A Review of The Investigation on The Effectof Fiber Fillerson The Mechanical Behaviorof Composite Laminates

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Abstract- *Academic and industry researchers are focused on developing a material that satisfies various parameters such as durability, manufacturability, low cost, lightweight, adaptability, high strength, bio-degradability, etc. to meet the current day trends across aerospace and automotive industries. In engineering and technology, fiber-reinforced matrix composites and their applications are extensive. The addition of fillers (both natural and synthetic) along with matrix and fibers is considered to be a better option to increase the efficiency and performance of the composite materials. Recently, researchers have focussed on adding fillers along with matrix and its hybridization to lift the composite properties and applications. This review paper briefly describes the investigation of the effect of fiber fillers on the mechanical behavior of composite materials and structures.*

Keywords- Composite materials & structures, Matrix, Fibers, Fillers, Mechanical properties.

I. INTRODUCTION

As discussed in the abstract, composite materials and structures are major research areas that are well-suited for aerospace and automotive applications. Generally, composites are cheaper and have a good strength-to-weight ratio. Recent day researchers have focused greatly on developing a material with matrix and fiber along with fillers (either natural or synthetic). The addition of fillers influences the mechanical properties of the composite materials significantly. To prepare a material that satisfies various properties and to enhance mechanical properties, the filler addition to the matrix and hybridization of fibers are a better option. This review paper briefly describes only the addition of fillers to the mechanical properties of a composite material. The filler addition influences the properties of the composites which depends on the filler size, shape, aspect ratio, surface area, etc. to meet the current trends of the material for the engineering applications.

The addition of fillers to the matrix enhances properties and processability and reduces the cost of material. The fillers may be micro or nano-sized particles. From the various research studies, it is concluded that the use of nano-sized filler would be an ideal option to improve properties as nano-sized particles are characterized by as high aspect ratio and specific surface area. The interaction between the polymer fiber and matrix increases with the addition of an optimum composition of fillers. After a certain limit of addition of fillers results in decreased properties because the agglomerations of the fillers take place. Hence, the application of nanofillers within the polymer matrix is an extensive research area in the field of engineering and technology.

Natural fibers are environment friendly, as it is biodegradable, and good recyclability. They are cheaper than conventional synthetic fibers. They are abundant in nature, and renewable, causing low risk to human health. Composites replace conventional materials like steel, aluminum, etc in most of the aircraft components due to their high strength-to-weight ratio. But almost all synthetic fibers are used in aerospace due to their higher strength than natural ones, and for safety. However, by using milled fillers of natural fibers, we try to improve the strength of natural fiber composite up to about 70-80% of that of synthetic fibers, so that natural fiber composites may be incorporated in aircraft components shortly. The damaged or utilized composites can be treated appropriately (mechanically, chemically, or thermally to extract the fibers alone to be used as fillers in new composite laminates, as these fibers can be milled (powdered/chopped), and used as fillers to enhance the mechanical properties of the composites.

Generally, the addition of fillers along with resin and fiber improves mechanical properties. Including fillers in the interlayer enhances the delamination resistance by providing a bridging effect, therefore demanding additional energy to initiate the crack in the interlaminar domain, which results in turn in enhanced fracture toughness. The mechanism observed suggests that crack propagation is stabilized even leading to its

arrest/deflection, as a considerable amount of milled fiber filler was oriented transverse to the crack path. In contrast, at higher filler loading, a tendency towards stress concentration grows due to local agglomeration and improper dispersion of excess fillers in inter/intralaminar resin channel, causing poor adhesion to the matrix, which leads to a reduction in fracture toughness, and strength and strain to failure. The literature review which follows next briefly describes the investigation of the effect of fiber filler on the mechanical behavior of composite structures and materials.

II. LITERATURE REVIEW

[1] G.L. Devnani, Shishir Sinha. Effect of nanofillers on the properties of natural fiber reinforced polymer composites. ScienceDirect Materials Today: Proceedings 18 (2019) 647–654 ICN3I-2017

Investigation of the effect of nanofillers on the mechanical properties of fiber-reinforced polymer composites. The addition of nanofillers influences the mechanical properties and water absorption properties. To keep a balance in terms of properties, it is evident to use the optimum composition of filler material to improve properties significantly. Various nanofibers are used as fillers such as granite, nano-Sio2, CNT, graphene, etc.

[2] Vikas Dhawan, Sehijpal Singh and Inderdeep Singh. Effect of Natural Fillers on Mechanical Properties of GFRP Composites. Hindawi Publishing Corporation. Journal of Composites. Volume 2013, Article ID 792620, 8 pages http://dx.doi.org/10.1155/2013/792620

This paper briefly presents the effect of natural fillers on the mechanical properties of the GFRP composites. The natural fillers used are rice husk, wheat husk, and coconut coir. The matrix materials used along with GFRP are polyester and epoxy resins. The addition of fillers leads to the cost and weight reduction of the glass fiber-reinforced composites. From the paper, we found that the natural fillers with polyester-based composites provide better results than the epoxy-based composites. Water absorption is more in polyester-based composites. In general, we infer that to improve the properties of the GFRP, coconut coir fillers should be used instead of rice husk and wheat husk. Figure 1 clearly illustrates that the izod impact strength of polyester-based composites with coconut coir as fillers was found to be the best among all the composites fabricated.

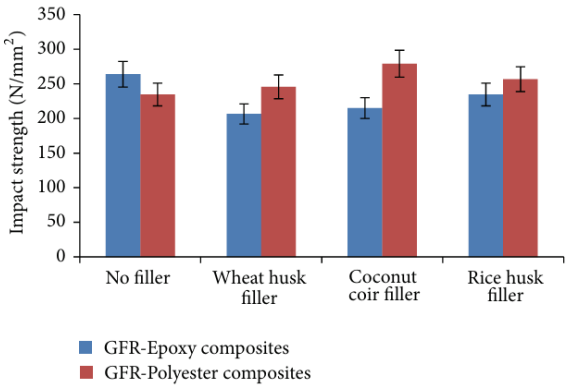


Figure 1: Izod Impact Strength of composites with/without filler.

[3] K. Saravanakumar, Harini Subramanian, V. Arumugam, H. N. Dhakal. Influence of milled glass fillers on the impact and compression after impact behavior of glass/epoxy composite laminates. Polymer Testing Volume 75, May 2019, Pages 133-141

Investigation into the effect of milled glass fiber fillers on GFRP with epoxy resin was carried out in this research study.With the optimum usage of the milled glass fiber filler on GFRP with epoxy resin, we can infer that the improvement in impact damage and residual CAI behaviors was evident. The glass filler-loaded samples resulted in a higher peak force than the baseline samples of GFRP. Thus, the improved properties of the glass fiber filler loaded GFRP are very good materials for the application of materials in aerospace and automotive industries as they possess good load-bearing applications.

[4] Kannivel Saravanakumar, Vellayaraj Arumugam, Rotte Souhith and Carlo Santulli. Influence of Milled Glass Fiber Fillers on Mode I & Mode II Interlaminar Fracture Toughness of Epoxy Resin for Fabrication of Glass/Epoxy Composites. Fibers 2020, 8(6), 36; https://doi.org/10.3390/fib8060036

Investigation of mode I and mode II interlaminar fracture toughness tests on GFRP were performed with various loadings of recycled milled glass fiber. The addition of milled glass fiber fillers (5 wt.%) with GFRP along with epoxy resin resulted in significant improvement in the interlaminar fracture toughness without affecting the flexural properties. Fractured surfaces analyzed using scanning electron microscopy (SEM) revealed several mechanisms, such as crack deflection, individual debonding, and filler/matrix interlocking, all contributing in various ways to improve fracture toughness.

[5] Manickam Ramesh, Lakshmi Narasimhan Rajeshkumar, Nagarajan Srinivasan, Damodaran Vasanth Kumar, and Devarajan Balaji. Influence of filler material on properties of fiber reinforced polymer composites: A review. E-Polymers 2022; 2:898–916. https://doi.org/10.1515/epoly-2022-0080

This paper briefly reviews the influence of filler material on the properties of FRP composites. In many cases, the addition of fillers with FRP composites resulted in obtaining higher mechanical and thermal properties. Filler material increases the adhesion between fiber and matrix and thus enhances water resistance. The filler addition increases the sound absorption coefficient of the FRP composites due to the porosity nature of the filler (refer to Figure 2). Such filler-reinforced composites find their applications in many areas requiring electrical conductivity, dielectric medium, and in electrical and electronics applications due to the formation of dense percolation networks.

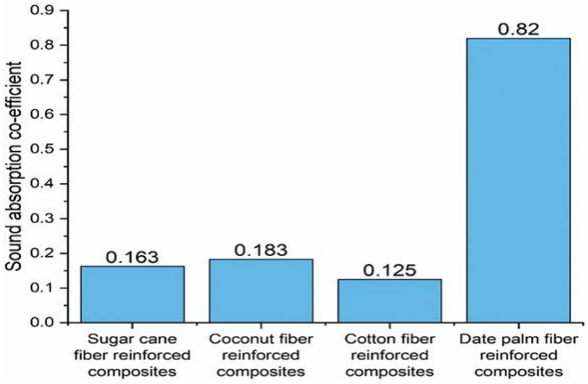


Figure 2: Sound absorption coefficient of hybrid composites

[6] A. Włodarczyk-Fligier, M. Polok-Rubiniec, B. Chmielnicki. Polypropylene-Matrix Polymer Composites with Natural Filler. Arch. Metall. Mater. 66 (2021), 1, 313-319. DOI: 10.24425/amm.2021.134789

Investigation into the effect of natural filler on polypropylene matrix polymer composites was carried out. The filler material used in this research study is walnut shell flour filler with various concentrations. A small effect on the filler fraction size was studied and observed. The low density of the material depends in particular on the material porosity. The composite material was characterized by low density, which increased with the rising filler content. The composites produced with filler are characterized by an increase in hardness and stiffness along with the increase in the filler content in the polypropylene matrix and a decrease in tensile strength was observed.

[7] Mauro Giorcelli, Aamer Khan, Nicola M. Pugno, Carlo Rosso, Alberto Tagliaferro. Biochar is a cheap and environmentally friendly filler able to improve polymer mechanical properties. Biomass and BioenergyVolume 120, January 2019, Pages 219-223.

This research study reports the use of biochar derived from the maple tree as a filler material in epoxy resin matrix composites. The stiffnessofthematrixwasenhancedby the addition ofsmallamountsofBiochar.Higherfiller contents ledtolowerenhancementof thestiffness.The biochar filler additionaffects thecompositebehavior transforming theblankepoxy frombrittle toductile composite.The addition of filler enhanced the young modulus and resilience. 1wt% addition led to a small enhancement of tensile toughness. From the study, we can infer that the addition of an optimum amount of biochar filler material influences the mechanical properties of the composite laminates.

[8] Halimatuddahliana Nasution, Hamidah Harahap, Rima Riani, Askalani Iqbal Pelawi. The Effect of Filler Particle Size on the Mechanical Properties of Waste Styrofoam Filled Sawdust Composite. International Journal of Science and Engineering Investigations vol. 7, issue 72, January 2018 ISSN: 2251-8843

Investigation into the effect of filler particle size on the mechanical properties of waste styrofoam-filled sawdust composite was carried out. The composites contained wt.% of 70 and 30 of Styrofoam and sawdust. The compatibilizer used was maleic anhydride. Results concluded that the incorporation of 150 microns has increased the mechanical properties of the composite such as tensile strength (33 MPa), flexural strength (15.4 MPa), and impact strength (300 J/cm2). The scanning electron microscopy (SEM) images of the 150-micron composite sample showed good distribution and a reduced amount of the voids present in the composite (refer to Figure 3).

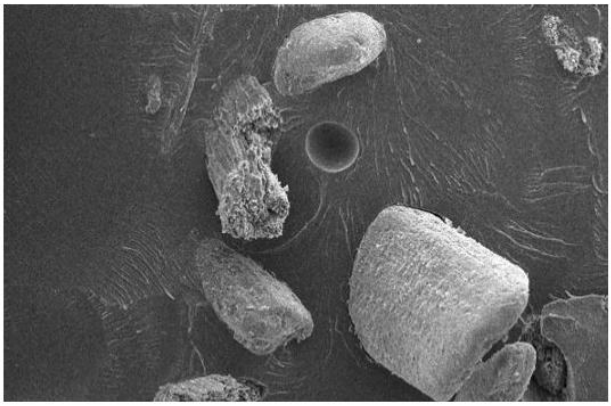


Figure 3: SEM micrographs of surface Styrofoam-sawdust composite (150-micron composite sample)

[9]Sunnatilla Aliev, Elmurod Egamberdiev, Sadriddin Turabdjanov, Shokhzodbek Rashidov and Asror Juraev. Role of fillers in the production of wood-polymer composites. E3S Web of Conferences 434, 02030 (2023) ICECAE https://doi.org/10.1051/e3sconf/202343402030

Investigation of the effect of various properties by incorporating the filler with wood polymer composites (WPC). The resulting physical and mechanical properties are much greater than expected. The possibility of using WPC with fillers in outdoor construction work was confirmed with the properties of water absorption and swelling composition. The filler incorporated WPC materials have a sufficiently high resistance to climatic factors.

[10] Erna Frida, Nurdin Bukit, Ferry Rahmat Astianta Bukit, Bunga Fisikanta Bukit. Effect of Hybrid Filler Oil Palm Boiler Ash – Bentonite on Thermal Characteristics of Natural Rubber Compounds. Ecological Engineering & Environmental Technology 2023, 24(2), 205–213 https://doi.org/10.12912/27197050/156961

Investigation on the thermal characteristics of natural rubber compounds with the addition of hybrid filler that is the oil palm boiler ash bentonite. The mechanical properties of the natural rubber compounds increase significantly with the addition of the hybrid filler. From the study, it is inferred that there is excellent interaction between the natural rubber compounds and hybrid filler material system and hence proved that the material is semicrystalline so that it can be processed.

[11] Oghenerukevwe Prosper, Hilary Uguru. Effect of Fillers Loading on the Mechanical Properties of Hardwood Sawdust/Oil Bean Shell Reinforced Epoxy Hybrid Composites. 2018 IJSRSET | Volume 4 | Issue 8 | Print ISSN: 2395-1990 | Online ISSN: 2394-4099

This research study aims to prove that HSD, OBPS, and epoxy would be a substitute for Wood-based material composites in many industrial applications. The addition of natural fillers to epoxy matrix material improved the mechanical properties of the composite laminate (up to 50%), but after further increment in the weight of fillers led to a decrease in the mechanical properties. From the study, it is inferred that the composite material's mechanical properties are completely influenced by the filler loading and matrix adhesion.

[12] Sudeep Deshpande, T Rangaswamy. Effect of Fillers on E-Glass/Jute Fiber Reinforced Epoxy Composites. Int. Journal of Engineering Research and Applications ISSN: 2248-9622, Vol. 4, Issue 8 (Version 5), August 2014, pp.118-123

Investigation on the effect of mechanical properties of fiber-reinforced epoxy composite with the addition of varying concentrations of bone and coconut shell powders was carried out. The maximum impact strength was observed in the composite filled with 15% volume bone powder. The maximum ultimate tensile strength was observed in a composite filled with 10% volume coconut shell powder. Thus, it is inferred that the filler addition influences the mechanical properties of the fiber-reinforced composites.

[13] Gogu Venkateswarlu, Ravirala Sharada, and Mamidi Bhagvanth Rao. Effect of fillers on mechanical properties of PTFE-based composites. Scholars Research Library Archives of Applied Science Research, 2015, 7 (7):48-58

This research study focuses on the incorporation of fillers into the mechanical properties of polytetrafluoroethylene (PTFE). The different fillers that were used for the systematic study are glass, granite, graphite, garnet, alumina, antimony trisulphide, carbon, marble, mica, sand, bronze, wollastonite, porcelain, china clay, and tixolex – 25. Results indicated that the highest hardness value-based composites were found to be 15,20 and 25% in the case of garnet-filled PTFE, 50% in the case of marble-filled PTFE and 40% in porcelain-filled PTFE, 5% bronze-filled PTFE shows highest tensile strength and % elongation values. Some fillers failed to be incorporated as a filler due to various reasons such as failure in some experimental tests.

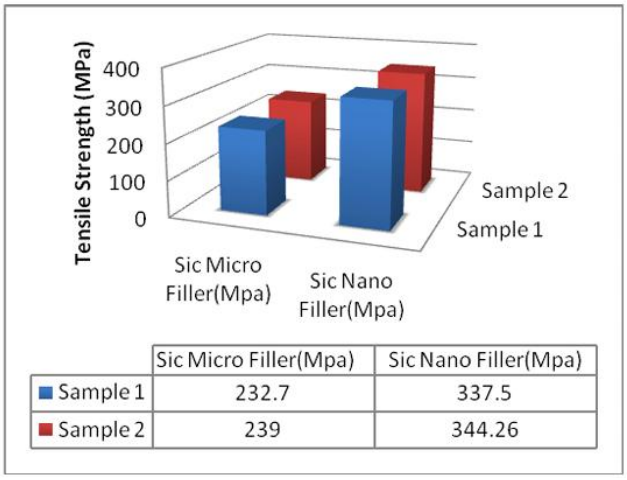
[14] Sanjay Kumar M Sajjan, Vittal Kumar A Bongale, Atith D, B Yogesha. Study on the Mechanical Properties of Natural Fiber Reinforced Hybrid Composites with Natural Rubber as a Filler. International Journal for Research in Engineering Application & Management (IJREAM) ISSN: 2454-9150 Vol-06, Issue-09, DEC 2020.

Investigation on the effects of mechanical properties on the natural fiber reinforced hybrid composites with natural rubber as a filler material. The composites were fabricated by vacuum bagging technique. The tensile properties of ramie-sisal composites remain the same despite the addition of filler. The tensile strength of the basalt-based composites was influenced by filler addition. The addition of natural rubber fillers enhanced the flexural properties of ramie-basalt composites. The impact properties are not influenced by the rubber composition.

[15] Stanley Jonathan M, Sharan Kumar L, Sudarshan D. S, Sharath Kumar M, Dr. Yogesha. K. K, Sandesh S

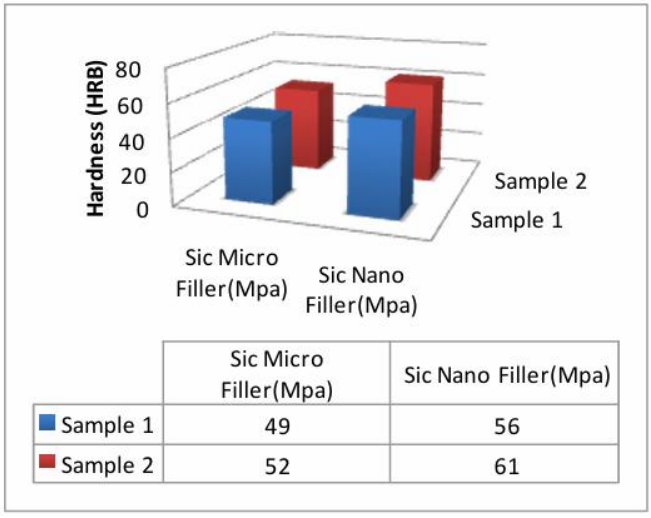
Nayak. Effect of Silicon Carbide Fillers on the Mechanical Properties of Glass Fibre Reinforced Epoxy Polymer Composite. International Research Journal of Engineering and Technology (IRJET) Volume: 08 Issue: 07 | July 2021.

Investigation on the effect of mechanical properties of GFRP with silicon carbide as micro and nanofiller. The composites were fabricated by the hand layup method. Figures 4, 5 & 6 illustrate the influence of fillers on the tensile, hardness, and flexural strength.The tensile strength, hardness, and flexural strength of nano-filled composites are found to be higher than micro SiC-filled composites. At 5 wt.% filler-loaded nano SiC-filled composites performed better as compared to the micro SiC-filled composites.



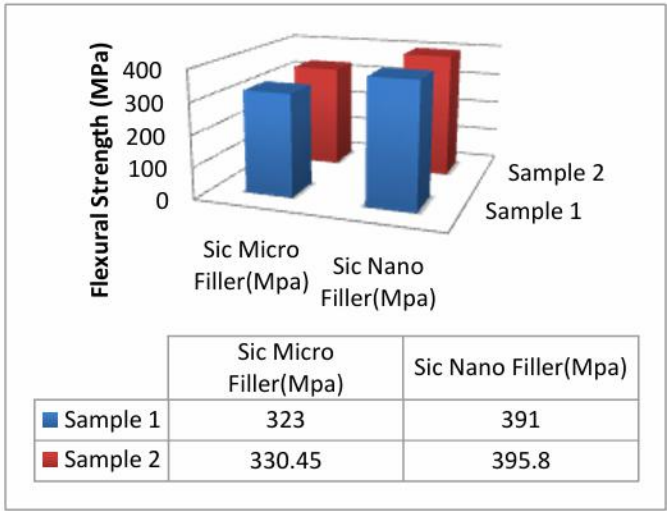
	Sic Micro Filler(Mpa)	Sic Nano Filler(Mpa)
Sample 1	232.7	337.5
Sample 2	239	344.26

Figure 4: Tensile strength of micro and nano SiC-filled composites



	Sic Micro Filler(Mpa)	Sic Nano Filler(Mpa)
Sample 1	49	56
Sample 2	52	61

Figure 5: Hardness of micro and nano SiC-filled composites



	Sic Micro Filler(Mpa)	Sic Nano Filler(Mpa)
Sample 1	323	391
Sample 2	330.45	395.8

Figure 6: Flexural strength of micro and nano SiC-filled composites

[16] Saravanakumar Kannivel, Harini Subramanian, Vellayaraj Arumugam, and Hom N. Dhakal. Low-Velocity Impact Induced Damage Evaluation and Its Influence on the Residual Flexural Behavior of Glass/Epoxy Laminates Hybridized with Glass Fillers. Journal of Composites Science. July 2020. 4(3): 99

This research work investigates experimentally the low-velocity impact-induced damage behavior and its influence on the residual flexural response of glass/epoxy composites improved with milled glass fillers. The low-velocity impact damage employing varying impact velocities (3 m/s, 3.5 m/s, and 4 m/s) was induced on the baseline and filler-loaded samples with different fiber orientations. The residual performance and their damage modes were characterized using post-impact flexural (FAI) test and acoustic emission (AE) monitoring. In all fiber orientations, the filler-modified glass/epoxy samples showed improved impact strength and stiffness properties. A substantial improvement in impact damage tolerance, especially for samples impacted at 3.5 m/s and 4 m/s was observed. The presence of filler at the interlaminar zone contributed to improved energy dissipation through filler debonding and pull-out. This further contributed to arresting the crack growth, showing reduced damaged area. The inclusion of milled fibers on glass/epoxy laminates enhanced the impact of toughness and residual flexural behavior.

[17] M. Polok-Rubiniec, A. Włodarczyk-Fligier. Polypropylene matrix composite with charcoal filler. JAMME Volume 103 Issue 2 December 2020

Incorporation of charcoal powder as filler to investigate the thermal, electrical, and mechanical properties

of polymer composites. The samples were made by injection molding. After the experimental study and analysis, it is inferred that charcoal powder can be used successfully as a filler material for the polymer-based matrix to improve the mechanical properties of the composites. With an increase in the volume fraction of the filler in the matrix, the material's hardness increases significantly. The addition of filler into the matrix, increased electrostatic properties and worsened the electrical insulating properties.

[18] İlyas Kartal, Hilal Selimoğlu. Usability of Pine Sawdust and Calcite Together as Filler in Polyester Composites. IJCESEN. Vol. 9-No.3 (2023) pp. 267-273

This research study involves the investigation of polyester composites with polyester resin as matrix material and the fillers used are calcite and pine wood sawdust. Hence the usability of both natural and synthetic filler was investigated. Study from the tensile test, a partial decrease was observed as the sawdust filler increased, while this decrease was less in the case of calcite. No obvious change in impact properties was observed. The hardness results increased with the addition of both sawdust and calcite.It was understood from the SEM images that the fillers were homogeneously mixed in the structure (refer to Figures 7, 8, 9 & 10). Finally, it is determined that the sawdust and calcite filler could be used together as fillers for material applications for large load-bearing capacities.

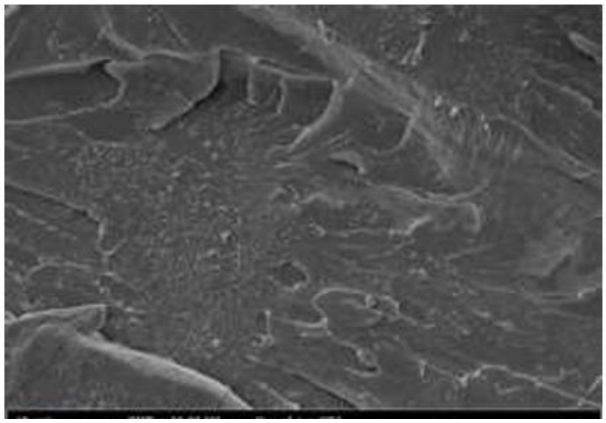


Figure 7: SEM image of the neat polyester sample

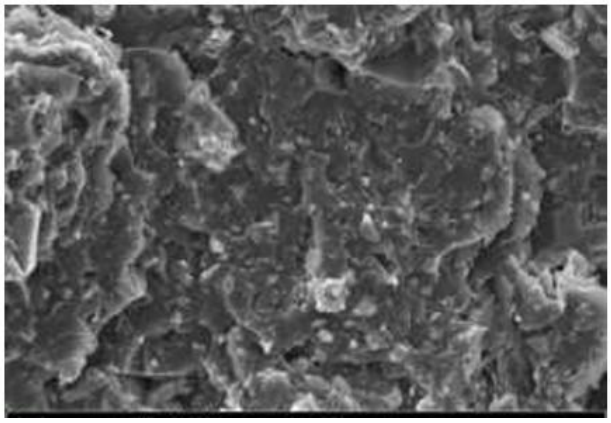


Figure 8: SEM image of 20CC sample

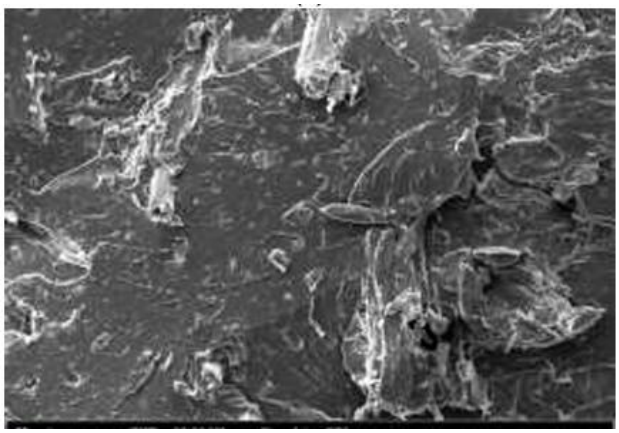


Figure 9: SEM image of 5CC15PS sample

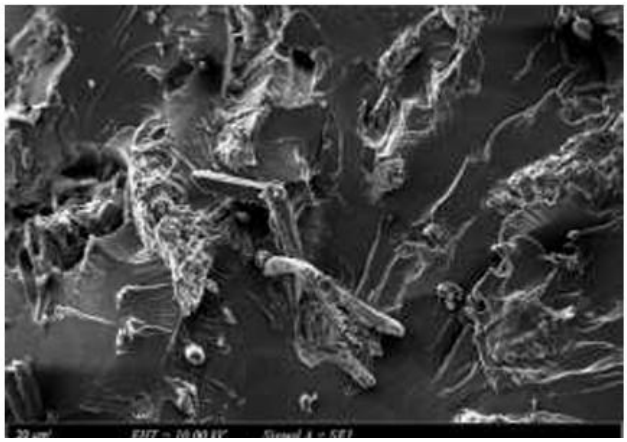


Figure 10: SEM image of 20PS sample

III. CONCLUSION

From the literature review, it is clear that the influence of mechanical properties of the composite material with the addition of fillers (natural and synthetic fiber milled). The addition of optimum composition of fillers enhances the mechanical properties of composite materials. To satisfy the current trends of a wholesome material, the addition of fillers with matrix is considered to be a better option. Thus, the

produced composite materials and structures are better suited for the application of aerospace and automotive industries.

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