also the values for these properties in case of gas tungsten arc welding process depends mainly on the type of filler material (welding consumable) being used.

3. CONCLUSION

From the review of four different welding processes for welding of AISI 316L austenitic stainless steel, the following conclusions are made;

- For plates of thicknesses up to 10mm (0.4 inch), the manual shielded arc welding results in the superior mechanical properties of the weldments that are tensile properties including percent elongation, impact properties and hardness properties.
- Next to shielded metal arc welding, gas tungsten arc welding is the most suitable type of welding process that results in the better mechanical properties as a whole.

4. REFERENCES

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