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INFLUENCE OF GROOVE ANGLE ON STRENGTH AND DISTORTION OF J- GROOVE BUTT WELD JOINT

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ABSTRACT

Welding, one of the most convenient and rapid method used for joining metals in navy, process industry in fabrication, maintenance, repair of parts and structures. The pipe used in process industry has welding strength as its important parameter. In this paper investigation of J-groove geometry to find out tensile and impact strength in case of butt weld joint will be done. For J-groove geometry different models of pipe with varying included angle from 15^0, 22^0, 30^0, 40^0 will be made. Currently the V-groove geometry with included angle up to 45^0 is in use, after studying the Indian Welding Journal, Indian Welding Society it is observed that distortion and residual stresses increases with increase in groove angle and its strength also increases with groove angle increasing the weld material which affect the economy of welding. In this paper we aim at overcoming these disadvantages by making use of J-groove geometry as on comparison after studying different papers concludes that J-groove geometry has less residual stresses and distortion than V-groove geometry and also requires less weld materials. The industries facing the disadvantage with V-groove geometry can make use of the satisfactory results obtained from this project. Tensile test to check maximum tensile force sustaining capacity and micro and macro inspection test to check welding quality and other parameters has been conducted. Other tests carried out includes impact test to check maximum energy absorbing capacity, we also measured dimensions of specimen before and after welding to find out longitudinal and transverse distortion if any by making use of four specimens. Finally, an experimental result simulates with Finite Element Analysis results.

KEYWORDS: Single J-Groove Butt Weld Joint, Mechanical Properties, Distortion, Groove Angle, Electric Arc Welding.

Introduction

In current scenario welding has vast application in shipping industry, process industry, in fabrication maintenance, repairs of parts and weld structures. The welding process is used to manufacture a simple steel bracket to the nuclear reactors. There are many methods which are used for metal joining process but welding is one of the fast and convenient method.[1] The welding is defined as the process of joining method by heating them to their melting temperature and causing the molten metal flow together. Because of vast application of welding in industry there is needed to optimize welding process parameters and to increase reliability reproducibility and viability. we have to study the different defect such as distortion hot cracking in a systematic and logical approach. Distortion is one of the most widely observed defects in welding process so it is essential to this parameter. The distortion is an unwanted physical change because of welding involves highly localized heating of metal being jointed together.[3] Due to high heating metal are fused together and they will set up non uniform stresses inside the component because of expansion and contraction of the heated material. Initially compressive stresses are created in the surrounding of material due to expansion of the material. The tensile stresses are created due to cooling of the material and contraction of weld metal. So due to uneven cooling and heating some amount of residual stresses are set up in the material.[5]

In this paper detailed discussion is carried out on mechanical properties such as tensile strength and

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impact strength by selecting proper angle in the shielded metal arc welding and finally the experimental results simulates with FEM results.

MATERIALS AND WELDING METHODS

In materials methodology a detailed discussion is carried out about material used for base material as well as weld material, specimen preparation and welding geometry used.

2.1 Materials

The materials used for experimentation are mild steel SAE 4800 hollow pipes and electrodes. The SAE 4800 hollow pipe of dimensions 45mm outer diameter and 16mm thickness are used. The electrodes used for welding and SAE 4800 pipes are of 10 gauge (3.15mm dia.) and 8 gauge (2.5mm dia.) general purpose mild steel electrodes. The welding electrodes are manufactured by “ADOR WELDING LIMITED”(ADVANI OERLICON) and the category is SUPERBOND the 2.5mm dia. Electrodes are used for initial penetration run for better welding and 3.15 mm dia. Electrodes are used for further welding.

Fig. 1 Base material

Table 1: Chemical composition of base metal

Elements	C	Mn	P	S	Si	Cr	Cu	Mo	Ni
Weight, max, %	0.23	0.66	0.09	0.016	0.24	1.29	0.40	0.24	2.9

Fig. 2 Welding electrodes

2.2 Preparation of welding specimen

The selection of groove geometry is affects by two main factors first one is machining cost to obtain the required groove geometry and second is cost of weld metal on the basis of amount of weld metal required for welding. Other than above factor such as welding speed, accessibility of groove, residual stresses and distortion these are the factors which are also consider for selection of groove geometry. There are different types of groove geometries are available but U and J groove geometry are more economical than V and bevel groove geometry in terms of amount of weld metal required for welding and also offers less distortion and residual stresses. So by considering above factors we have chosen J groove geometry for edge preparation for our experimentation. The shaping, lathe machine are used to obtain various groove angles of single J groove butt weld joints., The groove geometry and groove angles produced after machining for experimental set up given below.

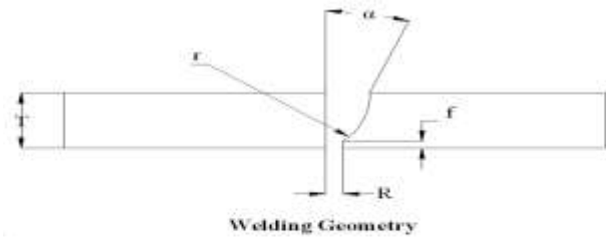

Fig. 3 Welding geometry

Table 2: Welding samples

Sample	Angle in degrees	Root opening in mm	Thickness in mm
R-1	15	2	16
R-2	22	2	16
R-3	30	2	16
R-4	40	2	16

Fig.4 Edge preparation for welding

2.3 Welding method

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The commonly used welding method for general purpose application is electric arc welding. Electric arc welding is also used in following applications such as guide way for trains, ships, bridges, building structures, automobiles and nuclear reactors. The electric arc welding method requires a continuous supply of either direct current or alternating current supply. This creates an electric arc to generate heat to melt the metal and to form a weld. The electric arc welding is a complex process which involves extremely high temperatures which produces distortion and residual stresses inside the joint. Due to the presence of distortion and residual stresses the strength of joints reduces and which becomes more dangerous to fracture, corrosion and other types of failures.

Fig. 5 Electric arc welding

1. Experimental methodology

The tensile strength, impact strength and distortion are evaluated by using following tests.

3.1 Tensile test

The tensile test is used to find out ultimate tensile strength and yield strength of butt weld joint. To carry out this test we have to prepare standard specimen as per ASTM.

3.2 Specimen preparation for tensile test

To prepare tensile test specimen we have to cut four longitudinal strips of 300mm length and 30mm width from 15^0, 22^0, 30^0 40^0 single J-groove butt welded joint specimens. After machining on these strips we prepare four circular specimens for tensile test.

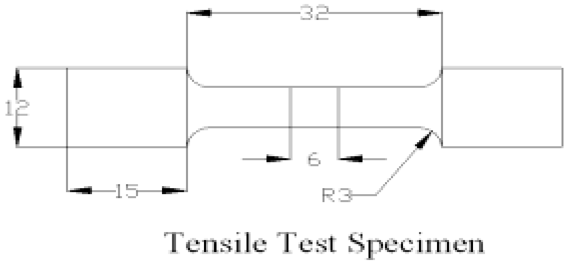

Fig. 6 Tensile test specimen

3.3 Process set up for tensile test

The specimen is placed in the machine in between the grips and an extensometer is used to measure the deformation. Once the machine is started it will apply an increasing load on the specimen throughout the test up the failure of specimen. The associated software will records the values of ultimate tensile stress, yield stress and deformation as shown in table.3 the set up used for tensile test and the specimens after the tensile test are shown below.

Fig. 7 Process setup for tensile test

Fig. 8 Tensile test specimen after test

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Table 3: Tensile Test results for all specimens

Sample No.	Groove Angle (Ɵ)	Specimen	Yield Strength in MPa	UTS In MPa
1	0^0	R	1500	1700
2	15^0	R-0	1076.85	1162.41
3	22^0	R-1	1081.69	1168.87
4	30^0	R-2	1091.42	1177.54
5	44^0	R-3	1100.06	1180.62

3.4 Impact test

This test is used to find out the value of impact strength by measuring the energy absorbed by the specimen before failure. To carry out this test we have prepare specimen as per the standards. To find out impact strength there are two methods first one is Izod impact test and charpy impact test. In this experimentation we used Charpy impact test to measure the energy absorbed by the specimen before failure which gives us impact strength.

3.5 Specimen preparation for charpy impact test

To prepare charpy impact test specimen we have to cut four longitudinal strips of 70mm length and 15mm width from 15^0, 22^0, 30^0 40^0 single J-groove butt welded joint specimens. After machining on these strips we prepare four rectangular specimens for charpy impact test.

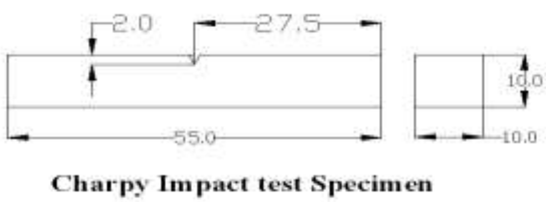

Fig. 9 Charpy impact test specimen

3.6 Process set up for charpy impact test

The specimen prepared is V-notch specimen which is commonly used for weld metal testing. The quality of preparation of these entire specimens is extremely important also the specimens must be exactly dimensioned including surface finish and notch for the accuracy of results. The specimen is placed on the anvil support of the machine and the hammer is released so that it strikes the specimen at the opposite face of the notch. The observer will records the values of energy, absorbed by the specimen, the observations are shown in table.4 the set up used for charpy impact test and the specimens after the test are shown below.

Fig. 10 Charpy impact test machine

Fig. 11 Charpy impact test specimen after test

Table -4 Impact Test results for all specimens

Sample No.	Groove Angle (Ɵ)	Specimen	Impact strength Joules
1	0^0	R	55
2	15^0	R-0	30
3	22^0	R-1	32
4	30^0	R-2	34
5	40^0	R-3	36

3.7 Distortion measurement

In welding there are different types of distortions are present but in this experimentation we measured transverse and longitudinal distortion at different locations of the specimen. To measure the transverse and longitudinal distortion we used vernier caliper and dial gauge indicator. The longitudinal distortion is measured by the vernier caliper and transverse shrinkage is measured by dial gauge indicator. The instruments used for distortion measurement are shown in fig.12, 13

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Fig. 12 Vernier caliper

Fig. 13 Dial gauge indicator

2. FEM analysis of butt weld joint

FEM analysis gives the solution of all engineering problems using computers. Engineering problems includes complex geometry and loads. They are very difficult to analyze and solve theoretically. In FEA these kinds of problems are easily solved or analyzed. To solve any problem in FEA we required three steps.

- Pre-processing or modeling the structure
- Analysis
- Post processing

4.1 Procedure to perform FE Analysis

ANSYS is finite element program which can be work in different field such as static structural, non linear, thermal, implicit and explicit dynamics, fluid flow, electromagnetic and electric field analysis. The following procedure was conducted in ANSYS 15.0 to measure ultimate tensile stress, yield stress, deformation and impact strength of single J-groove butt weld joint.

4.2 Importing geometry

ANSYS comes with IGES support by default but there are different geometry interfaces are available for PRO/E, CATIA, UG, SOLIDWORK, PARASOLID. The single J-groove butt weld joints prepared in CREO for 15^0, 22^0, 30^0 and 40^0 groove angles.

4.3 Creating material property

While selecting material properties it is assumed that martial is isotropic in nature. The properties selected for butt weld joint analysis are given in table.5

Table -5 Properties of material

Material Properties	Yield strength (MPa)	Ultimate strength (MPa)	Density (g/cm³)	Elongation (%)	Elastic Modulus (Gpa)	Thermal Conductivity (W/mK)	BHN	Poisson's Ratio
Mild steel SAE 4800	1500	1700	7.850	10-22	200-209	46.8-52	163-514	0.27-0.3

4.4 Selecting element type

We select SOLID187 element for analysis of single J-groove butt weld joint. The geometry of SOLID187 is as shown in fig.14

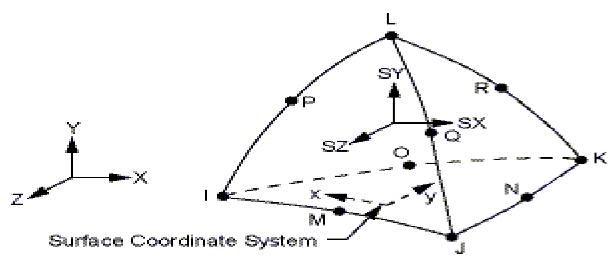

Fig. 14 SOLID187 Geometry

4.5 Creating FEM meshing

In FE method we divide the structure in to number of small pieces that can be described with an equation. These small pieces are called finite element. Finally we sum up the response of all these small pieces in to response of entire structure for meshing the hex dominant mesh was selected because it has maximum accuracy during the solution. The model made in CREO software is as shown in fig.15, 16

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Fig. 15 Geometrical model of tensile specimen & butt joint in CREO

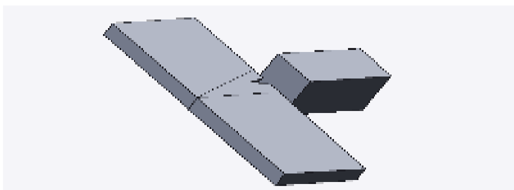

Fig. 16 Geometrical model of impact specimen in CREO

Steps in creating finite elements

- Assign attributes to geometry
- Specify mesh controls on the geometry
- Mesh

The meshing is done for weld metal as well as base metal.

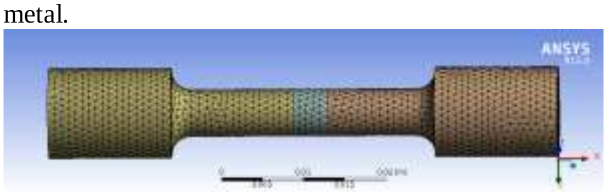

Fig. 17 Meshing of tensile specimen by uniform quad method

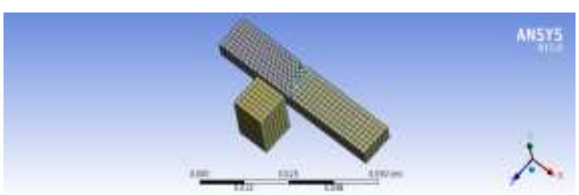

Fig. 18 Meshing of impact specimen by uniform quad method

4.6 Apply load and boundary condition

Load and boundary condition can be applied in both the pre-processor and solution processor.

- Apply forces on body with specific magnitude and direction.
- Selection of faces where fixed supports were applied.

Load- For tensile test we apply 33750N at the free end of the specimen. For impact test we apply 5.9 m/s velocity to the hammer.

Constrain- For the tensile test a fixed support was applied at one end of specimen and other end is free to apply load. For impact test side faces of the specimen are fixed and velocity is given to the hammer.

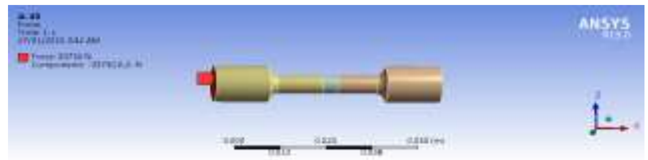

Fig. 19 When 33750N force is applied in X direction

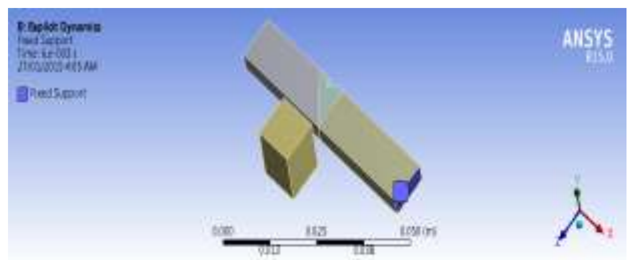

Fig. 20 When faces impact specimen are fixed

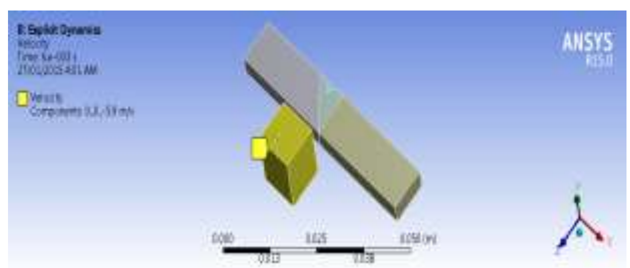

Fig. 21 Hammer with velocity 5.9 m/s

4.7 Solving

The basic equation of the finite element method used for solving was, [K]{u}={F}, where [K] is the assembled stiffness matrix of the structure, {u} is the vector of displacements at each node, and {F} is the applied load vector.

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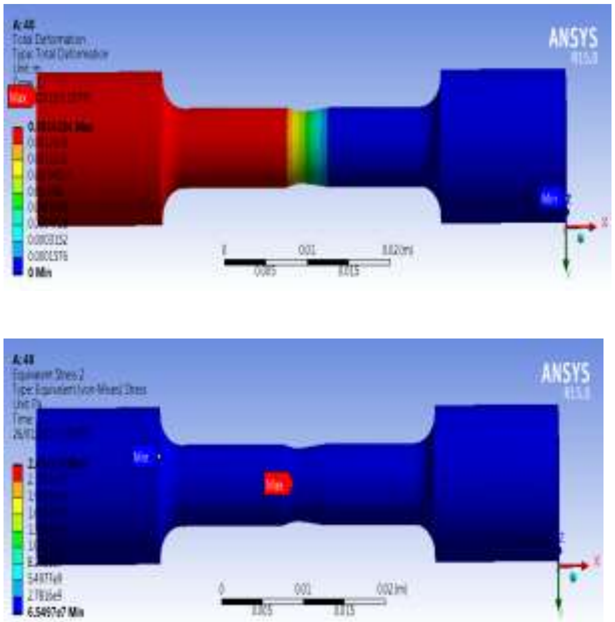


Fig. 22 Total deformation and Equivalent stress in tensile test specimen

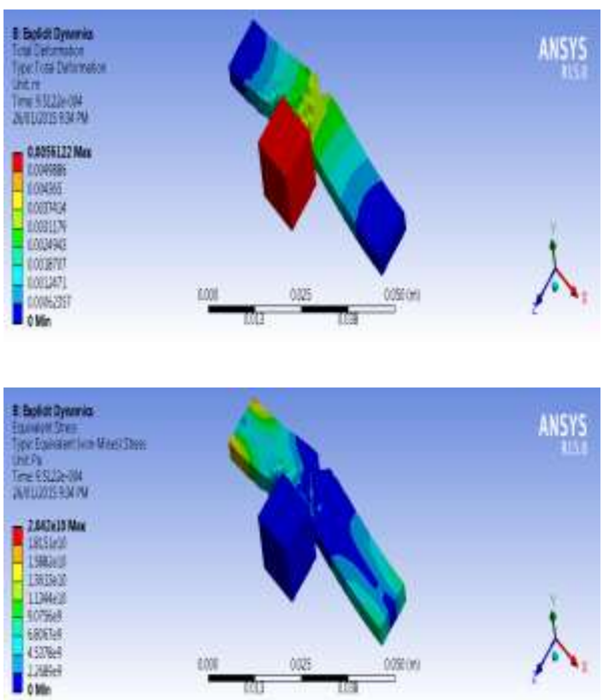


Fig. 23 Total deformation and Equivalent stress in impact test specimen

4.7 Post processing

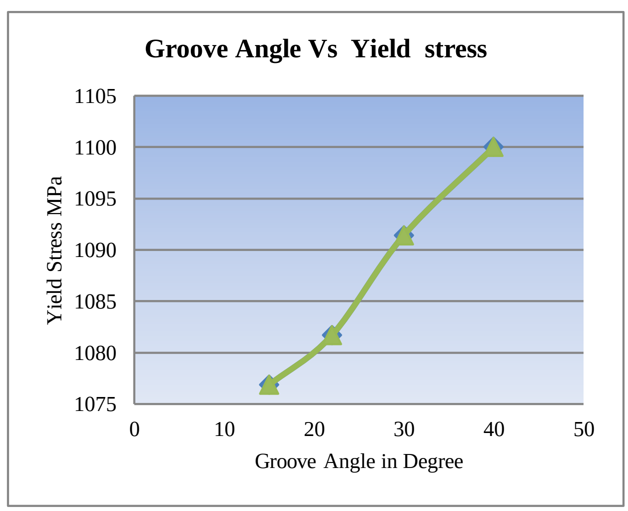
The General Postprocessor was used to look at the results over the whole model at one point in time.

Table -6 Observations of FEA for all specimens

Sample No.	Included Angle (θ)	Specmen	Tensile Strength		Impact Strength in jouls
			Yield Stress in MPa	UTS in MPa	
1	0^0	R-0	695.56	750.24	25
2	15^0	R-1	720.15	788.56	26.10
3	22^0	R-2	768.45	800.42	28.80
4	30^0	R-3	855.56	940.52	32.20

RESULT AND DISCUSSION

From the above experimental and computational data, we are going to compare experimental results with computational results.



Graph -1 Groove Angle Vs yield strength

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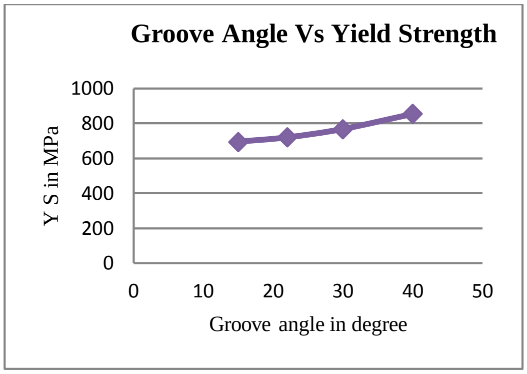
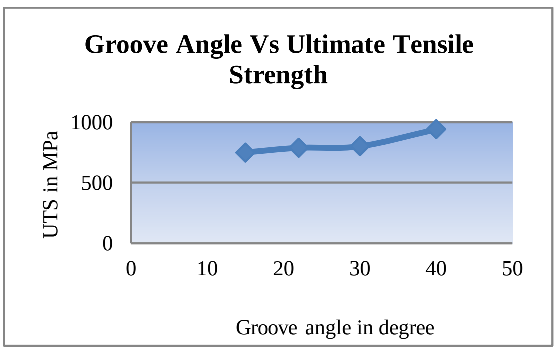
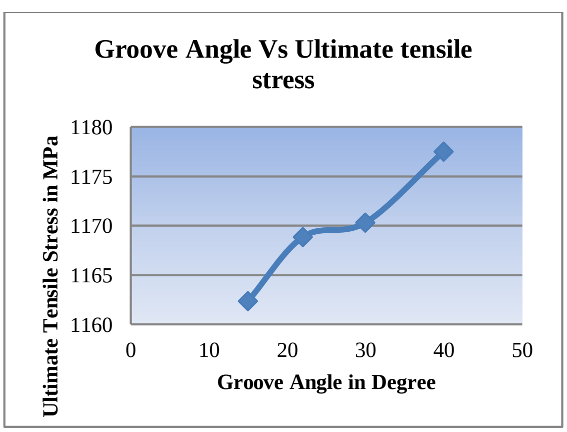


Graph -2 Groove angle Vs Yield strength of butt joint in FEA

From the above two graphs i.e. groove angle verses yield strength for experimental and FEA, it shows that as the groove angle increases the yield strength of single J- groove butt weld joint increases and at 40^0 we have maximum yield strength.

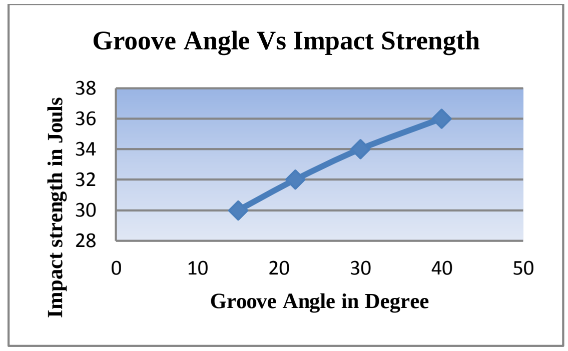


Graph -3 Groove angle Vs Ultimate tensile strength of butt joint in FEA

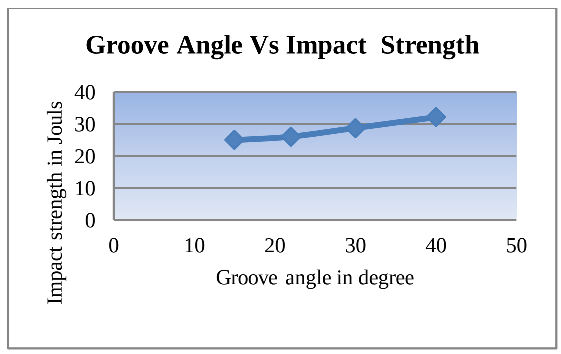


Graph -4 Groove Angle Vs Ultimate Tensile Stress

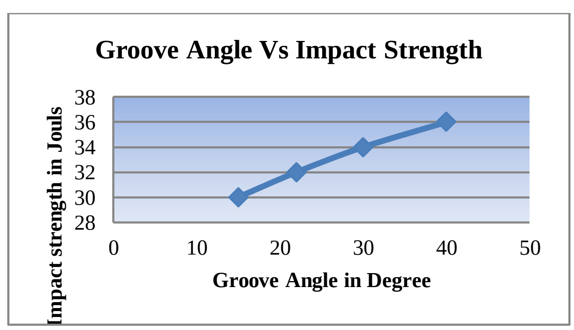
From the above two graphs i.e. groove angle verses ultimate tensile strength for experimental and FEA, it shows that as the groove angle increases the ultimate strength of single J-groove butt weld joint increases and at 40^0 we have maximum ultimate tensile strength.



Graph -5 Groove Angle Vs Impact Strength



Graph -6 Groove angle Vs Impact strength of butt joint in FEA



Graph -7 Groove Angle Vs Impact Strength

From the above two graphs i.e. groove angle verses impact strength for experimental and FEA analysis ,

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it shows that as the groove angle increases the impact strength of and at 40^0 we have maximum impact strength. single J- groove butt weld joint increases

The results obtained by experimental and FEM investigation will useful to the engineers. The variations of transverse and longitudinal distortion were found very less in single J- groove butt weld joint.

CONCLUSION

From the present investigation and the discussion presented in the earlier experimentation and FE method, the following conclusions are drawn.

- The tensile strength has obtained 73.33 % for 40^0 included angle as compared to unwelded pipe. Also tensile strength obtained from ANSYS is 57.03% for 40^0 groove angle.
- It is observed that, by changing included angle, there is an increase in strength of pipe.
- The impact strength has obtained 52.94 % for 40^0 included angle as compared to unwelded pipe. Also impact strength obtained from ANSYS is 46% for 40^0 groove angle.
- The commonly used groove angle is $45^0$for V-groove butt weld joint which required more weld metal as compare to 40^0 J-groove butt weld joint the cost of welding increases. So we can prefer 40^0 J- groove butt weld joint.
- The value of transverse and longitudinal distortion is very less because of thickness of pipe.
- In future while making the butt weld joint prepare the single J-groove butt weld joint instead of V-groove, so it will increase the strength of weld and it also reduce the cost of welding by reducing the requirement of weld metal.

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