# Welding Research: Effect of Joint Design on the Corrosion Resistance of Welds

**Jastej Singh**
Sant Longowal Institute of Engineering & Technology, Punjab
Email: jastej87@gmail.com

## Introduction

Before reading the actual story of the research carried out and its outcomes, let us familiarize ourselves with the characters involved in this story. Whenever we have to join two or more materials together permanently, one word comes to the mind; yes that's right! 'Welding'. Since welding joins materials permanently unlike other methods such as nuts and bolts, it is important in our lives. Welded structures are all around us. Let us see some of the examples: LPG cylinders, frames of bicycles, bikes, cars, buses, metallic structures under flyover bridges, etc. Apart from these common observations, welded structures are used in engineering applications like in aircrafts, nuclear reactors, space vehicles, etc. When two materials are to be joined together by welding, extreme heat is used to melt the materials and an extra material is supplied from outside in the joint area. Since the materials are getting melted by the heat used in the welding, their structure (technically speaking: '*microstructure*') gets changed. Due to these changes, the joint made may prove to be superior or inferior (in terms of properties) than the original base material joined, that depends upon numerous factors. We have to be very sure that the welded structures are of superior quality and should be capable of withstanding the service conditions in which they are subjected to, has the capacity to lift loads, bear corrosive environments, etc. This is done by performing

* Mr. Jastej Singh, Ph.D. Scholar from Sant Longowal Institute of Engineering & Technology, Punjab, is pursuing his research on "Weld Procedural Effects on Metallurgical, Impact Toughness and Corrosion Behavior of AISI 2205 Duplex Stainless Steel Electron Beam Welds." His popular science story entitled "Welding Research: Effect of Joint Design on the Corrosion Resistance of Welds" has been selected for AWSAR Award.

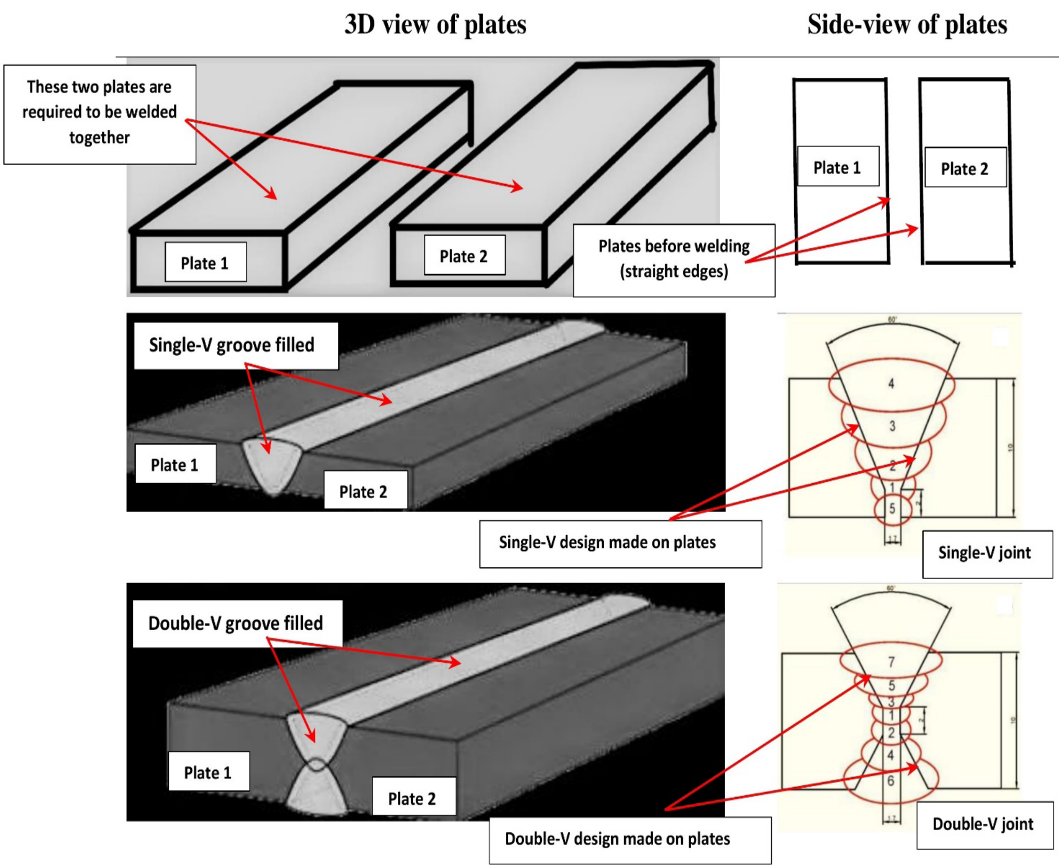


*Figure. 1. Diagrams of two types of weld joint designs used in the present work.*

simulations and experiments for specific applications before actual welding is performed on the structures meant to serve in actual practical conditions.

The present research was focused on "**understanding the effect of joint design and high-temperature exposure on the corrosion performance** *(means the ability to withstand against corrosive environment)* **of the welded joints of 304L grade stainless steel**". First, let us understand the meaning of "*joint design*" in context with welding procedures. Have a look at Figure 1 given below; there are two plates that we want to join together by welding, their edges are straight; these are not ready for welding. An additional step is required, i.e., cutting the straight edges in such a way that a groove or seat is formed which will be filled by additional material (called as *filler material*) during welding as mentioned above. The shape of the groove cut on the plates is called the "*joint type or design*". There are various joint types, the selection of which is based on various requirements, but single-V and double-V types are the most commonly used and also were used in this work. See how two types of joints were made, one was single-V and the other was double-V as evident from their shape.

## Background of the problem

The term *"corrosion"* is a disease to materials just as various diseases to human bodies. This can cause materials to fail during service applications and it can become a cause for accidents or failures of structures. There are different corrosion types depending on the environment. The severity of different corrosion types on materials can be understood from various accidents which have resulted in the loss of human lives. Let us see some of such accidents from the past in which corrosion of materials was one of many factors responsible: Bhopal gas tragedy-India (1984), Prudhoe Bay oil spill-USA (2006), Carlsbad pipeline explosion-New Mexico (2000) etc. Thus prevention against corrosion is a major challenge and it is a key area of research. The knowledge of how a material is going to behave when it is subjected to a corrosive environment is required beforehand. The material used in this research was *"304L stainless steel"*. When we read or hear the word "Stainless Steels,", one thought comes to our mind that they do not corrode or they are not affected by rust. That is true in case of normal environmental conditions because for a steel to be called *"Stainless"*, it should have at least 12% chromium in it to resist corrosion. Stainless steels are basically materials that are made up of elements like carbon, chromium, nickel, and iron apart from the addition of various other elements. Most common stainless steel used is the grade 304 (belonging to the so-called *Austenitic Stainless Steels family*), also known as 18/8 steel. The utility of this steel is seen from its applications ranging from most common ones like thermos flasks to highly advanced ones like in satellite launch vehicles. One of the most important problems affecting this steel (and also other austenitic stainless steels) is *Sensitization.* If these steels are exposed to high temperatures like in the range of 600°C-850°C for a certain period of time, its elements, namely chromium and carbon combine together to form compounds. Now this compound formation will create regions in steel that are deficit in chromium (as total chromium content is going to be the same, compound formation means chromium content in certain regions will increase and in certain regions, it will decrease); now these regions will no more resist corrosion as already discussed; we need at least 12% chromium for corrosion resistance. The occurrence of such compound formation is termed as *sensitization* which if it occurs makes these materials prone to corrosion attack and the material is said to be *sensitized*. *"Degree of sensitization (DOS)"* is the technical term used to indicate the extent of sensitization in a material. Higher the value of DOS, it means more sensitization in the material and vice-versa. Apart from exposures to high temperatures, sensitization in materials can also occur during their welding. Another type of corrosion that this material is prone to, is *pitting corrosion.* Pitting corrosion is a highly dangerous form of corrosion which damages the materials. This usually occurs in the presence of a corrosive environment especially containing chloride ions; for example sea water.

## Research conducted and its findings

Now, we have become familiar with the terms like *joint design*, *sensitization*, *pitting corrosion*, *degree of sensitization (DOS)*, we can move forward in knowing the aim of the research carried out and its outcomes. The present work focused on knowing *the effect of joint design and high-temperature* *exposures on the sensitization and pitting corrosion resistance of 304L stainless steel welded joints* (metal inert gas (MIG) welding was used). The objectives of this research are presented in the form of questions for clarity and answers are given after each question. This represents the actual output obtained from this research. The complete results of this research are published in the form of a scientific article in the *Journal of Manufacturing Processes*.

Q: 1) If we use two most commonly used joint designs namely single-V and double-V to weld 304L stainless steel, which joint type will give more corrosion resistant weld joints?

Ans. Single-V joint design can prove to be a better selection for better corrosion resistance.

Q: 2) What is the effect of time duration when these steels are exposed to high temperatures on the corrosion performance of these welds?

Ans. It was found that as the exposure time increased, welds became more prone to sensitization and pitting corrosion, thus indicating that, higher the exposure time to high temperatures, higher will be the vulnerability to sensitization and pitting corrosion attack.

Q: 3) If 304L stainless steel weld joints are exposed at 750°C in a furnace, and we have to cool them to room temperature with the following options available: 1) Just let them in the furnace (slow cooling), 2) take them out of furnace and leave in open air (relatively faster cooling) and 3) put them directly in water for instant cooling (fastest cooling); which method will be highly desirable/undesirable in affecting the corrosion resistance of weld joints?

Ans. Slower cooling like in case of a furnace is not desirable. Faster cooling should be done for prevention against sensitization.

Q: 4) Is there a correlation between a stainless steel getting sensitized and its vulnerability to pitting corrosion attack?

Ans. Yes, there is. The results of the experiments revealed a clear relation between the extent of sensitization and pitting corrosion attack. Higher the sensitization in a material, lower will be its pitting corrosion resistance and vice-versa.

Knowledgebase generated from this research is beneficial to the scientific community

"If we have a component made up of austenitic stainless steel, which is going be welded and subjected to a corrosive environment, selecting single-V joint design over double-V design could prove to be a better decision". The technical reason behind it is that the total heat required to complete welding was less in case of the single-V joint type. In a nutshell, those welded joints are good that require less heat input for their welding and better corrosion resistance could be expected from them as compared to the joints made using relatively higher heat input.