Mechanical Properties Of Cenosphere (0-40%) Filled Polypropylene Composite.

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Abstract— The polypropylene and the composite containing cenosphere were produced and tested for the mechanical properties comprising tensile, flexural and impact strength properties. The mechanical properties analysis was conducted as accordance to ASTM 638 for tensile, ASTM 790 for flexural and ASTM D256 for impact properties. Different weight percent of cenosphere (0, 10, 20, 30 and 40 %) were utilized in the polymer composite to discover the effects of filler towards the mechanical properties of the composite. The impact testing conducted revealed a decreasing pattern for the impact strength as the weight percentage of the cenosphere is increasing. The same pattern depicted by the sample for tensile strength and elongation at break of the specimen in which the tensile properties resulting in decreasing value as the mass loading of cenosphere increases. However, the flexural strength of the sample shows fluctuation in its value with increment of cenosphere mass loading. The behavior of the mechanical characteristics of the composite is mostly due to interfacial adhesion between the filler and the polymer.

Keywords: cenosphere, polypropylene, tensile, flexural, impact

I. Introduction

Polypropylene (PP) is one of the thermoplastic that is widely used in the industry due to its excellent properties[1] PP is also described to have a low density, good surface hardness, good electrical attribute and possess good mechanical and barrier characteristic towards water [2]. The use of fillers in the polymer production has been explored extensively due to the ability of the fillers to enhance the properties of the composite polymer. There are numerous work reported on the use of fillers in polymer. A study on the use of the snail shell powder as filler in the PP has been found that the use of filler in the polymer is improving the properties of the composite in mechanical aspect [3]. Besides that, there is a research that investigates the use of hollow glass microsphere as filler in epoxy composite enhanced the thermal stability of the filled composites. There is also a study conducted for silica partparticle size on the mechanical and rheological properties of the microcellular injection molded PP/silica composites were investigated. The study has shown improved tensile strength of the sample composite[4].

Cenosphere is basically is a waste product from the combustion of coal and also known as the fly ash. Flyash has also been described in various reports as reinforcing filler in polymer to develop composite with specific application. Flyash has been broadly applied in the concrete product, cement production, sewage sludge stabilization, reinforced plastic and other diverse usage.

The cenosphere is distinguished by the low bulk density (0.2-0.8 g/cm^3) and can be separated by gravitational method as well as being easily collected from water surface of lagoons intentional for ash storage [5]. Cenosphere has excellent properties such as light weight, good packing factor, chemical inertness, high thermal resistance and good electrical properties [6-10]. The study of cenosphere should be expanded as this waste is produced in large amount and will eventually lead to environmental problem because fly ash was previously simply disposed. According to Kolay and Bhusal [9], 136.1 million tons of coal combustion products were produced in the United States and 55.5% of it is being disposed in landfills and ash ponds. This statement also supported by Labella et al [11] that stated more than half of coal combustion products were disposed to landfills in United States. This impact on the environment can be reduced by utilizing cenosphere in industrial sector. Cenosphere has already been used as the filler in study but with different type of polymer. One of the researches done is by using flyash cenospheres combined with MWCNT (Multiwall Carbon Nanotubes) as fillers in high density polyethylene (HDPE) to explore the mechanical, thermal and flammability characteristics [8]. The study has highlighted the presence of the compatibilized composite depicts better mechanical properties than neat HDPE. Similar study also conducted but without combination of MWCNT and focusing on the optimisation of polymer processing parameter[12]. The study added that the increase in cenosphere content in the HDPE has increased the tensile strength in composite. Besides that, there are previous study that employed the use of cenosphere as filler in the PP that acts as matrix and it depicted a decrease in the strength value of the composite compared to the neat PP [13]. Thus, this paper made an exertion to produce work that examines effect at higher value of cenosphere mass loading.

The main objective of this study is to produce pure polypropylene composite and filler-added polypropylene composite of different composition (10, 20, 30, 40) of cenosphere as sample specimen were prepared for these mechanical testing. Besides that, the study is conducted to determine the tensile, impact and flexural strength of pure polypropylene and cenosphere filled polypropylene composite.

II. METHODOLOGY

2.1 Material

There are two main component in the study conducted which are cenosphere and polypropylene. Cenosphere is used as the filler in the polypropylene polymer. The cenosphere used in the study will be sieved to 300µm. The cenosphere is graded by using sieve in order to acquire the consistent particles size diameter. The sieve shaker used for acquiring the desired particle size of cenosphere is shown as in the Fig. 1. The cenosphere used in the experimental work is obtained from the coal power plant of Sultan Salahuddin Abdul Aziz Shah that is located in Kapar, Selangor.

The polypropylene used for this research is a homopolymer type is supplied from the Total Petrochemicals & Refining USA.

2.2 Composite Preparation

The composite were prepared with filler loadings of 0, 10, 20, 30 and 40 % by weight of cenosphere. The weight is varied in order to test its effect on the mechanical properties of the composite.

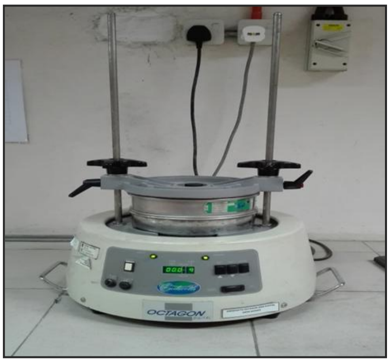

Fig.1: the Endecotts Octagon 2000 Digital sieve shaker

Fig. 2: Injection moulding machine, IMM (BOY22A)

The polypropylene composite sample has its own designation that is established on its mass percent of the cenosphere so that data collection can be more systematic and in orderly manner. The designation of the sample is as shown in Table 1.

Table 1: Designation of polypropylene composite sample

Polypropylene (wt%)	Cenosphere (wt%)	Designation of the sample
100	0	PP Neat
90	10	PP/C10
80	20	PP/C20
70	30	PP/C30
60	40	PP/C40

The equipment used for the composite preparation procedure is injection moulding machine, IMM (BOY22A) as shown in fig. 2. The clasp type of the machine is horizontal with a closing force of 220 N. The machine has a screw diameter of 32mm and injection volume of 36.5 cm^3. The operation used parameter used for the injection moulding machine machine is shown in the Table 2 and Table 3.

Table 2: temperature profile set in injection moulding machine

Zones	Temperature (ºC)
Feed	35
Z-1	175
Z-2	185
Z-3	200
Z-4	220

Table 3: moulding machine processing parameter utilization

Process parameter	Amounts
Injection pressure	50 bar
Injection speed	50 mm/min
Holding time	14 s
Back pressure	5 bar
Cooling time	18 s

Fig. 3: Universal testing machine Tinius Olsen (H50KT)

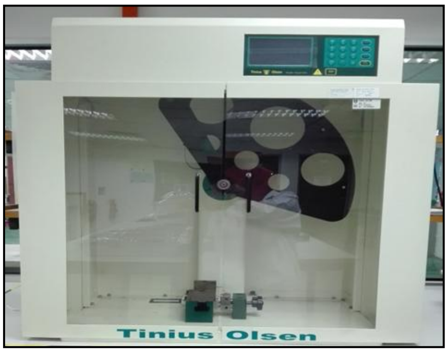

Fig. 4: Impact tester Tinius Olsen Model Impact 503

2.3 The Analysis Of The Composite Procedure

The analyses conducted on the composite are regarding the tensile, impact and flexural strength. The testing was conducted based on American Standard Testing Method depending on the type of mechanical properties.

2.3.1 Tensile Properties

The tensile testing is operated by using the standard testing of ASTM 638. The testing of specimen sample is conducted by using universal testing machine of Tinius Olsen (H50KT) as shown in Fig. 3. The test speed employed for the tensile testing is 50 mm/min. The minimum number of sample needed for running the investigation is 5 for every composite. The tensile test of the composite will be conducted by placing the specimen in the grips of the universal tester at the specified grip distance and pulled until failure occurs. The shape of the specimen is in dumb-bell shape.

2.3.1 Flexural Properties

The flexural testing is operated by using the standard testing of ASTM 790. The testing of specimen sample is conducted by using universal testing machine of Tinius Olsen (H50KT). The test speed employed for the tensile testing is 50 mm/min.

2.3.3 Impact Properties

The impact testing is operated by using the standard testing of ASTM 256. The testing of specimen sample is conducted by using plastic impact machine of Tinius Olsen (IT503) as shown in the fig. 4. In this test, one end of a specimen is fixed in a cantilever position by means of a vice and a striker on the arm of a pendulum will then strikes the specimen.

III. RESULT AND DISCUSSION

3.1 Sample fabrication

From the experimental work, it was found that after cenosphere was sieved, it then weighed and mixed with PP at 70 g in order to produce sample according to the weight percentage specification. Table 4 depicts the sample designation and the weight used for sample fabrication.

Table 4: Details of sample designation and composition

Sample designation	Weight percentage of the cenosphere (flyash), %	Mass of censophere required (g)	Mass of polypropylene (g)
PP Neat	0	0	70
PP/C10	10	7	63
PP/C20	20	14	56
PP/C30	30	21	49
PP/C40	40	28	42

Table 5: Standard dimension for the tensile testing sample

Parameter	Size (mm)
Full length	165
Parallel length	57
Gauge length	50
Parallel section width	13
Thickness	7
Grip section width	7
Distance between grips	115

3.2 Impact Properties

The sample for impact testing produced according to ASTM 256 with the dimension of 4 x 12.7 x 3.2mm as shown in the Fig. 5. Fig. 8 depicts the behavior of impact strength as the weight percent of cenosphere increases in the PP composite. As shown in the figure, the impact strength of sample decreases as the weight percent of cenosphere increases. According to Mohamad et al. [14], the impact strength of the material indicate the resistance to fracture upon loading.

Fig. 5: Impact sample shape of the polypropylene

Fig. 6: The dumb-bell shaped sample for tensile sampling

Fig. 7: Flexural sample of the polypropylene composite

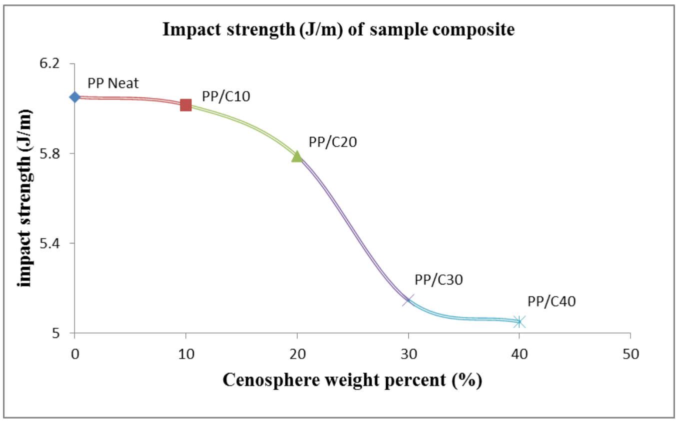

Fig. 8:Impact strength versus cenosphere weight percent in PP composite

As the neat PP has the highest value of 6.0506 J/m compared to the other sample, it has the highest resistance to fracture upon impact loading. The value of impact strength also corresponds to the energy needed by the plastic sample to break the bond within them before they break.

The value of impact strength decreases gradually by 0.58% from PP Neat sample to the PP/C10 sample. The value of impact strength continues to reduce at PP/C20, PP/C30 and PP/C40. However, there is higher disparity between point PP/C20 and PP/C30 in 11.07% and the impact strength continues to decrease progressively at position PP/C30 to PP/C40. The impact strength decreases gradually since the crack generated from impact propagates towards a poor interfacial region [15]. The research also stated that the alleviation of the impact strength is due to restrictions of the matrix molecules mobility as the matrix adhesion is very strong. The restrictions lead to brittle material that corresponds to reduction of impact strength[16]. In this study, the result of impact strength of PP Neat sample to PP/C20 reaches the same consistency with previous study of [13] in which the impact strength decreases as the mass loading of cenosphere increases.

3.3 Tensile Properties

Tensile sample composite were produced based on standard dimension of ASTM 638. Fig. 6 shows the flexural sample of the polypropylene composite. As seen in the figure, the sample is in the shape of dumb-bell. The dimension specification is based on Table 5.

3.3.1 The Tensile Strength of the Specimen

Fig. 9 shows the maximum stress of the sample during the testing. From the figure, it can be seen that PP neat sample has the highest tensile strength compared to the other sample containing cenosphere.

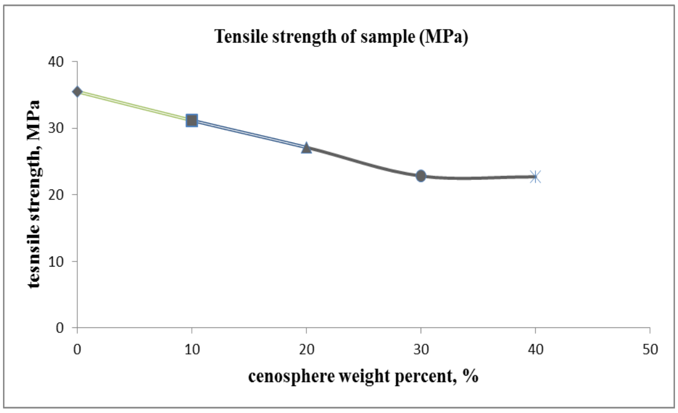

Fig. 9: Tensile strength variation value of the specimen

The change in the tensile strength of each sample is basically due to filler-matrix interfacial adhesion. As the weight of cenosphere increases in the specimen, it leads to inadequate state of filler-matrix interfacial adhesion to counteract the fracture of the specimen. The premature or the early fracture of the sample is due to poor interface that is portrayed as easy debonding of the fillers blended with occurrence of voids in the sample [13].

3.3.2 The Tensile Elongation at Break of the Specimen

The elongation at break is one of the important criteria in describing the ductility of a material. The ductility is also described as the tensile fracture toughness of the sample in the work conducted [17]. From the fig. 10, the elongation at break drops drastically from PP neat sample to the PP/C10 sample in which the value drops from 175.30 % to 55.92 %. The value of elongation at break at point PP/C10 to the PP/C40 also drops however it drops with small variation. The value of this data shows analogous in which the elongation at break of the sample decreases as the weight percent of cenosphere increases. As mentioned in previous section of tensile strength, the strength of the specimen depending on the interfacial adhesion between filler and the reinforcing and toughening of the material relies on interfacial adhesion as its correlate with the filler specific surface area. In this case, it can be inferred that as the weight percent of cenosphere increases, the surface area of filler reduces that leading to the low ductility of the specimen [17]. The research also added that the cracks of the specimen will absorb the tensile fracture energy that is useful for the material ductility improvement. From the result gained, the decrease of elongation at break value indicates that lower fracture energy is being absorbed during the process of testing that contribute to lower ductility of sample.

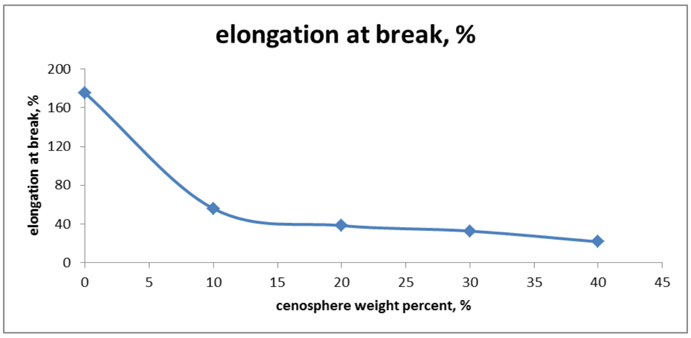

Fig. 10: Elongation at break (%) at different weight percent of the cenosphere of PP composite.

3.4 Flexural Strength

In flexural properties testing, the dimensions of the sample is based on ASTM 790. Fig. 11 depicts the flexural sample of polypropylene composite. The dimensions of the sample is 127 x 12.7 x 3.2 mm. Fig. 8 depicts a decreasing value of flexural strength as the mass loading of filler increases from 0 % to 30 %. However, the value rose at the weight percent of 40. From the value, it can be seen that the PP neat and PP/C40 has better load transfer which enable the specimen to have higher strength in withstanding the bend during the process. [18] added that the chemical reaction at the interface of the filler and the matrix may affect the load transfer of the material. From this study, it indicates that the filler agglomeration was low at the interface for PP/C40 sample helps in the load transfer causing it to have higher value of flexural data compared to other sample containing cenosphere.

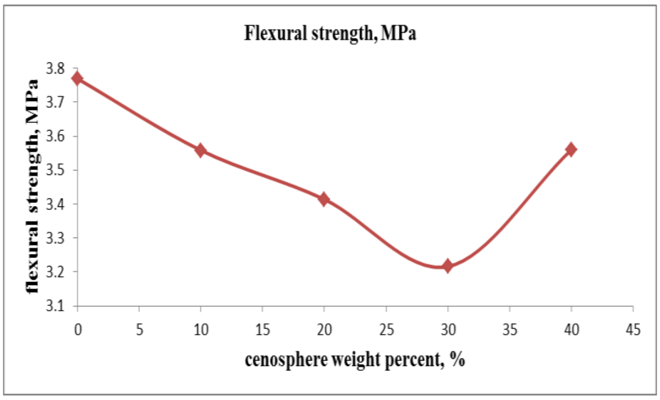

Fig. 11: Flexural strength data versus the cenosphere weight percent

IV. Conclusion

In this study, the composite specimen needed for the mechanical testing had been produced using injection moulding machine by employing parameters listed in Table 2 and Table 3. The best sample for tensile, flexural and impact test were chosen based on physical appearances of the sample. The effects of filler in the polypropylene on its mechanical properties were studied as the mass loading of the filler which is the cenosphere is varied from 0 to 40 %. From the mechanical testing of impact, it can be seen that the impact strength decreasing gradually as the weight percent of the cenosphere increases. The same trend can be seen for tensile strength and elongation at break for the sample. The flexural properties however show slightly different trend in the analysis process in which the value of flexural strength decreases for the first 3 data and rises at PP/C40 point.

The behavior of the mechanical characteristics of the composite is mostly due to interfacial adhesion between the filler and the polymer. From the result of impact and tensile strength, it can be stated that the higher loading of cenosphere leads to the poor interfacial adhesion of the material. From the study also, it can be seen that the weight percent of the cenosphere brings significant effect towards the strength of the material.

From the research conducted, there are several recommendations that can be proposed in expanding the understanding of the mechanical properties of material as well as polymer study. The morphology study of the polymer composite should be studied as the structure of the filler and matrix plays an important role in the understanding the mechanical properties values obtained. Correlation between the morphology study and mechanical analysis can be conducted for further work. Besides that, the effect of filler modification or 2 filler combination on the matrix should be experimented. The modification or combination may lead to enhancement on the polymer properties

V. ACKNOWLEDGMENT

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VI. References

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