Stress Analysis and Strength Evaluation of Scarf Adhesive Joints Subjected To Bending Moments

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ABSTRACT

Adhesive joints are used to join two materials by using adhesive. Light weight, uniform stress distribution are the important factors which differentiates adhesive joints from other conventional joints. Scarf adhesive joint is one of them. The strength of scarf adhesive joint depends on the parameters like scarf angle, bond length, surface roughness, adhesive thickness, type of adhesive etc. Effect of these parameters on adhesive joint strength is to be studied. For this purpose samples of scarf adhesive joints with different combinations of affecting parameters will be prepared. By varying the values of affecting parameters in certain levels, strength of joint is found out and variations in the strength to be studied. By applying design of experimentation technique optimum values of these parameters for maximum strength to be found out

In designing scarf adhesive joints, an important issue is how to determine the scarf angle, the adhesive material properties and the adhesive thickness from a mechanical engineering standpoint. Thus, it is necessary to examine the effect of the scarf angle, the adhesive material properties and the adhesive thickness on the interface stress distributions in the joints and the joint strengths.

***Keywords:** Adhesive Joint, ANSYS, Scarf adhesive joint, Surface Roughness.*

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1. INTRODUCTION

In engineering applications material joining is very old but important process. Bolting, riveting, welding, soldering are the some conventional methods of joining the two materials. Adhesive bonding is oneof the materials joining method from that. Joining of two materials by placing adhesive between them and allow it to solidify is nothing but an adhesive bonding or adhesive joints. The conventional methods like bolting, riveting, welding causes stress concentration on a surface of a joining material which results in damage of material parts. While uniform stress distribution which avoids concentration of stresses is the main advantage of adhesive joint method. Hence adhesive joint rises as the alternative method to the conventional joining methods. Low structural weight, ability to join two dissimilar materials is the other advantages of adhesive joints.

Aerospace industries first used the adhesive joints on larger scale due to the fact that they are light in weight. And then many researchers starts working in this field. In order to increase the strength of adhesive joints different types of adhesive joints like single lap adhesive joint, double lap adhesive joint, butt adhesive joint, stepped lap adhesive joint etc. are invented. Scarf adhesive joint is one of them in which scarf angle is a most critical parameter. Surface roughness, bond length, adhesive thickness, surface area (function of scarf angle), properties of adhesive to be used are the other important parameters to be considered which affects the strength of scarf adhesive joint greatly. So the study of these parameters is important to determine the strength of scarf adhesive joint.

2. FEM CALCULATIONS FOR STRESS DISTRIBUTION

Static structural analysis of scarf adhesive joint is carries out to check deformation and stresses in the plates under constant static load. Analysis gives strength of the joint under applied static load. This analysis also helps to validate experimentation results.

Geometry is shown in fig.1 two steel plates are joined with Araldite adhesive. This plate is analyzed in Ansys to tests its structural performance. Material is SS 304. Table 1 shows mechanical properties of the material SS 304 used in the analysis.Figure 2 shows anexample of mesh divisions in 2-D and 3-D FEM calculations. The smallest element size waschosen as 5×5μm in 2-D FEM calculations and as 5×5×5μm in 3-D FEM calculations at theinterfaces between the adhesive and the adherents. SS304 stainless steel chosen as the adhered materials and epoxy (Araldite 420 A/B) as the adhesive. Figure 2 shows the dimensions of the specimens used in the experimentsfor measuring the strains and the joint strengths of scarf joints subjected to static bendingmoments. The adhesive thickness t1 of the specimens was chosen as 0.1 mm, the adhesive lengthl as 30mm and the adhered thickness t2 as 10 mm. The materials of the specimens was the sameas in the FEM calculations. The bending experiments

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were carried out after bonding andsolidifying a pair of specimens with different materials for eight hours with the epoxy bond at60˚C. Figure 3 shows the schematic of the experimental apparatus. The four-point bendingmoments were applied to the test specimen

Fig.1- Finite Element Model of the Scarf Joint

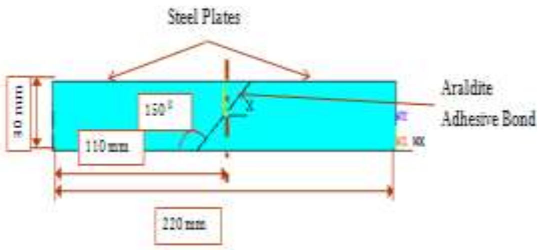

Fig.2 .Dimensions of the specimen for 30°angle

Scarf joint Geometry is mounted on the moving jaw of the UT and then it is slowly inserted in to the fixed jaw.The geometry is mounted on the jaw such a way that the 100 mm length is available for the testing b/w two jaws. Once the job is held firmly inside the both jaws the tension load is applied by moving the movable jaw in the upward direction. The jaw is moved upward at the speed of 10 mm/min.The other test conditions are Temperature = 25 ^{0}cPretension Applied = 0 N

Fig.3 Schematics of the experimental setup for Measuring the strains and the joint strengths

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3. SCARF JOINT ANALYSIS

All the parts in the scarf joint are modeled using the solid volumes in the ANSYS.Solid 45 element type is used for map meshing the volume.Two different material properties are created and applied to the model accordingly. The axial load is applied to the nodes on moving jaw engagement length nodes on the top side. The nodes on the fixed jaw engagement length are fixed in all direction. FEA simulations were conducted on mild steel scarf joints bonded with epoxy adhesives in order to assess the reliability of different failure criteria for predicting joint strength. The FEA results were used to assess the effects of taper angle (i.e. 25°, 45°and 60°) and adhesive layer thickness (i.e. 0.25, 0.5 and 1.0 mm) on thejoint strength. A full factorial analysis has been carried out on the FEA data from simulations carried out on the scarf joints bonded with epoxy to determine empirical relationships between the main factors and joint strength. Predicted strength values are compared with experimental data and analytical predictions

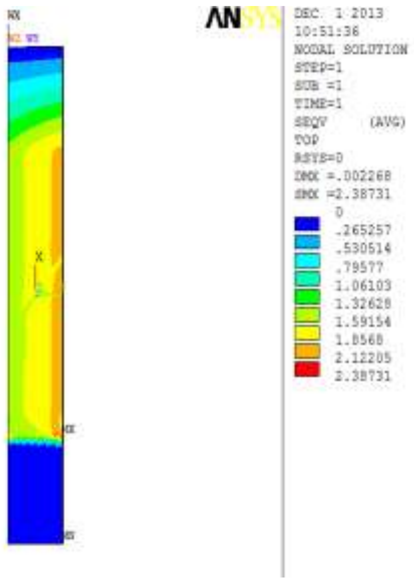

Fig.4. von Mises Stress Plot

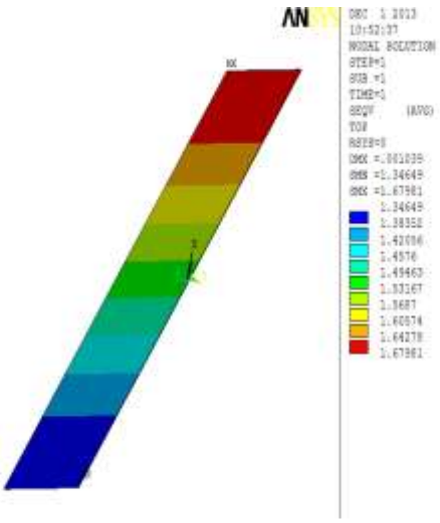

Fig 5. Von Mises Stress distribution Plot

4. RESULTS AND OBSERVATIONS

Fig.6 Tensile test Result

Table 1.Observation Table

Time(sec.)	Disp.(mm.)	Load (N.)	Stress(MPa)	Strain (%)
2.5	0.1	225	0.751	0.1
3.2	0.2	265	0.882	0.2
3.8	0.3	274	0.915	0.3
4.4	0.4	323	1.078	0.4
5.1	0.5	363	1.209	0.5
5.7	0.6	402	1.339	0.6
6.4	0.7	470	1.568	0.7
7	0.8	480	1.601	0.8
7.6	0.9	510	1.699	0.9

Table 2 Results Summary for FEA of the Scarf Joint

Design	Force Applied (N)	Angle for the Scarf Joint	Max von Mises Stress in the joint Adhesive Layer (MPa)
Design 1	509.6	30 Degrees	1.68
Design 2	509.6	45 Degrees	0.82
Design 3	509.6	65 Degrees	0.65

5. CONCLUSION

FEA on the different angles of the scarf joint has shown that for the same axial loading 65 degree scarf joint is showing the minimum von Misesstresses in the Model.The FEA and Actual testing on the model for Design 1 shows close results of the stresses in the joint.The maximum stress in the stress distribution of the adhesive joint is the point where crack initiation started in the testing.

REFERENCES

[1] Aksentyan.O.K., Lushchik.O.N. Soviet Applied Mechanics, vol. 18, No.7,631-636, 1982
[2] E.D.Reedy.JR, T.R.Guess, Int.J. Solids Structures, vol. 30, No. 21, 2929-2936, 1993.
[3] Adams.R.D, Coppendale.J, J.Adhes, vol. 10, No. 1, 49-62, 1979,
[4] Do Won Seo, Jae Kyoo Lim, Composites Science and Technology, vol. 65, 1421-1427, 2005.
[5] E.D.Reedy, JR. Int.J.Solids Structures. 30(6), 767-777, 1993.
[6] A.Ochsner, M.Stasiek, G.Mishuris, J.Gracio, Int. J. Adhesion & Adhesives, vol. 27, 703-711, 2007.
[7]T.Sawa, A.Iwata, H.Ishikawa, Trans. of JSME, vol. 29, No.258, 4037-4042, 1986.
[8] Seo. D.W., Lim. J.K., Composites ScieScience and Technology, vol. 65, 1421-1427, 2005.
[5] E.D.Reedy, JR. Int.J.Solids Structures. 30(6), 767-777, 1993.
[6] A.Ochsner, M.Stasiek, G.Mishuris, J.Gracio, Int. J. Adhesion & Adhesives, vol. 27, 703-711, 2007.
[7]T.Sawa, A.Iwata, H.Ishikawa, Trans. of JSME, vol. 29, No.258, 4037-4042, 1986.
[8] Seo. D.W., Lim. J.K., Composites Science and Technology, vol. 65, 1421-1427, 2005.
[9] Reedy Jr. E.D., Guess.T.R, J. Adhesion Science and Technology, vol.10, No. 1, 33-45, 1996.
[10] T.Sawa, K.Temma, Y.Tsunoda, J. Adhesion and adhesives, vol. 9, No. 3, 161-169, 1989.
[11] Y.Nakano, T.Sawa, F.Nakagawa, JSME International J., vol. 35, No.2, 145-151, 1992.
[12] Lang, T. P., Mallick, P. K., J. Adhesion and Adhesives, vol.18, No. 3, 167-177, 1998.
[13] D.Chen, S. Cheng, Int. J. Solids Structures, vol. 29, No. 7, 845-853, 1992.
[14] Adams.R.D., Harris.J.A. Organic Coating & Applied Polymer Science Proceedings, vol. 47, 243-246, 1982
[15] Narasimhan. S, Pandey, P.C., Defence Science Journal, vol. 53, No.2, 175-188, 2003.
[16] J.M.Liu, T.Sawa. H.Toratani, J.Adhesion Sci. Technol., vol. 12, No. 8, 795-812, 1998.
[17] T.Sawa, J.M.Liu, K.Nakano, J.Tanaka, J.Adhesion Sci. Technol., vol. 14, No. 1, 43-66, 2000.
[18] Tong.L., Sheppard.A. Kelly.D., Int. J. Adhesion and Adhesives, vol. 15, No. 1, 43-48, 1995.
[19] T.Sawa, Suzuki, S.Watanabe, M.Horiuchi, Trans. of JSME (Part A), vol. 59, No.564, 1881-1887, 1993.
[20] J.M.LiuT.Sawa, J.Adhesion Sci. Technol., vol. 15, No.1, 43-61, 2001.
[21] I.Higuchi, T.Sawa, H.Suga. J. Adhesion Sci. Technol., vol.16, No.12, 1585-1601, 2002.