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Groove Design and Its Influence on Strength of SMAW Joint

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Abstract:- This study investigates the mechanical properties of the mild steel after performing the welding operation by SMAW process. Three specimen of 45°, 60°,75° groove angle configurations were prepared and welded for this purpose. Various tests like tensile strength test, hardness test, and bending test were performed and the results for the welded joint were noted. The results obtained from the welded zone, HAZ (heat affected zone), and unaffected base metal zone (BM) were compared with each other. The results showed that the tensile strength increases linearly with the increase in groove angle. So the tensile strength for 75° groove angle is more than the other two. But the hardness values of this welded joint were so great than the other two joints. While the 45° groove angle welded joint has the least tensile strength, and also the hardness vales were low. So after checking all the mechanical properties of the three types of welded joints, the joint with groove angle of 60° was confirmed to be the optimum value in the SMAW process and also this angle is suggested to be used in industries.

I. INTRODUCTION

Unlike the manufacturing processes employed to produce a single component, the joining processes are used to assemble different members to yield the desired complex configuration. Such a complex geometry is either too difficult or impossible to obtain by using only the manufacturing processes. The joining processes are so related to the production system that these are also considered to form a class of manufacturing techniques. The joining of different elements can be either temporary or permanent in nature. Also, the mechanism of bonding may be either mechanical or atomic. All the joining processes involving atomic bonding are of permanent nature. In mechanical bonding, the strength of the joint is less than the combined strength of the original members. In atomic bonding, the situation is not same.

Another phenomenon used to classify the joining processes is based on the composition of the joint. According to this, all the joining processes can be grouped into three categories, which are, (1) autogenous, (2) homogenous, and (3) heterogenous. In all the autogenous processes no filler metal is consumed during joining. All the types of Solid phase welding like friction welding, electron beam welding, laser welding etc., and also resistance welding comes under this category. In the homogenous joining processes, the filler metal is used. The filler material used to provide the joint is similar to the parent metals to be joined. Electric Arc Welding, Gas Welding and the Thermit Welding belong to this category. For the heterogenous processes the filler metal's material is different from the parent material. Examples of this category are Soldering and Brazing. There is a special case for heterogenous process, like the two materials which are almost insoluble in each other can also be joined. For example, consider Iron and Silver. The joining of these two materials can be achieved by using a filler metal of third type but which s soluble in both the parent materials.

We know that the atomic bonding forces between two metallic atoms decreases very rapidly if the interatomic distance increase. That is, the bonding force almost reduces to zero. In contrast, if we reduce the interatomic distance to a very small value, then the force increases sharply to attain a very large value. Thus, if we put all the effort to bring two metallic surfaces together such that only the grain boundaries are the barriers for the atoms of two metals, then the two bodies will adhere with a very large force, resulting in the process called as Welding. Welding process is a fabrication process that joins materials, usually metals or thermoplastics, by causing coalescence. This is often done by melting the workpieces and adding a filler material to form a pool of molten material (the weld puddle) that cools to become a strong joint, but sometimes pressure is used in conjunction with heat, or by itself, to produce the weld. This is in contrast with soldering and brazing, which involve melting a lower-melting-point material between the workpieces to form a bond between them, without melting the workpieces. Many different energy sources can be used for welding, including a gas flame, an electric arc, a laser, an electron beam, friction, and ultrasound. While often an industrial process, welding can be done many different environments, including open air, underwater and in space. Regardless of location, however, welding remains dangerous, and precautions must be taken to avoid burns, electric shock, poisonous fumes, and overexposure to ultraviolet light.

II. LITERATURE REVIEW

Rouhollah Mohsen Pezeshkian had investigated the mechanical and microstructural properties of the P460N steel after the steel parts are joined by Shielded metal arc welding process (SMAW). P460N alloy steels come from the fine grain normalized steel family. This type of alloys are widely used in petroleum industries, chemical industries, power plants and also for the production of heat exchangers, gas cans, LPG bottles and in other fields. In his study,he had prepared three specimen with the groove angles of 60°,45°,75° and joined them using SMAW process. And then he had performed some tests like Tensile strength test, grain size test, and metallographic test on the welded joint metal, heat affected zone (HAZ), and Base metal (BM). Then he compared all the test results. And then he concluded that the yield stress in welded specimen cross-section done by SMAW process with the groove angles of 45° and 75° is less than that of the base metal (P460N steel). In SMAW method with groove angle of 60° yield stress in welded portion is more than that of base metal which is acceptable from engineering and standard point of view. And after performing the metallographic test on the three specimen he concluded that the grain size of the weld metal and the HAZ in the specimen with groove angle of 60° is much closer to the base metal compared to all other sizes. From this prospective, the 60° groove angle is evaluated as the proper groove angle [1].

Saiedeh Safaiepour studied the mechanical properties and metallurgical properties on the weld joint made by SMAW process. In his study he took five specimen with the groove angles of 45°,60°,65°,70°,75° and joined them using the SMAW process. He then performed the tensile strength test, impact strength test, bending test, and the grain size test on all the five specimen. He studied that the impact energy results in HAZ were different so that HAZ areas in the specimen with 45°,60° and 65° groove angles have less impact energy compared to base metal. But in the specimen with 70° and 75° groove angle, impact energy was more in base metal. This increase can be due to the formation of intermetallic compounds that are formed by high entered heat energy created by welding conditions in these regions. By performing tensile strength test, he studied that the tensile strength in all the cases for all the welded metals is more than that of the base metal. But the yield stress in the groove angles of 45°, 65°, 70°, 75° is less than that of the parent metal. Whereas, for the groove angle of 60° the yield stress in welded metal is more than that of the base metal. Since, the base of engineering plan is yield stress he preferred 60° angle rather than 75° angle [2].

Bekir Cevich explained that the quality of the welded joints depends on many factors such as welding current, voltage, welding speed, shielding gas type, and the welding position. One of the main factors in the welding position is the Groove design. This is because different stresses (tensile, compressive, bending.) can occur on the welded joints. For this reason, while designing welded constructions, it is important to join them with the most appropriate groove configuration by considering the stresses the welded joints can be exposed to. In his study he explained the effect of groove configuration on the mechanical and metallurgical properties of S275 structural steel joined by SMAW process. S275 structural steels are widely used as structural steel tubes, construction pipes, foundation pipes, piling tube sheet, and profiles especially in structural engineering. Then he performed the tensile, hardness and bending tests to determine the mechanical properties of the SMAW joint for different grooves. As a result of his microstructure studies, it is seen that different structures such as ferrite, widmansttaten ferrite, and acicular ferrite were formed in the weld metal and coarse-grained region. He observed that the hardness of the weld metal was higher than HAZ and the base metal in all the joints. He found that the bending strength of the welded samples were lower than that of the base metal. The lowest bending strength was obtained in the joint made with V-type welding configuration. In bending test results, it was observed that fractures occured in all the wled samples. In all of them the fracture occured mainly near to the base metal-weld metal transition zone [3].

III. METHODOLOGY

➢ *Material Selection*

Mild steel plates of sizes 150x50x5 mm^3 were selected as base material because this material is widely used for the engineering applications in the industries. Mild steel has the excellent weldability. The metal is mostly used for the fabrications work and building of structures. This metal is also widely used in constructional field, automobile field etc., due to its excellent weldability.

Element	%
Carbon	0.20
Manganeese	1.60
Sulphur	0.045
Phosphorous	0.045
Silicon	0.45

Table 1:-Chemical composition of base material

➢ *Selection Of Groove Angle*

Selection and preparation of weld groove is an important step in the fabricaton of a welded joint. Selection of a correct joint design of a welded member leads to perform within load service, corrosive resistant atmosphere and safety. The weld joint which we use to join the welded members should have the required load bearing capacity when the load is applied in any direction. This should have good surface finish to make a sound weld joint. It should be designed in such a way that it will produce minimum distortion and residual stresses in the weldment as well as it should be economical. Since the distortions and residual stresses are main causes for the failure of weld joints. Based on thickness and width of the base plate 45°,60°,75° groove angles were selected. Then the three specimen were bevelled to the required angles with a hand grinding machine. In this procedure the mild steel plates were held fixedly in the bench vice. Then the grinding wheel was allowed to bevel the edges of the plates to the required angles. The spatters formed on the surfaces of the steel plates are also removed to make a smooth surface. The grinding process being performed is shown below.

Fig 1

➤ *Welding Procedure*

The welding process is done using Shielded Metal Arc Welding process. The DC rectifier manufactured by MEMCO industries having welding current rating of 450Amps with 60% rated duty cycle was used as a power source for the welding process. The butt weld was made in following steps.

Step1: In this step a supporting plate was taken and a notch was made exactly near the groove. The notch was made by grinding it on a fixed grinding machine.

Step2: Here the E6013 electrode was taken and tack welds were kept on each side of the steel plate. Then tack welds were allowed to cool for a while. The tack welds being made are shown in the figure below.

Fig 2

Step 3: The supporting member was also attached such that the notch on the supporting one was exactly above the groove. Then this joint was also allowed to cool.

Fig 3

Step 4: Following the third step, three welding passes were made. The first one is called the Root pass (pass1), the second one as the hot pass (pass2) and the third one as the capping pass (pass3).

Fig 4

This is the joint after completing the entire process.

The welding parameters used for different passes is shown in the table below.

Pass no.	Size of the electrode used	Current used (Amps)
Root pass	3.15mm	90A
Hot pass	3.15mm	100A
Capping pass	3.15mm	100A

Table 2:- Welding parameters for different passes

IV. RESULTS AND DISCUSSIONS

The testing was carried out physically on various testing machines such as universal testing machine, rockwell hardness testing machine. The tests performed were tensile test, bending test, and hardness test. Thus all the results are noted and analyzed which are as follows.

➤ *Tensile Test Results*

The testing specimen was kept in universal testing machine and the tensile test was conducted for all the three specimen. The loads and the deformation for all the groove angles were noted and are as follows.

For 45° groove angle the load was increased gradually and the changes in dimensions are noted. Thus the maximum load applied was 59 kN where the fracture was observed. The load is applied till the failure is observed. Initially, the deformation was not observed till 50 kN. Thereafter, the steady deformation is observed. The deformation observed was of 13mm when the fracture has occurred. The results are as follows.

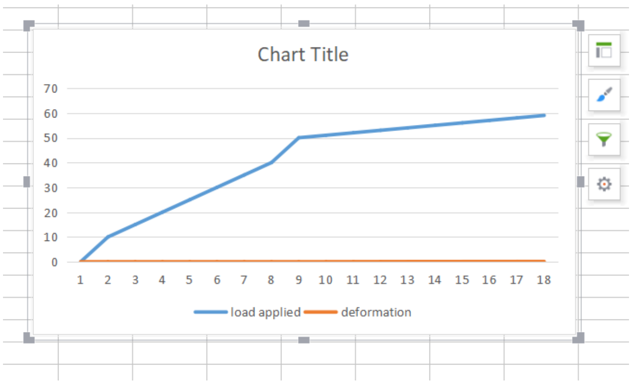

Fig 5:- 45° groove angle

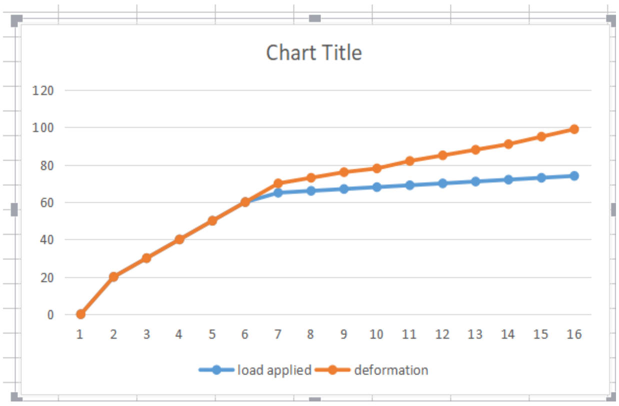

Fig 6:- 75° groove angle

- *Hardness Test Results*

For 45° angle the hardness test results are as follows

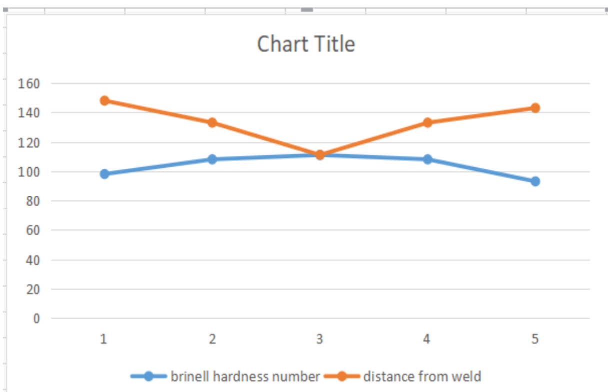

Fig 7

For 60° groove angle the hardness test results are as follows

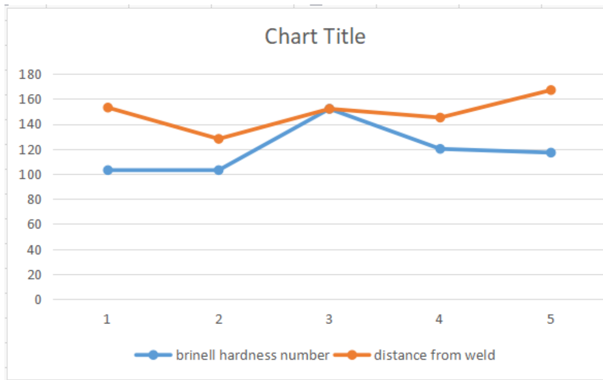

Fig 8

For 75° groove angle the hardness test results are as follows

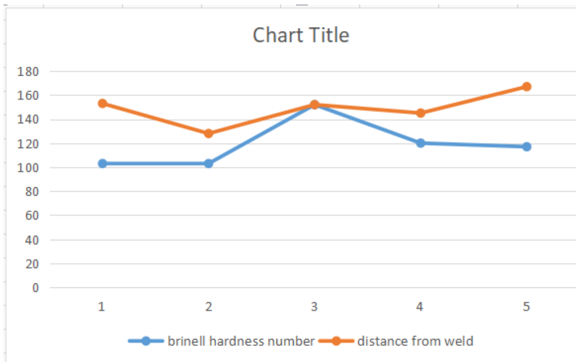

Fig 9

From this it has been concluded that the hardness value of weld zone is higher than any other zone. From the hardness test results it has been concluded that the hardness of the weld in 75° angle is greater than the other two which is not very advisable. And the lowest hardness values were found in 45° angle which is also not recommended. So the optimum values were found in 60° groove angle.

V. CONCLUSION

The groove angle configuration is the most essential part of the welded joint. The tensile strength increases linearly with the groove design. So the 75° groove angle has the highest tensile strength than the 45° and 60° angles. But the hardness results show that the 75° groove angle has more hardness values than the other two which is not at all desirable. Since, the increase in hardness values decrease the ductility and increases the brittleness. So after analyzing all the results, we found that the tensile strength in 45° is the least while the hardness values are permeable. So to obtain the optimum values of hardness and tensile and all other mechanical properties the standard groove angle is 60°. Thus, the groove angle configuration of 60° is the best value for any type of operation used in industries.

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