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A Review Article on Analytical, Experimental and Comparative Study of Adhesive Scarf Joint

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Abstract*: Structures built from different components which require some means of joining. Bonding with adhesives has major advantages compared to traditional joining methods like welding, riveting or fasting e.g. reduction of stress concentrations, reduced weight, easy joining for very thin surfaces as well as used for two different materials also. An investigation based on several experimental and finite element analysis studies was carried out to understand the failure mechanisms of scarf adhesive joint under tensile load. Various parameters were investigated such as the bondline thickness, adherend thickness, scarf angle for either same adherend or different adherend and used different adhesive for the investigation. Also the external parameter like temperature considers for some experiments also they combine two different adhesive to get better result. A lot of studies and researches have been done to improve all these characteristics that are reviewed in this paper.*

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I. Introduction

The adhesive is very commonly used in fields like railways, automobile, aerospace, wind energy, construction, and medical because of its suitable mechanical properties. It is very recommend for any fracture home appliances of different materials. We can joint material by various methods like fastening, clamping, fitting, welding etc. But what if the material can’t be bolted, riveted, or welded. So, in such a case the adhesive joint is preferred. The adhesive joints used to join two subtracts in a same way of technology for assembling subtracts and being used in several industries like Automotive, Aerospace, and civil engineering. An adhesive, same as cement, mucilage, glue or paste is any non-metal substance applied over a surface of substrates or two surfaces of substrates of two different substrates that bound them and avoid their separation.[1] the common definition of adhesive joint is a joint made through notching, chamfering or otherwise cutting away two pieces to correspond to each other and overlapping the adherend as by gluing, bolting, welding, brazing, etc.

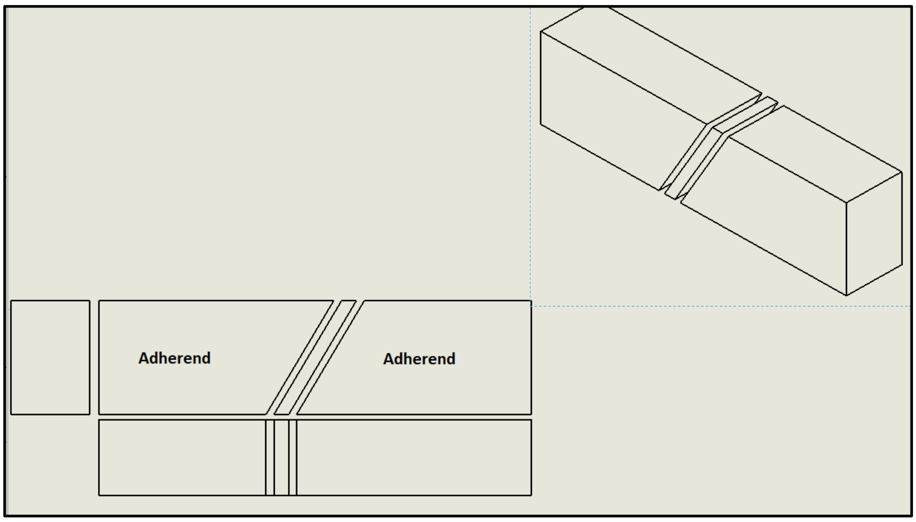

Figure 1: Scarf Adhesive Joint

The adhesive joint has many advantages over conventional joining techniques like mechanical fastening, riveting, welding, thermal bonding, sewing, etc.[2] That include the stress concentration, weight of joint, material going to bond. As there is hole in a plate which is going to bonded by conventional joint hence that increase the stress concentration over hole and hence increases the weight of rivet or fastener used for joint, instant if we use adhesive joint there is no such hole required and hence no stress concentration increases and rise in weight of joint is negligible. Other main advantage of adhesive is we can joint two very thin adherend easily. We can also joint two different materials by adhesive material. [2]

The earliest era human used adhesive like substances was around 200,000 years ago [3] when Neanderthals produced tar with help of dry distillation of birch bark for bonding stone tool to wooden handles.[4] The 1st references of adhesives in literature seen in approximately 2000 BC. The Greeks and Romans give better contributions to the growth of adhesives. In European country, glue was not used till AD 1500–1700. From then until the 1900s increases in use of adhesive discovery were occurs. From last century development of adhesive accelerated rapidly and innovation in the field of adhesive is continues to the till date [5].

1.1 APPLICATION

The application of scarf adhesive joint is generally in all fields like railways, automobile, aerospace, wind energy, construction, medical, furniture, electronics, woodworking factories, paper industries and footwear industry.[6] The chats represent the area contribution in adhesive joint. The scarf joint is commonly use in ship and boat-building, as well as timber framing and wooden bridge construction (Keyed-hook scarf joint). The scarf joint is also use in decorative situation like application of trim or mounding (Plain scarf joint). The scarf joints are used in the restoration of vintage aircraft. The scarf joints are also used to afix a neck or headstock in a musical instrument like guitar.[7]

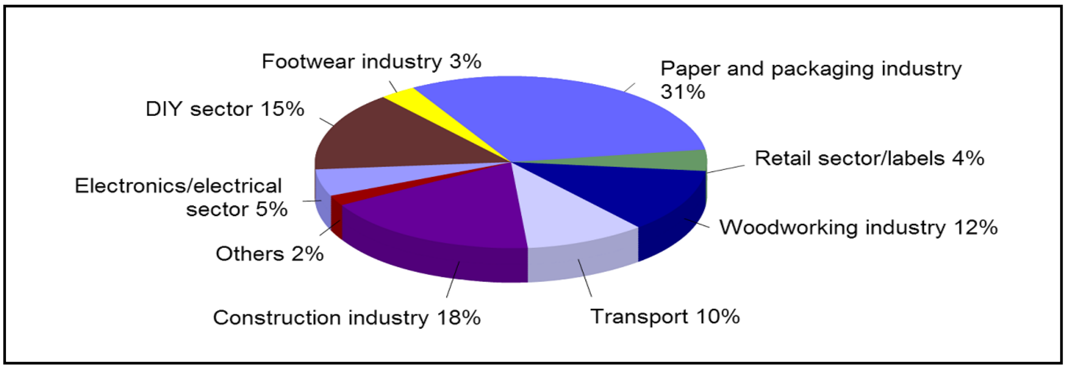

Figure 2 Application of adhesive joint

II. Literature Review

R. D. ADAMS and N. A. PEPPIATT [8] [9]They work on the effect of stress on the end parameter adherend length; overlap length; spew size (within the limits 0.015 in, 0.38 mm, to 0.9 times the adherend thickness); adhesive-layer thickness; adherend thickness. They conclude that the epoxy adhesive joints strength do not vary significantly for define adhesive-layer thicknesses used in practice. Also the maximum principal stresses at the ends of the adhesive layer is maximum that can't be ignored and the maximum principal stresses at the ends of the adhesive layer are predicted to be at right-angles to the direction of cracks formed in the spew of failed lap joints, if spew is provide to adhesive joint the strength of joint increases.

Tsai, M YMorton, J [10] The single lap joint has been analyzed by using the geometrically Nonlinear FEA and the results is then compared to the pre-available theoretical solutions. And conclude that Hart-Smith's model[11] is more feasible and reasonable for the small single-lap joint with a variable thickness of the adhesive than the modified Goland and Reissner [12]and Oplinger models, whereas the Oplinger model gives a more satisfactory approximation for the long single-lap joint with variable of thickness and material properties in the adhesive layer. [13] [14]

P.C. Pandey, H. Shankaragouda, Arbind Kr. Singh [15] This paper presents non-linear finite analysis of adhesive joint with considering the elastoviscoplasticity constitutive modal of the adhesive material also consider finite rotation of the joint. They examine Stability of the viscoplastic solution and time dependent behavior. Parametric study has been conducted along with particular reference to shear stress and peel stress along the inter surface. They have been found that the viscoplastic effect has a significant effect on the distribution of shear stress and peel stresses. The accuracy of stress distribution is not significant affected by the choice of temporal decartelization of the viscoplastic strain rate.

Lucas F.M. da Silvaa, R.D. Adamsb [16] They examine the effect of temperature on the design of adhesive joint and combined two adhesives material which can sustained at high temperature as well as at low temperature and then a numerical analysis was conducted using finite element models to study the behavior of stress distribution in a mixed adhesive joint so as to find the best possible structure of both same material titanium/titanium and different material titanium/composite double lap joints. They conclude that a theoretical analysis of the adhesive shear stress distribution has gives that the mixed adhesive joint allows operation from both low to high-temperatures with the combination of a lower temperature adherend (LTA) and higher temperature adherend (HTA). The joint will sustained at high load capacity than the HTA alone at low temperatures or the LTA alone at high-temperatures. They also find that it will not be better than the LTA alone at low-temperatures or better than the HTA alone at high temperature.

Fan-Rong Konga, b,- Min Youa, Xiao-Ling Zhenga, Hai-Zhou Yua [17] In this study they analyzed stress distribution of adhesively bonded metal/metal single lap joints under specific cleavage loading using three-dimensional (3D) model further analyzed under the elastic–plastic finite element method (FEM) and also investigate effects of thickness of adherend, thickness of adhesive, elastic modulus of adhesive and Poisson's ratios of adhesives on 3D stress distribution of adhesive layer of cleavage joints.

René Q. Rodrígueza, William P. Paivaa, Paulo Solleroa, Eder L. Albuquerqueb and Marcelo B. Rodrigues [18] They analyzed basically 4 major analytical model in the history of adhesive bonding 1.Volkersen [19] 2.Goland & Reissner [12] 3.Hart-Smith [11] 4.Ojalvo & Eidinoff Ojalvo & Eidinoff [20] by using FEA software like ABAQUS® & Matlab® and analyzed the effect of shear and peel stress. Finally they conclude that Hart-Smith elastic-plastic model is the method whose failure loads best approximated to the experimental failure load and the method Ojalvo & Eidinoff model is a best approximated to numerical results .As a result, the best rectification of methods for adhesive bonded joint analysis would be Ojalvo & Eidinoff for peeling Hart Smith elastic-plastic model for shear.

Yeliz Pekbey [21] He examine the stress behavior of adhesive single-lap joint loaded in the elastic and elastoplastic range. The stress distributions across the adhesive joint were achieved both numerically and analytically. The residual stresses after elastoplastic loading were also examine. The results gain from numerical analysis identifies that the residual stress was essential, as the joint strength can be rises by residual stresses. In addition with residual stress, the effect of the thickness of adhesive, adhesive length and thickness of adherend on the shear stress distribution of the adhesive joint was also examined using elastoplastic finite element method numerically. He concludes that Stress distribution was not symmetric along both right and left side of joint length for the finite element cases. Also he observes that the strength of joint increases and decreases as increasing in thickness of adherend and increase in overlap length respectively.

ozeroz, Halilozkan [22] They describe the new design of adhesive joint and that is Bi-adhesive the adhesive which contains two material one having stiff in nature and other is of flexible nature. The stiff adhesive used at centre of joint and the flexible adhesive used at corner of the joint. They examine Bi-adhesive single lap joint using FEA and compare numeric (2D & 3D FEA Result) with analytical result. They give the knowledge that the stress concentration at the end of the joint is more compare to centre of joint and hence they use bi-adhesive in place of singe adhesive. They come on the conclusions that Hybrid adhesive joints will reduce the stress concentrations and give better joint strength by varying the adhesive stiffness along the joint. Results showed that the hybrid adhesive joints with two different Modulus of elasticity can offer more strength comparatively. The model of stress theoretical was examined in the numerical experiments, and a close result is observed between the finite element result and analytical result.failure is only due to the shear stress. The decrement in the residual shear stress is observed due to increase in the thickness of the adhesive. Thus, the thickness of the adhesive is optimized to resist the behavior of the adhesive.

L. D. R. Granta, R. D. Adamsa and Lucas F. M. da Silvab [23] They carried out the experimental investigation and FEA modeling analysis of T peel joint which is one adhesive joint type which widely used in automobile industries. They choose adhesive and adherend as a toughened epoxy and mild steel as it used generally in the car body shell. Various parameters such as the bondline thickness, adherend radius, porosity of joint and spew fillet are taken in to consider and finally conclude that initial crack was found at the corner of T peel joint at angle around the radius of approximately 70˚. Increase in porosity does not significantly affect the strength the T-peel joints at larger bondline thicknesses, but it does for thin bondlines.

C. Soutis and F. Z. Hu [24] They describe design methods for adhesively bonded scarf repairs requires criteria to examine both durability and strength. In that study, a three dimension stress analysis examined to determine the stresses in flush-scarf-repaired laminate under uni- axial compressive force so that we can predicates the optimum scarf angle and similar points of failure[25]. And conclude that the simple scarf-joint analysis underestimates the strength of the scarf patch repair around more than 40 % and also predicts that an optimum scarf angle of 4 deg compared with an angle of almost 7 deg obtained by the average stress failure criterion . A 4-deg scarf angle would drag too much safe material and weaken the rectified laminate. By adding a safety factor to that value to take consideration of endurance life, fatigue, manufacturing anomalies and temperature effect would reduce angle from 4 deg probably down to 1 –2 deg , which is highly difficult to manufacture.[26] Increase in porosity does not significantly affect the strength the T-peel joints at larger bondline thicknesses, but it does for thin bondlines.

David W. Adkins, R. Byron Pipes [27] They works on the End Effects in Scarf Joints. They used adhesive as Hercules AS 1/3501-6 carbon/epoxy. In this experiment they analyze scarf joints with different small scarf angle and sharp - tipped adherends. Their works include graph plotted for Adhesive stress factor for various scarf adhesive joints with sharp-tipped adherends**.** The dip in the curve causes the high modulus adherend tip. Because of its modulus the tip area strains is less compared to the adherend to which it is bonded. At the free end, the tip of the adhesive and the adherend is strained more. They find in this study that large adhesive stresses produced in the boundary layer and notice more as the angle of scarf reduces. High stresses occur both at the ends of the adherends and inside the joint.

L. J. HART-SMITH [28] He works on the adhesive bonded scarf and stepped lap joints and use adherend as titanium and adhesive as HTS Graphite-Epoxy**.** He examines the effect of Adhesive plasticity and adherend stiffness imbalance and thermal mismatch. The scarf joint analytical portion include a simple analytical formula which gives as a close lower bound, which gives to be so close to the more precise solutions that can be significantly use directly for all realistic joint proportions. Digital computer programs also develop for stepped-lap joints. It gives that unlike scarf joint, with increasing overlap the shear strength of stepped lap joint cannot be increase. He concludes that the effect of adherend thermal mismatch on the joint strength of scarf adhesive joints is insignificant for very long and very short overlaps. For tensile loading adherend thermal and stiffness imbalances decreases while they counteract each other for the compressive loading.

R.D.S.G. Campilho, M.F.S.F.de Moura, D.A. Ramantani, J.J.L. Morais & J.J.M.S. Domingues [29]

They works on the buckling behavior of carbon–epoxy adhesively-bonded scarf repairs and used the adhesive as carbon–epoxy (Araldite® 2015) for angle of scarf around 2 to 45◦. Numerical works done using the FEM and a mixed-mode cohesive damage model implemented in the ABAQUS® software. Double Cantilever Beam (DCB) and End-Notched Flexure (ENF) tests have been conducted for the cohesive laws in pure modes. Using this and the other cohesive parameters are examined by conducting the experimental and numerical P–δ curves. And come on the conclusion that the numerical and experimental P–δ curves for 45◦ and 2◦ scarf angle initially, an elastic region was observed, during that region no global buckling of joint occurred. For the larger scarf angle (15, 25 and 45o), cohesive failures in the adhesive layer near the epoxy adhesive interface occurred, which were captured by the numerical simulations. With reduction in scarf angle the buckling strength of scarf joint increases slightly.

Mohd Afendi, Tokuo Teramot, Hairul Bin Bakri [30] They works on the Strength prediction of epoxy adhesively bonded scarf joints of dissimilar adherend which are SUS304 stainless steel and YH75 aluminium alloy and used angle of scarf 45,60 and 75 degree**.** In this study, investigated done by experimentally, analytically and numerically the effects of bond thickness and scarf angle on the strength of scarf joints of dissimilar adherends bonded with a brittle epoxy adhesive. Several scarf angles and various bond thicknesses under the uni-axial tensile loading is used to examine the Strength of epoxy adhesively bonded scarf joints of dissimilar adherends. They used the bond thickness between 0.1 and 1.2mm. Finite element analysis (FEA) is also conducted to examine the stress distributions in the adhesive layer of scarf joints by ANSYS 11 code. On conducting analysis work they find that mechanical properties of epoxy adhesive layer are different from bulk epoxy adhesive also find that by ANSYS Failure of surface initiated at corner of joint having 45–75degree scarf angle.

D.F.O SILVA, R.D.S.G campilho, F.J.G silva, U.T.F Carvalho[31] In this study, Experimental and numerical analysis of scarf aluminum adhesive joints was carried out with different scarf angles (α) and adhesives of different ductility were tested. They used adherend as AW6082-T651 aluminum alloy and adhesive are Araldite AV138, Araldite 2015 and Sikaforce 7752 and performed experiment under the approximate temperature and relative humidity 23 degree and 60% respectively of test velocity 1 mm/minute. Results shows that mechanical behaviour of the scarf bond is highly dependent on the both type of adhesive and value of scarf angle α. A higher peak stresses and instability in damage propagation found in more stiff and brittle while more uniform stress distributions and a more uniform damage growth during loading in a less stiff and ductile adhesive. It was also found that, the percentile deviation between CZM law shapes becomes smaller as the adhesives ductility increases. The maximum differences between the mixed-mode and independent-mode formulations were 0.74% for the Araldite® 2015, 1.66% for the Araldite® AV138 and 0.68% for the Sikaforce® 7752. For all adhesives, the percentile reduction between both independent-mode & mixed-mode models also reduces with increasing scarf angle α.

R.D.S.G. Campilhoa, T.A.B. Fernandesa [32] they work on the Comparative evaluation of adhesive joints bonded with different adhesives by cohesive zone modelling. Used Aluminium as adherend and adhesives can be strong and brittle (epoxy Araldite® AV138) , less strong and ductile (epoxy Araldite® 2015) and new family of polyurethane adhesives combines high strength and ductility (Sikaforce® 7888). In this work, the performance of the three above mentioned adhesives was tested in adhesive joints with varying values of overlap length (LO). The experiment work conducted on FEA based on Cohesive Zone Models (CZM). They find that with increase in overlap length failure load is increase slowly when adhesive is epoxy Araldite AV138 ,so joint strength is poor, for adhesive is epoxy Araldite 2015 Failure load is increase moderately so strength of joints is higher than adhesive Araldite AV138 and the third adhesive showed the highest strength and improvement rate of failure load.

HE Dan, Prof.Toshiyuki SAWA, Takeshi IWAMOTO, Yuya HIRAYAMA [33] they works on the stress analysis and strength evalution of scarf adhesive joint subjected to static tensile loading used adherend SS400(JIS) mild steel and adhesive as epoxy In this paper, the stress distributions in scarf adhesive joints of adherend SS400(JIS) mild steel under static tensile loadings are analyzed using both the 2D and the 3D finite element method (FEM). The FEM conduced in ANSYS. The comparison between the results of the interface stress distributions of 2D& 3D were conducted. The effects of scarf angle, adhesive Young's modulus and adhesive thickness were also examined on the interface stress distributions. Finally conclude that scarf angle about 52° in 2D FEM calculation singular stress vanishes, however it doesn't vanish in 3D FEM. joint strength is maximum for a scarf angle of approximately 60°. As increasing in young's modulus singular stress at the edge of the interface decreases. With increase in the adhesive thickness the singular stress at the edge of the interface also increases. The singular stress obtained from the 3D FEM was larger than that obtained from the 2D FEM.

III. Conclusion

Lot of studies and researches has been done to improve all these characteristics that are reviewed in this paper. Following are the findings based on review multiple studies on adhesive bonded scarf joint by the author. The last decades, the investigation on the adhesive material has been well established and their applications have been enhanced. FEM, analytic and experimental analysis are used for design and various parameter of scarf joint. Optimizations research covered the mechanical properties of joint, strength of joint and composite adhesive material. Nevertheless there is no study on the NDT testing of scarf adhesive joint with the common parameter like thickness of adherend, thickness of adhesive and scarf angle which gives us knowledge of bonding quality and detect weak bonds that occur due to bonding interface contamination.

Reference

[1]. Z.Bao, M.Gao, Y.Sun, R.Nian, &M.Xian, "The recent progress of tissue adhesives in design strategies, adhesive mechanism and applications," Materials Science and Engineering: C, 110796. 2020. doi:10.1016/j.msec.2020.110796.

[2]. J.-N.Zhang , H.Zhu, T.Liu, Y.Chen, C.Jiao, C.He, &H.Wang, "Strong adhesion of hydro gels by polyelectrolyte adhesives," Polymer, 122845, 2020. doi:10.1016/j.polymer.2020.122845.

[3]. P. Mazza, F. Martini, B.Sala, M. Magi, M. Colombini, G. Giachi, F. Landucci, C. Lemorini,F. Modugno, E. Ribechini, "A new Paleolithic discovery: tar-hafted stone tools in a European Mid-Pleistocene bone-bearing bed," Journal of Archaeological Science. 33 (9): 1310, Jan 2006.

[4]. K.Arora, H.Xie, &E. D.Meter, "Methodology for Mitigating the Impact of Adhesive Shrinkage for PAAW Technology Applications," Procedia Manufacturing, 26, 1398–1410,

[5]. 2018.doi:10.1016/j.promfg.2018.07.108.

[6]. S.Ma, Y.Wu, &F.Zhou, "Bio-inspired Synthetic Wet Adhesives: from Permanent Bonding to Reversible Regulation," Current Opinion in Colloid & Interface Science, 2019. doi:10.1016/j.cocis.2019.11.010.

[7]. Kinloch, A.J. (1987). Adhesion and Adhesives: Science and Technology (Reprinted. Ed.). London: Chapman and Hall. p. 1. ISBN 0-412-27440-X.

[8]. Keegan, John (1989). The price of Admiralty. New York: Viking. P. 280. ISBN 0-670-81416-4.

[9]. JOURNAL OF STRAIN ANALYSIS VOL 9 NO 3 1974 IMechE 1974 , DOI: 10.1243/03093247V093185 The Journal of Strain Analysis for Engineering Design 1974 9: 185 R D Adams and N A Peppiatt S

[10]. ADAMS, R D. and PEPPIA'IT, N. A. 'Effect of Poisson's ratio strains in adherends on stresses of an idealized lap joint', J. Strain Analysis 1973 8,134-9.

[11]. Tsai. M. Y. and Morton, J. (1992a). On analytical and numerical solutions to the single-lap joint. Center for Adhesive and Sealant Science, VPI. Report CASS,/ESM-92-8.

[12]. Hart-Smith. L. J. (1973). Adhesive-bonded single-lap joints. NASA, CR-I 12236

[13]. GOLAND, M. and REISSNER, E. 'Stresses in cemented joints', J appl Mech, nuns Am SOC mech Engrs 1944 66,

[14]. Tsai. M. Y. and Morton. J. (1993). Global and local stress analyses of a short single-lap joint (in press).

[15]. Tsai. M. Y. and Morton, J. 11992b). A stress analvsis of a thermallv loaded bimaterial interface: a localized hybrid analysis. Me&. M&r. 13, 'I 17 130.

[16]. P.C. Pandey, H. Shankaragouda, Arbind Kr. Singh 0045-7949/99/$ - 1999 Elsevier Science Ltd. All rights reserved. PII:S0045-7949(98)00168-0

[17]. Lucas F.M. da Silvaa, R.D. Adamsb -0143-7496/$ - see front matter r 2006 Elsevier Ltd. All rights reserved. doi:10.1016/j.ijadhadh.2006.09.007

[18]. Fan-Rong Konga,b,- Min Youa, Xiao-Ling Zhenga, Hai-Zhou Yua -0143-7496/$ - see front matter r 2006 Elsevier Ltd.doi:10.1016/j.ijadhadh.2006.01.010

[19]. René Q. Rodrígueza , William P. Paivaa , Paulo Solleroa , Eder L. Albuquerqueb and Marcelo B. Rodriguesc https://www.researchgate.net/publication/292587611

[20]. Vokersen O., "Nietkraftverteiligung in zugbeanspruchten nietverbindungen mit konstanten Laschenquerschnitten", Luftfahrtforschung, 1938, pp. 15:41.

[21]. Ojalvo I.U, Eidinoff H.L., "Bond Thickness Effects upon Stresses in Single-Lap Adhesive Joints", American Institute of Aeronautics and Astronautics Journal, 1978, Vol.16, No 3, pp. 204:211.

[22]. Y. Pekbey Sci Eng Compos Mater 2014; 21(3): 389–400 DOI 10.1515/secm-2013-0145

[23]. Halil ozer1 and ozkan oz - Hindawi Publishing Corporation Mathematical Problems in Engineering Volume 2014, Article ID 852872, 16 pages http://dx.doi.org/10.1155/2014/852872
[24]. L. D. R. Grant , R. D. Adams & Lucas F. M. da Silva (2009) Experimental and Numerical Analysis of T-peel Joints for the Automotive Industry, Journal of Adhesion Science and Technology, 23:2, 317-338, DOI: 10.1163/156856108X383529
[25]. C. Soutis and F. Z. Hu - AIAA JOURNAL, VOL. 38, NO. 4: TECHNICAL NOTES, the American Institute of Aeronautics and Astronautics, Inc
[26]. Soutis C., and Hu, F. Z., "Design and Performance of Bonded Patch Repairs of CompositeStructures,"Proceedings of the InstituteofMechanical Engineers, Vol. 211, Pt. G, 1997, pp. 263–271.
[27]. Soutis, C., and Hu, F. Z., "Repair Design of Composites and Ef ciency of Scarf Patch Repairs," Proceedings of the ICCM, edited by M. L. Scott, Vol. 11, Woodhead Publishing Ltd., Gold Coast, Australia, 1997, pp. 395– 404
[28]. David W. Adkins, R. Byron Pipes (1985) DOI: 10.1201/9780429198656 ISBN: 9780429198656
[29]. L. J. HART-SMITH - Doc. no -19740005084 Hart-Smith, L. J.(McDonnell-Douglas Corp. Long Beach, CA, United States) - MACHINE ELEMENTS AND PROCESSES -NASA-CR-112237 CONTRACT_GRANT: NAS1-11234
[30]. R.D.S.G. Campilho, M.F.S.F.de Moura, D.A. Ramantani, J.J.L. Morais & J.J.M.S. Domingues INEGI - Institute of Science and Innovation in Mechanical and Industrial Engineering doi: 10.1016/j.proeng.2015.08.047 DOI: 10.1163/156856109X433045
[31]. Afendi M, et al. (2011), doi:10.1016/j.ijadhadh.2011.03.001
[32]. D. F. O. Silva; R. D. S. G. Campilho; F. J. G. Silva; U. T. F. Carvalho Applied Adhesion Science DOI: 10.1186/s40563-018-0115-2
[33]. R.D.S.G. Campilhoa, T.A.B. Fernandesa Procedia Engineering 114:102-109 DOI: 10.1016/j.proeng.2015.08.047
[34]. HE Dan, Prof.Toshiyuki SAWA, Takeshi IWAMOTO, Yuya HIRAYAMA International Journal of Adhesion and Adhesives 30(6):387-392 DOI: 10.1016/j.ijadhadh.2010.02.002
[35]. INEGI - Institute of Science and Innovation in Mechanical and Industrial Engineering
[36]. doi: 10.1016/j.proeng.2015.08.047
[37]. INEGI - Institute of Science and Innovation in Mechanical and Industrial Engineering
[38]. doi: 10.1016/j.proeng.2015.08.047
[39]. INEGI - Institute of Science and Innovation in Mechanical and Industrial Engineering
[40]. doi: 10.1016/j.proeng.2015.08.047
[41]. INEGI - Institute of Science and Innovation in Mechanical and Industrial Engineering
[42]. doi:10.1016/j.proeng.2015.08.04

Krunalkumar patel, et. al. "A Review Article on Analytical, Experimental and Comparative Study of Adhesive Scarf Joint." *IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)*, 17(5), 2020, pp. 35-40.