THEORETICAL AND EXPERIMENTAL ANALYSIS OF T-JOINT IN TIG WELDING PROCESS

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ABSTRACT- Arc welded structures are extensively used in automobiles, constructions and power plants. As the main cause of weldment failure is design defect and overload, hence it is necessary to analyze the maximum stresses in the weldment. In this work deals with investigation of welded T-joint by TIG welding process with varying gap and angle between the parent material to determine the breaking stress under tensile load in the weldment. Finite element analysis used to carried out the maximum breaking stress using Ansys software. Experimental analysis used to carried out the maximum breaking stress under tensile load. Taguchi optimization method used to optimize the fillet weld section in experimental analysis. Angle, arc force and gap between parent materials are the three process parameters used for the taguchi optimization technique.The FE analysis & analytical results of breaking stress is also carried out and verified with the experimental result. The optimized best fillet weld section (low carbon steel AISI1020 and copper) is carried out and used to restrict the weldment failure.

Keywords: Arc welded structure, Weldment failure, Taguchi optimization, low carbon steel AISI1020, Copper

1.INTRODUCTION

The fillet welded joints commonly suffer from various welding deformation patterns, such as, angular distortion, longitudinal & transverse shrinkage in fabrication of structural members in shipbuilding, automobile and other industries that angular distortion defined through numerical calculation[1-3].The stresses in the weldment are evaluated by varying the gap between the base plates which may occur during manufacturing[4].It is distinguished from other forms of mechanical connection, such as riveting or bolting, which are formed by friction or mechanical interlocking. It is one of the oldest and reliable methods of joining[5].The residual stress in a welded T-joint, comparing those computed by 3D models with those computed by 2D models[6].

A mathematical model for predicting weld penetration as a function of welding process variables. The constrained optimization method is then applied to this model to optimize process variables for maximizing weld penetration [7-9].Welding offers many advantages over bolting and riveting. Welding enables direct transfer of stress between members eliminating closure and splice plates necessary for bolted structures. Hence, the weight of the joint is minimum. Generally welded joints are as strong as or stronger than the base metal, thereby placing no restriction on the joints.

Some of the disadvantages of welding are that it requires skilled manpower for welding as well as inspection. Welding in the field may be difficult due to the location or environment. Welded joints are highly prone for cracking under fatigue loading large residual stresses and distortions are developed in welded connections.

2.NUMERICAL CALCULATION

2.1 WELDMENT UNDER TENSILE LOAD

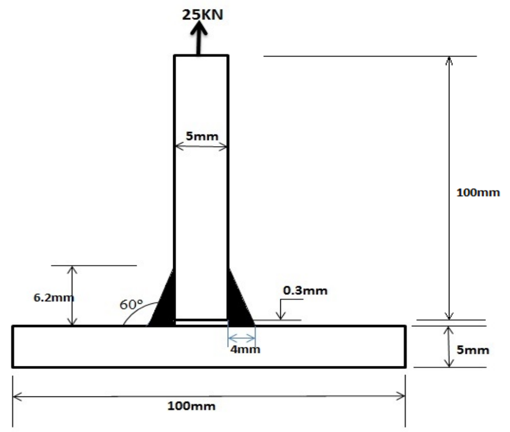

Fig. 2.1 Arc weld of T-joint under tensile load for 0.3mm gap and 60º angle

The above Fig 2.1 represents the T-joint fillet weld sections with dimensions (100x50x5mm) with fillet angle 45º. Here 25 KN tensile acting upward on the top of the section. The base weld material is plain carbon steel and filler material is copper (Cu).

T-joint fillet welds the dimensions are specified are as follows.

- F-Tensile load on vertical plate (N) = 25KN
- w-Leg length of weld (mm) = 4.0 mm
- h -Throat of fillet weld (mm)
- = w X [cos45º]
- l-Length of weld or size of weld (mm) = 50mm
- l_T-length of top load section = 5mm
- b_T-breath of top load section = 50mm
- l_t-throat length = 4mm
- t- throat thickness = 1mm
- A -Area of weld section

The material properties are specified are as follows,

- Modulus of elasticity of base plate material (E) = 2.1 x 10^MPa
- Poisson's ratio of base plate material (μ) = 0.3
- Modulus of elasticity of weld material (E) = 1.1 x 10^5 MPa
- Poisson's ratio of weld material (μ) = 0.37

Formula used,

Area of weld section(A) $= 2A_f+A_l-A_t$

Where,

A_f – Area of fillet section $= 2x(\cos\theta\times w)$ x l

A_l – Area of load section $= l_T x\, b_T$

A_t – Throat area $= t\, x l_t$

Therefore,

Breaking stress = (Breaking Load(P)/Throat Area) X Stress Concentration Factor(k)

$$=\frac{P}{A_t} \text{ x k}$$

Stress concentration factor (k) parent material is the range of 3.5 to 4 given by Frank Karl Heinz [16].

2.2 BREAKING STRESS

The model calculation of breaking stress for tensile load with different angle and varying gap between parent materials given below,

1. 25KN load, θ = 45º and 0.3 mm gap

   Breaking stress (σ_b) = $\frac{F}{A} \times$ k

   $A = 2\,A_f + A_l - A_t$

   $=2(\cos45 \times 6.2 \times 50)+(5 \times 50)-(.3 \times 4)$

   $=531.8\text{mm}^2$

   $= \frac{25000}{531.8} \times 4$

   σ_b = 188.04 Mpa.

2. 25KN load, θ = 60º and 0.3mm gap

   $A= 2(\cos60 \times 4 \times 50)+(5 \times 50)-(0.3 \times 4)$

   $= 448.8\text{ mm}^2$

   $= \frac{25000}{448.8} \times 4$

   σ_b = 222.2 Mpa

3. 25KN load, θ = 30º and 0.3mm gap

   $A = 2(\cos30 \times 4 \times 50)+(5 \times 50)-(.3 \times 4)$
   $= 768.4\text{ mm}^2$

   $= \frac{25000}{768.4} \times 4$

   σ_b= 130.1 Mpa.

2.3 NUMERICAL RESULTS

Tabulated breaking stress values from numerical calculation

The Maximum breaking stresses present in T-joint weldment at the throat thickness with the gap variation are given in table1 and the variation of Maximum breaking stress with respect to gap is also shown in Table. 4.1. Where 30º, 45º & 60º chamfer is provided on the vertical plate by varying the gap of 0.3, 0.6 and 0.9mm.

Gap between parent plats(mm)	**Breaking stress for 25KN(Mpa)**		
	30º	**45º**	**60º**
0.3	130.10	188.04	222.20
0.6	130.34	188.50	223.41
0.9	130.60	189.90	224.60

Table.2.1 Numerical results for breaking stress with different angle and gap between parent materials

3. EXPERIMENTAL ANALYSIS

3.1 OPTIMIZATION

Optimization is used to reducing the time, cost of weld simulation parameters [10,11].Choosing welding process necessary to obtain the weld bed shape because of due to weld current, weld speed, arc voltage and its time consuming and this effects of weld parameters using optimization [12]. Defined as the process of finding the conditions that give the minimum or maximum value of a function, where the function defines the effort required or the desired benefit. The act of obtaining best result under the given circumstances. Design, construction and maintenance of engineering systems involve decision making both at the managerial and the technological level.

3.2 TAGUCHI TECHNIQUE

Taguchi is the one of the optimization technique. Dr.Taguchi of Nippon telephones and telegraph company, Japan has developed a method based on orthogonal array experiments which gives much reduced "variance'' for the experiment with optimum settings control variables [12]. Thus the marriage of Design of Experiments with optimization variables to obtain BEST results is achieved in the Taguchi method. "Orthogonal Array" provide a set of well balanced experiments & Dr.Taguchi's signal-to-Noise ratios(S/N), which are log functions of desired output, serve as objective functions for optimization, help in data analysis and prediction of optimum results.

4. EXPERIMENTAL WORK

In this process TIG welding process is used with AISI1020 low carbon steel (parent material) and cu (filler material) with dimensions (100x50x5) mm.

A welded T-joint is considered for determination of breaking strength is shown in fig.4.1. For experimental testing process, two vertical plates are welded with fillet weld at base plate top and bottom side having the cross section of 100 X 50 X 5 mm and 60 X 50 X 5 mm thick. The fillet weld size on bottom side is of 8 mm which is more than the top side fillet weld size of 4 mm, for studying the breaking strength of top side T-joint weld which is having less strength than the strength of bottom side of fillet weld.

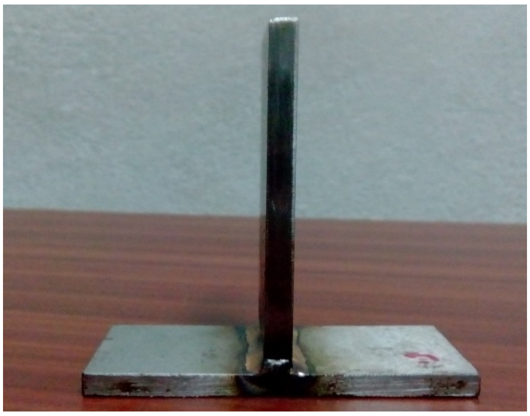

Fig 4.1 welded T-joint material by Tungsten Inert Gas welding process

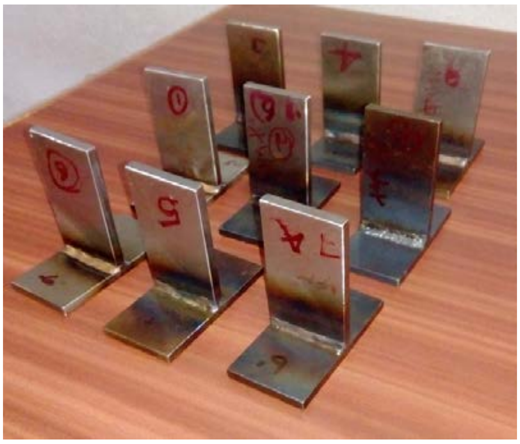

Fig.4.2 Nine types of weld T- joint welds by TIG welding process

4.1 DESIGN OF EXPERIMENT

Taguchi's designs aimed to allow greater understanding of variation than did many of the traditional designs. Optimizing process parameters of MIG welding process and compare the experimental result with FEA for optimizing parameter by using (DOE) technique[13].Taguchi contended that conventional sampling is deficient here as there is no way of obtaining a random sample of future conditions. Taguchi proposed extending each experiment with an orthogonal array should replicate the random environment in which the experiment would function.

Ex. No	Gap (mm)	Arc force (mm/s)	Angle (degree)
1	0.3	5	45
2	0.3	10	53
3	0.3	15	60
4	0.6	5	53
5	0.6	10	60
6	0.6	15	45
7	0.9	5	60
8	0.9	10	45
9	0.9	15	53

Table4.1 Experimental layout using L_9 Orthogonal Array

Welding process parameters

Parameters	Level-1	Level-2	Level-3
Gap (mm)	0.3	0.6	0.9
Arc force (mm/s)	5	10	15
Angle Degree	45	53	60

Table 4.2 Process parameters

ULTIMATE TENSILE TESTING

Fig4.3 Universal testing machine (UTM)

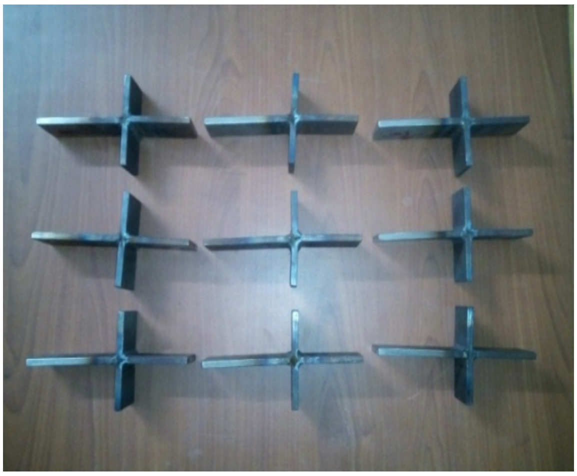

Fig 4.4 Nine types of t-joint weld section for testing purpose

Fig 4.5 Testing before and after breaking

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Universal testing machine used to test the tensile strength and compressive strength of the material. For this process two vertical plates are welded with fillet weld at top and bottom side of base plate having the cross section of 100mm X 50mm X 5 mm and 60mm X 50mm X 5 mm thick. The small cross section of the plate fixed at the top of the testing machine and the bottom cross section move forward due to load applied. Finally the weld has broken to two pieces at a maximum load. From this testing breaking load and breaking stress of the weld material are to be carried out by computerized program.

5.FINITE ELEMENT ANALYSIS

In this project finite element analysis was accomplished using the ANSYS software. The primary unknowns in this structural analysis are displacements and other magnitudes, such as strains, stresses, and reaction forces, are then derived from the nodal displacements.

5.1 STATIC ANALYSIS

Static analysis deals with the conditions of equilibrium of the bodies acted
upon by forces. A static analysis can be either linear or non-linear. In static analysis loading and response conditions are assumed, that is the loads and the structure responses are assumed for varying slowly with respect to time. The kinds of loading that can be applied in static analysis is included,

1. Externally applied forces, moments and pressures
2. Steady state inertial forces such as spinning & gravity
3. Imposed non-zero displacements

If the stress values obtained in this analysis crosses the allowable values it will result in the structure failure in the static condition itself. To avoid such a failure, this analysis is unavoidable.

5.2 EQUIVALENT (VON-MISSES) STRESS

Von misses stress is widely used by designers to check if their design will be withstand a given load condition.

Von misses stress is considered to be a safe haven for design engineers, if the maximum value of von misses stress consumed in the material is more than strength of the material. Its work good for most kinds, specifically when the material is ductile in nature.

1. **For 25KN load, θ = 45º and 0.3 mm gap**

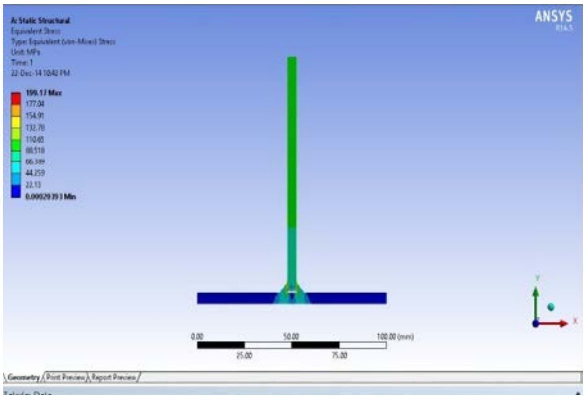

Fig5.1 Equivalent von-misses stress for 45º degree and 0.3mm gap

The above Fig.5.1 represents the equivalent von misses stress value is

199.17 Mpa for 45º and 1mm gap between the parent material.

2. 25KN load, θ = 60º and 0.3mm gap

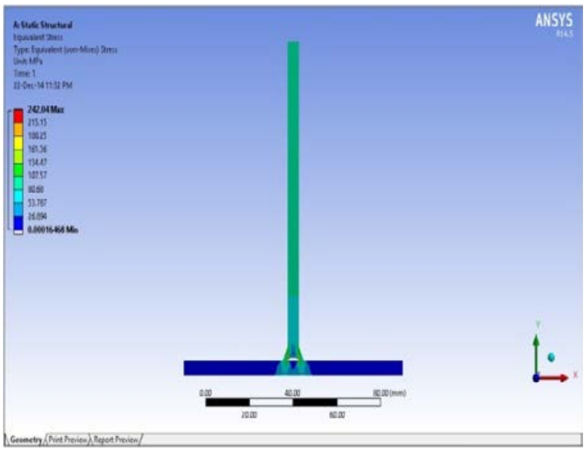

Fig5.2 Equivalent von-misses stress for 60º degree and 0.3mm gap

3. 25KN load, θ = 30º and 0.3mm gap

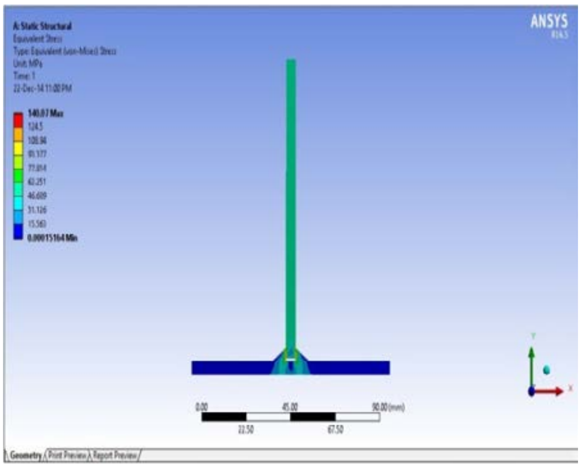

Fig5.3 Equivalent von-misses stress for 30º and 0.3mm gap

5.3 ANALYSIS RESULT

FE analysis is also carried out by considering the chamfer on vertical plate. The Maximum von-misses stresses present in T-joint weldment at the throat thickness with gap variation are carried out and the variation of Maximum breaking stress with respect to gap and angle is also shown in Table.5.1. Where 30º, 45º & 60º chamfer is provided on the vertical plate by varying the gap of 0.3, 0.6 and 0.9mm.

Gap between parent plats(mm)	Breaking stress for 25KN(Mpa)		
	30º	45º	60º
0.3	140.07	197.17	242.04
0.6	142.89	197.91	247.02
0.9	149.12	205.09	252.73

Table.5.1 Analysis results for Von misses stress with different angle and gap

The above table shows the breaking stress for gap between parent plates. The maximum breaking stress 252.73Mpa for 60º angle with 0.9mm gap welded section. From the analytical and numerical results the equivalent von misses stress 80% approximately equal. The FE analysis of T-joint weld for the same geometry revealed the maximum Von-misses stress of 252.73Mpa it's approximately equal to numerical maximum breaking stress of 224.6Mpa.

6. RESULTS AND DISCUSSION

1) The finite element and numerical analysis results of equivalent von misses stress are carried out and it's approximately equal to the numerical breaking stress. The FE analysis of T-welded joint for the same geometry revealed the maximum Von-misses stress of 252.73Mpa it's approximately

equal to numerical maximum breaking strength of 224.6Mpa.

0.9 mm and 60º	NUMERICAL RESULT	FEA RESULT
Breaking stress	224.6Mpa	252.73Mpa

2) From the finite element analysis maximum breaking stress is 252.73Mpa (0.9mm gap and60º) and minimum breaking stress is 140Mpa (0.3mm gap and 30º).

3) The experimental and finite element results of breaking stress are carried out. The maximum breaking stress for experimental result is 236Mpa its approximately equal to the same geometry revealed the maximum Von-misses stress of 242Mpa.

0.3 mm and 60º	EXPERIMENTAL RESULT	FEA RESULT
Breaking stress	236.2Mpa	242.04Mpa

4) From the experimental analysis maximum breaking stress is 232Mpa (0.3mm gap and60º) and minimum breaking stress is 151Mpa (0.3mm gap and 53º).

5) The optimization of T-joint weld is successfully carried out both analytical and experimentally.

6.1 TESTING RESULTS

Ex.No	**Gap (mm)**	**Arc force (mm/s)**	**Angle (degree)**	**Breaking load (KN)**
1	0.3	5	45	22.4
2	0.3	10	53	23.5
3	0.3	15	60	26.5
4	0.6	5	53	21.7
5	0.6	10	60	22.3
6	0.6	15	45	19.2
7	0.9	5	60	20.2
8	0.9	10	45	18.3
9	0.9	15	53	17

Table 6.1 Breaking load for fillet weld materials by UTM

The table 6.1 represents the breaking loads for T-joint welds with varies gap and angle. From this testing result carried out a maximum breaking load 26.5KN for 0.3 mm gap and 60º angle of fillet weld by taguchi method. Using this breaking load maximum breaking stress can be calculated as follows.

Maximum breaking load = 26.5 KN

Maximum breaking stress =236.2 Mpa for 0.3mm and 60º angle.

6.2 SAMPLE REPORT

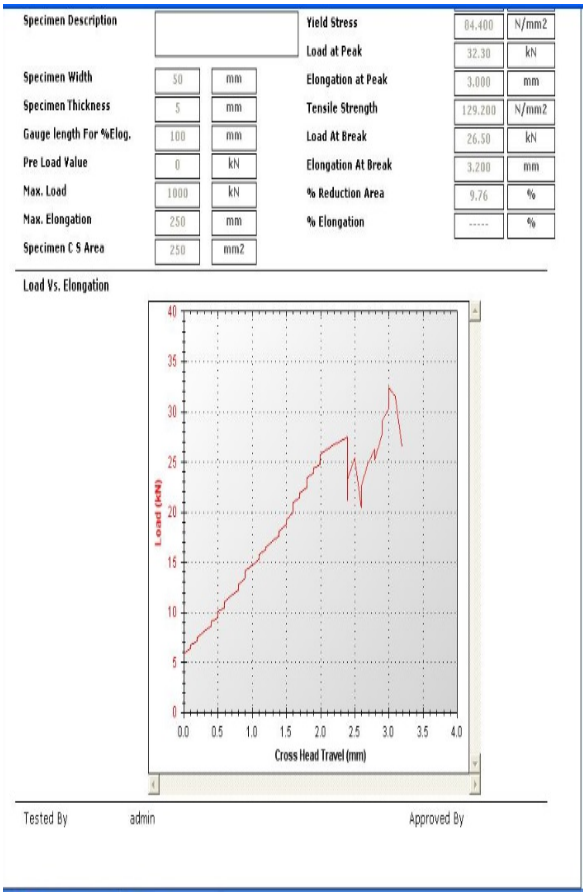

Fig 6.1 Sample report for maximum breaking load

CONCLUSION

The finite element analysis is used in this work to evaluate the deformation breaking stress of weld T-joint to restrict the weldment failure (using low carbon steel as a base metal and copper filler material). Static stress analysis performed on the weldment under tensile load revealed the maximum Von-misses stress with respect to the gap between base plates using ANSYS work bench 14.5.The design and analysis of welded T-joint has been done successfully.

The experimental analysis is carried out by using taguchi technique to evaluate the maximum breaking stress and results are compared with FE analysis and both are approximately acceptable. The conclusion obtained by this project work are summarized below,

- The 60º angle parameter is gives better breaking stress results in experimental &analytical compared then 30º and 45º.
- The experimental investigation shows the 0.3 gap between parent material with 60º angle gives a maximum breaking stress.
- If the gap is increased means breaking stress will gradually decreased by experimental analysis.
- Low carbon steel AISI1020 is gives fine welding with copper and it's did not create any crack or flows during welding process.
- Arc force 15mm/s is giving a fine welding and increase the weldability of the T-joint.
- Using this optimized angle and gap between parent material is restrict the weldment failure.

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