INTI JOURNAL | eISSN:2600-7320
Vol.2020:26

Tensile Test of Fly Ash-Polypropylene Hybrid Composite Via Ansys Simulation

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Abstract

The utilization of power plant by various nations is the direct result from the need to satisfy the ever increasing demand for electricity. One of the major drawback for the use of power plant is the resulting fly-ash waste. The goal of this study was to investigate the tensile strength of a newly developed fly-ash-polypropylene (PP) hybrid composite via Finite Element Analysis (FEA) simulation. Four (4) types of hybrid composite were simulated in this study which were: (i) 100% PP, 0% fly-ash, (ii) 90% PP, 10% fly-ash, (iii) 80% PP, 20% fly-ash, and (iv) 70% PP, 30% fly-ash. The properties of the composite for four (4) different samples were obtained from the literature and via calculations. The results showed that shows that for sample 1, 2, 3 and 4; the maximum stress of 20.218 MPa, 20.171 MPa, 16.859 MPa and 15.37 MPa were simulated. Furthermore, only sample 1 managed to record the factor of safety to be above 1.0. Hence, it is safe to deduce that tensile strength of the newly developed fly-ash- polypropylene hybrid composite is decreasing with the increasing percentage of fly-ash. The reduction in tensile strength proves that there is the absent of a chemical bond between the polypropylene and fly-ash. Further addition of fly-ash onto the hybrid composite increases the material linear elastic fracture because of creation of lager defect. Therefore, the fly-ash-polypropylene hybrid composite is not suitable for the engineering application where tensile strength matters the most. For future studies, other types of mechanical properties assessment is recommended to be conducted on the fly-ash-recycled-plastic hybrid composite.

Keywords

fly-ash-polypropylene hybrid composite, tensile test, renewable material

International Conference on Innovation and Technopreneurship 2020
Submission: 4 September 2020; Acceptance: 16 October 2020

Introduction

Pollution can be in the form of energy or chemical substance such as heat, noise, or light. One of the most alarming environmental issues faced presently is plastic pollution, as increasingly creation of disposable plastic items overpowers the worlds ability to deal with them. Developing nations like Africa and Asia are facing plastic pollution the most, it is because garbage collection systems are not enough or non-existent. Some of the developed countries are facing the same issue because of their low recycling rate and have troubles collecting the discarded plastic. To overcome this issue, most countries have started recycling the plastic and awareness has been raised among people regard the usage of plastic and their disadvantages. Conversion of waste plastic into something useful is known as recycling plastic process. Collecting the plastic, which is recyclable, separating them according to their properties and melting them into pallets which can be used to create products such as, chairs, plastic cups, tables and bags. Since 1970s, recycling of plastic has been encouraged because it protects the environment (Plastic Recycling History - Recycling Plastic Benefits. 2019). This study focused solely on fly ash and plastic waste.

The goal of this study was to investigate the tensile strength of a newly developed fly-ash-polypropylene (PP) hybrid composite via Finite Element Analysis (FEA) simulation. Four (4) types of hybrid composite were simulated in this study which were: (i) 100% PP, 0% fly-ash, (ii) 90% PP, 10% fly-ash, (iii) 80% PP, 20% fly-ash, and (iv) 70% PP, 30% fly-ash. The properties of the composite for four (4) different samples were obtained from the literature and via calculations. The findings of this study opens the door for the possibilities in the utilization of composites out of waste material which are being used in automotive industry. Thus, facilitates in solving the issue in relation to pollution, whilst, simultaneously pushing the technological advancement in engineering. Fly ash is already being used in construction industry, but still 75-80% of fly ash is unused and is dangerous for environment, by making a hybrid composite, it will help reduce the amount of unused fly ash.

Researches have been conducted with different methods and ideas to reuse fly ash. Some researcher performed an experiment using dry fly ash class C and PET shredded bottles and mixed them in different proportions as performed by Li. Y et. al, (2003). Li. Y et. al, (2003) found that with the increment of fly ash percentage in mixture from 0 to 65%, compressive strength also increased from 77 MPa to 110 MPa approximately. This is of course a useful finding where the composite could be utilized in for an engineering application where compressive strength is a vital aspect.

Doddipatla & Agrawal (2018) conducted an experiment where polypropylene was mixed with untreated and treated fly ash to assess the composition of mixture. 3-Amino propyl trimethoxy Silane (APTMS) and Trimethoxy (propyl) Silane (TMPS) were used as coupling agent to treat the Fly ash to form treated fly ash. Treated fly ash and Polypropylene were then mixed together (Doddipatla & Agrawal, 2018). Composition percentage of fly ash used for this research were 5,10,20,30 and 50%. Samples were formed using treated and untreated fly ash separately mixed with Polypropylene. Tests were performed and the results obtained showed not much of difference between tensile strength of treated fly ash composite and untreated fly ash composite. However, by taking the average tensile strength, fly ash treated with TMPS showed better strength. Fly ash treated with TMPS showed better tensile modulus as compared to untreated and treated Fly ash with APTMS. In conclusion, to obtain better mechanical properties, fly ash treated with TMPS looks like a better option (Doddipatla & Agrawal, 2018).

Next, Ahmad & P. A. Mahanwar (2010) conducted a study on HDPE plastic with fly ash were used as filler. Three (3) different sized particles of fly ash were tested. Test results showed the flexural, tensile strength and the moduli increases with the increment of fly ash wt.% in the composite. Composite with fly ash of more than 10%wt showed reduction in the tensile elongation. Smaller size fly ash particles showed better strength and elongation. Particle size of fly ash did not have much effect on the impact resistance and Modulus of the composite (Ahmad & P. A. Mahanwar, 2010). Similarly, a study to determine the mechanical properties of composite of polypropylene filled with rice husk ash as filler by Fuad et al., (1995). Amorphous, black, and white rice husk ash were used in this composite as fillers with wt% between 10-40. Results showed that Black rice husk ash increased the flexural modulus of composite compared to white and amorphous rice husk ash. Composite prepared with rice husk and polypropylene showed comparable results with those of polypropylene composite filled with commercial silica as noted by Fuad et al., (1995).

A study was performed to determine the mechanical properties of recycled aluminium-Fly ash composite (Hayyawi et. al., 2016). The study conducted experiment on composites with varied fly-ash percentage (0%, 3%, 6% and 9%). Hayyawi et. al., (2016) found hardness was increasing with the increasing percentage of fly ash added to aluminium and maximum hardness was obtained at maximum percentage of Fly ash add (9%). Tensile strength also increased but it dropped down when it reached to the composite with 9% fly ash, this is due to clustering of reinforcement particles present in the composite (Hayyawi et. al., 2016).

In short, all of these study illustrates the positive result given by the addition of fly ash in the development of new composite. The composite of fly ash class C and PET shredded bottles, as well as, fly ash and banana fibre; both results in the increment of compressive strength. The addition of fly ash with APTMS and TMPS both showed increment in mechanical properties. Furthermore, the fly ash and HDPE plastic composite results in the flexural, tensile strength and the moduli increment with the increase of the fly ash wt.% in the composite. Therefore, these experiments have been proven that the addition of fly ash in increasing the performance of composite is indeed promising. Nonetheless, the mechanical properties test for a fly-ash-polypropylene (PP) hybrid composite has yet to be conducted.

Methodology

Finite Element Analysis (FEA) Simulation

Finite element analysis (FEA) simulation was performed via ANSYS software. The aim for the FEA simulation was to perform the tensile test onto the specimens as in Figure 1 in order to determine the deformation, strain, stress, yield strength and the factor of safety (FS) for each of the specimens due to the weight percentage variations of recycled platics and fly-ash. The maximum number of substeps applied in ANSYS is 150. The mechanical properties of the composites are obtained from the previous experimental research on composite of fly ash and polypropylene (Doddipatla & Agrawal, 2018) and (Chandra et. al., 2009) as shown in Table 1.

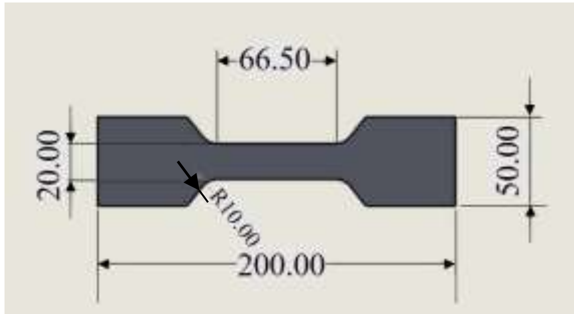

Figure 1. Dimensions of the specimen for tensile test

Table 1. Properties of Sample 1, 2, 3 and 4

Sample	Density (kg/m^3)	Tensile Ultimate Strength (MPa)	Tensile Yield Strength (MPa)
Sample 1 (100% PP, 0% Fly ash)	946	21.05	20.5
Sample 2 (90% PP, 10% Fly ash **)**	1067.4	19.9	19.4
Sample 3 (80% PP, 20% Fly ash)	1188.8	16.7	16.3
Sample 4 (70% PP, 30% Fly ash)	1310.2	15.1	14.8

Results and Discussion

Table 2 summarized the FEA analysis for the four (4) samples. The result clearly indicates that only Sample 1 has a FS value above 1.0, while the other samples showed consistent decrement of FS as the weight percentage of fly-ash is increasing within the hybrid composite. The stress-strain diagrams of composite of fly ash and Polypropylene are shown in Figure 2 for sample 1, 2, 3 and 4 accordingly. From the Stress vs. Strain graph, it clearly shows a linear elastic deformation trend, as the curve shifts to plastic deformation from elastic deformation. Usually, a composite has a lower tensile strength as compared to that of neat resins, by looking at graphs it shows that sample 1 reaches the max stress at 20.218 MPa, sample 2 at 20.171 MPa, sample 3 at 16.859 MPa while sample 4 at 15.37 MPa. From this result, it is apparent that the tensile strength of the hybrid composite is decreasing with further addition of fly-ash. The value of tensile strength of neat Polypropylene from the graph obtained by performing the simulation shows the similar values to published experiment by Doddipatla & Agrawal (2018). The reduction in tensile strength indicates the absent of chemical bonding between Polypropylene and fly ash. Addition of more fly ash increases the material linear elastic fracture because of creation of lager defect.

Table 2. Results for Tensile Testing Simulation

Sample	Deformation (m)	Strain	Stress (MPa)	Yield strength	FS
1	$2.0217x10^{-3}$	$2.8834x10^{-2}$	20.218	$2.05x10^{7}$	1.0139
2	$2.0031x10^{-3}$	$2.6845x10^{-2}$	20.171	$1.94x10^{7}$	0.9617
3	$1.5907x10^{-3}$	$2.2470x10^{-2}$	16.859	$1.63x10^{7}$	0.9668
4	$1.4866x10^{-3}$	$2.0585x10^{-2}$	15.37	$1.48x10^{7}$	0.9629

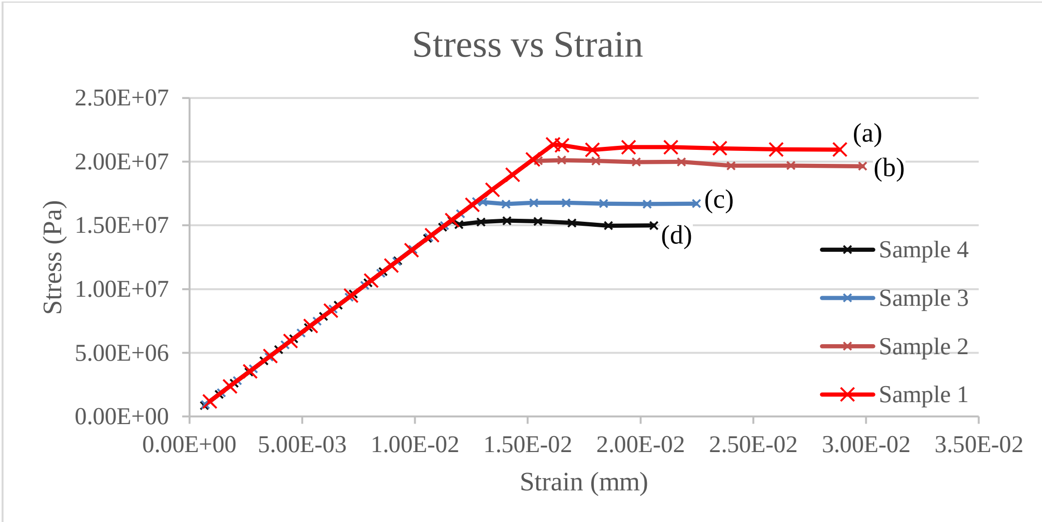

Figure 2. Stress vs. Strain graph for sample (a) Sample 1, (b) Sample 2, (c) Sample 3 and (d) Sample 4

Conclusion

Conclusively, based on the result of the FEA simulation, it is safe to deduce that tensile strength of the newly developed fly-ash- polypropylene hybrid composite is decreasing with the increasing percentage of fly-ash. This is mostly likely due to the absent of a chemical bond between the polypropylene and fly-ash. Further increment of fly-ash's weight percentage onto the hybrid composite results in the increase of the material linear elastic fracture due to the creation of larger defect. Therefore, from this study, the fly-ash-polypropylene hybrid composite is not suitable for the engineering application where tensile strength matters the most. For future studies, other types of mechanical properties assessment are recommended to be conducted on the fly-ash-recycled-plastic hybrid composite.

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