

# Influence Of Various Process Parameters On GTAW Welded Butt Joints Of Aluminium Alloy AA6351

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**Abstract:** -- Aluminium and Aluminium alloys are rapidly growing materials and has found many new applications in engineering materials. Applications of Aluminium and Aluminium alloys are increasing because of light weight, high strength to weight ratio, high corrosion resistance, low cost etc. Joining is a key technology in all the major applications of Aluminium which can be usually achieved by various welding techniques. GTAW( Gas Tungsten Arc Welding ) is one of the most promising methods for welding of Aluminium. However Aluminium suffers changes in hardness and tensile strength, when different welding parameters are varied. For instance if one parameter is kept constant and the remaining varied then a drastic change in hardness, tensile strength and microstructure may be seen. This study basically deals with influence of two basic parameters ( welding current and shielding gas flow rate ) on GTAW welded butt joints of AA6351. After welding was performed Vickers hardness test and Tensile test was conducted to know the influence of process parameters on hardness and ultimate tensile strength respectively. and later Microstructure test was also conducted to know the microstructural changes in the base metal after welding has been performed. Each of the test result was then analyzed to come to a conclusion.

**Keywords:** AA6351, GTAW, Welding parameters, Vickers hardness test.

## I. INTRODUCTION

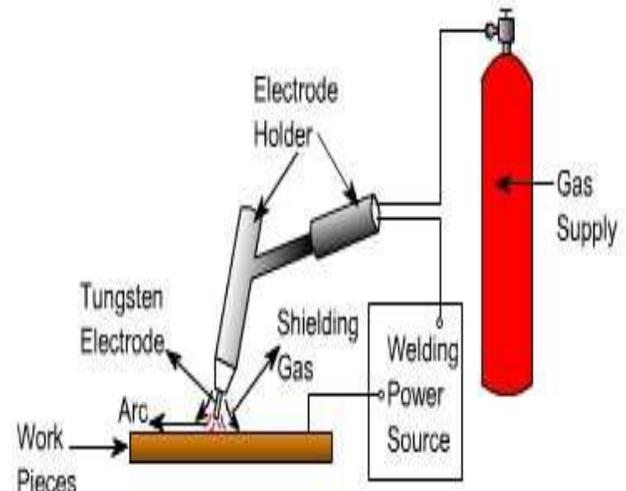
Owing to its wide range of advantages, mainly being high strength to weight ratio, good machinability, and high corrosion resistance; aluminium is also called as the “king of metals.” In spite of aluminium being the most abundant metal, the start of use aluminium was a slow and modest one because of the difficulties which were involved in refining of aluminium from ore. However over the period of time, particularly after alloy development aluminium's superior properties were recognized and industrial fields were opened, from then the use of aluminium is still growing and leading to many new applications. The aluminium industry now ushers the world into the second century of “the age of aluminium.”

### A. GTAW welding

GTAW(gas tungsten arc welding) or most commonly known as TIG(tungsten inert gas) welding is one of the most promising methods for joining of aluminium and its alloys, because of its advantages such as it produces very attractive welds with good profile, and also because it has the potential of welding higher thickness plates which is comparatively less in other welding techniques such as conventional arc welding due to the involvement of high amount of heat [1].

GTAW welding is an arc welding process that uses a non consumable electrode to produce the weld. The weld area is protected from atmosphere by a shielding gas generally Argon or Helium or sometimes mixture of both Argon and Helium. Power is usually supplied from a

power source through a handpiece or welding torch and is delivered to a tungsten electrode which is fitted into the handpiece. An electric arc is then created between the tungsten electrode and the work piece using constant current power supply. The electric arc can produce very high temperatures and this heat can be focused to melt and join two different materials. A filler metal may also be fed manually for proper welding. A schematic layout of GTAW welding is shown in fig 1. Sometimes the weld pool can be used to join the base metal without filler metal.



*Fig.1 Schematic layout of GTAW welding.*

**B. Alloy specification**

Aluminium alloys are alloys in which aluminium is predominant metal and other alloying elements may be Copper, Magnesium, Manganese, Silicon, Tin, and Zinc. Aluminium is mostly alloyed which markedly improves its mechanical properties. It is used as pure metal only when corrosion resistance or workability is more important than strength or hardness.

For this study aluminium alloy AA6351 was considered, it is a wrought alloy of aluminium which is initially cast as ingots or billets and subsequently hot and/or cold worked mechanically into the desired form. It is used in the manufacturing of tubes, pipes, and in the form of plates can be used for a variety of applications. It consists of aluminium in the major quantity and other elements such as mentioned in the table below.

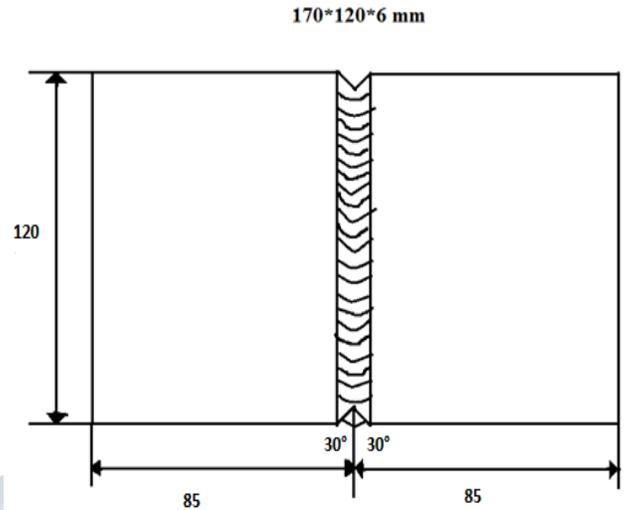
**Table. I Chemical composition of AA6351.**

ELEMENT	CONTENT(%)
Aluminium	97.8
Silicon	1
Manganese	0.6
Magnesium	0.6

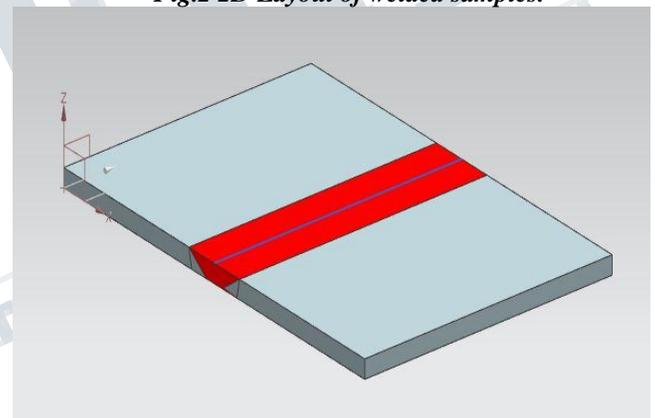
**EXPERIMENTAL WORK**

The main aim of this study is to know the influence of two process parameters *Welding current* and *Shielding gas flow rate*, on the GTAW welded butt joints of aluminium alloy AA6351. As we have discussed earlier that when during welding if one the welding parameter is kept constant and the other varied then there may be changes in hardness, tensile strength [2], and as well as change of microstructure in the HAZ(heat affected zone) of base metal [3].

For the experiment a total of nine pieces were welded. The dimensional specification of welded sample in 2D and 3D are shown in the fig 2 and 3 below.



**Fig.2 2D Layout of welded samples.**



**Fig.3 3D Layout of welded samples.**

First Two blocks of 120mm\*85mm\*6mm were machined on one of the side to make a groove of 30° then they were welded using filler wire ER4043 to form a butt joint.

For the first three samples *Welding current* was kept constant and *Shielding gas flow rate* was varied, the values are tabulated as shown in the table II .

**Table. II Values with constant Welding current and varying Shielding gas flow rate.**

Sample Number	Welding current(AMPS)	Shielding gas flow rate( lt/s)
1.	210	0.167
2.	210	0.217
3.	210	0.250

For the next three samples *Shielding gas flow rate* was kept constant and *Welding current* was varied, the values are tabulated as shown in the table III below.

**Table. III Values with constant Shielding gas flow rate and varying Welding current.**

Sample Number	Shielding gas flow rate(lt/s)	Welding current(AMPS)
4.	0.134	220
5.	0.134	230
6.	0.134	240

For the remaining three samples both *Welding current* and *Shielding gas flow rate* were varied, the values are tabulated as shown in the table IV below.

**Table. IV Values with varying Welding current and Shielding gas flow rate.**

Sample Number	Welding current(AMPS)	Shielding gas flow rate(lt/s)
7.	230	0.134
8.	240	0.167
9.	250	0.2

The nine samples after welding was performed are shown in the fig 4. Each of the sample was then proceeded for testing.



**Fig.4 Nine welded samples.**

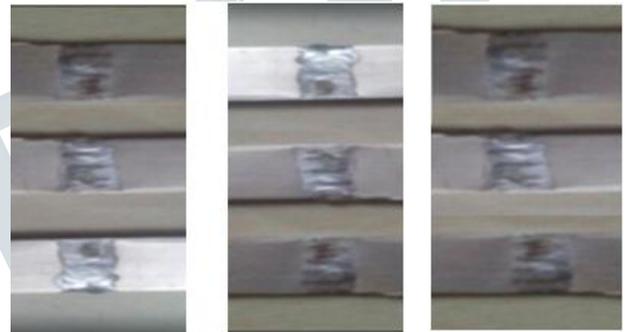
## TESTING

### A. Vickers hardness test

In this study Vickers hardness was calculated on the welded area to know the hardness of welded joints. The sample was first prepared according to required dimensions and then testing was conducted. The unit of hardness given by Vickers hardness test is known as Vickers pyramid number(HV).

1 HV = 9.807 Mpa.

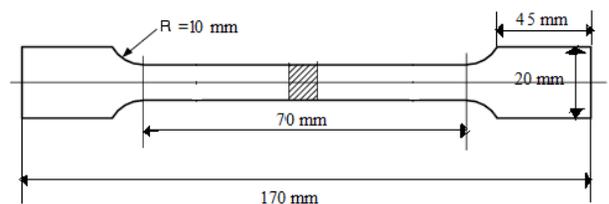
The samples on which Vickers hardness test was conducted are shown in the fig 5 below.



**Fig.5 Nine samples of which Vickers hardness test.**

### B. Tensile test

Tensile test was conducted to know the ultimate strength of the welded samples. The samples were first prepared according to required dimensions as shown in fig 6.



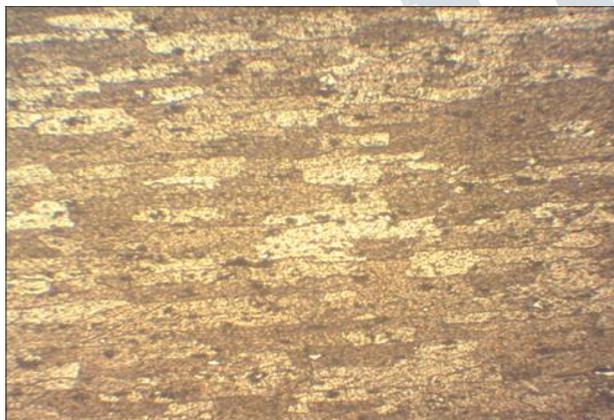
**Fig.6 Dimensions of specimen used for tensile test.**



**Fig.7 samples prepared for tensile test.**

**C. Microstructure test**

It was conducted to know the microstructure of weld as well as microstructural changes in HAZ of base metal after welding was performed. The microstructure of AA6351 is shown in the fig 8, and after welding was performed the microstructure of weld and how microstructural changes took place in HAZ will be discussed in later section.



**Fig.8 Microstructure of original metal AA6351.**

**RESULTS**

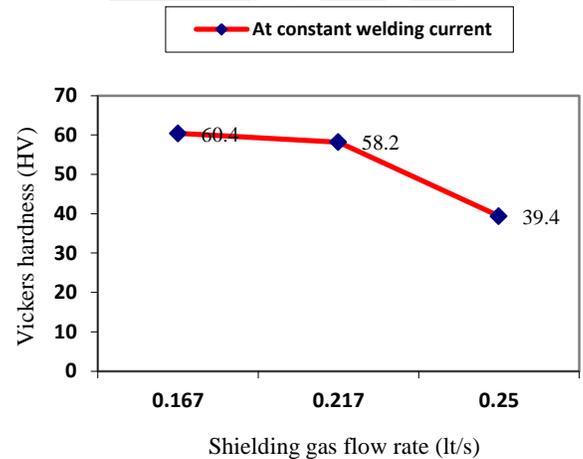
*Results when Welding current was kept constant and Shielding gas flow rate was varied.*

During the welding of first three samples when Welding current was kept constant and Shielding gas flow rate was varied, the obtained values of Vickers hardness and ultimate tensile strength are tabulated in table V below.

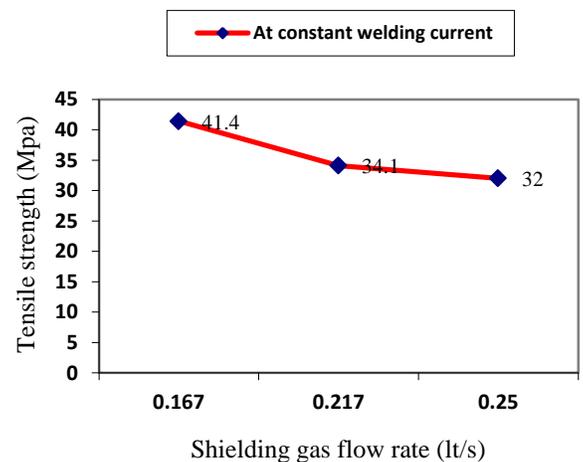
**Table.V Values obtained from tests with constant Welding current and varied Shielding gas flow rate.**

Sample Number	Welding current (AMPS)	Shielding gas flow rate(lt/s)	Vickers hardness (VH)	Tensile strength (N/mm)
1.	210	0.167	60.4	41.4
2.	210	0.217	58.2	34.1
3.	210	0.250	39.4	32.0

As welding current was kept constant, the variation of Vickers hardness and Tensile strength with Shielding gas flow rate are shown in the fig 8a and 8b below.



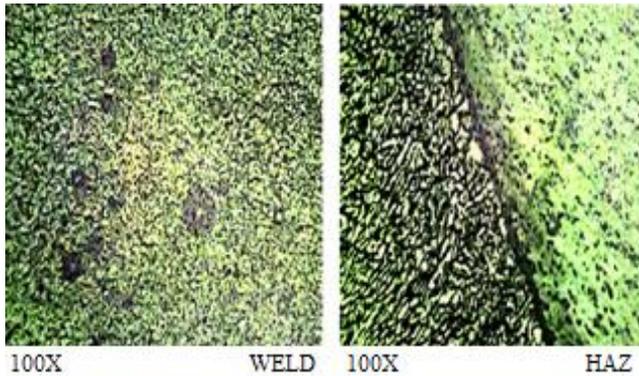
**Fig. 8(a) Variation of Vickers hardness with Shielding gas flow rate.**



**Fig. 8(b) Variation of Tensile strength with Shielding gas flow rate.**

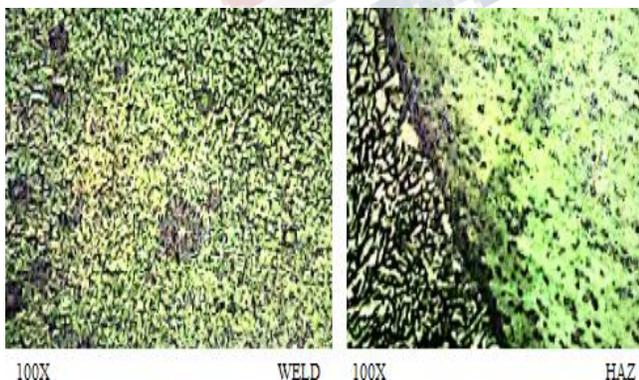
Microstructure test was conducted for each of the sample welded at constant welding current and varying values of shielding gas flow rate, which are shown in figures below.

Microstructure of 1st sample shown in fig 9a consists of dendrites of aluminium solid solution with fine grains, non-uniform grain pattern, blow holes are observed at weld. HAZ shows fine intermetallic particles of grains in aluminium solid solution, crack observed along HAZ.



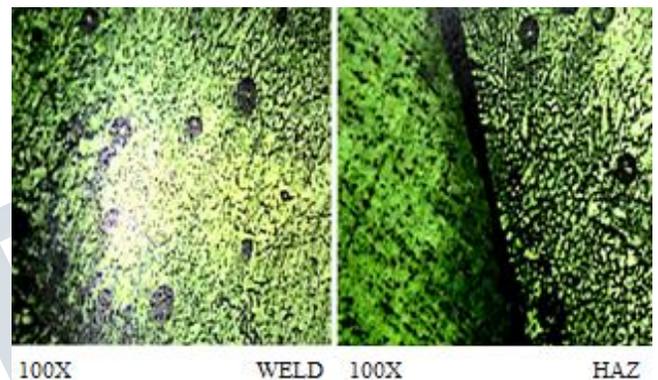
**Fig.9(a) Microstructure of weld and HAZ of 1st sample.**

Microstructure of 2nd sample in fig 9b consists of dendrites of aluminium solid solution with fine grains, non-uniform grain pattern, blow holes are observed at weld. HAZ shows fine intermetallic particles of grains in aluminium solid solution, crack observed along HAZ.



**Fig.9(b) Microstructure of weld and HAZ of 2nd sample.**

Microstructure of 3rd sample shown in fig 9c consists of dendrites of aluminium solid solution with fine grains, non uniform grain pattern observed, blow holes are observed at weld. Heat effected zone shows fine intermetallic particles of grains in Aluminium solid solution, Crack observed along HAZ.



**Fig.9(c) Microstructure of weld and HAZ of 3rd sample.**

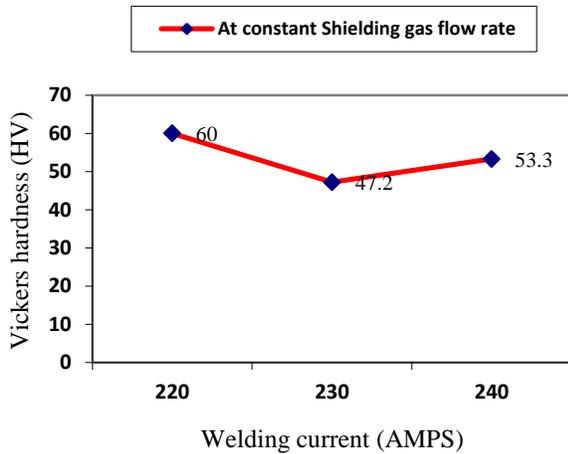
**B. Results when Shielding gas flow rate was kept constant and Welding current was varied.**

During the welding of next three samples when Shielding gas flow rate was kept constant and Welding current was varied the obtained values of Vickers hardness and tensile strength are tabulated in the table VI below.

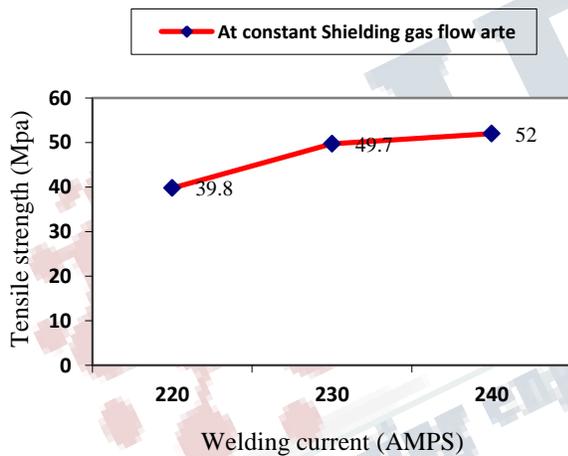
**Table.VI Values obtained from test with constant Shielding gas flow rate and varying Welding current.**

Sample Number	Shielding gas flow rate(lt/s)	Welding current (AMPS)	Vickers hardness (VH)	Tensile strength (N/mm)
4.	0.134	220	60.0	39.8
5.	0.134	230	47.2	49.7
6.	0.134	240	53.3	52.0

As Shielding gas flow rate was kept constant, the variation of Vickers hardness and Tensile strength with Welding current are shown in the fig10a and 10b below.



**Fig.10(a) Variation of Vickers hardness with Welding current.**

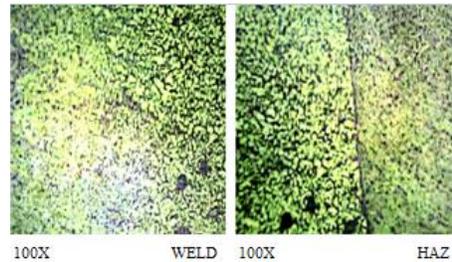


**Fig.10(b) Variation of Tensile strength with Welding current.**

Microstructure test was conducted for each of the sample welded at constant Shielding gas flow rate, and varying values of Welding current which are shown in the figures below.

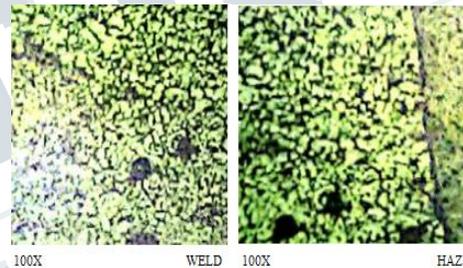
Microstructure of 4th sample shown in fig 11a consists of dendrites of aluminium solid solution with fine grains are seen uniform grain pattern observed, blow holes are observed at weld. HAZ shows fine intermetallic particles

of grains are seen in Aluminium solid solution. Crack observed along HAZ.



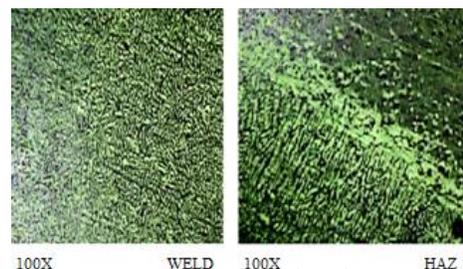
**Fig.11(a) Microstructure of weld and HAZ of 4th sample.**

Microstructure of 5th sample shown in the fig 11(b) consists of dendrites of aluminium solid solution with fine grains are seen uniform grain pattern observed, blow holes are observed at weld. Heat affected zone shows fine intermetallic particles of grains are seen in Aluminium solid solution. Crack observed along HAZ.



**Fig.11(b) Microstructure of weld and HAZ of 5th sample.**

Microstructure of 6th sample is shown in the fig 11(C). consists of dendrites of aluminium solid solution with fine grains are seen, uniform grain pattern observed, no holes are observed at weld. Heat affected zone shows fine intermetallic particles of grains are seen in Aluminium solid solution. No crack observed along HAZ.



**Fig.11(c) Microstructure of weld and HAZ of 6th sample.**

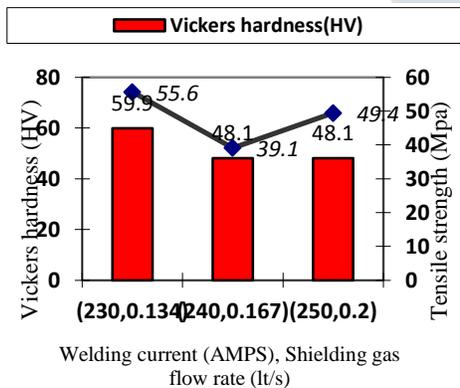
**C. Results when both Welding current and Shielding gas flow rate was varied.**

During the welding of remaining three samples when both Welding current and Shielding gas flow rate were varied the obtained values of Vickers hardness and Tensile strength are tabulated in the table VII as shown below.

**Table.VII Values obtained from test with varying Welding current and Shielding gas flow rate.**

Sample Number	Welding current (AMPS)	Shielding gas flow rate(lt/s)	Vickers hardness (VH)	Tensile strength (N/mm)
7.	230	0.134	59.9	55.6
8.	240	0.167	48.1	39.1
9.	250	0.2	48.1	49.4

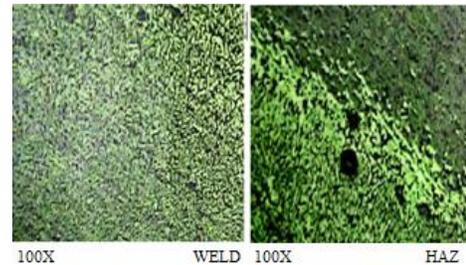
As both the parameters were varied, the variation of Vickers hardness and Tensile strength with Welding current and Shielding gas flow rate are shown in the fig 12.



**Fig.12 Variation of Vickers hardness and Tensile strength with Welding current and Shielding gas flow rate.**

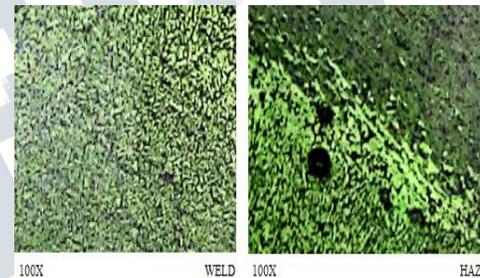
Microstructure test was conducted for each of the sample welded at varying welding current and Shielding gas flow rate, which are shown in the figures below.

Microstructure of 7th sample shown in fig 14a, consists of dendrites of aluminium solid solution with fine grains uniform grain pattern observed, no holes at weld. HAZ shows fine intermetallic particles of grains in Aluminium solid solution, No crack observed along HAZ.



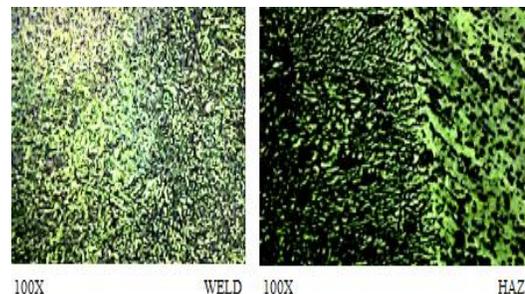
**Fig.14(a) Microstructure of weld and HAZ of 7th sample.**

Microstructure of 8th sample shown in fig 14b, consists of dendrites of aluminium solid solution with elongated grains, uniform grain pattern observed, no holes at weld. HAZ shows fine intermetallic particles of grains in Aluminium solid solution, No crack along HAZ.



**Fig. 14(b) Microstructure of weld and HAZ of 8th sample.**

Microstructure of 9th sample shown in fig 14c, consists of dendrites of aluminium solid solution with elongated grains, non uniform grain pattern observed, no holes at weld. HAZ shows fine intermetallic particles of grains in Aluminium solid solution, No crack along HAZ.



**Fig. 14(c) Microstructure of weld and HAZ of 9th sample.**

## V. DISCUSSIONS

*A. When Welding current was kept constant and Shielding gas flow rate was varied.*

During this case both Vickers hardness and Tensile strength showed inverse relation with Shielding gas flow rate, i.e. with increase in Shielding gas flow rate, Vickers hardness and tensile strength decreased.

Microstructure of 1st, 2nd, and 3rd sample showed blow holes at weld and crack along HAZ. The reason for this may be, the variation of Shielding gas flow rate and constant welding current.

*B. When Shielding gas flow rate was kept constant and Welding current was varied.*

During this case Vickers hardness showed varied relation with Welding current i.e. decreasing trend from 4th to 5th sample and increasing trend from 5th to 6th sample.

Tensile strength showed direct relation with welding current i.e. Tensile strength increased with increase in Welding current.

Microstructure of 4th and 5th sample showed blow holes at weld and crack along HAZ. The reason for this may be, the variation of Welding current and constant Shielding gas flow rate.

Microstructure of 6th sample was free from both blow holes at weld and crack along HAZ.

*C. When both Welding current and Shielding gas flow rate were varied.*

During this case Vickers hardness showed varied relation with both Welding current and Shielding gas flow rate i.e. decrease in the beginning and later constant trend.

Tensile strength also showed varied relation with both Welding current and Shielding gas flow rate i.e. decrease from 7th to 8th sample and then increase from 8th to 9th sample.

Microstructure of 7th, 8th, and 9th samples were free from both blow holes at weld and crack along HAZ. The reason for this may be, the variation of both parameters simultaneously.

## VI. CONCLUSION

On the basis of the experimental work following conclusions were drawn.

- Vickers hardness of the welded joints has been found comparable with Welding current and Shielding gas flow rate.
- It is found that Vickers hardness is maximum at Welding current of 210 AMPS and Shielding gas flow rate of 0.167 lt/s.
- Tensile strength of welded samples has been found comparable with Welding current and Shielding gas flow rate.
- Maximum Tensile strength occurs at Welding current of 230 AMPS and Shielding gas flow rate of 0.134lt/s.
- Microstructure of 6th and 9th sample welded at Welding current of 240 AMPS, Shielding gas flow rate of 0.134lt/s and Welding current of 250 AMPS, Shielding gas flow rate of 0.2lt/s, respectively ; has been found to be very fine particle grain structure without any blowholes in weld and without any cracks along the HAZ.

## REFERENCES

- [1] Kumar, S(2010) Experimental investigation on pulsed TIG welding of aluminium plate. *Advanced engineering technology*.1(2), 200-211
- [2] Hussain, A. K., Lateef, A., Javed, M., & Pramesh, T. (2010). Influence of Welding Speed on Tensile Strength of Welded Joint in TIG Welding Process. *International Journal of Applied Engineering Research*, Dindigul, 1(3), 518-527.
- [3] Norman, A. F., Drazhner, V., & Prangnell, P. B. (1999). Effect of welding parameters on the solidification microstructure of autogenous TIG welds in an Al- Cu-Mg-Mn alloy. *Materials Science and Engineering: A*, 259(1), 53-64.