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Analyzing the Parameters of SS 304 using TIG Welding

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Abstract— *Over the years the lifespan of many machines have been reduced or have not matched its estimated lifespan due to poor joints and the materials have not adapted to the working conditions. The poor joints may be due to the improper fasteners or due to the improper welding joints. The improper welding methods may be due to the welding method that may not be suitable for the working environment or may not be apt for the material that is used in the machine. Our project deals with studying and analyzing the properties of TIG welded SS 304 specimen by conducting various tests. SS 304 is the most commonly used metal in food processing machines because of its high corrosion resistance. But a slight drawback is that the machines that use SS 304 fail due to its poor fail welding joints. Hence this project deals with finding out whether the TIG welded SS 304 joint can withstand extreme conditions and various tests performed on it.*

Keywords— *SS 304, TIG Welding, Tensile Test, Hardness test, Microscopic Analysis, Factor of Safety, Toughness.*

I. INTRODUCTION

This project deals with analysing the properties of SS 304 specimen using TIG Welding. The main objective is to find out whether the TIG welding is suitable for Food Processing Machine like the Roaster Machine, hence SS 304 is considered. The other objectives of the project are to find which of the welded surface is stronger and apt for the used material and also to find out whether the welded joint is strong enough to withstand the extreme operating conditions. Several tests are conducted on the material and results are gathered based on which a conclusion is made. The material which is used is Stainless steel of grade 304. It is one of the most common materials used in food processing machines because of its high corrosion resistance. The steel contains both chromium (usually 18%) and nickel (usually 8%) metals as the main non-iron constituents. It is an austenite steel. It has a higher corrosion resistance than regular steel and is widely used because of the ease in which it is formed into various shapes. Gas tungsten arc welding (GTAW), also known as tungsten inert gas (TIG) welding, is an arc welding process that uses a non-consumable tungsten electrode to produce the weld. The weld area is protected from atmospheric contamination by an inert shielding gas (argon or helium), and a filler metal is normally used, though some welds, known as autogenous welds, do not require it. A constant-current welding power supply produces electrical energy, which is conducted across the arc through a column of highly ionized gas and metal vapours known as plasma.

II. MATERIAL AND METHOD

The material used in this project is SS 304 and the welding method that is going to be used to join the specimen is TIG Welding.

A. Stainless Steel 304

304 stainless steel is the most common form of stainless steel used around the world, largely due to its excellent corrosion resistance and value. It contains between 16 and 24 percent chromium and up to 35 percent nickel—as well as small amounts of carbon and manganese. The most common form of 304 stainless steel is 18-8, or 18/8, stainless steel, which contains 18 percent chromium and 8 percent nickel. 304 can withstand corrosion from most oxidizing acids. That durability makes 304 easy to sanitize, and therefore ideal for kitchen and food applications. It is also common in buildings, décor, and site furnishings. Grade 304 is the standard "18/8" stainless; it is the most versatile and most widely used stainless steel, available in a wider range of products, forms and finishes than any other. It has excellent forming and welding characteristics. For these applications it is common to use special "304DDQ" (Deep Drawing Quality) variants. Grade 304 is readily brake or roll formed into a variety of components for applications in the industrial, architectural, and transportation fields. Grade 304 also has outstanding welding characteristics. Post-weld annealing is not required when welding thin sections. The chemical Formula for SS 304 is

Fe, <0.08% C, 17.5-20% Cr, 8-11% Ni, <2% Mn, <1% Si, <0.045% P, <0.03% S

The Mechanical Properties of SS 304 is described in the table I.

TABLE I. Mechanical properties of SS 304.

Grade	**Tensile strength (MPa)min**	**Yield strength 0.2% Proof (MPa)min**	**Elongation (% in 50mm) min**	**Hardness**	
				Rockwell (HRB) max	**Brinell (HB)max**
304	515	205	40	92	201

The physical Properties of SS 304 is mentioned in the table II.

TABLE II. Physical properties of SS 304.

Grade	**Density (kg/m^3)**	**Elastic modulus (GPa)**	**Thermal conductivity (W/m.k)**		**Specific heat**	**Electrical resistivity (nΩm)**
			At 100 ° C	At 500 ° C	0-100 °C (J/Kg.K)	
304	8000	193	16.2	21.5	500	720

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Typical applications of SS 304 include Food processing equipment, particularly in beer brewing, milk processing & wine making, Kitchen benches, sinks, troughs, equipment and appliances, Architectural panelling, railings & trim, Chemical containers, including for transport and Heat Exchangers.

B. TIG Welding

The Principle of TIG welding is an electric arc welding process in which the fusion energy is produced by an electric arc burning between the work piece and the tungsten electrode. During the welding process the electrode, the arc and the weld pool are protected against the damaging effects of the atmospheric air by an inert shielding gas. The flow of electrons from the point of the electrode takes place at a very high speed and when it hits the work piece a substantial amount of heat energy is produced.

Tungsten is the main source of welding. Tungsten electrodes are available in different diameters from 0.5 to 8 mm. The most frequently used dimensions for TIG welding electrodes are 1.6 - 2.4 - 3.2 and 4 mm. The diameter of the electrode is chosen on basis of the current intensity, which type of electrode that is preferred and whether it is alternating or direct current.

Alternating current is characterized by the fact that the voltage changes polarity a certain number of times, usually 100 times per second. According to the theory of electrons the negatively charged electrons and positively charged ions will migrate when the arc is ignited.

The TIG welding equipment chiefly consists of machine setup as shown in Fig.1 with the following components.

- A TIG torch that is the tool the welder uses to control the arc.
- A power source which is capable of providing the necessary welding current.
- A TIG unit with incorporated control systems that make it possible to adjust the welding current, arc initiation etc.
- A shielding gas cylinder with pressure reducing valve and flowmeter.

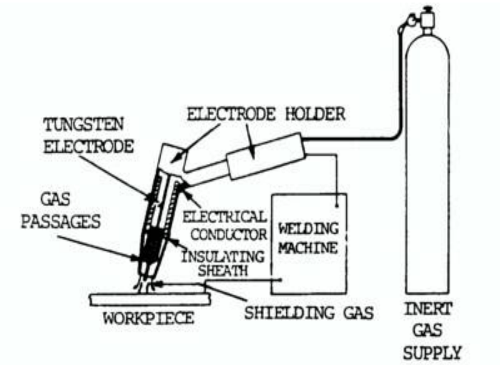

Fig. 1. TIG welding machine setup.

TIG welding process has a very large area of application due to its many advantages like

- It provides a concentrated heating of the work piece.
- It provides an effective protection of the weld pool by an inert shielding gas.
- It can be independent of filler material.
- The filler materials do not need to be finely prepared if only the alloying is all right.
- There is no need for after treatment of the weld as no slag or spatter are produced.
- Places of difficult access can be welded.

III. METHODOLOGY

SS 304 material is considered and a sheet of this metal of thickness 5 mm is taken for the purpose and it is cut into four 30x30 mm plates. It is divided into two pair and each pair is TIG welded as shown in Fig. 2. These work pieces are used for testing purpose.

Fig. 2. TIG welded specimen.

IV. TESTS PERFORMED

TIG Welded SS 304 specimen is considered and various tests are performed on it. This paper consists only of Destructive tests like Hardness test and Tensile test. Along with that a microscopic structural analysis is performed on the specimen.

A. Tensile Test

The tensile test is carried out on the TIG welded work piece. The work piece which is cut based on the tensile test standard, i.e., ASTM-E8M-04 is attached between the cross heads in the Universal testing machine shown in Fig. 3. The lower crosshead is fixed whereas the upper crosshead is movable. The maximum load range is given as 20000 N and the extension range is provided to be 50mm. The speed of the extension is set at 1.0 mm/min and the reading is noted with a preload of 0 N.

Fig. 3. Universal testing machine.

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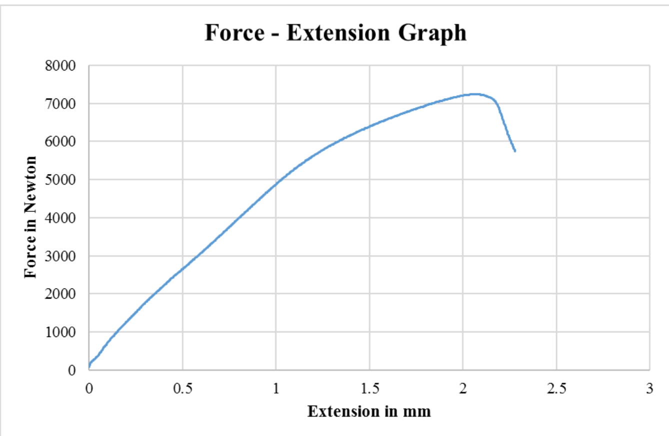
The test is begun right from the null position of the setup. Gradually the force is adjusted so that there is extension in the material till the specimen breaks due to tension as shown in Fig 4. The gradual change in the force and the extension is recorded by the output unit, computer. The Horizon software which is an inbuilt data analysis software plots a graph for the observed values which is mentioned in the table III.

Fig. 4. Tensile test specimen.

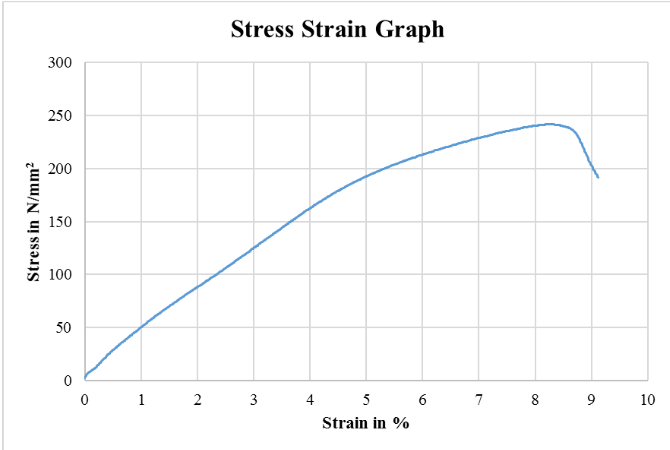
TABLE III. Some of the observed values in tensile test.

S. No.	Force (N)	Extension (mm)
1.	82.5	0
2.	945	0.14
3.	2647.5	0.5
4.	4432.5	0.9
5.	5917.5	1.3
6.	6772.5	1.7
7.	7087.5	1.9
8.	7245	2.045
9.	7245	2.05
10.	7245	2.08
11.	7245	2.085
12.	7230	2.1
13.	6772.5	2.2
14.	5962.5	2.26
15.	5745	2.28

Based on the observed values, two graphs are plotted which provides relation between Stress Vs Strain and Force Vs Extension which is provided in the Fig. 5(a) & (b).



(a) Force extension graph.



(b) Stress strain graph.

Fig. 5(a) & (b). Graph obtained in tensile test.

Based on the graph and the values various parameters are calculated using the formulae for better analysis of properties.

Based on the observed values, various parameters like Young's modulus, Factor of Safety, Toughness etc., are calculated.

Interference from the test,

Yield Stress = 241.5 MPa

Extension at breaking point = 2.28 mm

i.e., change in length = 2.28 mm

Hence, Strain = ΔL / L = 2.28 / 25

= 0.0912

% Strain = 9.12%

Young's Module = Stress/Strain

= 241.5*103 / 0.0912

= 2648026.3 Pa

= 2.65 GPa

On average, Mass of 500 kg acts on the surface

Therefore, Force = 4900N

Hence, Working Stress = 4900/0.30

= 163.33 MPa

Safety factor = Yield Stress/Working Stress

= 241.5 /163.33

FOS = 1.48

Toughness = Stress * Strain = 241.5 * 0.0912

= 22.0248 * 103 J/m3

Toughness = 22025 J/m3

B. Hardness Test

Hardness test is carried out using the Vickers Hardness Machine shown in Fig. 6 on the TIG Welded work piece of dimension 30x30 mm. It is made sure that the bottom surface of the work piece is flat and there are no impurities. Pre adjustments are made and the load is set to 0. The load is then applied starting from 20 and gradually increasing. The loads applied are 20, 40, 60, 80, 100 and once the load is applied indentation occurs as shown in figure 7.

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Fig. 6. Vickers hardness test machine.


Fig. 7. Hardness test specimen.

The corresponding indentation is noted down to calculate the Vickers Hardness Number. The Vickers Number is calculated for each load applied. Initially the test is conducted on the Welded Zone of the work piece. Then the heat affected zone and the unaffected zone are tested. The readings observed are mentioned in the table IV and the corresponding graph is given in Fig. 8.

TABLE IV. Hardness test values.

Load (gf)	Welded Zone (HRV)	Heat Affecting Zone (HRV)	Unaffected Zone (HRV)
20	58.3	42.1	33.9
40	123.4	98.6	72.3
60	193.6	174.3	154.8
80	281.8	255.6	236.1
100	361.4	327.8	304.6

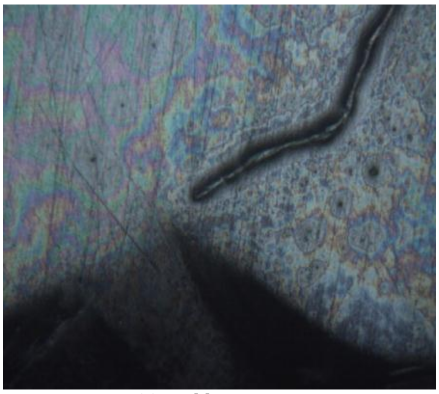
Fig. 8. Hardness testing graph.

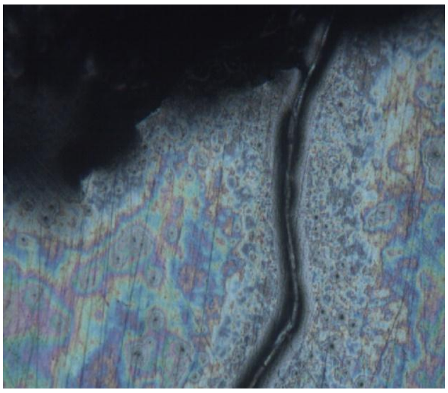
C. Microscopic Analysis

The specimen shown in figure 9 is cut into the dimension of 30x30 mm and used for analysis. The length of the weld is 30mm and width of the bead is 6mm. It is grinded by a grade of 320 grit. It is made into a polished surface. The specimen is later etched by a stainless steel etching reagent. Once these steps are completed it is examined for microscopic structure.


Fig. 9. TIG welded specimen for microscopic analysis.

Magnification of X50 is done for initial overview and then magnification of X100 is done for clear analysis. These magnified images provide a clear idea about the problems or characteristics of the welded specimen. The Welded zone, Heat affected zone and the unaffected zone are analyzed separately for better analysis of the specimen and the analyzed microscopic images are shown in the figure 10.


(a) Weld zone 50X.


(b) Weld zone 100X.

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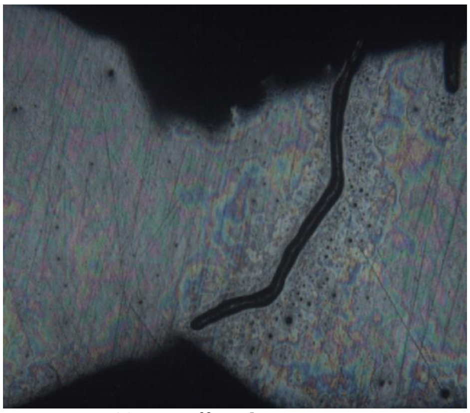
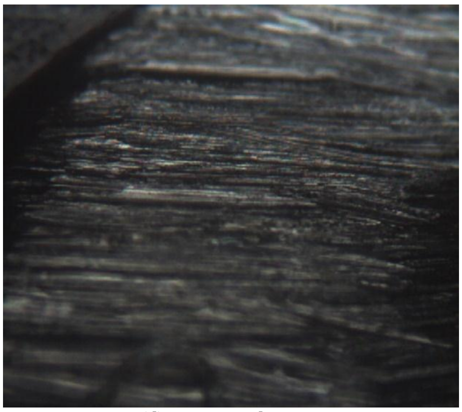


(c) Heat affected zone 100X.



(d) Base metal 100X.

Fig. 10 (a), (b), (c) & (d). Microscopic analysis of TIG welded specimen.

V. RESULTS

As per the objective of this project, several tests were conducted and various values were obtained for TIG welding. Based on all the observed values, TIG welding has its own good strength on SS 304. This can be justified by a simple means that the Factor of safety of TIG welded specimen is 1.48. In simple terms it can be said that the TIG welded joint can withstand 0.5 times more force than the actual calculated force. Various parameters like stress, strain, hardness, toughness etc., were calculated for the TIG welded specimen and are mentioned in the table V.

TABLE V. Values obtained for TIG welded specimen based on the tests.

S.No.	**Parameters**	**TIG Welding**
1	Yield Stress	**241.5 MPa**
2	Tensile strength	**241.5 MPa**
3	% Strain	**9.12 %**
4	Young's Modulus	**2.65 GPa**
5	Toughness	**22025 J/m^3**
6	Factor of Safety	**1.48**
7	Hardness(Welded Zone)	**58 – 361 HRV**
8	Hardness (Heat Affected Zone)	**42 – 327 HRV**
9	Hardness (Unaffected Zone)	**34 – 304 HRV**
10	Microscopic Analysis	**Slight Visible cracks due to drop test.**

VI. CONCLUSION

This project clearly states that the TIG welded sample holds good on a SS 304 specimen. The TIG welded specimen can hold onto a force of 0.5 times more than the calculated force. Hence its Factor of Safety is 1.48 which is excellent for any machine mainly Food Processing machine. Also, TIG is easily available and does not require a huge skilled labor to perform the welding. In simple terms it can be said that if the product has to be budget constrained and Good lifetime is needed, then TIG welding can be preferred.

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