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"Investigation of Lap Shear Strength on Hybrid FRP (Carbon / Glass) / Al6061 Single Lap Joint

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ABSTRACT: The joining strength of three different layered composites made of carbon-glass-carbon-glass, carbon-glass-glass-carbon, and glasscarbon-carbon-glass was investigated in the current work utilising a single lap joint. Composite materials containing carbon fibre and glass fibre reinforcement were bonded with 6 series aluminium alloy. As a joining method, adhesive joints, mechanical joints, and hybrid joints (a combination of adhesive and mechanical joints) were all employed. It was discovered that the mechanical and hybrid joints in the carbon-glass-glass-carbon layered composite performed better than those in other layered composites and adhesive bonding joints**.** The mechanical and hybrid joining of the carbon-glassglass-carbon layered composite was found to have the highest strength among all other combinations tested in this study, with maximum loads of 3.33 KN and 3.14 KN, respectively. The other combinations had maximum loads that were lower than 3.33 KN.

INTRODUCTION

Composite Materials: Composites are designed materials created by mixing two or more materials with unique qualities such that each material's characteristics are preserved in the final product. The matrix and the reinforcement are the two primary parts of a composite material. The reinforcement is integrated in a homogeneous, monolithic substance called the matrix. The matrix's primary purpose is to act as a medium for joining the reinforcements. Additionally, it serves to distribute load, provide the composite shape, and shield the reinforcements from environmental harm. The reinforcement offers features like as stiffness, strength, and others. For improved characteristics in Fibre Reinforced Polymer Composite (FRPC), the fibre length always remains greater than the diameter**.** Furthermore, discontinuous fibres have small aspect ratios and typically display random orientation, whereas continuous fibres have large aspect ratios and typically display a preferred orientation. The maximum amount of reinforcement that can be added to the matrix material is roughly 70% of the volume of the fibres; further addition will cause poor adhesion, which will drastically reduce the qualities of the composite**.** **Characteristics of a composite:** Any one of the three fundamental substances—polymers, metals, or ceramics—can be found in a matrix. The constituent materials' qualities, their distribution, and how they interact with one another all have a significant impact on the properties of composites. In addition to the constituent materials, the geometry of the reinforcement has a significant impact on the properties of the composite. The interfacial area, which is crucial in determining how much the reinforcement interacts with the matrix, is determined by the shape of the discontinuous phase (spherical, cylindrical, or 2 rectangular cross-sectioned prisms or platelets), size, and volume fraction. 2010 (Campbell)**.**

Classification of Composites: The matrix ingredient is typically taken into consideration when the initial level of classification is created. Organic matrix composites (OMCs), Metal matrix composites (MMCs), and Ceramic matrix composites (CMCs) are the three main composite classifications. In general, it is assumed that the term "organic matrix composite" refers to two groups of composites: polymer matrix composites (PMCs) and carbon matrix composites, also known as carbon-carbon composites. The second level of classification is divided into three categories: particle composites, laminar composites, and fibre reinforced composites. You can further categorise Fibre Reinforced Composites (FRP) into those with discontinuous or continuous fibres. Fibres incorporated in a matrix material make up Fibre Reinforced Composites**.** The matrix ingredient is typically taken into consideration when the initial level of classification is created. Organic matrix composites (OMCs), Metal matrix composites (MMCs), and Ceramic matrix composites (CMCs) are the three main composite classifications. In general, it is assumed that the term "organic matrix composite" refers to two groups of composites: polymer matrix composites (PMCs) and carbon matrix composites, also known as carbon-carbon composites. The second level of classification is divided into three categories: particle composites, laminar composites, and fibre reinforced composites. You can further categorise Fibre Reinforced Composites (FRP) into those with discontinuous or continuous fibres. Fibres incorporated in a matrix material make up Fibre Reinforced Composites. The matrix ingredient is typically taken into consideration when the initial level of classification is created. Organic matrix composites (OMCs), Metal matrix composites (MMCs), and Ceramic matrix composites (CMCs) are the three main composite classifications. In general, it is assumed that the term "organic matrix composite" refers to two groups of composites: polymer matrix composites (PMCs) and carbon matrix composites, also known as carbon-carbon composites. The second level of classification is divided into three categories: particle composites, laminar composites, and fibre reinforced composites. You can further categorise Fibre Reinforced Composites (FRP) into those with discontinuous or continuous fibres. Fibres incorporated in a matrix material make up Fibre Reinforced Composites.

LITERATURE SURVEY

1) "Julian Vorderbrüggen et al.'s research in 2019 focused on "Investigations on a materialspecific joining technology for CFRP hybrid joints along the automotive process chain." This book's objective is to thoroughly examine and assess the damage behaviour of self-piercing riveted hybrid joints made of metals and carbon fiber-reinforced polymers in respect to industry standards for the automotive sector. The drying process for cathodic dip coating in an auto body shop is then used as the basis for the thermal profile that hybrid joints go through. It is shown that self-piercing full riveted joints built of CFRP are harmed by the oven process". Fibre fractures, inter-fiber splits, and delamination are the symptoms of this damage. In response to these impacts, the selfpiercing rivet's geometric design has been improved in order to avoid damage during the oven process.This phenomenon might be explained by the fact that heating the CFRP laminate over the thermoset matrix's glass transition temperature reduces its compressive strength. As a result, at 180 °C, the laminate fails due to delamination, fibre and interfiber fractures, and compressive stresses brought on by the rivet shank pressing into the CFRP-sided punch hole. Based on DMA investigations, it was possible to determine that the glass transition area for the plastic matrix lies between 120 °C and 140 °C. Using ultrasound c-scans and other data, Additionally, the damage analysis carried out on microsections was validated, as was the estimation of a delamination factor, which assigns a value to the material's damage. The ultrasonic analyses might corroborate the earlier findings. Combining improvements from the joining and oven processes, a joining technology was created that enables the low-damage joining of CFRP with metals throughout the automobile process chain. "Xianlian Zhang et al. investigated pre-holed self-piercing riveting of carbon fibre reinforced polymer laminates with commercially pure titanium sheets in 2019. The objective of the novel pre-holed self-piercing riveting (PH-SPR) technique was to improve the dissimilar joining of the commercially pure titanium (TA1) sheet and the carbon fibre reinforced polymer (CFRP) laminate. which was made in this article. It was analysed how the PH-SPR joints compare to the normal SPR (R-SPR) joints in terms of joint quality, strength, failure behaviour, and forming structure. The impacts of process parameters on the PH-SPR joint were discussed methodically and empirically. It was discovered that a superior mechanical interlock may be made using PH-SPR. Prior to the rivet being forced out, the PH-SPR joints had a stronger joint than they had prior to the composite layer being ripped. The PH-SPR joints had a better influence on hardening the TA1 sheet than the R-SPR joints did, and they lost strength to the rivet significantly less. the PH-SPR process's joint strength: the longer the interlock length, the stronger the joint." The static failure mode of the joints was considerably influenced by the height of the rivet heads: for flat and bulgy rivet head heights, the composite layer tore and the rivet pulled out, respectively. The residual bottom thickness and interlock length values Yang Liu et al.'s 2019 research examined. By increasing the thickness of CFRP, it is possible to significantly increase the strength of 45-degree ply joints and the energy absorption of complex-angle ply joints. The study by Harish M. Rao et al. (2018) examined the effect of specimen configuration on the fatigue characteristics of self-piercing riveted aluminium to carbon fibre. This paper discusses the fatigue properties of SPR joints between CFRP and AA6111 aluminium alloy in lapshear and cross-tension specimens. Comparing lap-shear junctions produced with a flush head height to SPR joints constructed with a flush head height A higher tensile failure load and a slightly longer fatigue life were indicated by significant head height. The flushness of the rivet had minimal impact on the quasi-static failure load and fatigue life of the SPR joints in cross-tension joints. Two distinct failure types were seen under quasi-static loading; the lap-shear and cross-tension joints failed as a result of the bottom aluminium sheet's rivet coming loose. During cyclic load, the bottom aluminium sheet developed a kinked crack that led to the failure of the lap-shear joints, and the rivets in the top CFRP sheet pulled out during the cross-tension joints. In terms of fatigue life at normalised loads under 0.4, the CFRP-to-AA6111 lap-shear SPR joints fared better than identical sheets of AA6111 overall in fatigue tests. CFRP-to-aluminum SPR joints under crosstension demonstrated reduced fatigue lifetimes when compared to joints built from equivalent sheets of AA6111. 4. Regardless of the stack design, the major mode of failure in lap-shear SPR joints was fatigue crack development. starting at the area that has been plastically deformed close to the rivet-aluminum sheet interface and spreading to the bottom aluminium sheet. When cross-tension SPR connectors between CFRP and aluminium failed, the rivet head pulled through the CFRP sheet while identical AA6111 SPR junctions exhibited fatigue cracks in the top aluminium sheet close to the rivet-sheet contact. An strategy to combine discontinuous carbon fibre reinforced nylon 6 composite that utilises was studied by Zhenghua Raoa et al., in 2020. rivets that self-pierce. A revolutionary self-piercing-through riveting (SPTR) method has been developed to join discontinuous carbon fibre reinforced nylon 6 composite (Cf/PA6) that will serve as a peel stopper. This method was developed using SPTR of 2.5 mm thick compression moulded Cf/PA6 with 30% mass fibre.- The displacement properties of the riveted lap-shear joints were examined and modelled under a quasi-static force. The results showed that the conventional self-piercing riveting (SPR) joints had much lower static strength and displacement than the joints formed employing self-piercing through riveting. The material was compression moulded 2.5 mm thick Cf/PA6 with 30% mass discontinuous fibre. To understand the strengthening mechanism of the SPTR joint, experimental joint material, mechanical testing, and the creation of a process model utilising LS-DYNA were all carried out. The modelling outcomes qualitatively matched the geometry of the bent rivet, despite a difference in the distal ends of the rivet legs. According to the findings of both the experimental and the computational investigations, the skirt of the rivet flared outward and pierced through the workpieces, resulting in a mechanical interlock between the workpieces and the rivet as well as considerable deformation between the wall and bottom of the rivet.

An aluminium and continuous carbon fibre reinforced composite attachment technique using self-piercing rivets

Jian Wang et al. created alloy sheets in 2020. Because the rivet pierces the CFRP during the self-piercing riveting process, the 23 mechanical properties of the junction between carbon fibre reinforced polymer (CFRP) and aluminium alloy sheets are somewhat affected. This study recommends using post-curing self-piercing riveting (PC-SPR) to join in order to improve the junction's quality.

The PC-SPR approach can reduce stamping damage and stop delamination, tearing, and other faults that can occur when fully cured CFRP is riveted. In the PC-SPR junction, the prefabricated carbon fibre sheet can flex cooperatively with the prefabricated aluminium alloy sheet. During the autoclave forming process, the viscous fluid resin can fill the gaps left by stamping, improving The joint structure and CFRP thickness have an impact on the PC-SPR approach. Even though adding more thickness to CFRP can make it stronger, doing so at the expense of the material's capacity to successfully form an inlaid structure with the sheet of aluminium alloy beneath it proved counterproductive. one joint "MeltemAltinKarataset" al. (2018) conducted a review on the machinability of carbon fibre reinforced polymer (CFRP) and glass fibre reinforced polymer (GFRP) composite materials. When the feed rate was increased when using conventional machining methods (turning, milling, drilling, etc.), stronger compressive pressures were created, and when the cutting speed was increased while the feed rate was dropped, higher hole surface quality was attainable. Several investigations on the machining of CFRP and Maximum crack lengths rose with the procedure while they decreased with increasing jet pressure; the jet-lag angle also increased with higher cutting speeds and greater cutting quality. with more rapid cutting times. Studies have shown that while kerf breadth grew with increasing jet pressure and stand-off distance, it shrank with increasing feed rate and stand-off distance. It was discovered that high pressure and low feed rate values were required in order to lower the kerf angle and roughness values. (8) Sankaranarayanan et al.'s research in 2018 was centred on "Prospects of joining multi-material structures." The potential is examined in this study. Technologies that will be able to address issues in the future include bonding. Friction-assisted riveting using the Friction technique How the compelling joining technique addresses issues that arise when linking various components is remarkable. Additional research and development could look at the benefits of this procedure on a bigger scale. Due to their multiple materials, these constructions can go beyond environmental norms. In 2020, Piervincenzo "G. Catera et al. did a comparison study of interference fitting and adhesive bonding as joining techniques for the creation of hybrid metal-composite gear. This paper analyses two different joining procedures for steel and carbon fibre reinforced concrete in order to maximise the dynamic behaviour in terms of natural frequencies and damping qualitiesa hybrid gear made from polymer materials". Design and prototype of hybrid metal-composite gears using interference fitting and adhesive bonding are described in depth. A composite laminate is utilised in this hybrid metal-composite gear application. compared to a lightweight steel gear of the same mass, improves the modal behaviour. The recommended gearing technique is intended to replace conventional lightweight gears in industrial gearboxes, such as those used in the aerospace sector, where high-precision and high-power requirements mix with extremely hot operating environments. Future studies are required to examine the vibration, heat, wear, and fatigue. in line with FTIR. The mechanical and tensile properties, including the expansion, swelling, and thermal expansion, were consistent with what may be expected in a system with variable chemical crosslink density. When the hybrid polymers were examined for their capacity to bind adhesives, they showed great promise as adhesive binders for substrates made of aluminum.

PROBLEM IDENTIFICATIONS

With two fibres organised in the shape of three separate layers, the identification of strength and failure in the connection of a composite with metal using various joining techniques. Adhesive joining at three separate layers: strength and failure. "Strength and failure of three separate layer mechanical connecting. Strength and failure of three-layer hybrid joining (mechanical + adhesive).Three different layered composites of carbon fibre and glass fibre joined with a 6 series aluminium metal were subjected to tensile tests to determine the strength and failure of the adhesive joining, mechanical joining, and hybrid joining".

and the composite's strength. Fabrication is accomplished by hand lay-up. The easy removal of composite formed on its top surface is made possible by the use of polyester sheet as a base element. In a glass jar, the resin and hardener are combined in a 10:1 ratio. To create the finished product, resin and reinforcement are alternately applied using a brush and roller. The finished composite product is left at room temperature for 4 hours before use.This composite is taken from the polyester plate once it has dried completely. The first composite specimen is made up of a layer of carbon, glass, and carbon glass. The composite is made up of three types with distinct layers. The second composite specimen is made up of a layer of carbon-glass-carbon . The third composite specimen is made up of a layer of Glass, Carbon, and Glass.The prepared composite is cut into rectangular shapes measuring 95 mm in length and 35 mm in width, and the aluminium 6061, which has a 2 mm thickness, is also cut into rectangular shapes measuring 95 mm and 35 mm.Then, 35mm of composite and 35mm of aluminium 6061 are linked, making the combined length of the joined specimen 160mm and the joined length 35mm.Three different joining techniques are used: mechanical joining, adhesive joining, and hybrid joining.

RESULTS AND DISCUSSION

The linked composite using 6061 aluminium alloy was tested for strength using the tensile method. The tensile testing process and the tools used in this work are briefly explained in the sections that follow.Tensile testing, also known as tension testing, involves applying a controlled tension on a sample until it breaks. A tensile test can be used to precisely measure properties such as ultimate tensile strength, breaking strength, maximum elongation, and decrease in area. These findings can be used to compute the Young's modulus, Poisson's ratio, yield strength, and strain-hardening properties. “Uniaxial” tensile testing is the most widely used technique for figuring out the mechanical characteristics of isotropic materials. Some materials are tested using biaxial tensile methods. Different testing equipment have quite different ways of applying load to the materials.The most common tensile testing device is the universal testing machine. A universal testing machine (UTM), also known as a universal tester materials testing machine or a materials test frame, is used to measure the tensile strength and compressive strength of materials. A tensile testing equipment was formerly known as a tensometer. The word "universal" in the name alludes to the device's adaptability and the variety of common tensile and compression tests it can perform on different components, materials, and structures. Here, a universal testing machine (UTM) of model WDW-100 computer control electronic universal testing machine is used to test the specimen.

Table 1. Tensile test values

Sample ID	Ultimate Tensile Load(KN)		
	Adhesive joint	Mechanical joint	Hybrid joint
A1-1	1.81	3.29	2.24
A1-2	1.41	3.31	2.55
A2-1	1.17	2.73	3.14
A2-2	2.07	3.33	2.68
A3-1	1.75	2.99	3.10
A3-2	1.09	3.04	2.37

Table 2. Joined Strength values

S.NO	Name of the specimen	Joined strength(M.Pa)		
		Adhesive joint	Mechanical joint	Hybrid joint
1	A1-1	1.50	2.68	1.82
2	A1-2	1.15	2.70	2.08
3	A2-1	0.95	2.22	2.56
4	A2-2	1.69	2.71	2.18
5	A3-1	1.42	2.44	2.53
6	A3-2	0.89	2.48	1.93

TEST SPECIMEN:

“The three separate composite specimens that were connected together with 6061 aluminium metal are divided into two groups, making a total of six test specimens that are used for adhesive, mechanical, and hybrid joints.

Two specimens with the given names A1-1 and A1-2 are made of a carbon-glass-carbon-glass layered composite that is connected with 6061 aluminium. Two specimens with the given names A2-1 and A2-2 are made of a carbon-glass-glass-carbon layered composite that is connected with 6061 aluminium. A3-1 and A3-2 are two specimens of the Glass-Carbon-Carbon-Glass layered composite linked with 6061 aluminiums.”

The adhesive connect has a lower joint strength compared to the other two joins and exhibits thin layer cohesive failures in the tensile test on adhesively joined specimens. In comparison to the other specimens, the mechanical and hybrid joins in the carbon-glass-glass-carbon layered composite have a higher joint strength. Due to the fact that the outer layer is under the majority of the load, the carbon-glass-glass-carbon layered composite has a higher load capacity than the other two layers.

Due to the higher strength of carbon, the outer layer of this composite has a stronger strength because it is formed of carbon fibre.

CONCLUSION

"In this work, three different composite materials were created using three different kinds of layered carbon fibre and glass fiber/epoxy and joined with 6 series aluminium alloy sheet. Three different layered composites comprised of carbon-glass-glass, carbon-glass-glass-carbon, and glass-carbon-carbon-glass are joined using adhesive, mechanical (rivet), and hybrid methods. Tensile strength was used to analyse joint strength and failure modes. The following summarises the main conclusions: 1. The mechanical and hybrid junction of the carbon-glassglass-carbon layered composite, which is the strongest among all other carbon-glasscarbon-glass and glass-carbon-carbon-glass layered composite, achieved maximum loads of 3.33 KN and 3.14 KN among the three joints. The load capacity of adhesive joining is the lowest. 2. The mechanical and hybrid junction of the layered composite made of carbon, glass, glass, and carbon achieved combined strengths of 2.71 MPa and 2.56 MPa".

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