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Optimizing the Mechanical Properties of AISI 304 Steel in Gas Metal Arc Welding Process

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ABSTRACT: The objective of this research is to study the influence parameters affecting to mechanical property of austenitic stainless steel grade (AISI 304) with gas metal arc welding (GMAW). The research was applying the different values of wire speed and current for experiment, which have following interested parameters: welding current at (180, 250, and 320) amps, welding wire speeds at (2, 3 5 m/min), shield gas pure CO_2 welding voltage. The study was done in following aspects: tensile strength, micro hardness. A research study investigate the tensile strength of welding joint is maximum 320.4 n/mm² at wire speed 3m/min and 250 amps welding current. The maximum value of micro hardness for weld joint is 444.9 gf/mm² at 3m/min wire speed and 250 amps welding current and for haz 431.2 at 250 amp & 3m/min wire speed.

Keywords: Austenitic stainless steel; Micro hardness; Tensile strength

I. INTRODUCTION

Austenitic Stainless Steels have high ductility, low yield stress and relatively high tensile strength, when compare to typical carbon steamed. The composition of Stainless Steel consists of C-0.08%, Mn-2.00%, Si-1.00%, Cr-19.0 to 21.0%, Ni-10 to 12%, P-0.45%, S-0.03% etc. The Tensile strength and yield strength is 515 MPa & 205 MPa respectively The high chromium and nickel contents give the steel excellent oxidation resistance as well as high strength at high temperatures enabling its widespread usage in many application. The composition of 304 Stainless C-0.04%, Mn-2.0%, Si-0.75%, Cr-17-20%, Ni-8-13%, P-0.35%, S-0.15% etc. 304 stainless steel is standard grade and typically comprises 17-20% chromium and 8-13% nickel and fasteners manufactured from this material show excellent resistance to corrosion in all but the harshest environments. Alloys 304 are also resistant to moderately aggressive organic acids such as acetic and reducing acids such as phosphoric. The 9 to 11 percent of nickel contained by these 18-8 alloys assists in providing resistance to moderately reducing environments. The more highly reducing environments such as boiling dilute hydrochloric and sulfuric acids are shown to be too aggressive for these materials. The recrystallization temperature of AISI 304 is above 900 ºC and the minimum grain size obtained is in the range of 10–30 µm.

The metal 304 are widely used in different areas of applications like power generation plants, food processing and chemical industries. The metal can be joined through the different welding process. Austenitic stainless steel and low alloy steel possess a good combination of mechanical properties, formability, weld ability, and resistance to stress corrosion cracking and other forms of corrosion.

II. MATERIAL AND METHODS

A. Fundamentals of the Process

The process is illustrated in Fig. 1 after initial settings by the operator, the equipment provides for automatic self-regulation of the electrical characteristics of the arc. Thus, the only manual controls required by the welder for semiautomatic operation are the travel speed and direction, and gun positioning. The arc length and the current (wire feed speed) are automatically maintained with the proper equipment and settings.

B. Process Variables

The following are some of the variables that affect weld penetration, bead geometry and overall weld quality:

(1) Welding current (electrode feed speed)
(2) Polarity
(3) Arc voltage (arc length)
(4) Travel speed
(5) Electrode extension
(6) Electrode orientation (trail or lead angle)

(7) Weld joint position
(8) Electrode diameter
(9) Shielding gas composition and flow rate
(10) Metal transfer mechanism

C. Materials Used

Chemical composition of the base metals, filler metal and shielding gas used in the experiments is given below. These materials (SS304) were selected because they withstand at high temp and pressure and their properties (mechanical and chemical) does not change.

D. Welding wire material

They contain less than 0.2% carbon and usually have manganese, silicon, nickel, chromium, vanadium, and molybdenum in various amounts, usually totaling less than 5%. They may also have impurity elements such as phosphorus, sulfur, oxygen, and nitrogen". The selection of the welding wire (or the filler metal) is done according to AWS. SS304 with copper coated which specifies requirements for classification of wire electrodes for gas shielded metal arc welding of non-alloy and fine grain steels. Its composition is given at the Table 1.

Table 1. Chemical composition of SS304.

Chemical Composition of SS304									
SS	C%	SI%	Mn%	P%	S%	Cr%	Ni%	MO%	N%
304	0.04	0.75	2.0	0.035	0.015	17-19	9.5-11.5	0.20-0.50	0.10-0.18

III. EXPERIMENTAL PROCEDURE

Preparation of Weldments

Edge preparation: Specimen of SS304 rod of diameter 1.5cm was cut in the shape of smaller section, having 4cm length of each piece. Each specimen was machined to obtain v groove, having angle of 20º Diameter of Rod.

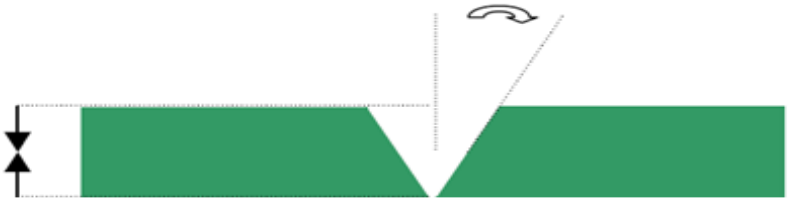

Fig. 1. Stainless Steel specimen with single v groove.

Welding of Rods. Prior to welding, the groove was thoroughly cleaned with wire brush, followed by cleaning with acetone, to remove the oxide layer In each placement, distance between the nozzle and work piece and the electrode extension were 19 and 10 millimeters, respectively. The orientation of the welding electrode with respect to the weld joint was 55°.-60° after checking the pressure of shielding gas cylinder, which was set to 3 kg/cm^2 , welding was started.

Weldment were prepared by using SS304 with copper coated filler wires, under different welding condition, as explained below:

1. Welding of specimen, performed by using AC- Current source.
2. Welding has performed by variation of three levels AC current (i.e.180 250, 320 amps).

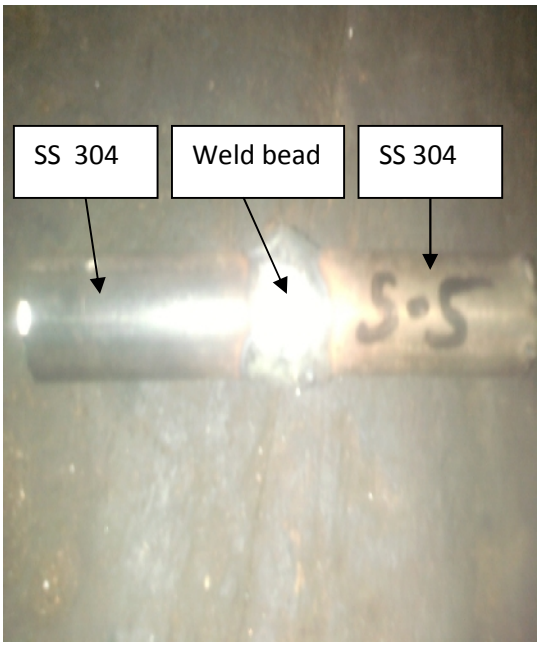

Fig. 2. Specimen when welding current is 180 and wire speed 2m/min.

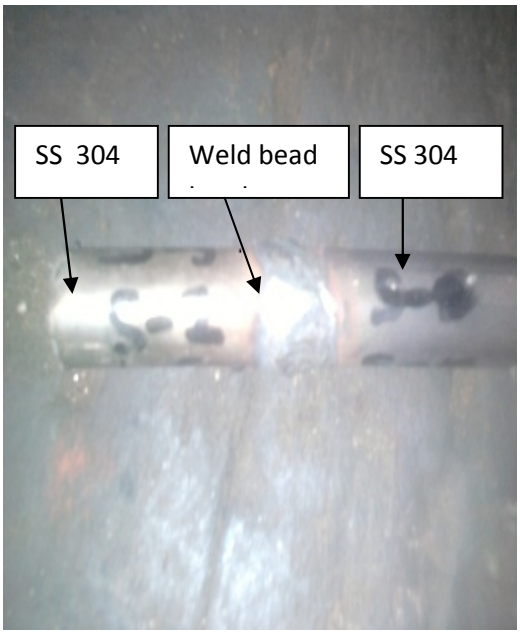

Fig. 3. Specimen when welding current is 180 and wire speed 3m/min.

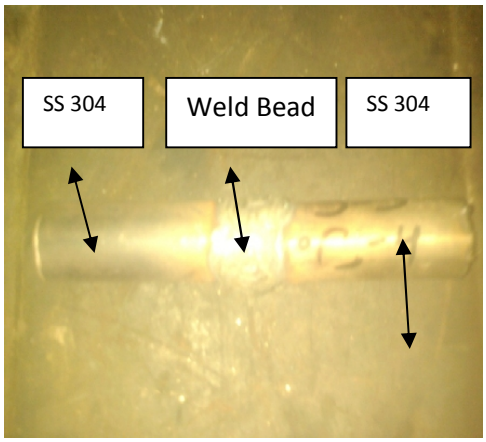

Fig.4. Specimen when welding current is 180 speed 5m/min.

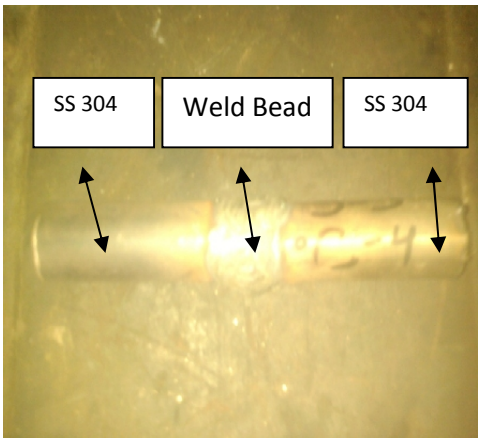

Fig. 5. Specimen when welding current is and wire is 250 and wire speed 2m/min.

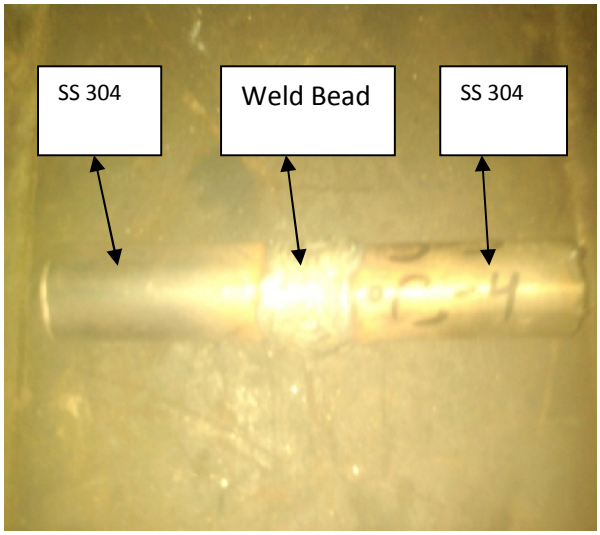

Fig. 6. Specimen when welding current 250 wire speed 3m/min.

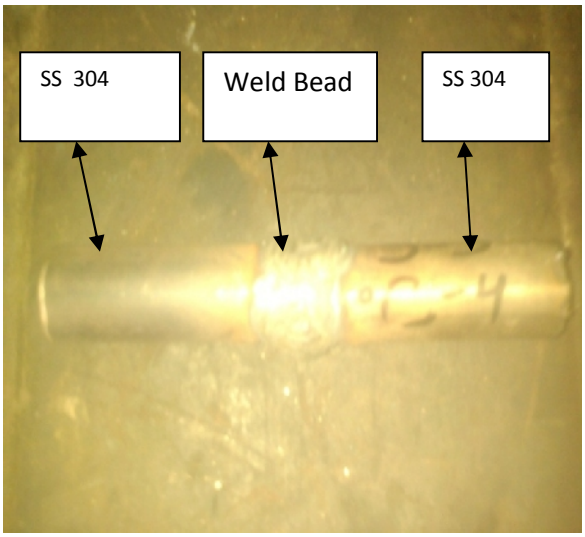

Fig. 7. Specimen when welding current is 250 wire speed 5m/min.

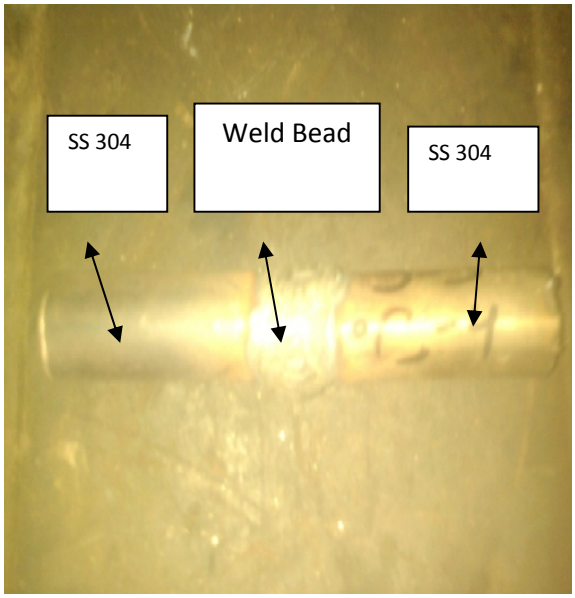

Fig. 8. Specimen when welding current is 320 and and wire speed 2m/min.

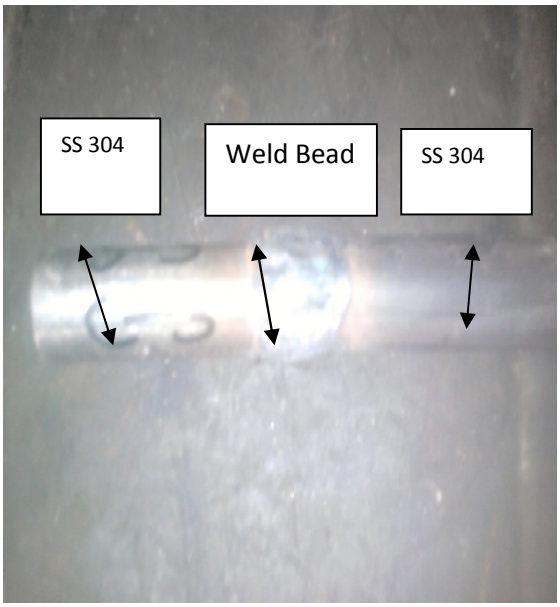

Fig. 9. Specimen when welding current is 320 and wire speed 3m/min.

Welding Parameters during Experimentation:

Input Parameters:

- Welding Current : variable
- Wire speed : variable
- Gas flow rate : constant
- Welding voltage : constant

Output Parameters:-

- Tensile strength.
- Micro hardness.

Experimental Observation:

The observations during experimentation are given in table 2.

The welding is done at (180, 250 and 320 amps).

- While during welding three different value of speed i.e.2, 3, 5m/min.
- During welding gas pressure is 3kg/cm² and welding voltage 24 volts is kept constant.

Table 2. Show the different value of speed, current, voltage, gas pressure during welding.

Specimen	Wire speed (M/MIN)	Current (Amps)	Voltage (VOLTS)	Gas pressure (kg/cm²)
1	2	180	24	3
		250	24	3
		320	24	3
2	3	180	24	3
		250	24	3
		320	24	3
3	5	180	24	3
		250	24	3
		320	24	3

V. RESULTS

Result with AC Current Source and Tensile Strength: Experiment were conducted at different value of AC current (180,250&320 Amps) keeping gas flow rate 3kg/cm² at three different values of welding wire speed (2,3&5 M/Min). Tensile strength and micro hardness were measured and tabulated. fig their variation with current shown in figure.

Result below from tables show the variation of tensile strength at different value of input current: Table show the tensile strength of specimen at 2m/min wire speed & constant gas pressure 3kg/cm² and voltage 24 volts.

Table 3.

Specimen	Current (amps)	Tensile strength (N/mm²)
1	180	177.4
	250	190.5
	320	143.4

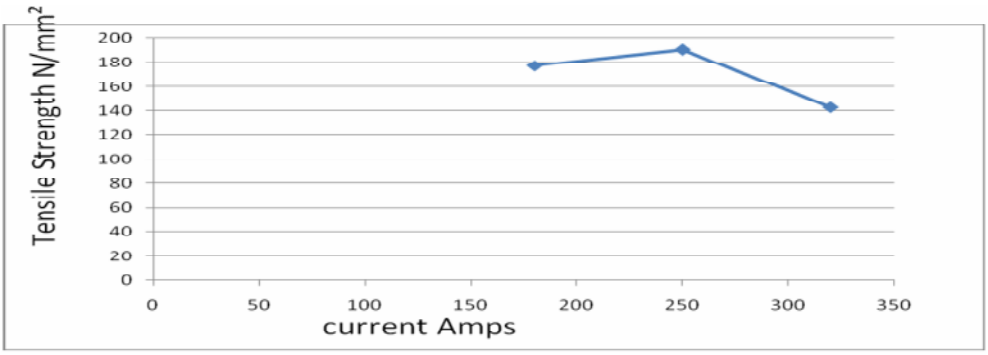

Fig. 10. Current v/s tensile strength at wire speed of 2m/min.

Table 4. Show the tensile strength of specimen at 3m/min wire speed & constant gas pressure 3kg/cm² and voltage 24 volts.

Specimen	Current (amps)	Tensile strength (N/mm²)
2	180	150.4
	250	320.4
	320	200.4

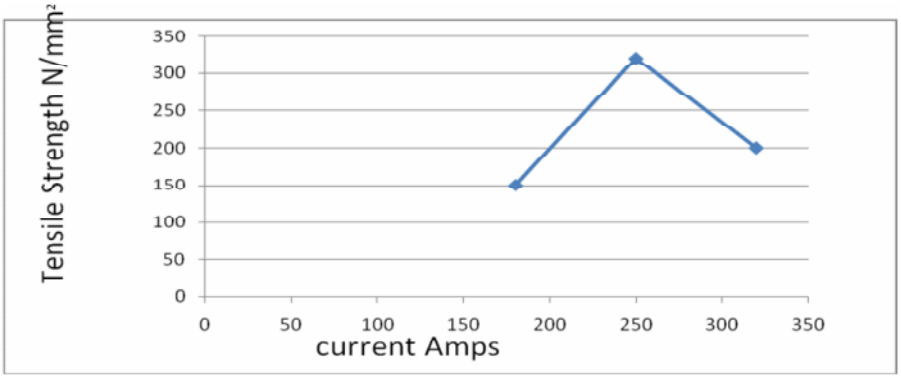

Fig. 11. Current v/s tensile strength at wire speed of 3m/min.

Table 5. Show the tensile strength of specimen at 5m/min wire speed & constant gas pressure 3kg/cm² and voltage 24 volts.

Specimen	Current (amps)	Tensile Strength (N/mm²)
3	180	207.3
	250	220.6
	320	137.5

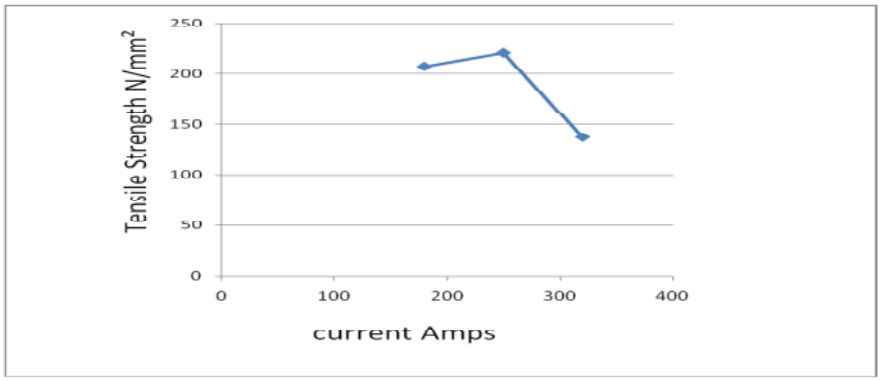

Fig 12. Current v/s tensile strength at wire speed of 5m/min.

Result Below from Table 6 to 11 Shows the Variation of Microhardness at Different Value of Input Current For Ss304.

Table 6. Show variation of micro hardness at different value of input current, wire speed 2m/min, welding voltage 24 volts and gas pressure is 3kg/cm² for HAZ.

Current Amps	Hardness number gf/mm²
180	325.3
250	375.4
320	318.4

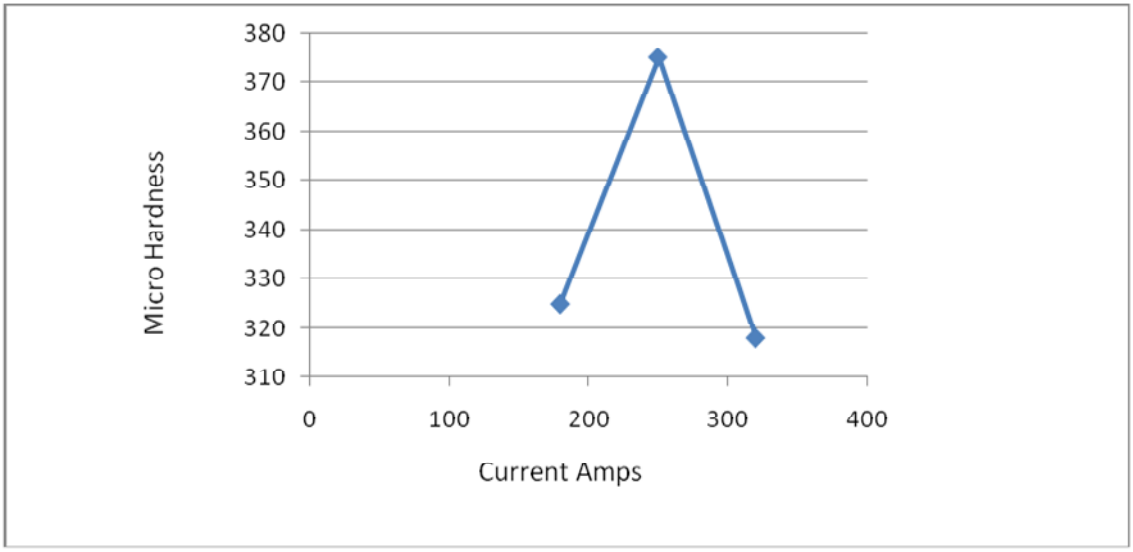

Fig. 13. Micro hardness v/s current when wire speed is 2m/min for HAZ.

Table 7. Show variation of micro hardness at different value of input current, wire speed 2m/min, welding voltage 24 volts and gas pressure is 3kg/cm² for weld joint.

Current Amps	Hardness number gf/mm²
180	396.4
250	431.3
320	388.4

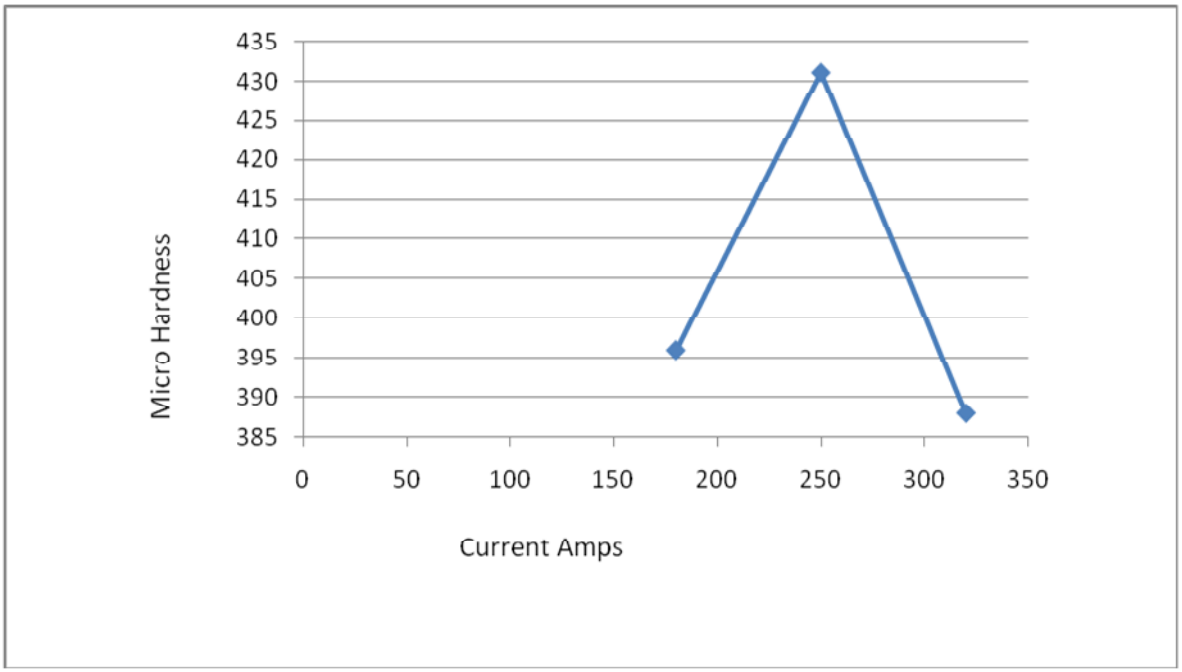

Fig. 14. Micro hardness v/s current when wire speed is 2m/min for Weld Joint.

Table 8. Show variation of micro hardness at different value of input current, wire speed 3m/min, welding voltage 24 volts and gas pressure is 3kg/cm² for HAZ.

Current Amps	Hardness number gf/mm²
180	381.3
250	431.2
320	379.4

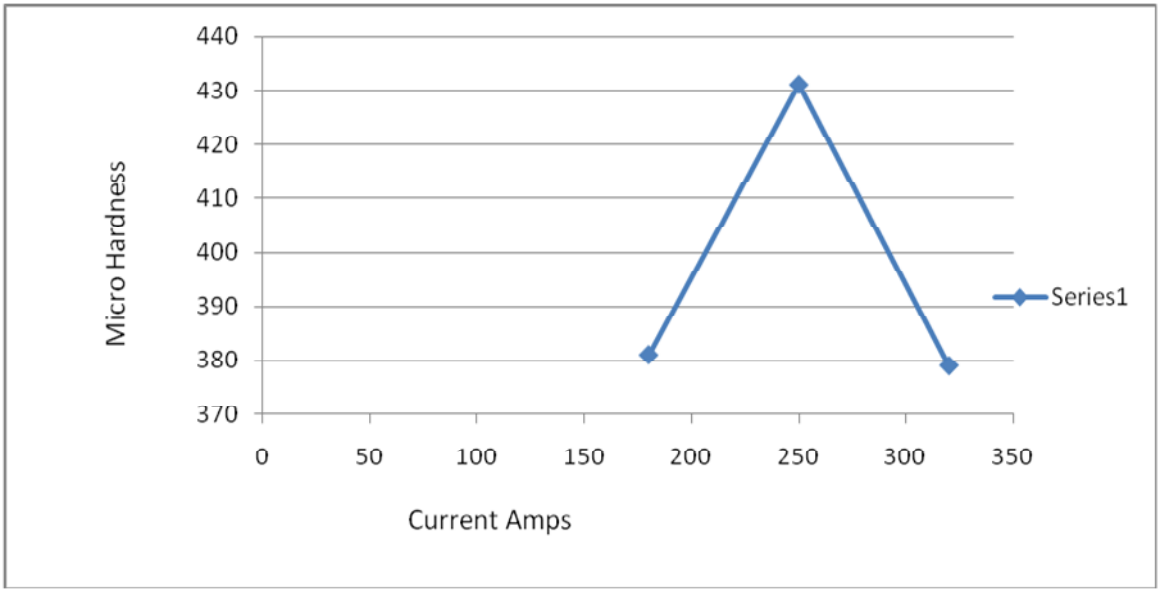

Fig. 15. Micro hardness v/s current when wire speed is 3m/min for HAZ.

Table 9. Show variation of micro hardness at different value of input current, wire speed 3m/min, welding voltage 24 volts and gas pressure is 3kg/cm² for weld joint.

Current Amps	Hardness number gf/mm²
180	409.4
250	444.9
320	404.5

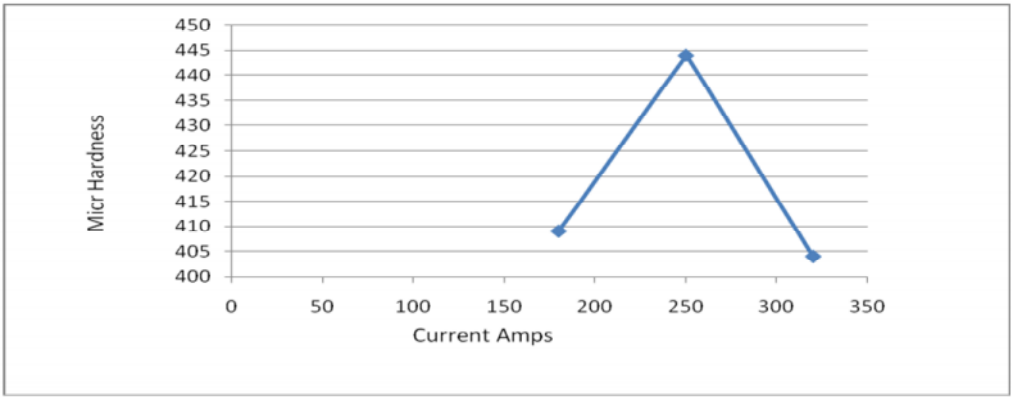

Fig. 16. Micro hardness v/s current when wire speed is 3m/min for Weld Joint.

Table 10. Show variation of micro hardness at different value of input current, wire speed 5m/min, welding voltage 24 volts and gas pressure is 3kg/cm² for HAZ.

Current Amps	Hardness number gf/mm²
180	325.3
250	343.3
320	305.4

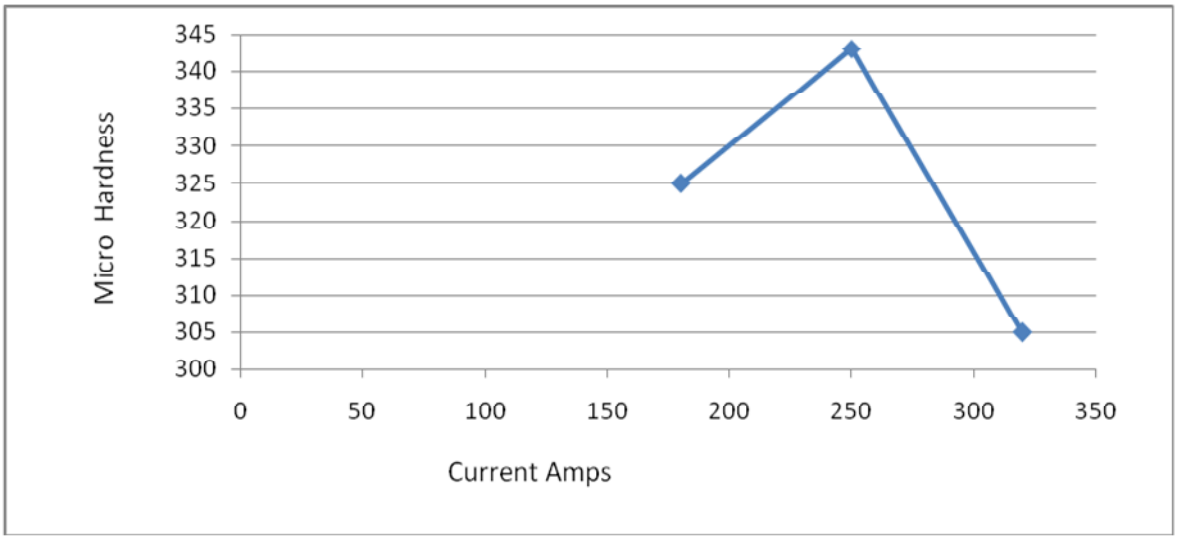

Fig.17. Micro hardness v/s current when wire speed is 5m/min for HAZ.

Table 11. Show variation of micro hardness at different value of input current, wire speed 5m/min, welding voltage 24 volts and gas pressure is 3kg/cm² for weld joint.

Current Amps	Hardness number gf/mm²
180	393
250	428.4
320	385.4

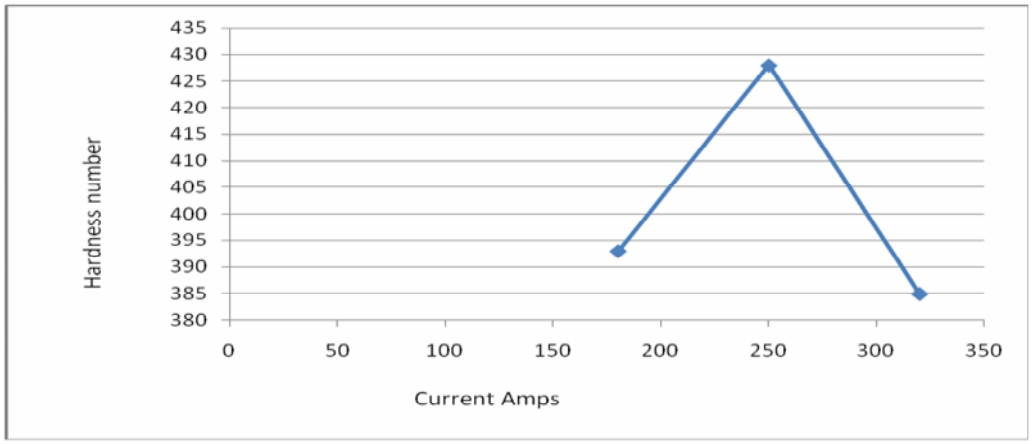

Fig. 18. Micro hardness v/s current when wire speed is 5m/min for Weld Joint.

VI. DISUSSION

Discussion for tensile strength of SS304 from table show the variation of current v/s tensile at different value of speed it is very much clear the maximum value of tensile strength 320.4 at 250 Amps current when wire speed is 3m/min.The variation of tensile strength is because of present of porosity in the weldment.

Discussion for micro hardness for metal SS304 at wire speed 2m/min at different value of current for HAZ & weld joint

From table 6 show the variation of current v/s micro hardness at different value of speed it is very much clear the maximum value of micro hardness 375.4 at 250 Amps current when wire speed is 2m/min for HAZ of SS304. From table show the variation of current v/s micro hardness at different value of speed it is very much clear the maximum value of micro hardness 431.3 at 250 Amps current when wire speed is 2m/min for weld joint of SS304.

Discussion for micro hardness for metal SS304 at wire speed 3m/min at different value of current:-

- From table ….show the variation of current v/s micro hardness at different value of speed it is very much clear the maximum value of micro hardness 431.2 at 250 Amps current when wire speed is 3m/min for HAZ of metal SS304
- From table ….. shows the variation of current v/s micro hardness at different value of speed it is very much clear the maximum value of micro hardness 444.9 at 250 Amps current when wire speed is 3m/min for WELD JOINT of SS304.

Discussion for micro hardness for metal SS304 at wire speed 5m/min at different value of current:-

- From table …… show the variation of current v/s micro hardness at different value of speed it is very much clear the maximum value of micro hardness 343.3 at 250 Amps current when wire speed is 5m/min for HAZ of SS304.
- From table …show the variation of current v/s micro hardness at different value of speed it is very much clear the maximum value of micro hardness 428.4 at 250 Amps current when wire speed is 5m/min for weld joint of SS304 .
- The variation of microhardness is due to the variation of microstructure in weld joint & HAZ .The fine or equiaxed grain has higher micro hardness than the coarse grain microstructure

VII. CONCLUSIONS

From the above result the following conclusion have been drawn

1) Tensile strength of welding joint have optimum value 320.4 N/mm² at 250 Amps of current at 3m/min wire speed.
2) The maximum value of micro hardness for the HAZ of SS304 is 431.2 at wire speed 3m/min when current is taken at 250 Amps.
3) The maximum value of micro hardness for the Weld joint of SS 304 is 444.9 at wire speed 3m/min when current is taken at 250 Amps.

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