Experimental Analysis on The Tensile Strength of Polyester Resin based Calcium Carbonate Powder and E-Glass Fibre Reinforced Composite

S T Wicaksono\textsuperscript{1*}, Hosta Ardhyananta\textsuperscript{1} and M B Waluyo\textsuperscript{1}

\textsuperscript{1}Department of Materials and Metallurgical Engineering, Sepuluh Nopember Institute of Technology, Surabaya, Jawa Timur 60111

*Corresponding author: sigittriw@gmail.com

Abstract. Calcium carbonate powder is contained in the waste produced from processing limestone. Limestone is used as an alternative substitute for organic fillers in polymer composites. The use of this waste can be a valuable resource as a replacement filler in polymer composites. The main purpose of this study is to reuse the waste materials calcium carbonate for composite materials. E-glass type woven roving is used as reinforcement and polyester resin was is as a matrix. In the present research, the addition of calcium carbonate waste powder in composites E-glass/polyester was investigated for tensile strength and density. In the hybrid, composite specimen of this study was prepared using hand lay-up technique. Tensile testing was carried out according to ASTM D368 standard. At first, calcium carbonate powder, glass fibre, and polyester were prepared in a specific volume and the specimens were prepared. Comparison filler plays an important role in producing the tensile strength of the composite. Thus, the fill ratio was considered as an experimental variable and were varied (2.5, 5.0, 7.5, and 10% by weight for calcium carbonate; 10, 12.5, 15, and 17.5% by weight for E-Glass. After testing was carried out, it is found that the strength of the material was increased as the volume of E-glass fibre increased.

1. Introduction

Fibre reinforced composite materials are made from two or more different constituent materials, which remain separate at micro and macroscopic level and possesses different physical and chemical properties. The fast advancement and utilization of composite materials starting in the 1940s had some driving forces. Composite polymer material as a substitute material is widely used. Metals being heavier and difficult to machine is being replaced gradually in all the fields by composite materials manufactured to suit the purpose with necessary strength and flexibility [1]. The development of polymer composites encourages researchers to conduct further research. Commonly the research done is varying the inert material (filler). The addition of this material aims to reduce resin costs or improve its physical properties such as stiffness, hardness and impact strength. In general, the fillers used are fibre s, particles or a combination of both. Commonly used fibre s are glass fibre, carbon, natural fibre s and others. for particles are granite powder, fly ash, alumina, SiO\textsubscript{2}, SiC and others. Nowadays calcium carbonate powder is also widely used as filler.

Calcium carbonate is an element contained in waste produced from the process of cutting natural rocks. The resulting powder is usually carried by water during the cutting process. This can pollute the
environment. Currently the reuse of natural particles as fillers is widely used because of their abundant availability and relatively low prices. In addition to natural particles, synthetic particles are also widely used as fillers in polymer composites. Natural particles play an important role in the development of composites. The addition of particles can improve the mechanical properties of composite materials. but the use of particles in certain compositions can reduce the strength of composite materials, so combining fibre and powder is very possible to overcome this problem.

Most studies relating fibre-reinforced polymer composites only focus on single reinforcement or only use one type of filler. The addition of glass fibres and particles can simultaneously create hybrid composites are relatively cheap and easy to use. Glass fibre was chosen as reinforcement because it can increase the strength of composite materials. hybrid composites are combinations that strengthen more than one reinforcing phase and single phase or single reinforcement phase with several phases or several strengthening phases. This composite has better flexibility compared to composites containing single filler. The effect of fibre and powder hybridization has been analysed. The results show that hybridization plays an important role to improve the mechanical properties of composites.

Subhrajit Ray et al. studied the behaviour of glass-epoxy composite erosion filled with granite powder according to the Taguchi experimental design [2]. They suggest mathematical models for calculating erosion rates and correlating with experimental results. The results showed the effect of control factors found to be significant for erosion rates. The percentage of fillers increases composite erosion resistance developed. Sanjay Soni et al. studied the effect of adding Milled Carbon in glass fibre reinforced epoxy composites on mechanical properties [3]. They found that the addition of milled carbon affected mechanical properties. Tensile strength increases with increasing milled carbon. Rajesh Purohit et al. conducted research related to the addition of fly ash powder in glass fibre reinforced composites to mechanical properties [4]. The test results showed a decrease in tensile strength as the addition of fly ash powder. Chethan Kumar et al. studied the effect of adding granite powder and fly ash on fibre-reinforced polymer composites [5]. Composites were prepared by hand layup methods. Press test results show an increase in compressive strength with increasing glass fibre volume.

In this study calcium carbonate powder was added to glass fibre reinforced polymer composites to obtain the best mechanical properties. The test sample was prepared by the hand layup method. Tensile testing was carried out according to ASTM D368 standard. The density test was also carried out.

2. Experimental

2.1. Polyester Resin

Polyester resin is a thermoset resin commonly used in the production of polymer composites. In this study Yukalac BQTN 157 ex polyester resin was used as a matrix in the composite. The polyester was

| Properties | Tensile strength (MPa) | Compressive strength (MPa) | Elastic Modulus (GPa) | Density (g/cm³) |
|------------|------------------------|---------------------------|----------------------|-----------------|
| Fibre Glass | 3445                   | 1080                      | 73                   | 2.58            |

Figure 1. Woven E Glass Fibre.
obtained from PT. Justus Kimia Raya. The use of catalyst was 1% of the total volume of resin used. The catalyst was MEKPO (Methyl Ethyl Ketone Peroxide).

2.2. Woven E Glass Fibre
Glass Fibre (Glass fibre) or yarn is formed from melted glass. In this form, the glass shows unusual properties: it will not crack, does not break and is easily formed without breaking [6]. Category of glass fibres are divided into three types: type E, type C and type S. The designation E stands for electrical because E glass is a good electrical insulator in addition to having good strength and a reasonable Young’s modulus; C stands for corrosion and C glass has a better resistance to chemical corrosion than other glasses; S stands for the high silica content that makes S glass withstand higher temperatures than other glasses [7]. Thus, the selection of the right type of glass fibre is very important to ensure a long service life and as needed. In this study, a Woven E Glass Fibre was used as reinforcement.

Glass is being widely used because of the following reasons. Glass fibre has good corrosion resistance, easily available and low-cost.

2.3. Particle
In this study, calcium carbonate was used as fillers. Calcium carbonate contained in waste powder was obtained from PT. Apaiser. Waste was obtained in various sizes, thus before it was used in a composite, the waste was sieved to get a homogeneous size and separate the physical impurities. The particle size that was used is particles that escapes from the sieving membrane of 40 µm.

2.4. Composite Fabrication
Composites were made in different volume fractions using the hand layup method. The fill ratio was varied, namely 2.5, 5.0, 7.5, and 10% by weight for calcium carbonate and 10, 12.5, 15, and 17.5% by weight for E-Glass. First the resin and particle mixing was mixed using a magnetic stirrer for 10 minutes at 50°C and 400 rpm (the speed was gradually increased from 100 to 400rpm). After the temperature of the polyester increases and the viscosity decreases, the calcium carbonate filler was then poured slowly into the beaker. The mixture was then left and cooled down to room temperature. After reaching room temperature, the catalyst was added with a ratio of 1% weight of the total resin to the curing process.

Before the mixture was poured into the mold, wax as a release agent was distributed to the surface of the mold. The wax helps the sample to be taken out easily after the drying process. Before placing the glass fibre layer, the resin mixture and particles were poured into the mold according to the shoulder of the mold. Then woven roving type glass fibre was inserted into the mold. Each layer of glass fibre was arranged by rolling the roller over it to ensure even distribution of the matrix. The mold was formed according to the ASTM Tensile dimensions. After the mixture has placed in the mold thoroughly, the mold was pressed and left for 12 hours. After 12 hours, the sample was removed from the mold.

There were four sample in total with combination of CaCO₃ (2.5, 5, 7.5, 10%) and fibre (17.5, 15, 12.5, 10%), respectively. The physical and mechanical properties of these samples were studied.

Figure 2. Samples were prepared based on the ASTM standards.
3. Result and Discussion

3.1. Tensile Strength

The sample is prepared according to the dimensions of the Tensile test according to ASTM D638 standards with a total length of 165. The specimen section consists of a holder (grip), control (gauge) and neck (neck). The specimen experiences controlled tension until it breaks. Extensions to breaking points, loads received by specimens to breaking points and ultimate tensile stresses are calculated by the machine. Thereafter, strain and Young’s modulus were calculated according to the formula using the data obtained from the machine. The tensile strength test graph decreases with increasing CaCO\textsubscript{3} powder. This percentage increase in the weight of CaCO\textsubscript{3} causes the spread of bad particles in polyester resin. This poor distribution causes the interface region bond to decrease and produce lower homogeneity. The highest tensile strength value (51.11 MPa) was observed in sample one (glass fibre 17.5\%wt and CaCO\textsubscript{3} powder 2.5\%wt). The lowest tensile strength value (29.96 MPa) was shown by sample four (glass fibre 10\%wt and CaCO3 powder 10\%wt).

![Tensile Strength graph]

Figure 3. Tensile Strength in different sample

3.2. Density

Density measurement was carried out by calculating the mass and volume of each specimen. Comparative evaluation of density of composites were evaluated and represented in Figure 4. According to Figure 4, sample 2 has higher density, with low CaCO\textsubscript{3} powder content. Whereas sample 4 has low density and high content of CaCO\textsubscript{3} powder causes a decrease in composite density. The highest density value (1.3777 g/ml) was observed in sample two (glass fibre 15\%wt and CaCO\textsubscript{3} powder 5\%wt). The lowest density value (1.3258 g/m) was shown in sample four (glass fibre 10\%wt and CaCO3 powder 10\%wt). CaCO\textsubscript{3} has a lower density than fibre and resin. It was occurred due to the the increase of powder volume result in the decrease of the composite density.

![Density graph]

Figure 4. Density in different sample

4. Conclusion
Industrial wastes can be reused as fillers in composites. Fibre reinforced polymer composites with the addition of CaCO$_3$ powder were successfully prepared by hand layup method. Tensile strength decreased with the increasing CaCO$_3$ powder content. In the density test, sample two with 5% CaCO$_3$ shows the highest value while in sample four with 15% CaCO$_3$ shows the lowest value. In future tensile test has to be conducted on the same composition samples, thus comparative studies can be made by using different composition to increase the tensile strength.

Reference

[1] A. Gopinath, M.S. Kumar, A. Babu. 2018. Mater. Today: Proceed. 5 (9) 20092.
[2] S. Ray, A.K. Rout, A. Kusahoo. 2017. IOP Conf. Ser.: Mater. Sci. Eng. 225 012097.
[3] S. Soni, R.S. Rana, B. Singh, S. Rana. 2017. Mater. Today: Proceed. 5 (2) 4050.
[4] R. Purohita, P. Sahub, R.S. Ranaa, V. Parashara, S. Sharma. 2017. Mater. Today: Proceed. 4 (2) 3102.
[5] B.N.T. Chetan and B.T. Ramesh. 2015. Inter. J. Mod. Trends Eng.Res. 2 (8) 49.
[6] A. Avdeeva, I. Shlykova, M. Perez, M. Antonova, S. Belyaeva. 2016. MATEC Web of Conference 53 01004.
[7] K.K. Chawla. 2007. Composite Materials Science and Engineering, 3rd ed. Springer, New York USA.
[8] M.S. El-Wazery, M.I. El-Elamy, S.H. Zoalfakar. 2017. Inter. J.Appl. Sci. Eng. 14 (3) 121.