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STUDIES ON IMPACT OF WELDING PARAMETERS ON ANGULAR DISTORTION AND MECHANICAL PROPERTIES OF STRUCTURAL STEEL WELDED BY SMAW

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ABSTRACT

The purposes of this paper are to check the impact of welding parameters on the angular distortion and mechanical properties of hot-rolled structural steel welded by SMAW. The main factors affecting the mechanical properties of the welded joints are current, arc voltage, welding speed, electrode diameter, angle of the tip, the thickness of the material, filler material used, forms of groove, etc. Since the welding method involves the heating and cooling cycle in a non-uniform, uneven manner, the distortion is inevitable. The welding method contributes to the occurrence of many forms of distortions like longitudinal, transverse, or angular distortions, etc. because of that reworks and time, price gets affected therefore it's to be controlled. Tensile test, hardness test, and impact test were performed to define the effect of factors on mechanical properties for welded specimen. The results have shown the significant contribution of current, welding speed, and different types of edge preparation on the distortion and mechanical properties of welded joints. It was also examined that weldment produced with single V grooved have better mechanical properties.

KEYWORDS: V grooved, Angular distortion, Mechanical properties, SMAW, Welding parameter.

I. INTRODUCTION

Shielded metal arc welding (SMAW), also can be mentioned as manual metal arc welding (MMA or MMAW), flux protected arc welding, or informally as stick welding, could also be a manual arc welding method that uses a consumable electrode covered with a flux to induced the weld. An electrical current, either AC or DC from a welding machine, is utilized to create an electrical arc between the electrode and therefore the metals to be joined. The base metal and the filler rod melt and form a weld pool that cools to create a joint. When the weld is ordered, the flux coating of the electrode disintegrates, giving off vapors that operate a protective gas and providing a layer of slag, each of that defends the weld space from surrounding contamination. Attributable to the pliability of the strategy and thus the simplicity of its instrumentality and operation, shielded metal arc welding is one in all the world's 1st and most well likable welding processes. It dominates alternative welding processes inside the upkeep and repair workshop, and although flux-cored arc welding is growing in quality, SMAW continues to be used extensively among the development of significant steel structures and in industrial fabrication. The method is utilized primarily to weld iron and steels however metallic element, nickel, and copper alloys can also be welded with this methodology.

For obtained desire weld joints, it's necessary to know optimum values of welding variables for the particular material otherwise a little mismatch can affect the mechanical properties of weld joints and have to spend extra time, price, materials, and other which is not avoidable in engineering.

1.1 SMAW Welding Parameter :

1. Welding Current: SMAW welding uses the constant electricity, therefore the parameter that may be changed is just electrical current. The factors that are taken into consideration when deciding what proportion electrical phenomenon that a welder getting to use are: electrode's diameter, base metal thickness, and welding position.

Incorrect setting of welding current is calamitous, whether or not it's too low or too high, if the welder cannot anticipate compensating for the uncontrollable arc, separation or defect will occur. A comparatively low welding current can result in lower heat input further low penetration.

2. Arc Voltage: The voltage is allowed to fluctuate systematically to compensate the arc length thus when the arc length varies the voltage will also change to stay the heat input as constant as attainable, the variation between the ranges of 17 – 45 volt, whenever outside of that range the arc can merely disappear.

3. Polarity: In SMAW and most of the welding procedure, there are three varieties of polarity: alternating current (AC), direct current electrode positive (DCEP), and direct current electrode negative (DCEN). Once we place positive polarity in electrode thus 2/3 of the heat will be focused on electrode. With such condition, the heat shall larger penetration within the exchange of narrower bead. Once we place negative polarity in electrode thus 2/3 of the heat is focused on the base metal. Then it doesn't give nice penetration, however, the weld bead is wider. AC is reasonably mixed polarities thus it's not vital in SMAW.

4. Welding Speed: Speed of welding is outlined because of the rate of travel of the work under the electrode along the weld bead. It is determined by **Speed of welding = Travel of electrode/ arc time** mm/min.

5. Heat Input: Heat input rate or energy of arc is additionally a very important parameter in welding joint which may be calculated by

Heat input rate = V×I×0.60/v (J/mm)

Where V= Arc voltage in volts

I= Welding current in ampere

v= welding speed or arc travel speed (mm/min)

1.2 The Advantages of SMAW :

SMAW is also customary in most industries, because it's various advantages over other forms of welding.

a) it's extremely transportable.

b) The instrumentality is easy and cheap.

c) SMAW isn't sensitive to wind.

d) There's no demand for a separate gas shielding.

e) It is utilized in many alternative environments.

f) Its totally different power capabilities.

g) It is used with many alternative metals.

h) Welders typically train in SMAW initial, so it's wide acquainted and prevailing across industries.

i) Several industries area unit already equipped with data and technology to simply perform SMAW.

1.3 Some Disadvantages of SMAW :

Although SMAW may be a widespread and customary method, it will have some limitations that build it less fascinating for a few comes. A number of the drawback of SMAW includes:

a) The shortage of automation implies that the productivity rates are less than alternative a lot of machine-controlled processes.

b) SMAW has lower deposition rates than other processes.

c) It depends heavily on the ability of the operator.

d) It isn't appropriate for metal or metallic element.

d) It will need a lot of close up because of spatter.

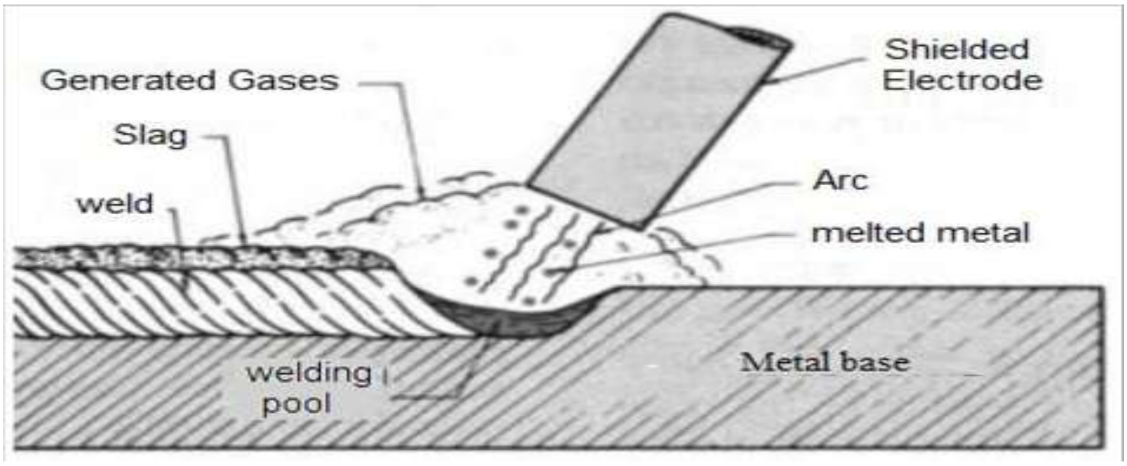

Fig.1 : Schematic diagram of shielded metal arc welding.

1.4 Weld Distortion:

Distortion happens from the enlargement and contraction of weld metal and adjacent base metal throughout the heating and cooling method of weld joints. Doing all fastening on one aspect can cause much more distortion than if the welds are alternated from one aspect to the other. Throughout the heating and cooling method, several factors have an effect on shrinkage of the metal and cause distortion, like physical and mechanical properties that modification as heat is applied.

A. Causes of Distortion:

1. impact of heat input
2. Inherent stresses within the parent metal
3. Joint restraint
4. Thermal properties-

a) Constant of enlargement
b) Thermal conduction
c) Yield purpose of the fabric etc.

B. Types of Distortion:

1. Transversal shrinkage
2. Longitudinal shrinkage
3. Angular distortion
4. Rotational distortion
5. Bending distortion
6. Buckling distortion

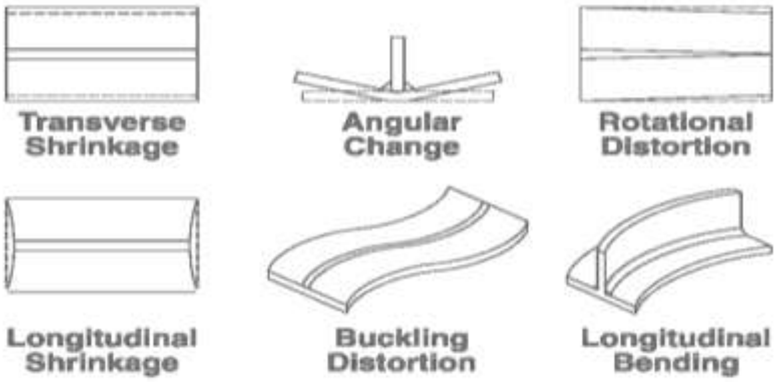

Fig-2: Different types of weld distortion.

C. Varieties of ways to scale back distortion:

Ways to scale back distortion are as follows:

1) Correct style, size of the weld, edge preparation, and use of weld technique.

2) The element components of fabrication should be accurately factory-made to the specified form and size.

3) Use of Pre-setting strategies.

4) Use of restraining strategies,

5) Use of attachment sequences and techniques.

6) Use of minimum quantity of weld metal to satisfy the attachment necessities.

7) Force balance.

8) Balance of weld regarding neutral axis of the work-piece.

9) Balance of weld round the Centre of gravity.

10) Reduction in variety of passes.

11) Use of intermittent weld wherever ever doable.

12) Use of shrinkage allowances.

13) Create a shrinkage force to figure within the desired direction.

II. MATERIALS COMPOSITION

For the experiment, a hot-rolled plate of structural steel (IS 2062) was obtained from the market. E6013 electrode of 3.15 mm diameter and 450 mm long were selected for the shielded metal arc welding (SMAW) process.

Table (1) Chemical Composition of base metal.

ELEMENT	Carbon	Manganese(max)	Sulphur(max)	Phosphorous(max)	Silicon(max)
% of Wt.	0.23	1.50	0.045	0.045	0.40

Table (2) Chemical composition of electrode

ELEMENT	Carbon	Manganese	Sulphur	Phosphorous	Silicon
% of Wt.	0.08	0.44	0.20	0.02	0.22

III. PROCEDURE

For the experiment three edge preparations were done to perform welding straight-edged, single beveled at 30° and single V grooved at 60° on Butt weld joints. Edges and surfaces of work-piece were suitably prepared using grinder and shaper machines prior to the welding processes. The sample was prepared in two 100×100×6 mm thick carbon steel plate pieces and welded together to provide a finished test plate. The welding was performed by the DC welding machine. In straight-edged joint 3 mm of root gap, 2 mm of gap in single beveled butt joint and in single V grooved butt weld joint provided respectively. The experiments were done under controlled and ranging welding variables.

Fig. [3] Surface Cleaning.

Fig. [4] Edge preparation.

Fig. [5] Prepared sample for welding process

Fig. [6] Prepared tensile test specimen of base metal

Welding operations are done in horizontal (flat) position by SMAW using the variable welding parameters: current at 80 A, 90A, 100A, and 110A, welding speed, and different types of edge preparation at different angles. Since voltage depends on arc length and has a small change in value hence we considered it as constant (input voltage 220 V).

3.1. Hardness Testing:

Vickers hardness testing machine used measuring the hardness of the welded joint. According to ASTM E384 standard, testing of welding joint perform. For indentation, a pyramid shaped with square base diamond tool used.

3.2. Tensile Testing:

The tensile testing was done in accordance with ASTM E8 standard. The samples were prepared by shaper and milling of the top and bottom surfaces to get rid of irregularities. The tensile test is conducted on UTM that is hydraulically operated.

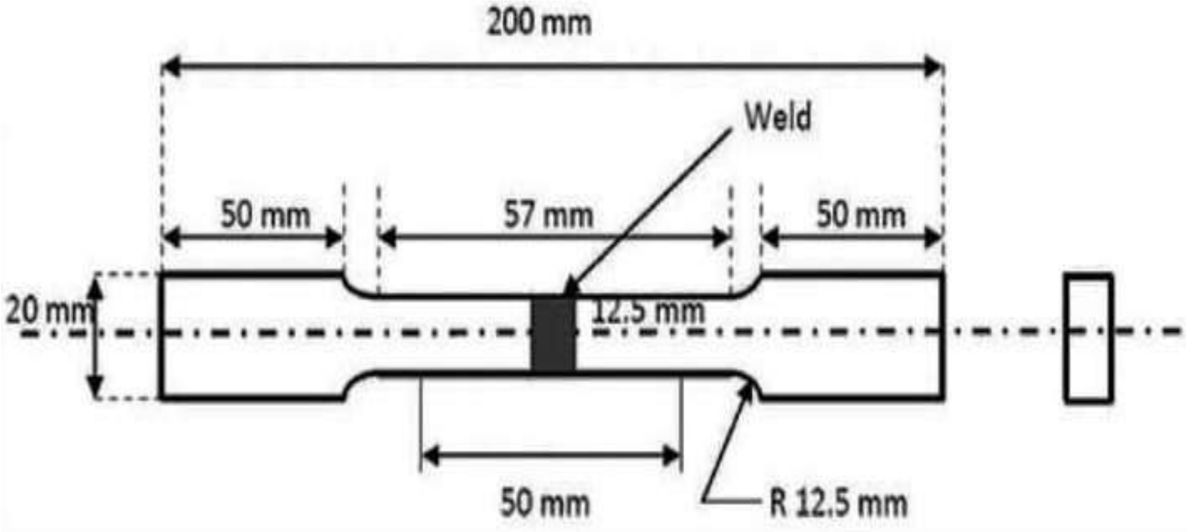

Fig-7: Standard Dimensions of Tensile Test.

3.3. Impact Testing:

Impact test conducted using the Charpy impact testing machine. The specimens with 2 mm deep V notch and 55 mm long were prepared according to ASTM E23. The specimen supported horizontally on an anvil and notch face opposite side of striker. A pendulum (striker) strikes from a high position with 300 Jules. An amount of energy observed in fracture the specimen which called V notched impact toughness.

3.4. Measurement of Angular Distortion:

To measure the angular distortion of the web in the butt-joint, a simple method was adopted which is exhibited in **Fig.8**. In the measuring process, Vernier caliper was used to measure the deflection distance. The angular deformation after weld of butt-joint is described using the deflection distance in this study.

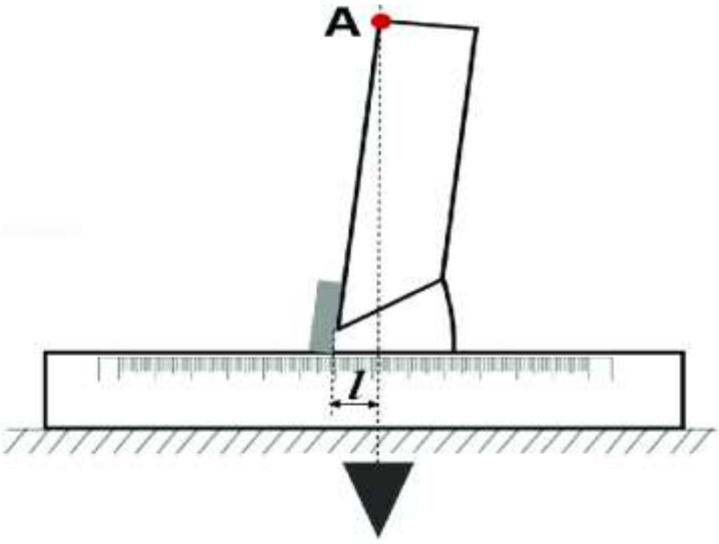

Fig-8 : Schematic Diagram of Measuring Angular Distortion.

3.5. Metallographic Test:

Metallographic samples were prepared in accordance with ASTM E23. On the test specimens sectioning, surface polishing, grinding, etching process applied. The 2% of the Nital etching solution used to reveal the microstructural features of welding joints. Microstructure examination had finished using an optical microscope.

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EXPERIMENTAL DATA

Table: 3

S.No.	Edge Preparation	Input Voltage (V)	Current (Amp.)	Welding Speed (mm/min)	Ultimate Tensile Strength (MPa)	Yield Strength (MPa)	Impact (J/mm^2)	Hardness (VH)	Angular Distortion (mm)	Penetration(mm)	% Elongation
1	Straight Edged	220	80	123	462.25	355.62	1.161	180.80	2.53	3.8	17.50
2			90	136	436.60	325.28	0.961	176.20	2.81	3.6	24.60
3			100	141	448.80	344.50	0.728	170.40	2.98	3.5	21.40
4			110	149	420.12	315.63	0.691	182.50	3.32	3.3	22.50
5	Single Beveled 30°	220	80	104	510.15	390.23	1.226	190.00	3.56	5.1	23.98
6			90	115	515.20	399.56	1.576	196.30	4.25	4.8	18.50
7			100	127	520.90	405.68	1.893	187.80	3.63	4.1	17.80
8			110	134	488.65	364.74	1.915	192.40	3.57	4.3	19.65
9	Single V grooved 60°	220	80	90	595.25	445.70	1.831	230.00	4.63	5.3	17.25
10			90	106	585.00	443.24	1.931	224.00	3.62	5.2	18.30
11			100	117	549.30	423.76	2.320	222.30	3.72	5.0	15.69
12			110	124	601.70	447.62	2.130	212.40	2.20	4.7	17.65
Base Metal					615.32	455.56	2.42	232.36			15.27

IV. RESULTS AND DISCUSSION

4.1. Effect of welding current on mechanical properties:

Fig.9&10 show the effect of welding current on the ultimate tensile strength (UTS) and yield strength (YS) respectively. It was observed from the results obtained that the ultimate tensile strength and yield strength values of weld joints initially decrease and at last increased which is produced with single V grooved. Single beveled but joints strength has increase in increasing in welding current till 110 A after that decreasing in welding current tensile strength and yield strength also decreasing respectively. However, weld produced with straight edge gave non linear pattern. The V grooved has maximum ultimate tensile strength (601.70MPa) and maximum yield strength (447.62MPa) at 110A which is optimum value respectively.

It was also observed that the maximum ultimate tensile strength value was near about base metal which is acceptable. And V grooved has better tensile and yield strength.

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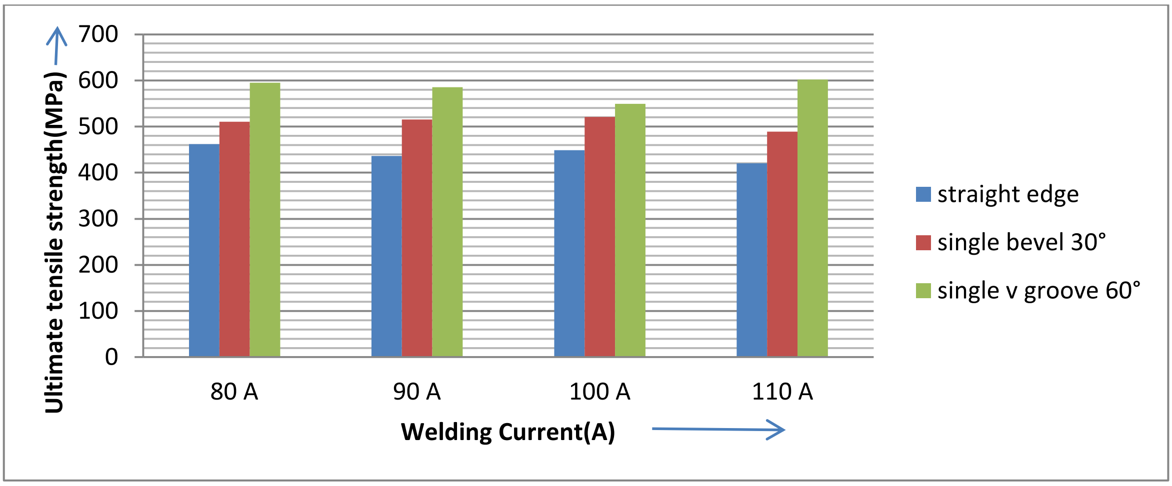

Fig-9: Effect of welding current on tensile strength

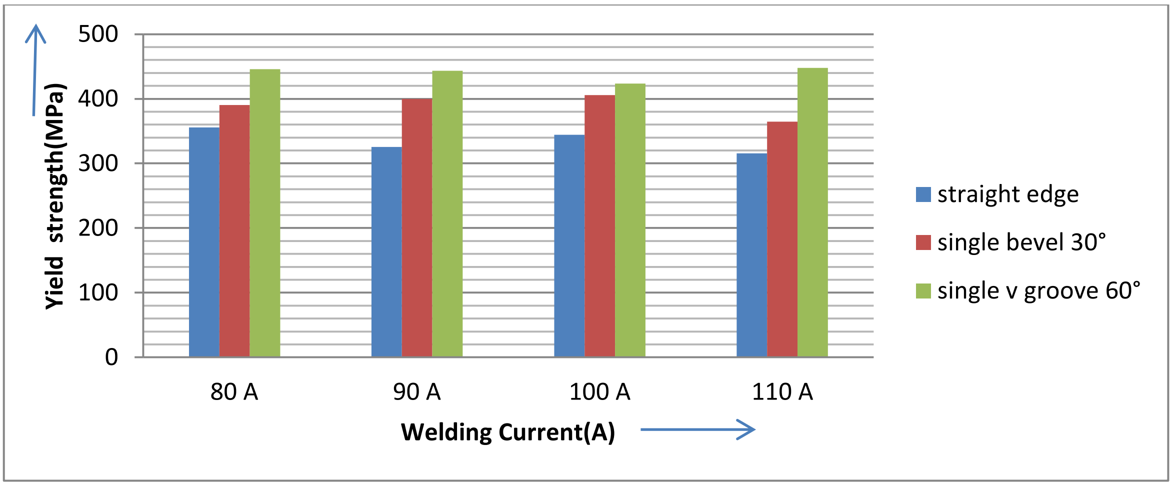

Fig-10 : Effect of welding current on yield strength

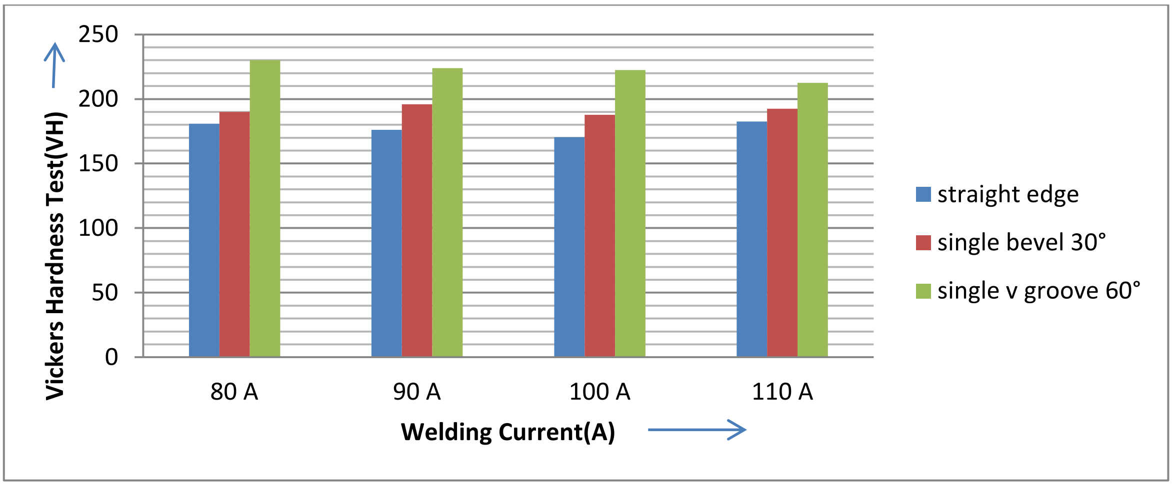

Fig-11: Effect of welding current on hardness

Fig.11 shows that there was a decrease in the hardness of the welded steel joints as the current was increased. Due to an increase in the current heat generation rate also increased that inflicting the grain size recrystallized and magnified in size. The equation H= (I×V)60/S also shows that as the welding current increases more heat is produced in weld inflicting more expansion and contraction between the weld and base metal which increased the residual stresses in lower mechanical properties. All the welds produced with straight-edged, single beveled, and single V grooved have reducing hardness properties an increase in current.

Fig.12 shows that the weldments created with single beveled and single V grooved have an increase in impact strength on increasing in welding current. With increased current, the heat generated increased causing the grain size recrystallization. That results increase in grain size increases the impact strength (toughness) of the weld.

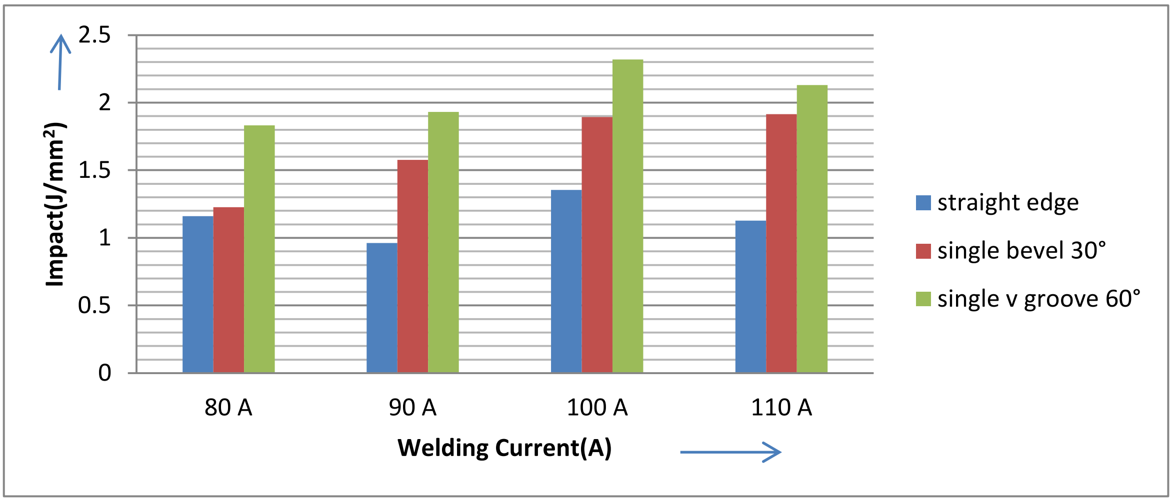

Fig-12 : Effect of welding current on impact

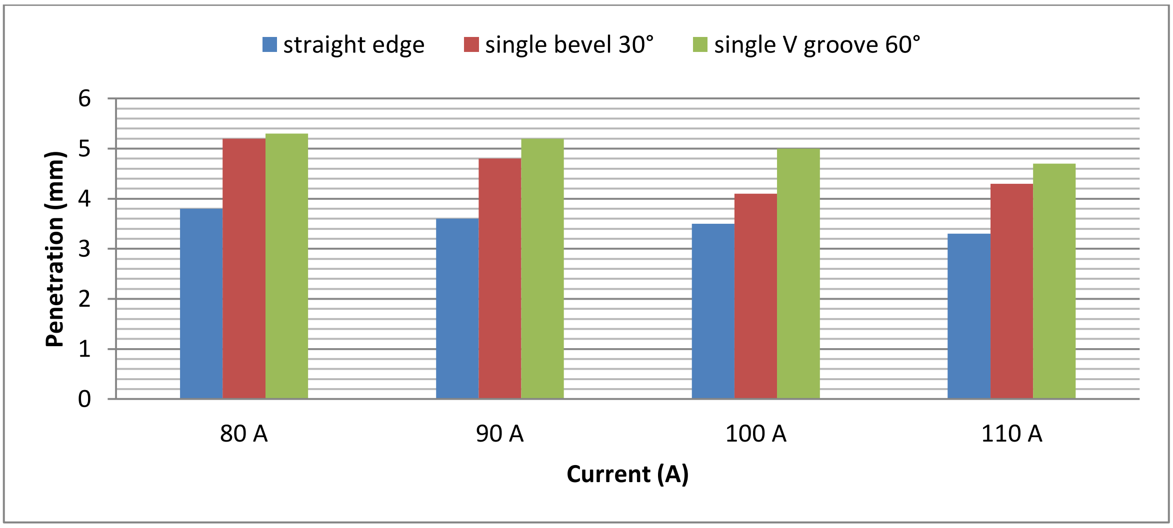

Fig-13 : Effect of current on penetration

Fig.13 shows, when an increase in current depth of penetration decreased. Since, on increasing current penetration should be also increased. It's happening due to the speed is also increasing on increasing in current. The maximum penetration 5.3 mm 5.1 mm obtained at 80 A for V groove 60 ° and single beveled at 30° respectively. Weldments made with single bevel and V groove have a linear trend.

Fig.14 shows weldments produced with all three types of edge gave none linear trend with an increase in welding current. They showed the same trend. It may be due to the increase in welding current the ductility of the weld with straight edge increased till maximum value at 90A before decreasing on the further increment of welding current. While the weldment produced with beveled angle has maximum value at 80A. It was also observed that the base metal have the least percentage elongation compared to other weld joints.

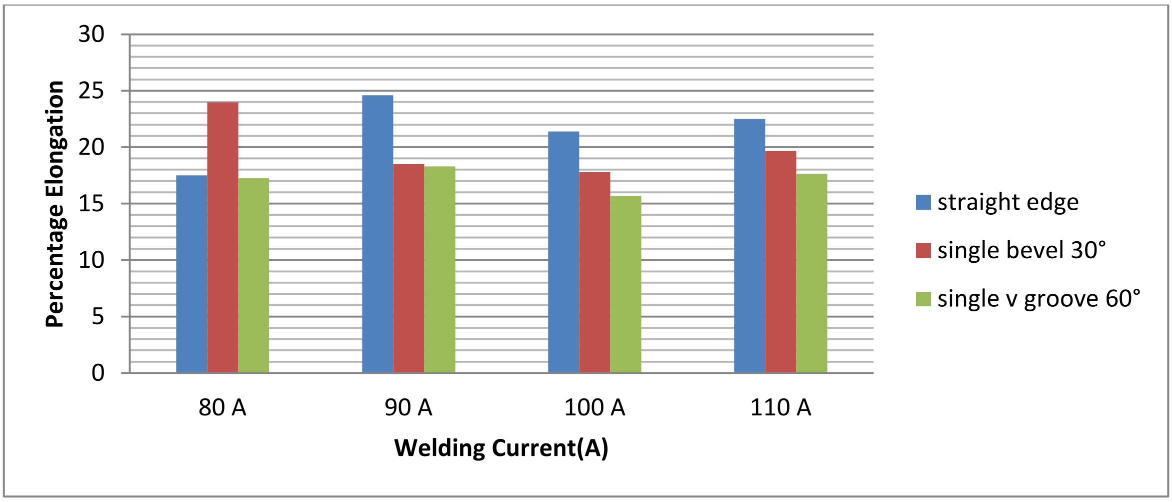

Fig-14 : Effect of welding current on percentage elongation

4.2. Effect of welding speed on mechanical properties of weld joints:

Fig.15&16 shows the effect of welding speed on the ultimate tensile strength and yield strength of the weld. It observed that on increase in welding speed decreased in both tensile strength and yield strength up to welding speed of 117 mm/min produced by single V grooved, further increased in increasing in welding speed. The maximum tensile strength (601.7 MPa) at the welding speed of 124 mm/min and maximum yield strength (445.7 MPa) at the speed of 90mm/min produced with V grooved.

The weldments produced with beveled angle have increased in strength up to welding speed 117 mm/min. And further decrease in increasing welding speed. It is observed that V grooved has better tensile strength and yield strength.

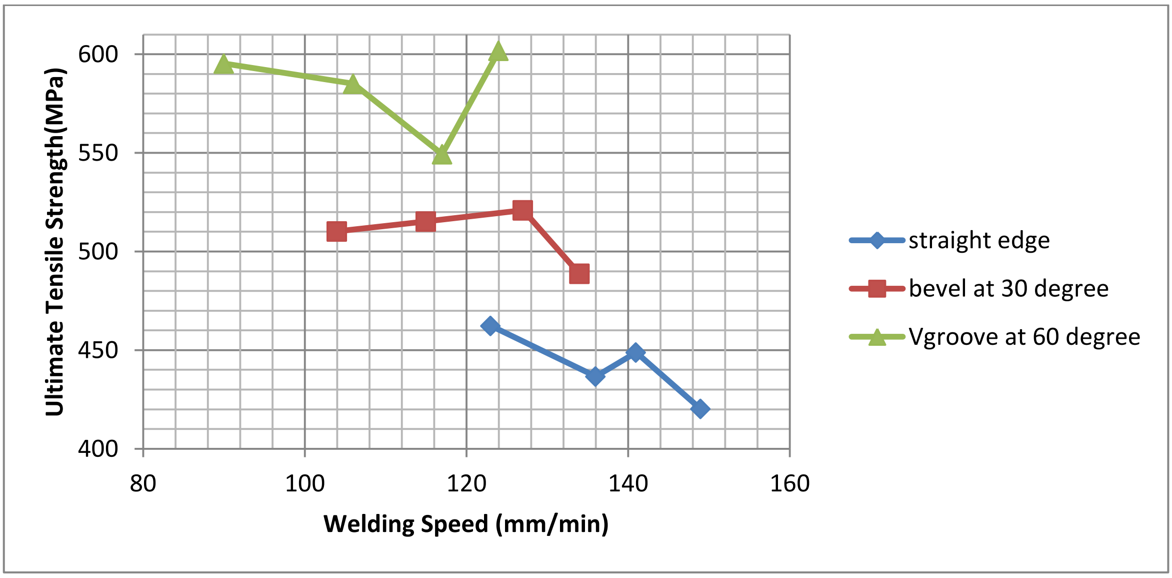

Fig-15 : Effect of welding speed on tensile strength

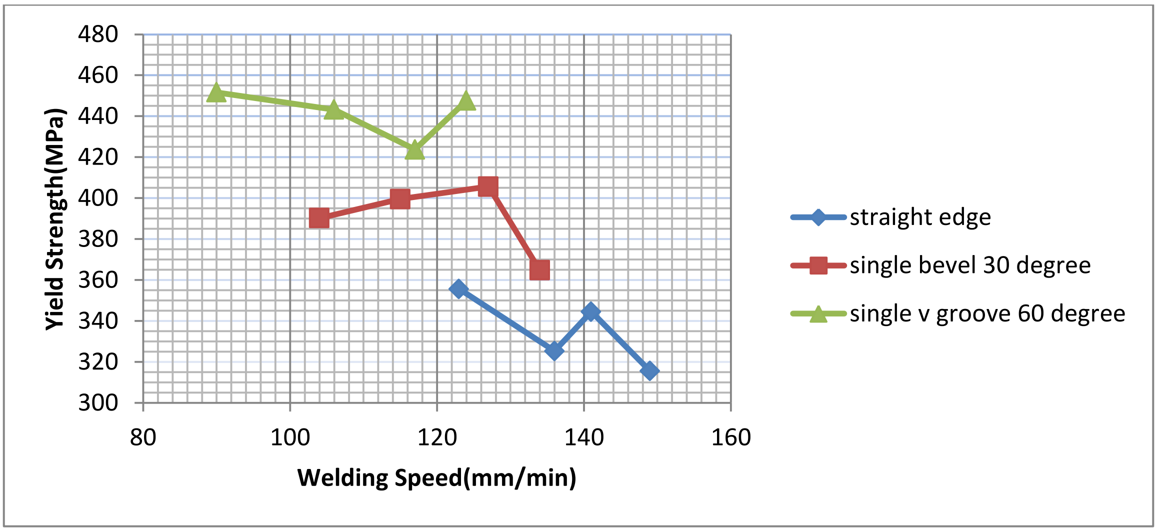

Fig-16 : Effect of welding speed on yield strength

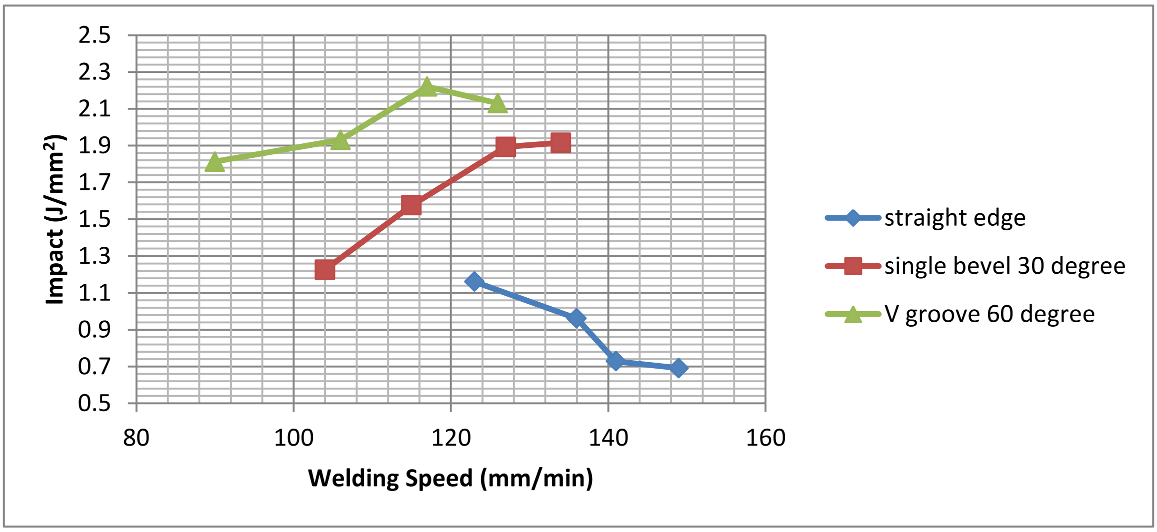

Fig-17 : Effect of welding speed on impact strength.

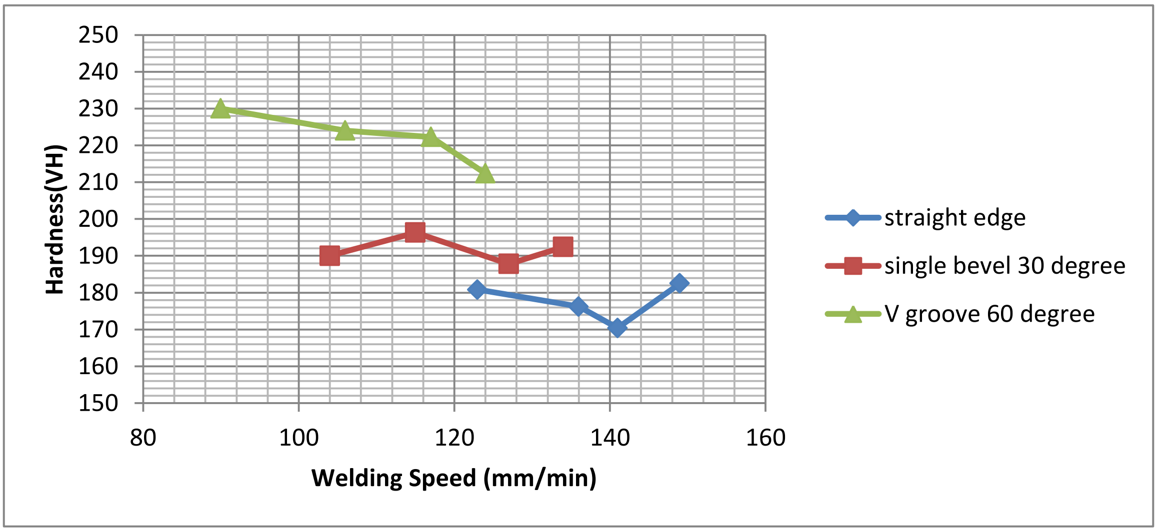

Fig-18 : Effect of welding speed on hardness.

Fig. 17 & 18 shows the impact test values increase in an increase in welding speed which are produced with single beveled and single V grooved, linearly decreased in increased in welding speed which is produced with straight edge. The maximum impact strength (2.32 J/mm^2) obtained at welding speed (117mm/min).

The welding speed and hardness relationship showed a linear relation in which hardness values decrease with an increase in welding speed produced with V grooved. Other welds have no linear trend. The maximum hardness value (230VH) obtained at welding sped 90 mm/min for V grooved weld joints. Decreasing in hardness value may be a defect in welding joints.

Fig. 19 shows the relation between welding speed and depth of penetration. The welds produced by straight-edged, single beveled, and single V grooved have linear trends which increase in welding speed results decrease in depth of penetration. While, welds produced with single beveled and V grooved have the highest penetration (5.3 mm) at the welding speed 104 mm/min and 90 mm/min respectively. It is observed that on welding speed exhibited depth of penetration decreased.

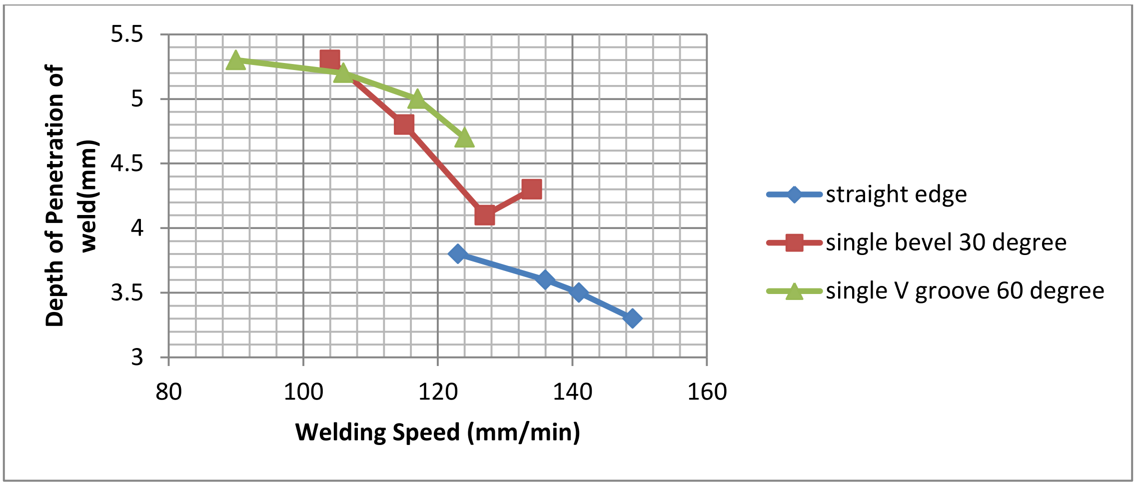

Fig-19: Effect of welding speed on penetration**.**

4.3 Effect of welding current and speed on angular distortion:

Fig. 20 shows on the increasing the welding current distortion got decrease in two weldments which are produced with beveled at 30° and V grooved 60°. In the other hand, straight-edged weld got an increase in distortion on increasing the welding current. The maximum parameter (4.63 mm) is obtained by V grooved, 80A. Welding current has an important role to minimize the distortion.

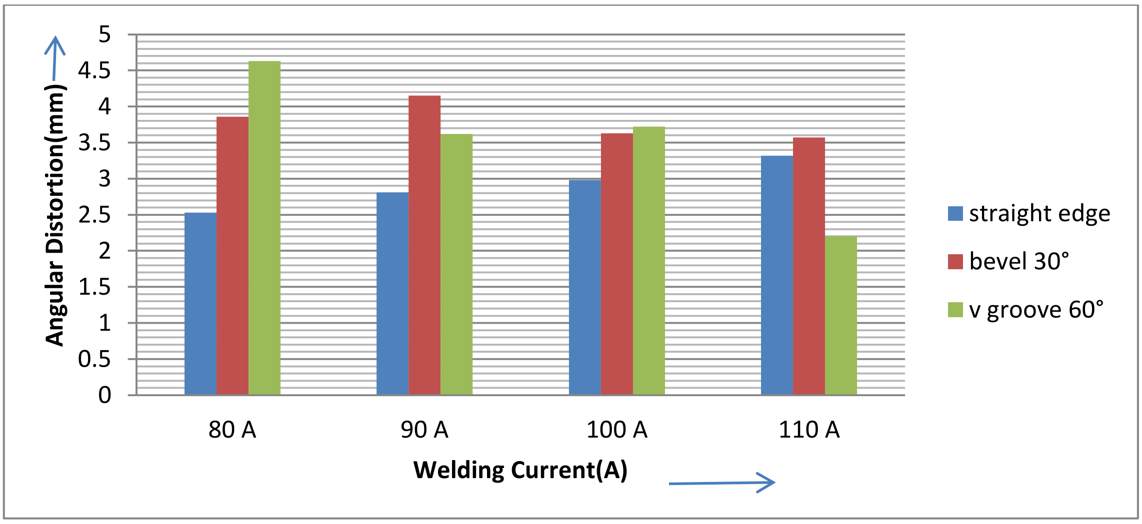

Fig-20: Effect of welding current on angular distortion

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Fig. 21 shows the relationship between welding speed and angular distortion. It shows the welding speed is also the most influencing parameter to the distortion on weld joints.

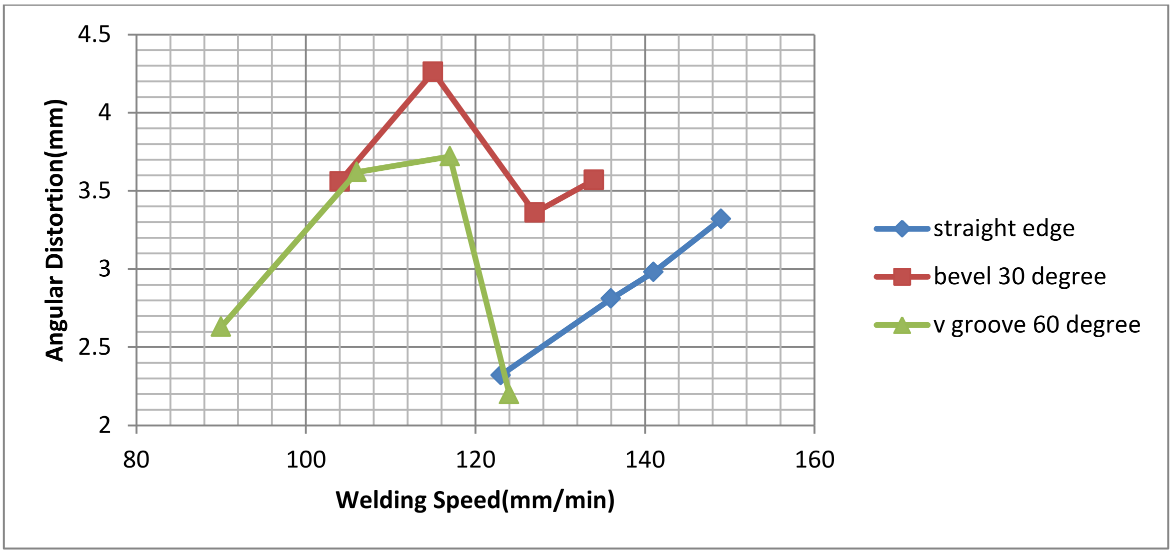

Fig-21 : Effect of welding speed on angular distortion**.**

4.4. Microstructural view:

The microstructural views have been shown in **Fig.22.** The changes in shielded metal arc welding parameters influence the effect of the microstructure of the weld metal. The increase in welding current, welding speed and different edge preparations affect the grain size of microstructure also different from one point to another point.

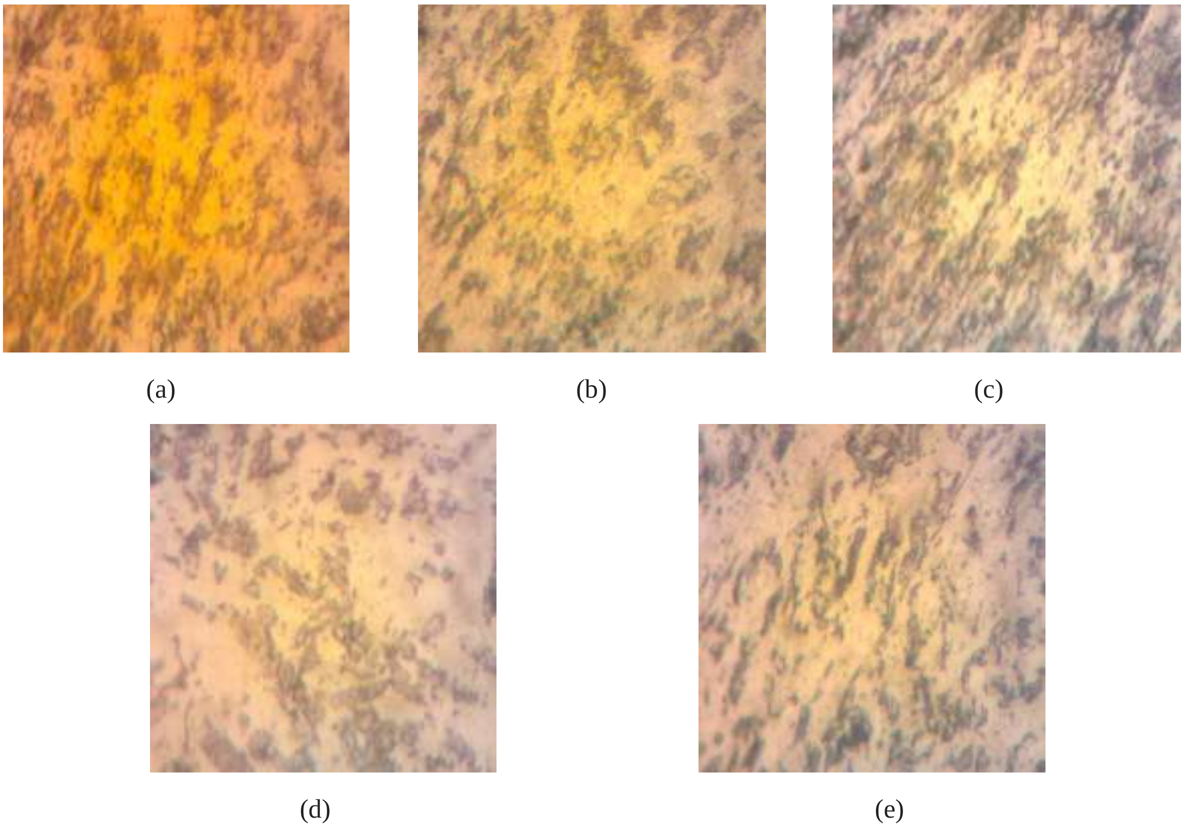

Fig-22 : Microstructural views of base metal and weldments welded in different welding parameters

V. CONCLUSION

This study investigated the impact of welding parameters on structural steel butt weld joint with totally different edge preparation which have vital contributions of welding current, welding speed, and edge preparation on angular distortion, mechanical properties, and microstructure of welds. The conclusions are given as-

1. It had been discovered that the ultimate tensile strength and yield strength values of weld joints initially decrease and further rise with an increase in welding current. The V grooved has maximum ultimate tensile strength (601.70MPa) and maximum yield strength (447.62MPa) at 110A that is optimum value respectively.

2. The impact values of weld joints made with single beveled at 30° and single V grooved at 60° increase with an increase in welding speed and welding current respectively. In the other hand hardness value of welds decrease respectively.

3. The weldments produced with single beveled and V grooved has the highest penetration (5.3 mm) at the welding speed 104 mm/min and 90 mm/min respectively. It is discovered that welding speed exhibited a depth of penetration minimized.

4. If the increase in welding current distortion decrease for single beveled at 30° and single V grooved at 60° weld joints; whereas the increase in welding current angular distortion additionally rose for straight-edged weld.

5. The rise in welding current, welding speed and different edge preparations has an effect on the grain size of microstructure additionally different from one point to another point.

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