Int. J. Advanced Design and Manufacturing Technology, 2023, Vol. 16, No. 3, pp. 55-62

DOI: 10.30486/admt.2023.1966352.1376 *ISSN: 2252-0406* *https://admt.isfahan.iau.ir*

Investigation of Adhesion Behavior of Aluminum Laminates /Carbon Fiber/ High Silica Fiber by Phenol Resins

Kazem Salimi, Alireza Naddaf Oskoei
Department of Mechanical Engineering
Imam Hossein Comprehensive University, Tehran, Iran
E-mail: ksalimi90@gmail.com, anadaf@ihu.ac.ir

Rouhollah Hosseini*, Mohammad Javad Zeinalbeik
Department of Mechanical Engineering
Imam Hossein Comprehensive University, Tehran, Iran
E-mail: R.Hosseini.mech@gmail.com, m.zeinalbeik@gmail.com
*Corresponding author

Received: 27 August 2022, Revised: 26 December 2022, Accepted: 18 January 2023

Abstract: Fiber-metal laminate is a material constituted of composite laminate and metal sheets, whose mechanical properties can be tailored by varying the thickness, the number of layers and bonding type. For this reason, in this research, strength test, adhesion test and flux test for a sandblasted and etched aluminum sheet that contained a seven-layer composite with 2 types of adhesion treatment (phenol adhesive/resin of composite material) and front side composite layup (High-silica/High-silica+Carbon) were investigated. It was found that the above-mentioned factors influenced the flexural strength of FML; precisely, the presence of an adhesive layer between the composite plies and the metal sheet made the flexural strength decrease, while this mechanical parameter increased passing from two metal sheets to only one. The results show that the presence of carbon layer has led to the greatest increase in strength due to strong bonding. Also, the results of the flux test show that the behavior of the two samples is very close to each other.

Keywords: Carbon, High Silica, Phenol Resins, Strength

Biographical notes: Kazem Salimi is a PhD student in Mechanical Engineering Department at Imam Hossein Comprehensive University. **Alireza Naddaf Oskouei** is Associate Professor of Mechanical engineering at the Imam Hossein Comprehensive University, Iran. He received his PhD in Mechanical engineering from University of Metz, France. **Rouhollah Hosseini** is Assistant Professor of Mechanical engineering at the Imam Hossein Comprehensive University, Iran. He received his PhD in Mechanical engineering from University of Tehran, Iran. **Mohammad Javad Zeinalbeik** is a PhD student in Mechanical Engineering Department at Imam Hossein Comprehensive University. His current research interest includes Composite Material and EMI Shielding.

Research paper

1 INTRODUCTION

Nowadays, fiber-metal laminates are increasingly adopted for applications in several fields, such as aeronautics, auto-motive, and sport goods, since they present outstanding mechanical characteristics. These composites are a kind of hybrid material consisting of metal sheets alternating with composite material laminates. The exceptional structural properties are due to the peculiarities of the materials the FMLs are made of. In fact, these composites constructed by aluminum and glass-fiber composite that are the most used one for aeronautical applications are less strong than those based on carbon-fiber rein-forced polymer [1-2]. Carbon fiber–reinforced aluminum laminates are about 10% stronger than glass fiber–reinforced aluminum laminates for tensile loads [3]. In general, carbon-based composites have superior characteristics, such as concerns energy-absorption capacity, yield strength, tensile modulus, and fatigue strength, in comparison with aramid or glass fiber–based composites [4]. These composites present another exceptional peculiarity; mechanical properties can be easily tailored to specific requirements by changing the composite ply orientation, the thickness, and the number of layers [5]; moreover, is some cases, they can simplify the manufacturing process [6].

Fire and heat are among the threats that industrial parts can face. Among the methods used to deal with these threats is the use of fabric-reinforced ablative composites. These composites are widely used due to their excellent performance including high strength, high temperature resistance and low density. Phenolic-silica composites can be mentioned as the best options used for ablative composites in thermal insulation. In this regard, the most important issue is the decomposition behavior of the polymer matrix because silica or reinforcing silica fibers have a higher thermal stability than the polymer matrix. Ablative composites are materials that sacrifice themselves to protect the parts of the device against environmental factors such as very high temperature, ultrasonic environments, high pressure and chemical conditions. These types of fiber-reinforced composites are widely used in industry, aerospace, and other fields due to their excellent performance, including high temperature resistance, high strength, and low density.

Structural frames are subjected to bending loading, which represents the most diffused and consequently most studied, failure mode. Hu et al [7] studied the flexural behavior of these composites based on carbon fiber–reinforced PMR polyimide and titanium, determining a good structural strength at both room and high temperature. The effect of the metal-layers position in the material stacking was analyzed by Dhaliwal and Newaz [8] that produced and tested some CARALL specimens with carbon-fiber laminate as outside layers. They compared the flexural behavior of those laminates with that of standard CARALL, presenting aluminum layers outside, and found a superior strength. The effect of the aluminum layers strength and the fibers orientations on the in-plane bending behavior of CARALLs was studied by Xu et al. They found an increment in the bending strength as the quantity of the longitudinal fibers and the aluminum strength were increased. As concerns the progressive failure mechanism, at first the aluminum layers yield happened, coupled with tension damage of both resin and fiber in the section bottom and compression damage of the resin in the section top. Then, the delaminating arose in the laminate misspend, because of the unstable deformation [9-12].

In a research, Wang et al. [13] added silicon carbide particles with different volume percentages to carbon/phenolic composite and investigated mechanical and thermal properties using pressure test, thermal conductivity test and thermogravimetric analysis and fatigue strength using plasma wind tunnel test and scanning electron microscope. Composite is made by VIM method. The obtained results showed that carbon/phenolic composites with 5 volume percent SiC have optimal properties. In addition, adding SiC particles can lead to an obvious decrease in compressive strength, but on the other hand, it has a positive effect on thermal stability, thermal conductivity and anti-erosion performance and increases their values. Also, Wang et al. [14] in another study investigated the effect of adding zirconium carbide particles to carbon/phenolic composite on thermal stability and sacrificial properties. The composites were made by VIM method and the results were checked by thermogravimetric analysis and plasma wind tunnel test and morphological characteristics were checked using X-ray diffraction, scanning electron microscope and energy dispersive X-ray spectroscopy.

The results have shown that increasing the amount of ZrC can lead to a visible increase in the performance of coal, but due to the formation of a ZrO2 layer on the erosion surface, there is a visible decrease in the linear erosion rates and the temperature of the back plate. In a research, Heydari vini et al [15] fabricated 5Wt % Al/alumina composites by accumulative roll bonding process up to eight steps using Al1060. Microstructure, mechanical properties and corrosion behavior of the composite were studied by scanning electron microscopy (SEM), potentiodynamic polarization and electrochemical impedance spectroscopy (EIS), measurement in 3.5wt% NaCl solution. Results showed that Corrosion behavior of the composite revealed a considerable improvement in the main electrochemical parameters, as a result of enhancing influence of cold rolling. Also, the electrochemical experiments showed that corrosion resistance of samples increased with increasing the number of ARB cycles. After 8- cycle, ARB has a low corrosion density in comparison with high corrosion density of annealed specimens. Also, Heydari vini et al [16] worked on another study. In this investigation, Al1060 and pure copper were used to fabricate bi-metal Al–Cu composites via accumulative press bonding (APB) process. The Al and Cu bars were press bonded and continued up to five pressing steps. It was shown that both Al and Cu deform in the same style in the Al–Cu samples after two steps-APB steps and afterward Cu layers started to neck. Also, it was realized that the average value for the strength of the Al/Cu composites is upper than that of these two MMCs fabricated via one metal. The peeling strength of these products enhanced via the APB steps. Moreover, the effect of APB steps on the fracture and peeling surfaces of bi-metal composites has been investigated using scanning electron microscopy (SEM).

In another research, Heydari vini et al [17] utilized the WARM ARB technique as supplementary technique to heighten the mechanical and microstructural evolution of the casted Al/Al_2O_3 composite strips and the microstructure evolution and mechanical properties of these composites were considered versus different WARM ARB cycles by tensile test, average Vickers micro hardness test, wear test and scanning electron microscopy (SEM). The SEM results revealed that during the higher warm- ARB cycles, big alumina clusters are broken and make a uniform distribution of alumina particles. Saade Abdalkareem Jasim et al [18] investigated the effect of APB method on the bonding properties of bulk samples such as the number of APB process, Al_2O_3 wt.% and the pressing temperature by the peeling test. They established that stronger bonding with a good quality can be obtained by increasing the pressing temperature and decreasing the Al_2O_3 particles wt.% as the reinforcement. Also, growing the step number of the APB method increases the bonding strength up to step 2 and then reduces the average peeling force due to the strain hardening result of the metallic matrix during the accumulative pressing. So far, a lot of research has been done on various types of composite structures in the fields of energy absorption, energy harvesting, impact and explosion, static and dynamic loads, etc.

Zahedinia et al [19] investigated the effect of explosion on the FML plates experimentally and numerically. In this research, the explosion test was carried out using a Shock tube machine. The results of the empirical test were compared with the numerical simulation of these plates by the finite element software. It was found that experimental and numerical results are in good agreement. At the end, the results of the experimental test and finite element simulation were compared and a good match between the results was observed. The results of the experiments have shown that these plates do not even in loading less than 10 grams of C4 (equivalent to a pressure of 28 MPa) inside the shuck tube, and they are delaminated and in Loading 20 grams ruptured.

In all experiments, it can be seen that the back aluminum plate, due to the reflection of the compressive wave that converts to the tensile wave, is removed from the panel and deforms the plastic and makes the composite less damaged. Kiani et al [20] investigated Non-linear response of Fiber Metal Laminates subjected to Dynamic loading. In this study, by using of governing equation of non-linear behavior of FMLs, the effect of various parameter such as visco-Pasternak foundation and dynamic loading in environment temperature have been investigated. For this purpose, the geometric nonlinearity effects are taken into account with the von Kármán large deflection theory and the governing equations of motion for the plate are derived by the use of the virtual work principle. The results indicated that increasing the peak pressure values would lead to an increase in deformation and a decrease in the frequency ratio of the system. The results also show that FMLs would be a good choice for structures under dynamic loading.

Kiani et al [21] investigated Transient Nonlinear Response of FML's under Uniform Time-dependent Pressure Loading. In this study, the theoretical and numerical analysis of fiber metal laminates (FML's) subjected to time-dependent uniform pressure load has been investigated. For this purpose, the plate is modeled based on the Reddy's higher order shear deformation plate theory and the effects of the von Kármán geometric nonlinearity are included in the derivation of the motion equations. Results showed that by reducing the positive phase time of loading and increasing the waveform parameter, the effect of the negative phase of loading is amplified and leads to an increase in dimensionless displacement in the center of the plate. Also, it was realized that the linear stiffness parameter in comparison with the shear layer parameter has less effect on the dynamic response. Khondabi et al [22] investigated the performance of sandwich panels with aluminum tops and polyurethane foam core with variable density against explosive load experimentally and numerically. In this article, the explosive resistance of sandwich structures with aluminum tops and polyurethane foam core with variable (graded) density has been investigated. In this research, by preparing polyurethane foams with different densities and making sandwich panels from aluminum sheets and polyurethane foam core, using an explosive shock tube device, the effect of the gradual change in the density of the foam core and the order of foam layers with densities have been studied on the displacement value of the back surface of sandwich structures. Experimental and numerical studies showed that the displacement of the back surface of a sandwich panel with a graded foam core in the case where the foam layer with a higher density is located on the side where the explosion occurs, compared to a sandwich panel with a single layer core and the same mass is less and is more suitable as the main structure. Also, in the case that the foam layer with lower density is on the side of the explosion, the energy absorption ability of the panel increased. In another study, Khondabi et al [23] investigated the effect of core density on the energy absorption capability of sandwich panels with aluminum plates and polyurethane foam core experimentally and numerically. In this article, by preparing polyurethane foams with different densities and making sandwich panels from aluminum sheets and polyurethane foam core, using an explosive shock tube device, a number of explosive tests are defined and the effect of foam density on the amount of displacement of the back surface of the sandwich structure and its energy absorption rate have been studied. The results showed that with the increase in foam density, the displacement of the back surface of the sandwich panel decreases, but the energy absorption of the panel also decreases. Khondabi et al [24] in another study, investigated Core and Face-Sheet Thickness Effects in Sandwich Panels with Foam Core and Aluminum Face-Sheets Subjected to Blast Loading experimentally and numerically. In this study, several aluminum sandwich panels with polyurethane foam core having different thickness were designed and tested using a shock tube facility. Some blast tests were performed in order to determine the effects of foam thickness on displacement of back face-sheet and energy absorption of sandwich structures. Using experimental investigation and parametric studies, it is shown that the amount of displacement of back face-sheet of sandwich structures is decreased and energy absorption is increased as foam and back face-sheet thickness is increased. Hatampour et al [25] investigated Plastic Deformation of Sandwich Panels Made of Reinforced Polymeric Foam under Explosive Loading. In this study, experimental investigation and regression analysis are investigated on plastic deformation of polyurethane composite sandwich panels reinforced with nanoclay under blast loading. For this purpose, polyurethane sandwich panels were prepared with different percentages of nanoclay and in different densities. The response surface methodology was used to investigate the effect of significant parameters, the percentage of nanoclay and density of polyurethane foam, on the displacement of composite sandwich panels and to optimize the parameters for minimum deformation. The results obtained from the regression model at 95% confidence level indicate a very good agreement between the experimental results and the values predicted by the model. The high value of the correlation coefficient between the studied parameters and the amount of plastic deformation of the sandwich panel (R 2 = 99%) indicate that the proposed model has higher accuracy. Finally, the optimal conditions for achieving the minimum displacement of composite sandwich panels were determined as 1.57% nanoclay content and foam density of 130 kg/m^3. In a study, Hoseini et al [26] investigated The Width Reduction Effect of a Piezoelectric Energy Harvesting Composite Beam on Output Power experimentally and numerically. In this research, a novel cellulose piezoelectric material embedded on a cantilever beam is used to harvest energy from the structure and the effect of reducing the width of the beam is investigated. In addition, in order to obtain the maximum output power, the series and parallel connections of the piezoelectric layers are considered. First, an experimental work is carried out on a fixed-width energy scavenger beam, and the current, voltage and output power are extracted. Then the target beam is divided into two and three equal parts and connected in series and parallel, and the results are analyzed for each case separately. Next, an analytical study of the effect of frequency on the width reduction of the beam is considered. For the first time in the analytical work, the effect of adding a piece of piezoelectric layer that covers a part of the cantilever beam is considered in terms of natural frequency and output power. Finally, the amount of energy harvested from the unit beam is analyzed analytically and the analytical solution output is verified with experimental results. The results show that there is a good agreement between the analytical and experimental data.

One of the fields that has been less addressed is the use of composite structures as thermal insulation, which is investigated in this article. According to the researches that have been reviewed, flexural behavior of composite based on carbon fiber–reinforced PMR polyimide and titanium and CARALL specimen were investigated. Also, some works done on various types of composite structures in the fields of energy absorption, energy harvesting, impact and explosion, static and dynamic loads are reviewed. The type of bonding composite to aluminum and the front layer of the composite affects some properties of the sample. The aim of the present work is concerning the flexural behavior study of CARALL specimens, analyzing the influence of both layer thickness and the adhesion between CFRP layer and aluminum sheet. In this research strength test, adhesion test and flux test for a sandblasted and etched aluminum sheet that contained a seven-layer composite with 2 types of adhesion treatment and front side composite layup have been investigated. One type, aluminum sheet bonded to composite by a phenol adhesive layer and, the front layer is a High-Silica and another type, aluminum sheet bonded to composite by the resin contained in the composite material and the front layers are High-Silica and Carbon.

2 EXPERIMENTAL PROCEDURES

The results of the phenol resin identification test are shown in "Table 1".

Table 1 Results of XRF analysis

Oxide	Wt%	Oxide	Wt%	Oxide	Wt%	Oxide	Wt%
Al_2O_3	0.82	SiO_2	86.18	P_2O_5	0.51	K_2O	0.15
TiO_2	0.92	Fe_2O_3	0.06	CaO	0.13	L.O.I	11.23

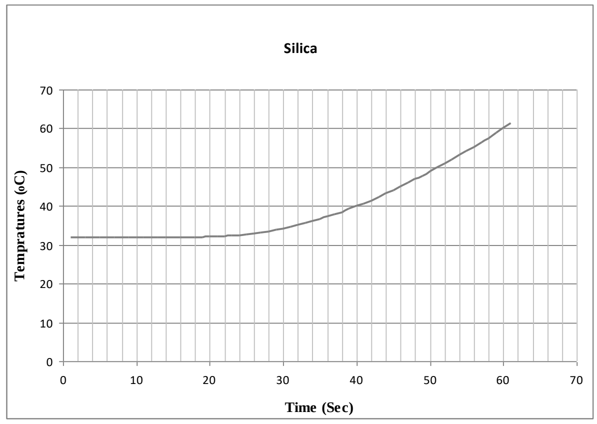
The results show a high purity of 88%, and the rest is additive. The results of the adhesion test are given in "Table 2". The results show that the adhesion strength is at the limit of phenol resin, which indicates its proper adhesion. This position is due to surface preparation. The results of the heat flux test are shown in "Fig. 2".

Table 2 Results of Pull-Off test

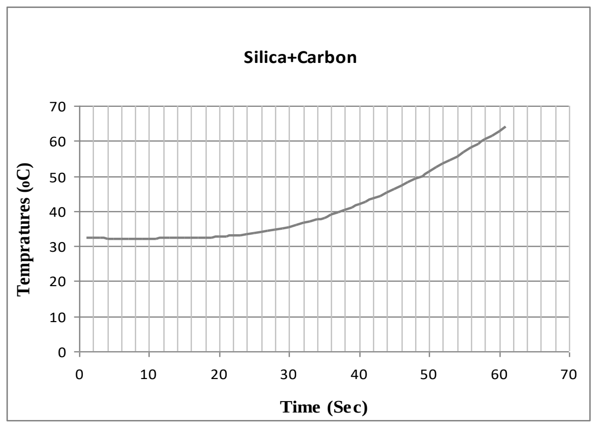
No.	1	2	3	4	5
Strength (MPa) Type (A)	5	5	5.5	5.5	5.5
Strength (MPa) Type (B)	6	5.5	6	5.5	6.5

According to the ASTM D 1259-18 standard, the percentage of non-volatile substances in the sample is 82.4 wt%. The density is 1.26 g/cm^3.

The laminates were produced by vacuum bag process, so the raw materials were stacked on a plane mold as requested; then the stack was closed in the bag and cured in the autoclave. After curing, the specimens were cut from the laminates and tested. The adhesion strength was determined by three points bending test according to ASTM D4541. Pull-Off strength test based on reference standard ASTM D 4541-17 was performed. The specifications of the model 108ELCOMETER devices are hydraulic, and the shape and drops of the gage used are circles with a diameter of 19 mm, and the specifications of the adhesive used are adhesive Cyanoacrylate with a curing time of 1 hour. The force application rate is 1 MN/s.



(a)



(b)

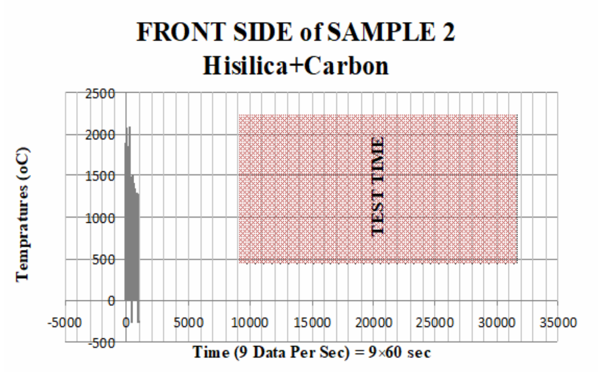
Fig. 1 Results of the flux test. a) High silica and b) High silica + carbon.

3 DISCUSSIONS

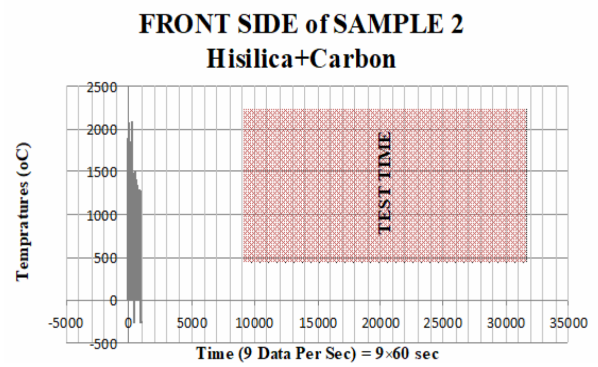
The results of the adhesion test are given in "Table 2". The results of the adhesion test show a strength value close to that of phenol resin.

In "Fig. 1", the conditions for performing the flux test include: acetylene flow rate (Nm^3/h) = 0.7 and oxygen flow rate (Nm^3/h) = 0.6 and acetylene pressure = 0.85 Bar and oxygen pressure = 2.18 Bar and burning time = 60 Sec. The sample surface temperature range is 1200 ºC. The results of which are shown in "Fig. 2". These two examples of behavior are very close to each other. But Temperature in silica+carbon sample is a little more than silica sample.

The full factorial plan of the experimental activity is composed of two levels for each of the examined factors, which are the stacking sequence and the bonding method. As concerns the former element, two FMLs were considered: one consisting of an aluminum layer consisting of seven ones made of composite, the other formed by seven layers of composite alternated with two carbon 200 and High-silica sheets. With regard to the bonding technique, the interface between composite and metal was assured by a phenol adhesive layer or by the resin contained in the composite material.



(a)

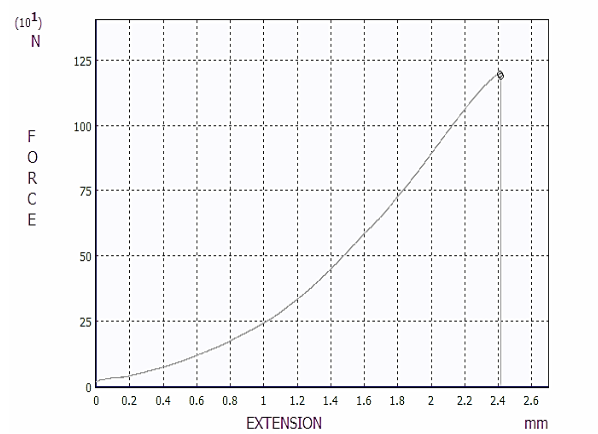


(b)

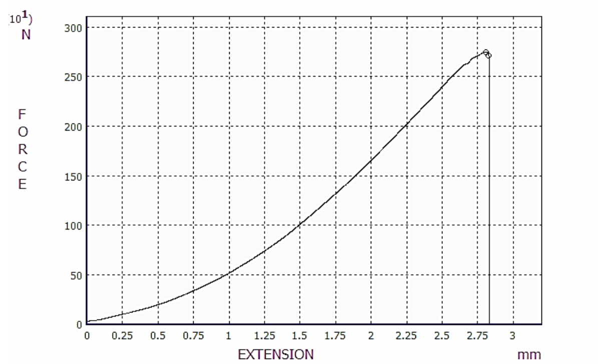
Fig. 2 Results of the flux test. a) High silica and b) High silica + carbon.

The adhesion strength was determined by three points bending test according to ASTM D4541, as shown in "Table 2". The adhesion strength ranged between 5.5 and 6 MPa (Type A) for the laminate with one anodizing aluminum sheet bonded with adhesive, while it oscillated between 5 and 5.5 MPa (Type B) for the same laminate without the adhesive, in which the composite material bonding on aluminum sheet was assured by the sole prepreg resin.

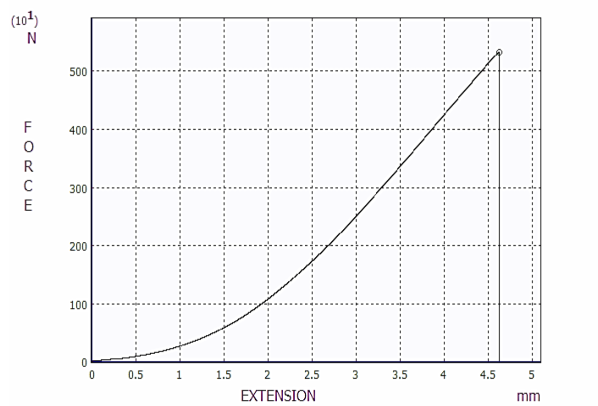
It is worth noting that the results found in this experimental campaign are in accordance with other works on this class of material. The coefficient of variation (CoV) was very low. In fact, it was equal to about 5.5% to 7.3%, and only for seven metal sheets bonded with resin it reached 10%. From the results in "Fig. 2", it can be noted that the highest flux belonged to the laminate with carbon sheet bonded with phenol resin, while the lowest value to that one with silica sheets joined with adhesive. Moreover, the data scattering is low, so the results are repeatable. Therefore, it can be concluded that the presence of adhesive was negative for the material flux, while the increase of metal sheet numerousness was beneficial. The negative influence of the adhesive is apparently in contradiction with past literature, but in the same paper, it is affirmed that the results depend on the specimen dimension, so a reliable comparison is difficult. The presence of adhesive lessens the overall fiber content, and so the material strength and flux are affected. "Table 2" is an example of the pull off test and "Fig. 1" shows the comparison of flux for the different types. The strength test results of phenol, phenol with high silica and carbon samples are given in "Fig. 3". The results show that the presence of carbon layer has led to the greatest increase in strength due to strong bonding. Also, in carbon sample, more extension than phenol and phenol with silica has been observed.



(a)



(b)



(c)

Fig. 3 Compression of strength test results of: (a): phenol, (b): phenol with silica, and (c): carbon samples.

4 CONCLUSIONS

In this research strength test, adhesion test and flux test for a sandblasted and etched aluminum sheet that contained a seven-layer composite with 2 types of adhesion treatment (phenol adhesive/resin of composite material) and front side composite layup (High-silica/High-silica+Carbon) were investigated. It was found that adhesion layer and front layer layup affect properties of the samples. The presence of an adhesive layer between the composite plies and the metal sheet made the flexural strength decrease, while this mechanical parameter increased passing from two metal sheets to only one. The results show that the presence of carbon layer has led to the greatest increase in strength due to strong bonding. Also, the results of the flux test show that the behavior of the two samples is very close to each other.

REFERENCES

[1] Xu, R., Huang, Y., Lin, Y., Bai, B., and Huang, T., In-Plane Flexural Behaviour and Failure Prediction of Carbon Fibre-Reinforced Aluminium Lami-Nates, J Reinf Plast Compos, Vol. 36, 2017, pp. 1384-1399.

[2] Rajkumar, G. R., Krishna, M., Narasimhamurthy, H. N., Keshavamurthy, Y. C., and Nataraj, J. R., Investigation of Tensile and Bending Behavior of Alu-Minum Based Hybrid Fiber Metal Laminates, Procedia Mater Sci., Vol. 5, 2014, pp. 60-68.

[3] Botelho, E. C., Silva, R. A., Pardini, L. C., and Rezende, M. C., A Review on The Development and Properties of Continuous Fiber/Epoxy/Aluminum Hybridcomposites for Aircraft Structures, Mater Res., Vol. 9, 2006, pp. 247-526.

[4] Kim, J. G., Kim, H. C., Kwon, J. B., Shin, D. K., Lee, J. J., and Huh, H., Tensile Behavior of Aluminum/Carbon Fiber Reinforced Polymer Hybrid Composites Atintermediate Strain Rates, J Compos Mater., Vol. 49, 2015, pp. 1179-1193.

[5] Şen, I., Alderliesten, R. C., Benedictus, Lay-up Optimisation of Fibre Metal Laminates Based on Fatigue Crack Propagation and Residual strength, Compos Struct, Vol. 124, 2015, pp. 77-87.

[6] Bellini, C., Polini, W., and Sorrentino, L., A New Class of Thin Composite Parts for Small Batch Productions, Adv Compos Lett., Vol. 23, 2014, pp. 115-120.

[7] Hu, Y. B., Li, H. G., Cai, L., and et al., Preparation and Properties of Fibre-Metal Laminates Based on Carbon Fibre Reinforced PMR polyimide, Compos Part B Eng., Vol. 69, 2015, pp. 587-591.

[8] Dhaliwal, G. S., Newaz, G. M., Experimental and Numerical Investigation of Flexural Behavior of Carbon Fiber Reinforced Aluminum Laminates, J Reinf Plast Compos., Vol. 35, 2016, pp. 945-956.

[9] Bellini, C., Di Cocco, V., Iacoviello, F., and Sorrentino, L., Experimental Analysis of Aluminium Carbon/Epoxy Hybrid Laminates Under Flexural Load, Frattura ed Integrità Strutturale., Vol. 48, 2019.

[10] Pan, L., Ali, A., Wang, Y., Zheng, Z., and Lv, Y., Characterization of Effects of Heat-Treated Anodized Film on The Properties of Hygrothermally Aged AA5083-Based Fiber-Metal Laminates, Compos Struct, Vol. 167, 2017, pp. 112-122.

[11] Rajan, B. M. C., Kumar, A. S., The Influence of The Thickness and Areal Density on The Mechanical Properties of Carbon Fibre Reinforced Alumin-Ium Laminates (CARAL), Trans Indian Inst Met., Vol. 71, 2018, pp. 2165-2171.

[12] Li, H., Hu, Y., Fu, X., Zheng, X., Liu, H., and Tao, J., Effect of Adhesive Quantity on Failure Behavior and Mechanical Properties of Fiber Metal Lam-Inates Based on The Aluminum-Lithium Alloy. Compos Struct., Vol. 152, 2016, pp. 687-692.

[13] Shuang Wang, H. H., Ye, T., and Jie. H., Effects of SiC Content on Mechanical, Thermal and Ablative Properties of Carbon/Phenolic Composites, Ceramics International, 2020.

[14] Shuang Wang, H. H., Ye, T., Effects of Zirconium Carbide Content on Thermal Stability and Ablation Properties of Carbon/Phenolic Composites, Ceramics International, 2019.

[15] Heydari Vini, M., Daneshmand, and S., Jahangiri Sadri, A., The Investigation of the Corrosion Resistance of Al/Alumina Composites Fabricated Via ARB Process. New Process in Material Engineering, 2022, Vol. 16, No. 3, pp. 43-54.

[16] Heydari Vini, M., Daneshmand. S., Mechanical and Bonding Properties of Bi-Metal Al/Cu Bulk Composites Produced Via ABP Technique, Surface Review and Letters, Vol. 28, NO. 11, 2021.

[17] Heydari Vini, M., Daneshmand. S., Mechanical and Wear Properties Evaluation of Al/Al2O3 Composites Fabricated by Combined Compo-Casting and WARB Process, Advances in Computational Design, Vol. 7, No. 2, pp. 129-137.

[18] Abdalkareem Jasim, S., Heydari Vini, M., and Daneshmand, S., Bonding Properties of $Al/Al_{2}O_{3}$ Bulk Composites Produced Via Combined Stir Casting and Accumulative Press Bonding. Surface Review and Letters, Vol. 29, No. 04, 2022.

[19] Zahedinia, M., Hosseini, R., Khodarahmi, H., and Ziashamami, M., Experimental and Numerical Study of Deformation of FML Plates with the Same Thickness Under Explosive Loading, Journal of Solid and Fluid Mechanics, Vol. 8, No. 4, pp. 129-142.

[20] Kiani, A., Hosseini, R., and Khodarahmi, H., Non-Linear Response of Fiber Metal Laminates Subjected to Dynamic Loading, In Persian, Journal of Science and Technology of Composites, Vol. 7, No. 1, 2020, pp. 768-778.

[21] Kiani, A., Hosseini, R., Khodarahmi, H., Investigation of Transient Nonlinear Response of Fiber Metal Laminates (fml's) under Uniform Time-Dependent Pressure Loading, Journal of Aerospace Mechanics, Vol. 18, No. 3, 2022, pp. 109-125.

[22] Khondabi, R., Khodarahmi, H., Hosseini, R., and Zia Shamami, M., Experimental and Numerical Investigation on Performance of Sandwich Panels Using Aluminum Faces and Polyurethane Foam Core with Variable Density Against Explosive Loading, Iranian Mechanical Engineering Research Journal, Vol. 22. No. 1, 2020.

[23] Khondabi, R., Khodarahmi, H., Hosseini, R., and Zia Shamami, M., Experimental and Numerical Investigation into the Effect of Core Density on the Energy Absorption of Sandwich Panels with Aluminum Face Sheets and Polyurethane Foam Core. Amirkabir J. Mech. Eng., Vol. 52, No. 10, 2021, pp. 705-708.

[24] Khondabi, R., Khodarahmi, H., Hosseini, R., and Zia Shamami, M., Experimental and Numerical Study of Core and Face-Sheet Thickness Effects in Sandwich Panels with Foam Core and Aluminum Face-Sheets Subjected to Blast Loading, Journal of Solid and Fluid Mechanics, Vol. 8, No. 3, pp. 91-106.

[25] Hatampour, M., Hosseini, R., Hasanzadeh, M., and Vahedi, K. H., Experimental Investigation and Regression Analysis on Plastic Deformation of Sandwich Panels Made of Reinforced Polymeric Foam under Explosive Loading, Modares Mechanical Engineering, Vol. 20, No. 11, 2020, pp. 2671-2678.

[26] Hoseini, R., Elhami, M. R., Mansouri Lotfali, S., Marashi, S., The Width Reduction Effect of a Piezoelectric Energy Harvesting Composite Beam on Output Power: An Experimental and Analytical Study, Journal of Aerospace Mechanics, Vol. 17, No. 3, 2021, pp. 71-83.