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FINITE ELEMENT ANALYSIS OF SCARFED LAP RIVETED AND WELDED JOINT WITH DIFFERENT LAP ANGLE

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ABSTRACT

Load bearing capacity and fatigue tests will be carried out between Scarf lap riveted joint and Scarf lap welded joint with different lap angle. Both experimental and computational studies are to be done and the results will be validate The fabrication of the Scarf lap riveted joint and scarf lap welded joint will be done and tested on Universal Testing Machine (UTM) after that the Finite Element Analysis with ANSYS will be done. After introducing the lap angle between the faying surfaces the fatigue test and load bearing of joint will be seen. There may be possibility of increasing the fatigue life and the joints may be reliable for the structure designs. The objectives of this project is to compare simple lap riveted and welded joints with scarf lap riveted and welded joints introducing with different lap angles and to find best suitable joint among scarf lap rivet and scarf lap weld on the basis of analysis.

Keywords— ***Scarf lap riveted joint, Scarf lap welded joint, Lap angle, Simple lap riveted joint, simple lap welded joint.***

INTRODUCTION

Many researches focus on regular lap joint those are commonly used in fuselage and airfoil. In this paper we are introducing the scarf lap joint with different lap angle which is introduced into faying surfaces which is rarely have been seen and reported. Various researches have been done on the scarf lap joint with different lap angle on its fatigue performance, for the structures but the design of details and fatigue performance are not readily available in literature. The Scarf lap joint is advantageous over the other lap joints. The important feature of Scarf lap joint is the lap angle, which has the influence on its fatigue performance also it is effective in load transfer. Consequently stress concentration reduced remarkably.

The experiments of joints have been studied by many scholars they proposed the joints with various tests. There they have studied and investigated the fatigue and fracture behaviour for Scarf lap joint with different lap angle. In previous studies it was found that the author has predicted the results with Smith Watson Method (SWT) and Wang Brown Method (WB) have structure reliability in designs. The SWT method was achieving better accuracy.

NECESSITY: Scarf joints have been found to exhibit the highest structural efficiency because joint eccentricities (which act as stress raisers) are minimized in the loading path and a more uniform stress distribution is obtained across the joint. This however, comes at a cost due to the fact that current scarf repair technology utilizes angles of 1 and 3 degrees, which over a thick section can cause a large waste due to removal of large amounts of undamaged parent material. As the thickness of the composite structure increases the repair size becomes much larger and the amount of undamaged material required to be removed also increases greatly. With this in mind research is being undertaken to better understand changes in scarf angle and how to optimize their size and load transfer efficiency. To achieve this, basics of load transfer in a scarf joint must be understood and once these basics are covered, computer FEA and physical testing can be used to study different joining techniques. The traditional scarf jointing techniques cannot match the strength and stiffness of a single member of the same dimensions. Due to their low bending capacity it has been historically understood that a scarf joint within a frame should be located where the bending moments are low in order to minimize the deflection. This initiative has carried through to modern design of traditional frames where the joint can be found either over a post or a brace. The amount of taper with a scarf joint is usually stated as the ratio of the thickness of the joining members to taper. Scarf joint widely used as high performance structural joint for various applications because of its high specific strength and stiffness.

OBJECTIVE: Structural Joint phenomena of Scarf joint are very important aspect in industrial sector, social sector and in every surroundings. So, it is very essential to find out in which case the joint strength is more. Scarf Joint analysis depends upon the lap angle of the joint. In this project there are two types of analysis 1) Experimental analysis 2) Computational Analysis is done on scarf lap and simple lap joint. The aim of this project is to find out the best suitable joint between scarf lap riveted joint and scarf lap welded joint.

THEME: The scarf Joints are used for effective analysis in all engineering structures, were strength is a prime concern. The project work has to be done to find out suitable scarf joint under tension and compression test. Experimental analysis is to be done for finding out optimum values of joint and stresses induced to calculate its strength and the result obtained has to be validated by computational analysis. (ANSYS 14.5)

SYSTEM DEVELOPMENT

Design Theory

The Stresses in the Structure Joints are complex. Differences in mechanical properties of the adherends induce complex stresses states in the joints even where the loading superficially looks relatively simple. It has been common to use stress criteria based on the measured strength of joints to the required area of joints. Generally the maintenance and repairs of structures joints is more complex than the case of conservative structures and advanced techniques are demanded for the damage and repairs of joints.

Scarf Joint

Determination of the maximum axial force for two pieces joined by adhesive can easily be determined using two equations that can be derived from the geometry of the problem by breaking the axial force component into a tensile force and shear force normal and parallel to the scarf joint. To specify the orientation of the inclined section **pq** by the angle α between the X-axis and the normal to the plane.

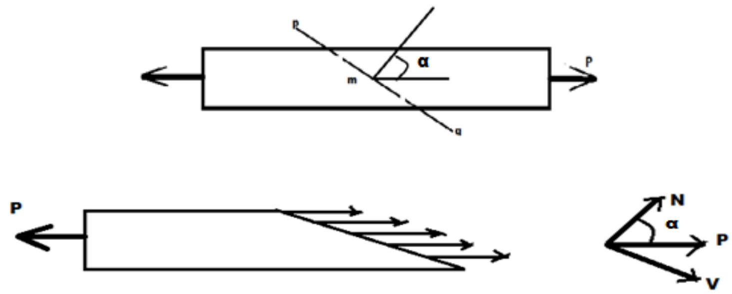


Fig 3.1: Stress acting on Scarf Joint

The force **P** can be resolve in two components.

Normal force **N** perpendicular to the inclined plane, N = P cos α

Shear force **V** tangential force to the inclined plane, V = P sin α

If we know the area on which the forces act, we can calculate the associated stresses

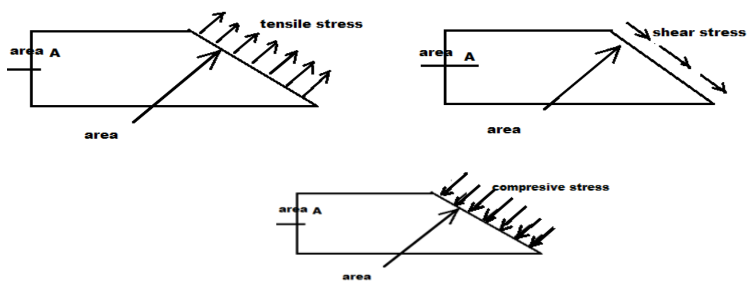


Fig 3.2: Associated Stresses on Scarf Joint

Rivet Joint:

A connection between two members which are riveted together by means of rivets. The rivets are use to make permanent fastening between the plates such as in structural work, ship building, bridges, tanks and boiler shells. The rivet joints are widely used for joining light metals.

Design Specification:

While designing the rivet joint following considerations has been taken as per design data book. The material used for flat plate and rivet is Mild Steel.

Thickness of plate t = 6 mm

Diameter of rivet hole	d = 2*t	= 2*6	= 12 mm
Pitch length	p =2.25*d	= 2.25*12	= 27 mm
Marginal pitch	m =1.5*d	= 1.5*12	= 18 mm

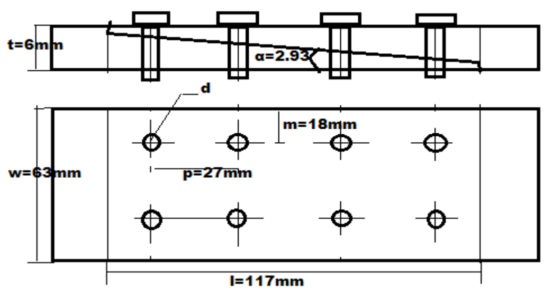
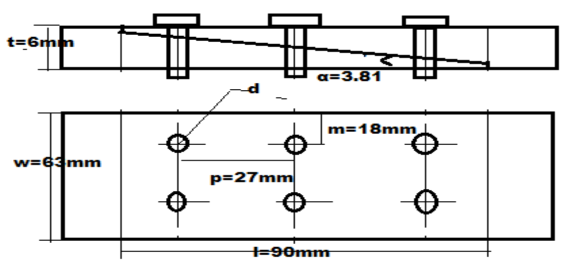
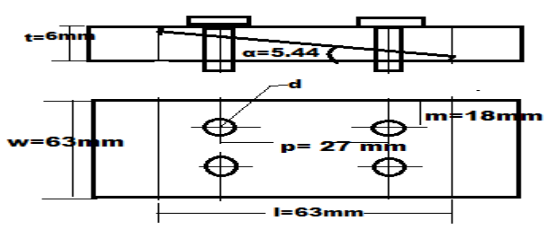
	**L = 117mm** $\alpha = \tan^{-1}\left[\frac{6}{117}\right]$ **t = 6mm** $\alpha = 2.93°$ **p = 27mm** **m = 18 mm** **d =12m**
	**L=90mm** $\alpha = \tan^{-1}\left[\frac{6}{90}\right]$ **t = 6mm** $\alpha = 3.81°$ **p = 27mm** **m = 18 mm** **d =12m**
	**L=63mm** $\alpha = \tan^{-1}\left[\frac{6}{63}\right]$ **t = 6mm** $\alpha = 5.44°$ **p = 27mm** **m = 18 mm** **d =12m**

Fig: Design Specification for rivet joint.

Welded Joint

A welded joint is a permanent joint which is obtained by the fusion of the edges of the two parts to be joined together with or without the application of pressure and filler material. Welding is extensively used in fabrication as an alternative method for casting or forging and as a replacement for the bolted and riveted joints. The Stresses in the welded joints are difficult to determine because of the variable and unpredictable parameters like homogeneity of the weld metal, thermal stresses in the welds, changes of physical properties due t high rate of cooling and overheating. As the weld is weaker than the plate due to slag and blow holes, therefore the weld is given a reinforcement which may be taken as 10% of the plate.

The main considerations involved in the selection of weld type are

-The shape of the welded component required.

-The thickness of the plates to be welded.

- The direction of the forces applied.

Design Specification:

While designing the rivet joint following considerations has been taken as per design databook. The material used for flat plate and rivet is Mild Steel.

Thickness of plate t = 6 mm

Size of weld, s = 5mm

Lapping Length L= 117 mm for $\alpha = 2.93\,°$

L= 90 mm for $\alpha = 3.81\,°$

L= 63 mm for $\alpha = 5.44\,°$

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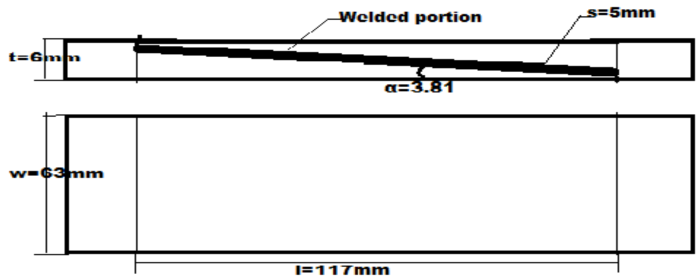
<td></td>
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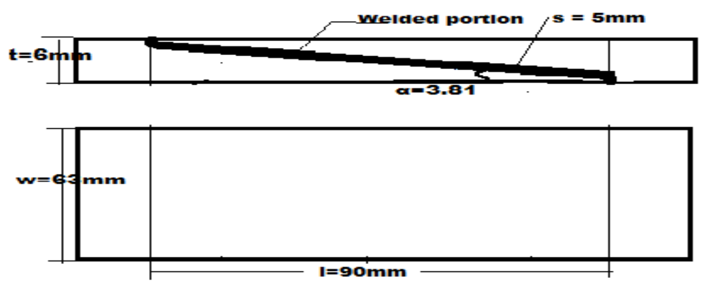
<td></td>
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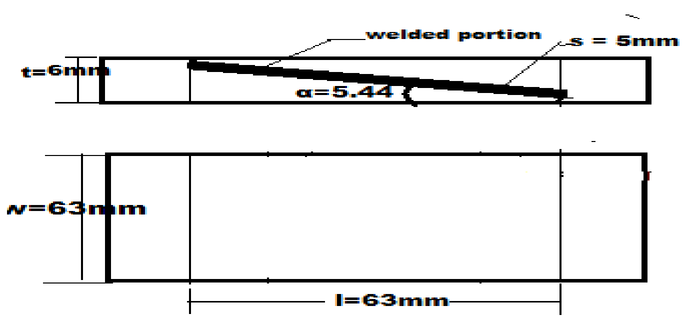
<td></td>
<td>w=63mm $\alpha = \tan^{-1}\left[\frac{6}{63}\right]$
L = 63mm $\alpha = 5.44\,^{\circ}$
t = 6mm s = 5mm</td>
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Fig: Design Specification for weld joint.

COMPUTATIONAL ANALYSIS

Table A.1 Scarf Lap Riveted Joint & Simple Lap Riveted Joint

		Scarf Lap Riveted Joint				Simple Lap Riveted Joint			
Lap Angle (α)	**Lapping Length (l)**	**Load (P)**	**Deformation (δl)**	**Shear Stress (τ)**	**Shear Strain (ε)**	**Load (P)**	**Deformation (δl)**	**Shear Stress (τ)**	**Shear Strain (ε)**
α =2.93°	117 mm	90 KN	0.0328mm	95.70 N/mm^2	0.001244	110 KN	0.1234mm	103.93 N/mm^2	0.001351
α =3.81°	90 mm	70 KN	0.0254mm	68.39 N/mm^2	0.000889	80 KN	0.08961mm	65.28 N/mm^2	0.000848
α =5.44°	63 mm	40 KN	0.0143mm	35.08 N/mm^2	0.000456	46 KN	0.05033mm	38.139 N/mm^2	0.000495

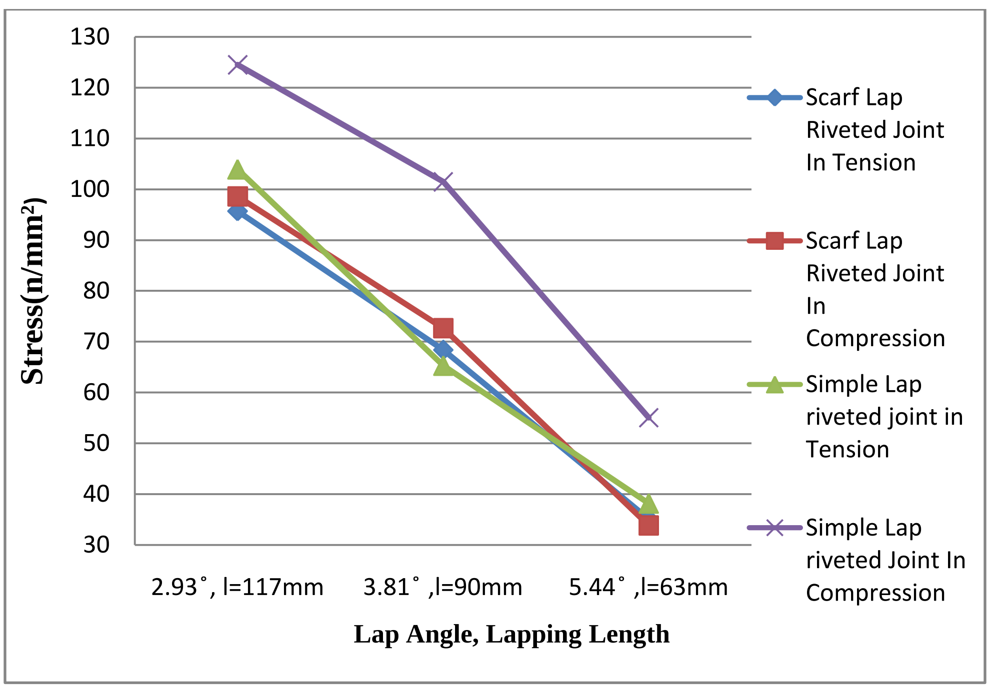


Table A.2 Scarf Lap Welded Joint & Simple Lap Welded Joint

		Scarf Lap Welded Joint				Simple Lap Welded Joint			
Lap Angle (α)	Lapping Length (*l*)	Load (P)	Deformation (δl)	Shear Stress (τ)	Shear Strain (ε)	Load (P)	Deformation (δl)	Shear Stress (τ)	Shear Strain (ε)
α =2.93	117 *mm*	118 KN	0.3143*mm*	199.04 N/mm^2	0.00258	120 KN	0.18044 *mm*	362.7 N/mm^2	0.00471
α =3.81	90 *mm*	96 KN	0.2103*mm*	104.98 N/mm^2	0.00136	110 KN	0.14335 *mm*	292.5 N/mm^2	0.00380
α =5.44	63 *mm*	76 KN	0.1260*mm*	72.298 N/mm^2	0.000939	80 KN	0.08231 *mm*	250.6 N/mm^2	0.00325

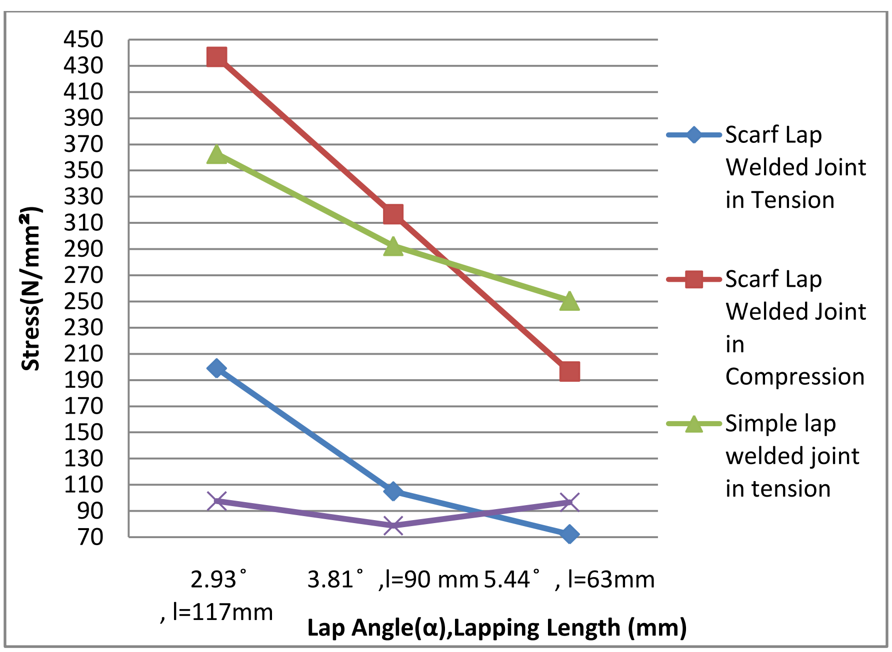
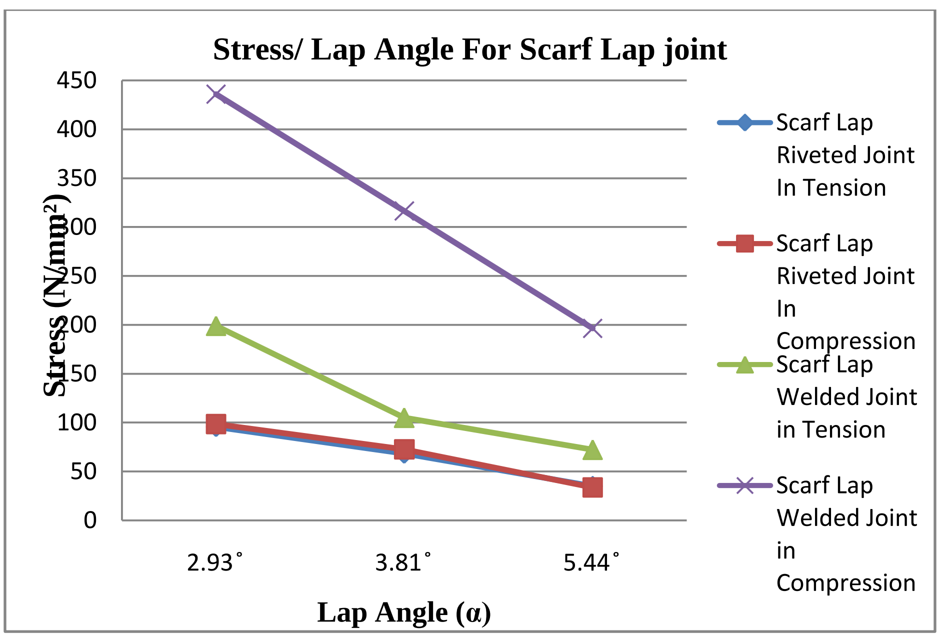


Table A.3 Scarf Lap Riveted Joint & Scarf Lap Welded Joint

		Scarf Lap Riveted Joint				Scarf Lap Welded Joint			
Lap Angle (α)	**Lapping Length** (*l*)	**Load** (P)	**Deformation** (δl)	**Shear Stress** (τ)	**Shear Strain** (ε)	**Load** (P)	**Deformation** (δl)	**Shear Stress** (τ)	**Shear Strain** (ε)
α =2.93°	117 *mm*	84 KN	0.03589 *mm*	61.35N/ mm^2	0.000239	118 KN	0.3143*mm*	199.04 N/mm^2	0.00258
α =3.81°	90 *mm*	46 KN	0.02555 *mm*	56.79 N/mm^2	0.000283	96 KN	0.2103*mm*	104.98 N/mm^2	0.00136
α =5.44°	63 *mm*	19 KN	0.01507 *mm*	47.84 N/mm^2	0.000306	76 KN	0.1260*mm*	72.298 N/mm^2	0.000939



INDENTATIONS AND EQUATIONS

The cross sectional area, Area = thickness of plate × Over lapping Length
Material Properties of Mild Steel
Young's Modulus: 200 GPa
Poisson's Ratio: 0.3
Ultimate Strength: 360 MPa
According to Finite element method we can discretise the Sample into elements.
Considering in one dimensional element then
For Element

Stiffness Matrix { K } $= \frac{\text{Area} * \text{Youn g's Modulus}}{\text{Length}} \begin{bmatrix} 1 & -1 \\ -1 & 1 \end{bmatrix}$

To find deformation (q)

{ K}×{ q } = { F }

Where ,

{K}= Global Stiffness matrix
{q} = displacement vector
{F} = load vector

To find Stress (τ)

$\tau =$ EBq
E = Young's Modulus =200 GPa
B = $\frac{1}{L} * [-1 \quad 1]$
q = Deformation

EXPERIMENTAL ANALYSIS

Table B.1 Scarf Lap Riveted Joint & Simple Lap Riveted Joint

		Scarf Lap Riveted Joint				**Simple Lap Riveted Joint**			
Lap Angle (α)	**Lapping Length (l)**	**Load (P)**	**Deformation (δl)**	**Shear Stress (τ)**	**Shear Strain (ε)**	**Load (P)**	**Deformation (δl)**	**Shear Stress (τ)**	**Shear Strain (ε)**
α =2.93°	117 mm	84 KN	0.03589 mm	61.35 N/mm^2	84 KN	102 KN	0.04353 mm	74.51 N/mm^2	0.000372
α =3.81°	90 mm	46 KN	0.02555 mm	56.79 N/mm^2	46 KN	50 KN	0.02777 mm	61.72 N/mm^2	0.000308
α =5.44°	63 mm	19 KN	0.01507 mm	47.84 N/mm^2	19 KN	21.3 KN	0.01690mm	53.66 N/mm^2	0.000268

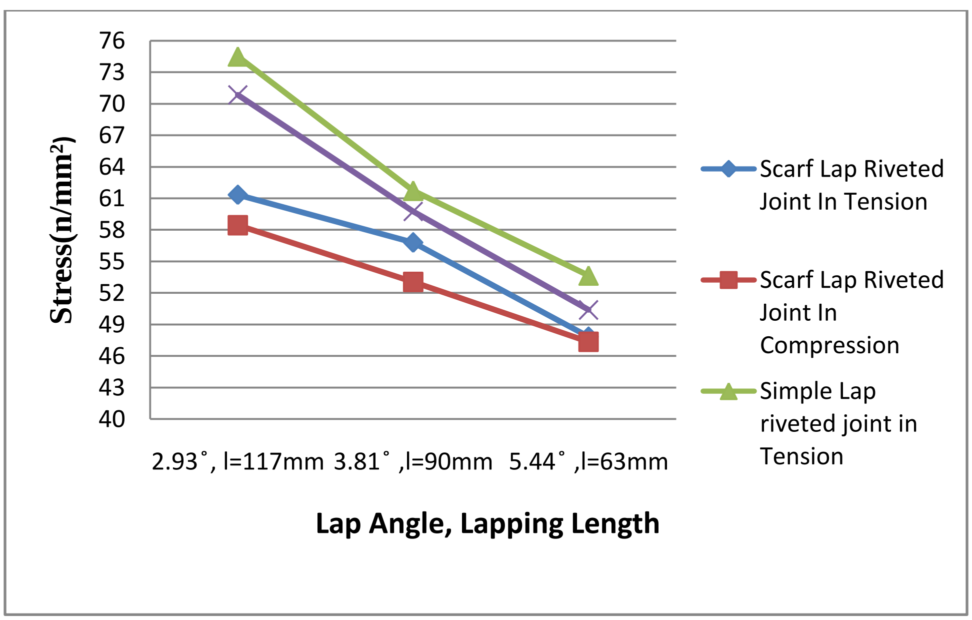


Table B.2 Scarf Lap Welded Joint & Simple Lap Welded Joint

		Scarf Lap Welded Joint				Simple Lap Welded Joint			
Lap Angle (α)	**Lapping Length (*l*)**	**Load (P)**	**Deformation (δl)**	**Shear Stress (τ)**	**Shear Strain (ε)**	**Load (P)**	**Deformation (δl)**	**Shear Stress (τ)**	**Shear Strain (ε)**
α =2.93	117 *mm*	115 KN	0.04914 *mm*	84.009 N/mm^2	0.000239	118 KN	0.05714 *mm*	86.35 N/mm^2	0.000430
α =3.81	90 *mm*	64 KN	0.03555 *mm*	79.01 N/mm^2	0.000283	66.7 KN	0.03755 *mm*	83.45 N/mm^2	0.000417
α =5.44	63 *mm*	28 KN	0.02222 *mm*	70.546 N/mm^2	0.000306	31.4 KN	0.02492 *mm*	79.11 N/mm^2	0.000395

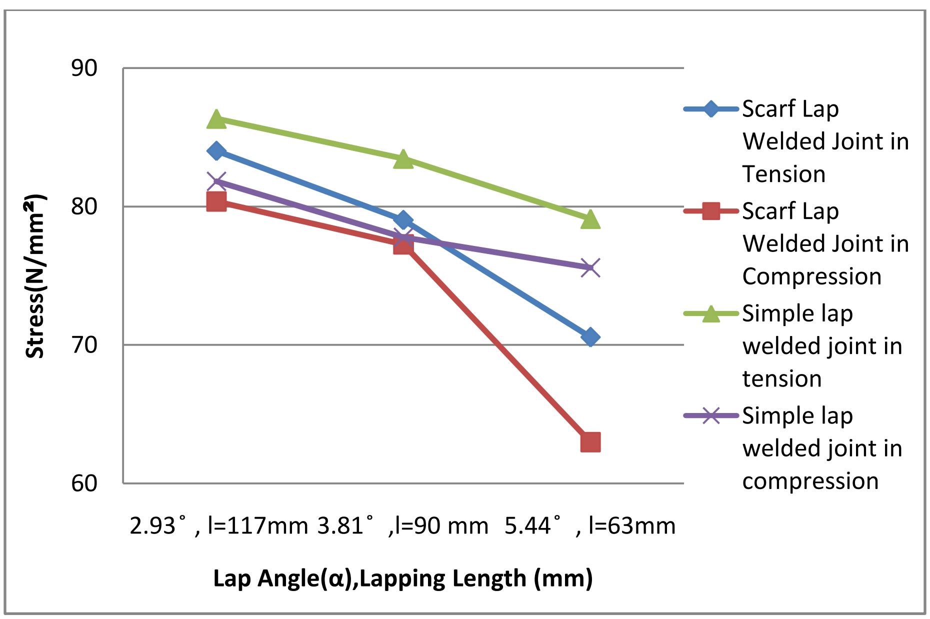
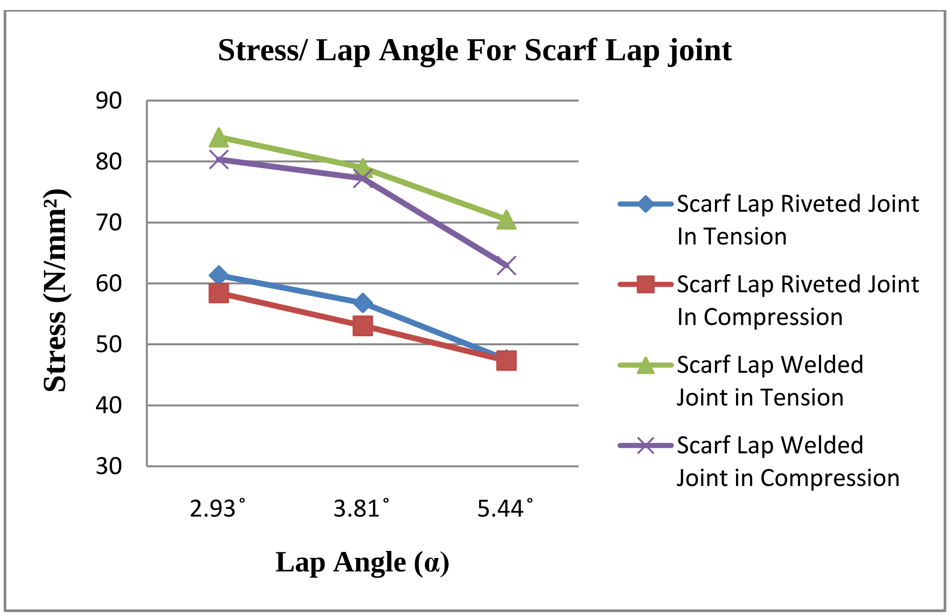


Table B.3 Scarf Lap Riveted Joint & Scarf Lap Welded Joint

		Scarf Lap Riveted Joint				Scarf Lap Welded Joint			
Lap Angle (α)	**Lapping Length (l)**	**Load (P)**	**Deformation (δl)**	**Shear Stress (τ)**	**Shear Strain (ε)**	**Load (P)**	**Deformation (δl)**	**Shear Stress (τ)**	**Shear Strain (ε)**
α =2.93	117 mm	84 KN	0.03589 mm	61.35N/ mm^2	0.000239	115 KN	0.04914 mm	84.009 N/mm^2	0.000239
α =3.81	90 mm	46 KN	0.02555 mm	56.79 N/mm^2	0.000283	64 KN	0.03555 mm	79.01 N/mm^2	0.000283
α =5.44	63 mm	19 KN	0.01507 mm	47.84 N/mm^2	0.000306	28 KN	0.02222 mm	70.546 N/mm^2	0.000306



CONCLUSION

This study investigated Experimental analysis and Computational Analysis of the elements that contribute to design and analysis of Scarf Lap Riveted And Welded Joint with Different Lap Angle i.e. (2.93°, 3.81°, 5.44°) and Simple Lap Riveted And Welded joint of lapping length i.e. (117mm, 90mm ,63mm). The joints is designed by using Pro-E software. The structural feasibility is analyzed by Finite Element Analysis method. The structure of the Scarf Joint is analyzed using ANSYS (14.5) software. and Pro-E Software is used to generate three dimensional model of Joint.

5.1 Scarf Lap Joint And Simple Lap Joint.

1. As the Lapping length is increasing from 63mm to 117mm and Scarf Lap Angle is decreasing from 5.44 ° to 2.93° the shear stress develop in both in Simple lap joint And Scarf lap joint gradually increase but more amount of shear stresses develop in Simple Lap joint as compare to Scarf lap joint.
2. As the magnitude of force increases, the shear stress develop in Simple lap joint also increases, but the shear stresses developed Simple lap joint is 15.93 % more than Scarf lap joint.
3. As the Scarf Lap angle decreases from 5.44 ° to 2.93° failure load increases in Scarf lap joint, same when Lapping length increases from 63mm to 117mm failure load increases.
4. The failure load in Simple Lap Joint is 21.54 % more than Scarf lap joint.
5. The deformation simultaneously strain of object from its original size is decrease.
6. The deformation in Simple Lap joint is more as compare to Scarf Lap joint, Scarf lap joint is more strong and rigid.

5.2 Scarf Lap Riveted Joint & Scarf Lap Welded Joint

1. Scarf Lap Angle is decreasing from 5.44 ° to 2.93° the shear stress develop in both in gradually increase but more amount of shear stresses develop in Scarf Lap Welded joint as compare to Scarf lap Riveted joint.
2. As the magnitude of force increases, the shear stress develop in Scarf lap welded joint also increases, but the shear stresses developed Scarf lap Riveted joint is 28.92 % less than in Scarf lap welded joint.
3. The failure load in Scarf Lap Riveted Joint is 28.03 % less than in Scarf lap welded joint.
4. The deformation simultaneously strain of object from its original size is decrease for both Scarf lap riveted and welded joint as the lap angle increases from 2.93 ° to 5.44°
5. The deformation in the Scarf lap welded joint is less, the Scarf lap riveted joint is more rigid and strong.

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[6] Young w. Kwon Douglas Loup have the thesis on scarf joint modeling and analysis of composite materials the objective of this study is to investigate joint strength of the scarf joint configuration with different material combinations tested under various loading conditions like tension, compression, bending and shear loading.

[7] Young W. Kwon Naval Postgraduate School USA has studied about Strength of Composite Scarf Joints.

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