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SHEAR STRENGTH PERFORMANCE ANALYSIS OF HYBRID JOINTS (ADHESIVE AND RIVET) – SINGLE LAP JOINTS

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ABSTRACT

Adhesive bonded are already playing a significant role in the development and production of metal aircraft structures and indication are strong that such joints will be even greater importance in filamentary composite structures. The performance of a hybrid joint (adhesive and rivet) depends on many parameters and its design becomes complex when the design aims to create a synergy between these two joining methods which are commonly used to composite or different (various) metal plates. The design is applied to analyze the parameters that influence the load transfer between the different components of the joints as well as the maximum stress in adhesive. A first decomposition of the joint into functional requirements and design parameters leads to a coupled design. A decoupled design is obtained through the recording and reformation of both functional requirements and design parameters. The design matrix is then used to propose a new design through physical integration of the design parameters. Comparison between the new design and baseline geometry shows a reduction in the maximal stress concentration inside the joint. This improvement should result in higher load transfer capability while maintain similar dimensions. In various applications and also for joining various composite parts together, they are fastened together using adhesives or Mechanical fasteners or rivets.

KEYWORDS: Adhesive and Rivet, Hybrid Joints, Shear Strength, Single Lap Join.

INTRODUCTION

A joint is a structural connection of two or more members for the purpose of load transfer. A joint members is typically referred to an adherent. In this study the main focus is placed on joints of two parts by adhesive and rivet Parts/components need to satisfy manufacturing, handling and transport size limitations, and therefore a large structure can in general only be obtained by the assembly of smaller components. Failure modes depend on joint type, joint geometry and laminate lay up for a given material system. In case of an adhesively bonded joint, the adherends are joined by a suitable adhesive. Adhesively bonded joint distribute load over a large area.

1.1 HYBRID JOINTS:

Strength Of Load Transfer In Hybrid Joints :

When designing a mixed technology of joining, one of the goals is to benefit from the strengths of each joining method or simply to improve the performance of the first one by adding additional joining methods. The distribution of the loading within the joint is one of the main issues the research emphasises. Thus, one of the most important studies was performed by Hart-Smith

1.2 PROBLEM STATEMENT:

The performance of a hybrid joint (adhesive and rivet) depends on many parameters and its design becomes complex when the design aims to create a synergy between these two joining methods which are commonly used to composite or different (various) metal plates. The design is applied to analyze the parameters that influence the load transfer between the different components of the joints as well as the maximum stress in adhesive. A first decomposition of the joint into functional requirements and design parameters leads to a coupled design. A decoupled design is obtained through the recording and reformation of both functional requirements and design parameters. The design matrix is then used to propose a new design through physical integration of the design parameters.

LITERATURE REVIEW

Marc Ouellet and Aurclian Vadean[1] (2013) Work proposed a new geometry for single lap hybrid joints. With functional requirements and design parameters defined,. Xiacong He, Fengshou Gu and Andrew Ball [2](2013) observed some fastening techniques such as self piercing riveting, mechanical clinching, and structural adhesive bonding are efficient joining methods which are suitable for joining advanced lightweight sheet materials that are hard to weld. V. Flore, F. Alagna, G. Galtieri, C. Borselline, G. Di Bella, A Valenza[3] (2012)has studied the mixed method used for the joining of aluminium alloys with glass reinforced polymers substrates.S. Venkateswarlu and K. Rajasekhar[4](2013) has studied composite material are widely used in the various fields. Caihua Cao[6](2003) joints represents a design challenges, especially for composite structures. Vlastimil Kune and Donald Erdman, Lynn Klett studied that material program, is to develop new experimental methods and analysis techniques to enable hybrid joining to become a viable attachment technology in automotive structures. Kemal Aidas and Faruk Sen (2013) studied that three dimensional finite element models are developed to investigate the effects of both tensile load and uniform temperature load on the stresses in hybrid joints.

DESIGN OF EXPERIMENTS:

3.1 OUTLINE EXPERIMENTAL DESIGN PROCEDURE:

Experiments are carried out by researchers or engineers in all fields of study to compare the effects of several conditions or to discover something new. If an experiment is to be performed most efficiently, then a scientific approach to planning it must be considered.

1. ***Statement of the experimental problem***.
2. ***Understanding of present situation***..
3. ***Choice of response variables.***
4. ***Selection of experimental design.***
5. ***Performing the experiment.***
6. ***Data Analysis.***
7. ***Analysis of results and conclusions.***
8. ***Confirmation test.***
9. ***Recommendation and follow up management.***
10. ***Planning of subsequent experiments.***

EXPERIMENTAL SETUP AND TEST DATA REPORT

The major steps of implementing the Taguchi methods are 1) To identify the factors / interactions 2) To identify the levels of each factor 3) To select an appropriate orthogonal array (OA) 4) To assign the factors / interactions to column of the OA 5) To conduct the experiment 6) To analyze the data and determine the oprimal levels and 7) To conduct the confirmation experiments. In this project we are considering 3 levels and 3 parameters. So their will be 3^3 experiments samples. So there will be 27 number of cases.. There are following combination of samples.

Table No. 1 Specimen of Hybrid Joints (Adhesive and Rivet Joints) Single Lap Joint

Sr. No.	Type Of Joints (A)	Material Of Plates (B)	Lap Length (C)
1	Adhesive	MS + MS	12.5mm
2	Adhesive	MS + MS	18mm
3	Adhesive	MS + MS	25mm
4	Adhesive	Al + Al	12.5mm
5	Adhesive	Al + Al	18mm
6	Adhesive	Al + Al	25mm
7	Adhesive	MS + Al	12.5mm
8	Adhesive	MS + Al	18mm
9	Adhesive	MS + Al	25mm

10	Rivet	MS + MS	12.5mm
11	Rivet	MS + MS	18mm
12	Rivet	MS + MS	25mm
13	Rivet	Al + Al	12.5mm
14	Rivet	Al + Al	18mm
15	Rivet	Al + Al	25mm
16	Rivet	MS + Al	12.5mm
17	Rivet	MS + Al	18mm
18	Rivet	MS + Al	25mm
19	Adhesive + Rivet	MS + MS	12.5mm
20	Adhesive + Rivet	MS + MS	18mm
21	Adhesive + Rivet	MS + MS	25mm
22	Adhesive + Rivet	Al + Al	12.5mm
23	Adhesive + Rivet	Al + Al	18mm
24	Adhesive + Rivet	Al + Al	25mm
25	Adhesive + Rivet	MS + Al	12.5mm
26	Adhesive + Rivet	MS + Al	18mm
27	Adhesive + Rivet	MS + Al	25mm

Dimensions Of Plate -Plate Length – 100mm , Width – 25mm Thickness – 2mm , Material – Mild Steel & Aluminium
Total Material – MS = Length = 2700mm,, Width = 25mm, Thickness = 2mm,, Total Material – Al = Length = 2700mm,
Width = 25mm, Thickness = 2mm,.Total Material = MS = 2 X 2700mm = 5400mm
Al = 2 X 2700mm = 5400mm, Total No. Of Plates = 54 MS Plates + 54 Al Plates

Experimental Setup: For performing shear strength analysis we have used Universal Testing Machine. In which one jaw is fixed and other jaw is used for the applying shear load. The computerized graph Load Vs Displacement is plotted..

ANALYSIS OF VARIANCE (ANOVA) MODELS:

ANOVA:

Multilevel Factorial Design

Factors	3	Replicates	1
Base Runs	27	Total Runs	27
Base Blocks	1	Total Blocks	1

Number of levels: 3, 3, 3
Regression Analysis: C8 versus A, B, C
Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Regression	3	2566971	855657	0.77	0.520

A	1	131014	131014	0.12	0.734
B	1	2395846	2395846	2.17	0.154
C	1	40111	40111	0.04	0.851
Error	23	25413246	1104924		
Total	26	27980216			

Model Summary			
S	**R sq**	**R – sq (adj)**	**R – sq(pred)**
1051.15	9.17%	0.00%	0.00%

Coefficients					
Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	2274	1033	2.20	0.038	
A	85	248	0.34	0.734	1.00
B	-365 -	248	1.47	0.154	1.00
C	7.5	39.5	0.19	0.851	1.00

Regression Equation
C8 = 2274 + 85 A - 365 B + 7.5 C
Fits and Diagnostics for Unusual Observations:
Std

Obs	C8	Fit	Resid	Resid
10	4415	2174	2241	2.30 R
12	5363	2268	3095	3.20 R

R Large residual

General Factorial Regression: C8 versus A, B, C
Factor Information:

Factor	Levels	Values
A	3	1, 2, 3
B	3	1, 2, 3

Stepwise Selection of Terms
α to enter = 0.15, α to remove = 0.15
The stepwise procedure added terms during the procedure in order to maintain a hierarchical model at each step.

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Model	8	24413422	3051678	15.40	0.000
A	4	14885222	3721305	18.78	0.000
B	2	10931556	5465778	27.58	0.000
2	4	3953666	1976833	9.98	0.001
A*B	2	9528201	2382050	12.02	0.000
Error	18	9528201	2382050	12.02	0.000
Total	26	3566794			

S	R-sq	sq(adj)	sq(pred)
445.146	87.25%	81.59%	71.32%

Multilevel Factorial Design

Factors:	3	Replicates:	1
Base runs	27	Total runs:	27
Base blocks	1	Total blocks	1

Number of levels: 3, 3, 3

Regression Analysis: C8 versus A, B, C

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Regression	3	2566971	855657	0.77	0.520
A	1	131014	131014	0.12	0.734
B	1	2395846	2395846	2.17	0.154
C	1	40111	40111	0.04	0.851
Error 23 25413246 1104924	23	25413246	1104924		
Total	26	27980219			

Model Summary:

S	R-sq	R-sq(adj)	R-sq(pred)

1051.15	9.17%	0.00%	0.00%

Coefficients:

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	2274	1033	2.20	0.038	
A	85	248	0.34	0.734	1.00
B	-365	248	1.47	0.154	1.00
C	7.5	39.5	0.19	0.851	1.00

Regression Equation

C8 = 2274 + 85 A - 365 B + 7.5 C

Fits and Diagnostics for Unusual Observations

Std Obs	C8	Fit	Resid	Resid
10	4415	2174	2241	2.30 R
12	363	2268	3 095	3.20 R

R Large residual

General Factorial Regression: C8 versus A, B, C

Factor Information

Factor	Levels	Values
A	3	1,2,3
B	3	1,2,3

Stepwise Selection of Terms

α to enter = 0.15, α to remove = 0.15

The stepwise procedure added terms during the procedure in order to maintain a hierarchical model at each step.

Analysis of Variance

Source	DF	Adj SS	Adj MS	F – Value	P – Value
Model	8	24413422	3051678	15.40	0.000
Linear	4	14885222	3721305	18.78	0.000
A	2	10931556	5465778	27.58	0.000
B	2	3953666	9528201	9.98	0.001
2-Way Interacion	4	2382050	2382050	12.02	0.000
A*B	4	9528201	2382050	12.02	0.000
Error	18	3566794	198155		
Total	26	27980216			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred
445.146	87.25%	81.59%	71.32%

Coefficients

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	1854.0	85.7	21.64	0.000	

A					
1	-533	121	-4.40	1.33	
2	0.000	121	894	7.38	1.33
B					
1	535	121	4.41	0.000	1.33
2					
A*B					
11	515	171	-3.00	0.008	1.78
12	376	171	2.19	0,042	1.78
21	1169	171	6.82	0.000	1.78
22	-536	171	-3.13	0.006	1.78

Regression Equation

C8 = 1854.0 - 533 A_1 + 894 A_2 - 362 A_3 + 535 B_1 - 340 B_2 - 195 B_3 - 515 A*B_1 1 + 376 A*B_1 2 + 139 A*B_1 3 + 1169 A*B_2 1 - 536 A*B_2 2 - 633 A*B_2 3 - 654 A*B_3 1 + 160 A*B_3 2 + 494 A*B_3 3

Fits and Diagnostics for Unusual Observations:

Obs	C8	Fit	Resid	Std Resid
11	3578	4452	-874	-2.40 R
12	5363	4452	911	2.51 R

R Large residual

Term	Coef	SE Coef.	T – Value	P-Value	VIF
Constant	1854.0	85.7	231’64	0.000	
A					
1	-533	121	-4.40	0.000	1.33
2	894	121	7.38	0.000	1.33
B					
1	535	121	4.41	0.000	1,33
2	-340	121	-2.80	0.012	1.33
A*B					
1 1	-515	171	-3.00	0.008	1.78
1 2	376	171	2.19	0.042	1.78
2 1	1169	171	6.82	0.000	1.78
2 2	-536	171	-3.13	0.006	1.78

Regression Equation:

C8 = 1854.0 - 533 A_1 + 894 A_2 - 362 A_3 + 535 B_1 - 340 B_2 - 195 B_3 - 515 A*B_1 1 + 376 A*B_1 2 + 139 A*B_1 3 + 1169 A*B_2 1 - 536 A*B_2 2 - 633 A*B_2 3 - 654 A*B_3 1 + 160 A*B_3 2 + 494 A*B_3 3

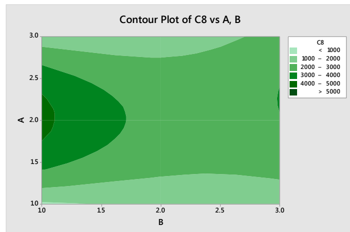
Fits and Diagnostics for Unusual Observations:

Obs	C8	Fit	Resid	Std Resid
11	3578	4452	-874	-2.40
12	5363	4452	911	2.51

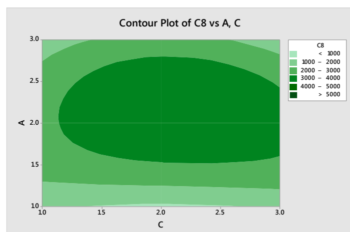
R Large residual

CONTOUR GRAPH AND REGRESSION ANALYSIS

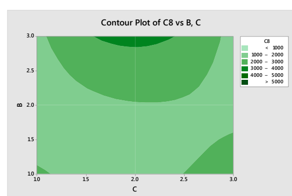
Contour Plots of Breaking Load versus Type of Joint, Type of Material and Lap Length of First Sample Lot of 27 samples:



Contour Plot of Breaking Load (C8) versus Type of Joint (A) & Type of Material (B)
FIGURE NO..1

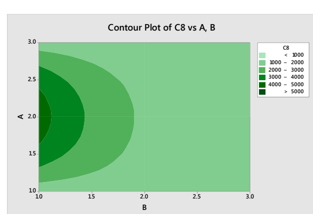


Contour Plot of Breaking Load (C8) versus Type of Joint (A) & Lap Length (C):
FIGURE NO..2

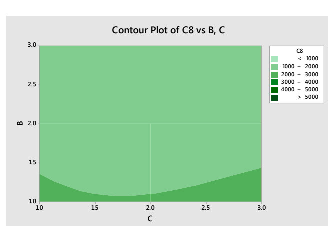


Contour Plot of Breaking Load (C8) versus Type of Material (B) and Lap Length (C):
FIGURE NO..3

Contour Plots of Breaking Load versus Type of Joint, Type of Material and Lap Length of Second Sample Lot of 27 samples:



Contour Plot of Breaking Load (C8) versus Type of Joint (A) & Type of Material (B):
FIGURE NO..4



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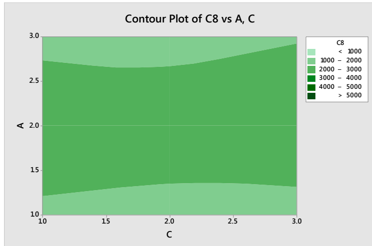
Contour Plot of Breaking Load (C8) versus Type of Material (B) and Lap Length (C):
FIGURE NO.5



Contour Plot of Breaking Load (C8) versus Type of Joint(A) and Lap Length (C):
FIGURE NO..6

REGRESSION ANALYSIS

Regression of I^st 27 samples:

Welcome to Minitab, press F1 for help.

Multilevel Factorial Design :

Factors:	3	Replicates:	2
Base runs	27	Total runs:	54
Base blocks	1	Total blocks	**1**

Number of levels: 3, 3, 3
Welcome to Minitab, press F1 for help.
Retrieving project from file: ‘E:\Software Based Contour Graph\bawaskar sir 1.MPJ’

Results for: Worksheet 2
Multilevel Factorial Design :

Factors:	3	Replicates	: 1
Base Runs		Total runs	27
Base Blocks	1	Total Blocks	1

Base runs	: 27	Total runs:	**27**
Base blocks:	1	Total blocks	**1**

Number of levels: 3, 3, 3
Welcome to Minitab, press F1 for help.
Retrieving project from file: ‘E:\Software Based Contour Graph\bawaskar sir 1.MPJ’

Results for: Worksheet 3
Multilevel Factorial Design

Factors:	3	Replicates	: 1
Base Runs		Total runs	27
Base Blocks	1	Total Blocks	1

Number of levels: 3, 3, 3

Regression Analysis: C8 versus A, B, C

Analysis of Variance

Source	DF	Adj SS	Adj MS	F- Value	P – Value
Regression	3	1600487	533496	0.30	0.827
A	1	1475928	1475928	0.82	0.374
B	1	21699	21699	0.01	0.913
C	1	102860	102860	0.06	0.813
Error	23	41301889	1795734		
Total	26	42902376			

Model Summary

S	R- sq	R- sq (adj)	R-sq(pred)
1340.05	3.73%	0.00%	0.00%

S	R-sq	R-sq(adj)	R-sq(pred)
1340.05	3.73%	0.00%	0.00%

Coefficients

Term	Coef	SE Coef	T Value	P Value	VIF
Constant	1170	1317	0.89	0.383	
A	286	316	0.91	0.374	1.00
B	35	316	0.11	0.913	1.00
C	12.1	50.4	0.24	0.813	1.00

Regression Equation

C8 = 1170 + 286 A + 35 B + 12.1 C

Fits and Diagnostics for Unusual Observations

Std				
Obs	C8	Fit	Resid	Resid
12	5317	2080	3237	2.62 R

R Large residual

<u>Regression of 2nd27 samples:</u>

Welcome to Minitab, press F1 for help.

Multilevel Factorial Design

Factors:	3	Replicates	: 1
Base Runs		Total runs	27
Base Blocks	1	Total Blocks	1

Number of levels: 3, 3, 3

Regression Analysis: C8 versus A, B, C

Analysis of Variance

Source	DF	Adj SS	Adj MS	F- Value	P – Value
Regression	3	2566971	855657	0.77	0.520
A	1	131014	131014	0.12	0.734
B	1	2395846	2395846	2.17	0.154
C	1	40111	40111	0.04	0.851
Error	23	25413246	1104924	0.04	0.851
Total	26	27980216			

Model Summary:

S	R sq	R sq (adj)	Rsq(pre)
1051.15	9.17	0.00%	0.00%

Coefficients

Term	Coef	SE Coef	T – Value	P – Value	VIF
Constant	2274	1033	2.20	0.038	
A	85	248	0.34	0.734	1.00
B	-365	248	-1.74	0.154	1.00
C	7.5	39.5	0.19	0.851	1.00

Regression Equation

C8 = 2274 + 85 A - 365 B + 7.5 C

Fits and Diagnostics for Unusual Observations

Obs	C8	Fit	Resid	Resid
10	4415	2241	2.30	2.30 R
12	5363	2268	2.30	3.20 R

R Large residual

RESULTS

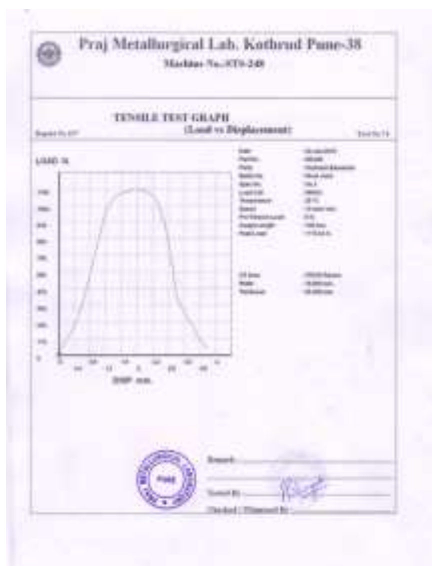


FIGURE NO..7 Sample plot for Rivet Joint Spec. No. 1 MS – MS Material

Above graph load vs displacement shows that the breaking load is high for the Rivet joint where as other graphs shows that adhesive joint has brittle fracture where as adhesive and rivet joint has gradual change in breaking load. There is sudden break observed in the adhesive joint. .

CONCLUSIONS:

Adhesive + Rivet Joint Sample,:

Type of Material	Value Of Breaking Load(N)	Average Value Of Breaking Load
Adhesive + Rivet Joint		
MS-MS Sample 1 and 2	(1167.18+1106.42)/2	1139.80N

MS-MS Sample 3 and 4	(1502.34+1381.80)/2	1422.07N
MS-MS Sample 5 and 6	(1178.94+1629.74)/2	1402.34N
AL – AL Sample 1 and 2	(1452.36+1449.42)/2	1450.89N
AL – AL Sample 3 and 4	(1214.22+1148.56)/2	1181.39N
AL – AL Sample 5 and 6	(1465.10+1339.66)/2	1402.38N
MS – AL Sample 1 and 2	(2487.24+1262.24)/2	1874.74N
MS – AL Sample 3 and 4	(4255.16+1667.96)/2	2946.56N
MS – AL Sample 5 and 6	(1398.46+2443.14)/2	1902.8N

1. Above observations show that for MS-MS material Sample 3 and 4 is strongest with breaking load 1422.07N where for AL – AL material sample 1 and 2 are strongest with breaking load 1450.89N and MS – AL material sample show that sample 3 and 4 are stongest with breaking load 2946.56N.

From the above observations MS – AL sample has strongest joint with breaking load capacity 2946.56N.

From above 3 observations i.e of Rivet, Adhesive, Rivet + Adhesive type samples it is observed that MS – MS sample of Adhesive Joint has the largest breaking load capacity of 5339.53N. Lap length of rivet joint 25mm has largest breaking load capacity. So lap length of rivet joint 25mm is most significant lap length having high breaking load capacity.

2. Also above observations show that material sample of Rivet 3 & 4 with have lowest breaking load capacity of 854.55N with the lap length 18 mm has lowest breaking load capacity.

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