Kumar et al. 2017. *Int. J. Vehicle Structures & Systems*, 9(2), 124-127
ISSN: 0975-3060 (Print), 0975-3540 (Online)
doi: 10.4273/ijvss.9.2.12
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International Journal of Vehicle Structures & Systems
Available online at www.maftree.org/eja

Numerical Analysis and Testing of Tungsten Inert Gas Welded T-Joints

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ABSTRACT:

Presently arc welded structures are extensively used in automobiles, constructions and power plants. As the main cause of weldment failure is design defect and overload, it is necessary to analyze the maximum stresses in the weldment. This work deals with investigation of welded T-joint by Tungsten Inert Gas (TIG) welding process with varying gap and angle between the parent materials to determine the breaking stress under tensile load in the weldment. Finite element analysis is carried out using Ansys software and results are compared with experimental analysis using Taguchi optimization method. Angle, arc force and gap between parent materials are used for the Taguchi optimization technique. The optimized fillet weld section (low carbon steel AISI1020 and copper) is arrived by restricting the weldment failure.

KEYWORDS:

Arc welded structures; Finite element analysis; Welded T-joint; TIG welding; Taguchi optimisation

CITATION:

A.A. Kumar, S. Ravichandran, M. Kumaresan and P. Sathish. 2017. Numerical Analysis and Testing of Tungsten Inert Gas Welded T-Joints, *Int. J. Vehicle Structures & Systems*, 9(2), 124-127. doi:10.4273/ijvss.9.2.12.

1. Introduction

The fillet welded joints commonly suffer from various welding deformation patterns, such as, angular distortion, longitudinal and transverse shrinkage in fabrication of structural members in ship building, automobile and other industries [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. Welding is one of the oldest and reliable methods of joining [5]. The residual stress in a welded T-joint can be computed by 3D and 2D models [6]. A mathematical model can be used for predicting weld penetration as a function of welding process variables. The constrained optimization method is then applied to this model to optimize the process variables for maximizing weld penetration [7-9]. Welded joints are highly prone for cracking under fatigue loading. Optimization is used to reduce the time and 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].

In this work finite element (FE) analysis is used to evaluate the deformation breaking stress of welded T-joint to restrict the weldment failure using low carbon steel as a base metal and copper filler material. Finite element analysis is carried out using Ansys software. The experimental analysis is carried out by using Taguchi technique to evaluate the maximum breaking stress and results are compared with FE analysis. Angle, arc force and gap between parent materials are used for the Taguchi optimization technique.

2. Materials and methods

Fig. 1 represents the welded T-joint fillet weld sections with dimensions (100mm×50mm×5mm) with fillet angle 60º. Tensile load of 25 kN is acting upward on the top of the section. The base weld material is plain carbon steel and filler material is copper. Their material properties are given in Table 1.

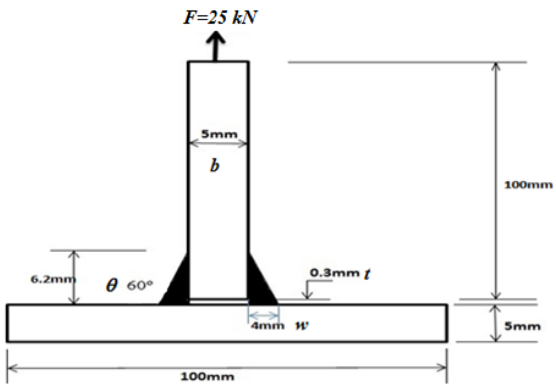

Fig. 1: Arc weld of T-joint with 0.3mm gap and 60º angle

Table 1: Material properties

Material/Property	Elastic modulus	Poisson ratio
Plain Carbon Steel	210 GPa	0.30
Copper	110 GPa	0.37

Breaking stress is the maximum stress that a material is capable of withstanding the tensile loading without rupture. The breaking stress is calculated using,

$$\sigma = k * F / A \quad (1)$$

Where k is the stress concentration factor in parent material which will be in the range of 3.5 to 4 [13]. F is the breaking load. A is the weld area as given by,

$$A = 2 * A_f + A_l - A_t \quad (2)$$

Where A_f, A_l and A_t are the areas of fillet, load section and throat respectively given by,

$$A_f = 2 * w * \cos(\theta) * l \,,\ \ A_l = l * b \ \text{ and } \ A_t = w * t$$

Where b is the thickness of the load plate, w is the leg length of weld, θ is the angle of weld, l is the length of weld and t is the gap between the plates. For a fixed weld leg length of 4mm, parent material plates of size 100mm×50mm×5mm with gaps of 0.3mm, 0.6mm and 0.9mm and 30°, 45° and 60° weld angles, the calculated breaking stresses using Eqn. (1) with k = 4 are presented in Table 2. The maximum breaking stress for an applied 25 kN is for 0.9mm gap and 60° chamfer angle.

Table 2: Numerical results for breaking stress with different angle and gap between parent materials

Gap between parent plates(mm)	Breaking stress for 25 kN (MPa)		
	30°	45°	60°
0.3	130.10	188.04	222.20
0.6	130.34	188.50	223.41
0.9	130.60	189.90	224.60

3. Finite element analysis

Finite element analysis was accomplished using ANSYS software. Static stress analysis of the welded T-joint is performed on the meshed model for an applied force of 25 kN. The base plate is constrained with fixed boundary conditions. The weld chamfer is modelled in details and the mesh is iteratively changed for various chamfer angles (30°, 45° & 60°) and gap between the welded plates (0.3mm, 0.6mm and 0.9mm). Von mises stress plots for chamfer angles of 30°, 45° & 60° for welded T-joint with gap of 0.3mm are shown in Fig. 2, 3 and 4 respectively. The variation of maximum breaking stress with respect to gap and chamfer angle for an applied load of 25 kN from the finite element analysis results is presented in Table 3. The maximum breaking stress is found to be 252.73MPa for 60° angle with 0.9mm gap welded section. For the same weld profile, the equivalent Von mises stress from the numerical results (224.6 MPa) is about 11.2% lesser than the one predicted by the finite element analysis.

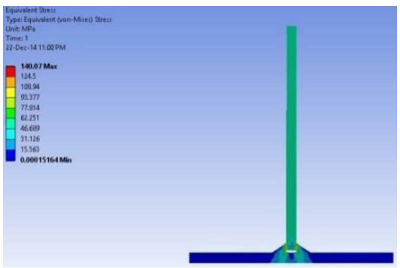

Fig. 2: Von mises stress for 30° and 0.3mm gap welded T-joint

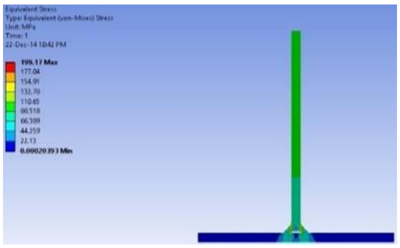

Fig. 3: Von mises stress for 45° and 0.3mm gap welded T-joint

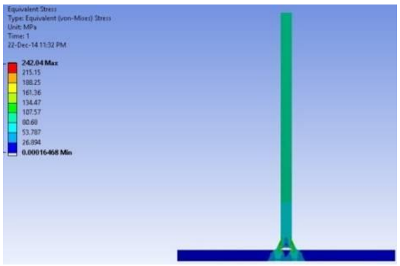

Fig. 4: Von mises stress for 60° and 0.3mm gap welded T-joint

Table 3: Von mises stress from finite element analysis results

Gap between parent plates (mm)	Breaking stress for 25 kN (MPa)		
	30°	45°	60°
0.3	140.07	197.17	242.04
0.6	142.89	197.91	247.02
0.9	149.12	205.09	252.73

4. Design of experiments

Taguchi optimisation is based on orthogonal array experiments which gives much reduced "variance'' for the experiment with optimum settings control variables [12]. Optimisation of MIG welding process parameters and comparison of the experimental results with FEA were reported by Scholar [14]. Table 4 shows the experimental layout of L_9 orthogonal arrays used in the Taguchi optimisation and the outcome of the optimisation are given in Table 5 for the first 3 levels.

Table 4: Experimental layout using L_9 orthogonal array

Exp. No.	Gap(mm)	Arc force (mm/s)	Angle (°)
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

Table 5: 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 (°)	45	53	60

5. Experimental work

In this work, the machining process is undertaken by Geekey Engineering Works, Chinavedampatty, Coimbatore. The welding is undertaken by S.S TIG Welders. TIG welding process is carried out using AISI1020 low carbon steel (parent material) and Cu (filler material) with dimensions 100mm×50mm×5mm. The welded T-joints as per Table 4 are shown in Fig. 5. For experimental testing, additional plate of 60mm× 50mm×5mm is welded with 8mm weld fillet to ensure that the breaking strength of weld at this loading plate is greater than the actual weld at the top plates. Fig. 6 shows the prepared 9 tensile test specimens for breaking stress prediction. The breaking load of the weld is determined by tensile test that is carried out using universal testing machine and with setup as shown in Fig. 7. A sample load vs. deflection report from the UTM is shown in Fig. 8. From this graph, the breaking load at weld is calculated by the computer program and is summarised in Table 6. The maximum breaking load obtained from the tensile test is 26.5 kN for 0.3mm gap and 60º angle of weld fillet. Using this breaking load, the breaking stress of weld is calculated as 236.2 MPa. For the same load level and weld configuration, the factored breaking stress from the finite element analysis is 242.04*26.5/25 = 256.6 MPa. In the same manner, the breaking stress for 0.3mm gap and 60º angle of fillet using numerical analysis is 222.20*26.5/25 = 235.5 MPa. The finite element analysis and numerical results are only about +8.6% and -0.3% of the breaking stress obtained from the experimental test results.

Fig. 5: Nine types of TIG welded T-joints

Fig. 6: Nine types of T-joint welds for testing

Fig. 7: UTM and specimen setup before test

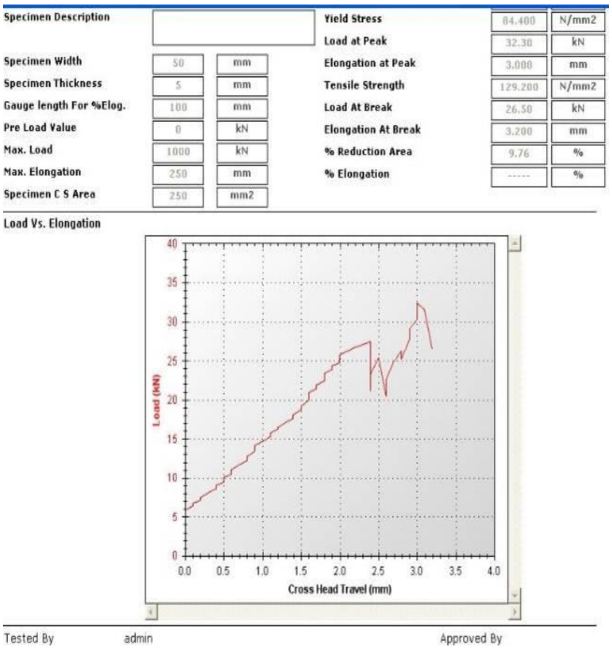

Fig. 8: Sample report for maximum breaking load

Table 6: Breaking load for fillet weld materials by tensile test

Exp. No	Gap (mm)	Arc force (mm/s)	Angle (º)	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	17.0

6. Conclusion

The design and analysis of TIG welded T-joints has been carried out successfully. Static stress analysis performed on the weldment under tensile load revealed the maximum Von mises stress with respect to the gap between base plates using ANSYS. The experimental analysis is carried out by using Taguchi technique to evaluate the maximum breaking stress and tensile test results are compared with finite element analysis and both are approximately acceptable. The 60º chamfer angle of weld gave better breaking stress results in experimental & analytical than 30º and 45º angles. The experimental investigation showed that 0.3 gap between parent materials with 60º angle gave a maximum breaking stress. If the gap was increased, the breaking stress has gradually decreased as observed in the experimental analysis. Hence, Taguchi optimisation with either finite element analysis or numerical analysis can be established to obtain a good weld design. Low carbon steel AISI1020 gave fine welding with copper and it did not create any crack or flaws during welding process. Arc force of 15mm/s gave a fine welding and increased the weldability of the T-joint. Using this optimized chamfer angle and the gap between parent materials the weldment failure was restricted.

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