TENSILE PROPERTIES OF BOTTOM ASH FILLED POLYPROPYLENE COMPOSITES

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***Abstract* — Coal Bottom Ash (CBA) are commonly recycled for usage in the construction industry. The main purpose of this research work is to study an alternative application for CBA by using CBA as a filler in Polypropylene (PP) forming CBA-PP composite and testing its tensile properties. This research also aims to identify optimum temperatures at each zone in an injection molding machine (IM used to produce these composites (or plastic molding). The composite of CBA-PP undergo the tensile test with increasing content of CBA of 0% (PP100), 5% (CBA5PP) and 10% (CBA10PP) by using Universal Testing Machine (UTM). The optimum temperature zones set up in IMM are 200, 210, 215, 215 and 240ºC for zones 1, 2, 3, 4 and 5 respectively were identified. The other parameters are at fixed value including the injection pressure (60 bar), mold temperature (33ºC) and the cycle time is 67.35 seconds. For tensile properties, the max stress (MPa) of PP100, CBA5PP and CBA10PP composites are 315.28, 292.26 and 282.00 MPa respectively while the elongation at break (%) are 26.64, 21.67 and 20.88% for PP100, CBA5PP and CBA10PP composites respectively. The analysis of tensile properties showed that the plastic deformation decreases, fracture point of strain axis is shorter, necking region is shorter as CBA content increased. The yield stress, yield percent, max stress and elongation at break percent were decreasing as the CBA content increased. This means that the specimen with increasing CBA content will slightly decrease in the plastic deforms characteristics but still in acceptable range.**

Keywords— Coal Bottom Ash, Polypropylene Composite, Tensile Properties, Injection Molding Machine (IMM), Universal Testing Machine (UTM).

I. INTRODUCTION

There are about 8 existing coal-fired power plants in Malaysia which are Jimah power plant (2009) located at Negeri Sembilan, Manjung (2002-2003) and Manjung-4 (2015) power plants located at Perak, Sultan Abdul Aziz Shah power plant located at Selangor also known as the earliest coal-fired power plant in Malaysia operated from 1988, Tanjung Bin 1-3 (2006-2007) and Tanjung Bin-4 (2016) power plants located at Johor, Mukah power plant and Sejingkat power plant located at Sarawak. Coal is a source used by thermal power plant to generate electricity. Mostly, generation of electricity at thermal power plant will produce solid waste (referred to as coal ash) as their by-product from the production because the process involves the combustion of bituminous coal as fuel. The solid waste (by-product) from the electricity production consists of coal fly ash (CFA), coal bottom ash (CBA), boiler slag and fuel gas desulfurization (FGD). Usually, CFA and CBA produced are 10% from the coal burned and the general production ratio of them is 80:20 respectively for years [1]. The type of furnace when pulverized the coal combustion will result to the type of by-product (i.e CFA, dry-CBA and wet-CBA). Consuming the large quantities of coal ashes are the result from the large utilization of coal from the large power plant.

CFA and CBA are classified as non-combustible materials where CFA will be entrained in the flue gas and collected in electrostatic precipitators or baghouses while CBA formed and collected at the bottom of furnace. CFA is used for the production of cement as the physical properties of CFA is more fine particles size and spherically compared to CBA. When the ash particles soften and stick to the wall of furnace, basically CBA is formed. CBA (larger particles) which is much coarser than CFA will agglomerate and fall to hoppers located at the base of the furnace [2]. CFA is widely used for construction industry since 1930's [3] especially in the production of cement that will be substituted into concrete and has proven that CFA increases the long term strength and workability. Furthermore, CFA has potential for applications of geotechnical engineering which is also very significant used in manufacturing construction industry. However, this research will be focused on the CBA only because currently CBA is still treated as a waste, especially in Malaysia. Today, CBA has widely been utilized in the construction industry such as road base and sub-base, structural fill, drainage media, aggregate for concrete, asphalt and masonry also manufactured soil products. CBA is replacing the sand and gravel which is primary raw material in production of concrete. For increasing the use of disposal wastes, this can reduce environmental impact. This study is to find an alternative application for CBA from construction industry. Therefore, CBA is used as a filler in a composite to produce a plastic molding also test the tensile properties.

However, there is another research using injection molding machine (IMM) to process CFA as a filler and high density polyethylene (HDPE) as matrix material for filled composites. This CFA-HDPE composite has an advantage in the making of complex 3D products and in large quantity production. The matrix composite known as plastic molding can also be used for inorganic or organic binders based filled composites for various structural and industrial applications. [4]. Therefore, this study will test on using CBA instead of CFA as the filler and polypropylene (PP) as the matrix material for the plastic molding. The optimum temperature zones using IMM for CBA-PP will also be determined based on the sample structure.

II. METHODOLOGY

A. *Materials*

The materials used for this study is coal bottom ash (CBA) and polypropylene homopolymer (PP). CBA samples were collected from Sultan Abdul Aziz Shah power plant located at Kapar, Klang. PP was supplied by Total Petrochemicals & Refining USA.

B. Coal bottom ash (CBA) filled with Polypropylene (PP) composites preparation

The sample of CBA acts as a filler was mixed into PP to be a composite. Coal bottom ash filled with polypropylene composites known as (CBA-PP). First, CBA was dried out under the sun for at least one day [5] for ensuring there is less moisture content in it. After that, CBA was grinded manually by using mortar before sieving which modeled of sieve shaker OCTAGON 200 by Endecotts for the size in range of 0-150 µm. The powdered or finer version of CBA following the mass composition of Table 2 was combined with PP as a composite in a beaker and weighted them to be 60 g by using an electronic balance. CBA-PP was stirred by using a spatula for ensuring they are perfectly mixed into each other before entering them into the hopper of IMM. The CBA-PP composites was formed using the IMM with increasing content of CBA filler at 0% (PP100), 5% (CBA5PP) and 10% (CBA10PP). Therefore, there are three types of samples with different weight percent of CBA into PP was prepared.

Table 1 : The details of composition and designation of CBA-PP composites

Composites No.	Polypropylene, PP (wt%)	Coal Bottom Ash, CBA (wt%)
1 (PP100)	100	0
2 (CBA5PP)	95	5
3 (CBA10PP)	90	10

C. Optimum parameters of Injection Molding Machine (IMM) to produce a plastic molding

The mould used for IMM for this experiment is tensile mould. The other IMM parameters were set at fixed values which includes injection pressure at 60 bar, mold temperature at 33 ºC and the cycle time is 67.35s due to the set files for tensile mould in the IMM. The variable parameters of temperature zones has a guideline of zone 1 must be less than 200 ºC, zone 5 must be greater than 220 ºC and the zones in between are in the range of 200 ºC to 220 ºC. 5 samples of each composites number was moulded. The optimum parameters of IMM as in Table 2.

Table 2 : The parameters and the set value.

	Parameters	Value	
Constant parameters	Mould	Tensile	
	Cycle time, s	67.35	
	Injection pressure, bar	60	
	Mold temperature, ºC	33	
Variable parameters	Heating/temperature zones, ºC	1	<200
		2	200-210
		3	210-215
		4	215-220
		5	>220

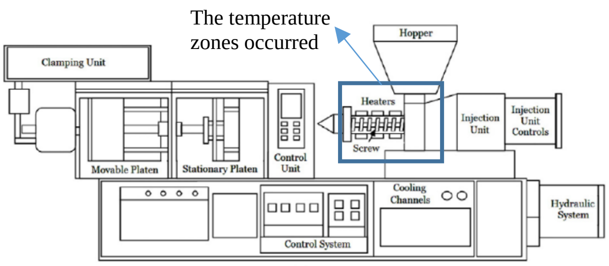

Figure 1 : The schematic sections of the injection molding machine (IMM)

D. Tensile test of plastic molding by using Universal Testing Machine (UTM)

The size of plastic molding is about 16.5 cm which is straight products length from IMM following ASTM 638. The thickness of the plastic molding was taken in the middle position of specimen by using calipers and the plastic molding was placed at grips at the end of the tensile tester. The tensile strength were tested at room temperature (25ºC) with a constant crosshead displacement rate which is 50 mm/min [6] according to ASTM 638. The stress-strain curves were plotted to see the tensile properties with increasing weight percent of CBA in CBA-PP composites analyzing by the calculation of elongation, fracture strain, tensile modulus and others.

Figure 2 : Universal Testing Machine

III. RESULTS AND DISCUSSION

A. Temperature zones parameters of IMM

Table 3 shows that the variable parameters of heating/temperature zones were identified for 1st, 2nd, 3rd, 4th and 5th zones to get the standard characteristics of plastic molding. Then, each set of composites number was entered into the hopper of IMM one after another until the plastic molding with a perfect shaped, no bubble and smooth surface were formed.

Table 3 : The optimum temperature zones used in IMM

	Parameters	Value	
Constant parameters	Mould	Tensile	
	Cycle time, s	67.35	
	Injection pressure, bar	60	
	Mold temperature, ºC	33	
Variable parameters	Heating/temperature zones, ºC	1	200
		2	210
		3	215
		4	215
		5	240

The plastic molding is not directly will formed in a perfect shaped for the first try. It all depends on the machine performance and the variable parameters set up. The other factors such as the accuracy of mold, properties of materials, operation of complete molding cycle and many more. Figure 3 is the plastic molding that is not in perfect shaped, rough surface, bubbles occurred, too much CBA inside the machine, not perfectly mixed and others.

Figure 3 : The plastic molding a) in standard characteristics (perfectly mixed) b) not in standard characteristics (not perfectly mixed)

Those plastic molding that is not in standard characteristics cannot be used for tensile strength or any of strength test because the structure inside the plastic molding is not perfect. The structural and environment factors of them is not in the same conditions and they cannot be compared with the standard characteristics one [7]. Figure 4 is the plastic molding that have the standard characteristics will undergo the tensile test with increasing content of CBA.

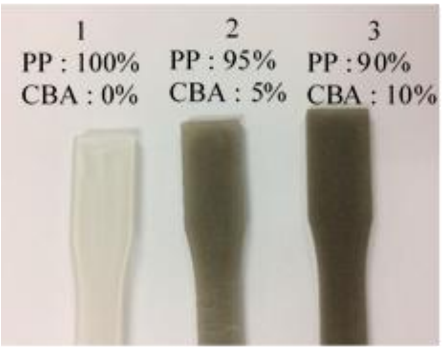

Figure 4 : The plastic molding for each composites number

B. *Tensile properties of plastic molding of CBA-PP composites*

This research is focusing on the tensile strength followed standard of ASTM D638 for mechanical properties only [8]. Table 4 shows the various tensile properties for values of CBA-PP composites. Each of these values is an average taken from test conducted on 5 samples of each composite, PP100, CBA5PP and CBA10PP.

Table 4 : The average values of 5 specimen for tensile properties of PP with CBA fillers

Sample name	PP100 (1)	CBA5PP (2)	CBA10PP (3)
Weight percent (wt%) of PP and CBA	PP : 100% CBA : 0%	PP : 95% CBA : 5%	PP : 90% CBA : 10%
Yield (MPa)	311.26	292.26	282.00
Yield (%)	17.39	16.01	14.558
Max Stress (MPa)	315.28	292.26	282.00
Elongation at break (%)	26.64	21.67	20.88

Based on the Table 4, the overall average result for all tensile properties of PP100, CBA5PP and CBA10PP were decreasing when CBA content is increasing. The decreasing value of % elongation determined means that the specimen deforms by stretching becomes shorter. The length of specimen after stretch is shorter as the CBA content is increasing. This is consider as ultimate elongation because the specimen has nothing more than the amount you can stretch before it breaks. The difference percent of elongation at break of PP100 with CBA5PP and CBA10PP over PP100 is by 18.68% and 21.64% respectively.

The analysis based on the % elongation at break is quite high because the difference is around 20%. With the addition of 5% and 10%, CBA filler in PP (for sample CBA5PP and CBA10PP), the drop in minimum stress when compared to pure PP (PP100) is below 10%. This means that the characteristics of CBA5PP and CBA10PP according to max stress is accepted due to lower than 10% when comparing to PP100 sample. The tensile strength is considered near to each other even when CBA is used as a filler in the PP composites for the plastic molding. Figure 5 shows the general information of analyzing stress vs strain curve where Ultimate Tensile Strength (UTS), the necking region, plastic behavior region and others are pointed.

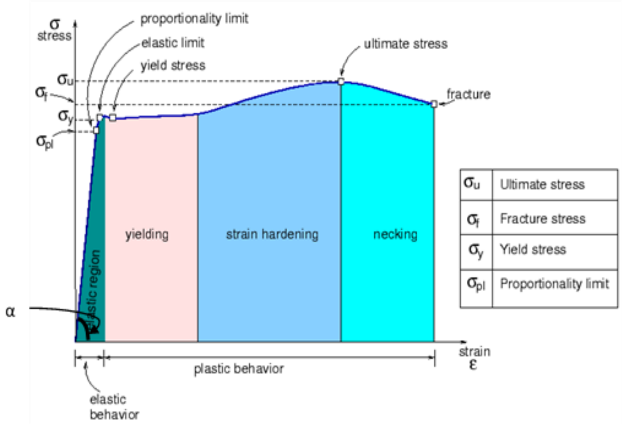

Figure 5 : The region and point of stress-strain curve

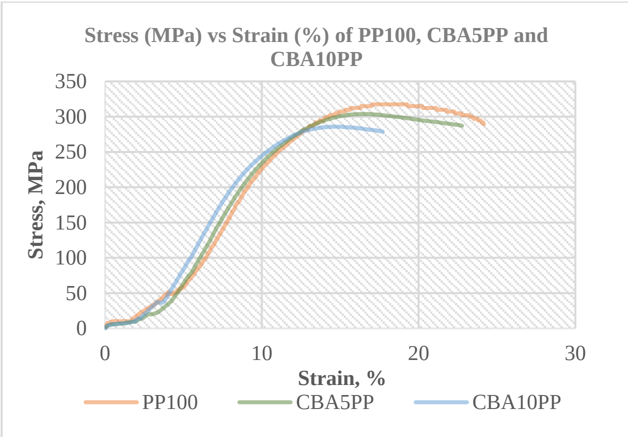

Figure 6 : The graph of Stress vs Strain for all 3 composites

According to Figure 6, the highest UTS or tensile strength (TS) or highest yield stress also known as max stress is by PP100 sample followed by CBA5PP and CBA10PP. This is because composites with pure PP can handle the most load applied to the specimen before or after deformation begins. The composites with 5% and 10% of CBA content as a filler has the lower maximum stress than pure PP. Other than that, the fracture point for pure PP is much longer than CBA5PP and CBA10PP by the x-axis (strain axis). This is due to the characteristics of polymer which is more elastic. The fracture point of CBA5PP and CBA10PP is decreasing which means the elasticity of the specimen is lower/shorter. The increasing ductility of those 3 specimens are CBA10PP followed by CBA5PP and PP100. The necking region is increasing when CBA content is decreasing. The necking is affected by the dissipation of mechanical energy and the deformation resistance of the neck [9]. The long necking region in PP100 specimen corresponds to the large plastic deformation observed in the stress-strain graph. The reduction in the strength was generally significant due to the effects of suction or a true cohesion of pozzolanic activity in CBA.

The stress-strain behavior of a composites with polymer material is depends on molecular characteristics, microstructure, strain-rate and temperature. The increase of CBA content in the composites result in lower plastic deformation, shorter necking region, faster the fracture point and lower the ultimate tensile strength (UTS/TS). Therefore, composites with pure PP is consider as (E) hard and tough pattern while composites with CBA content is hard and strong (D) pattern determined from the stress-strain graph.

The difference of those analysis is present but not to high when the percentage difference of CBA5PP and CBA10PP over PP100 is calculated. The other factors of analysis above is due to the structural and environment factors for the specimen. The viscous and elastic behavior are much stronger when strong time and temperature sensitivity of polymer properties resulting in the viscoelastic nature of polymers. The standard characteristics of the plastic molding is based on the optimum parameters set up in IMM and influenced the tensile properties. CBA can be used as a filler with PP composite in some application including laboratory equipment, loudspeakers, textile, reusable container, in packaging industry and others [12].

C. Failure fracture of plastic molding

The failure fracture is appeared during the tensile test for pure PP composites. This plastic deformation of failure fracture seems to draw the fibers leading to fracture [10].

The specimen is not directly broken, it has a long elastic formation like a stretch region that is going to be a permanent deformation after it breaks. The example of failure fracture as in Figure 5.

Figure 5 : The failure fracture of plastic molding

The failure of polymers in certain specimen is due to the excessive elastic deformation resulting from inadequate rigidity or stiffness, yielding or excessive plastic deformation resulting from inadequate strength properties of polymer where the primary interest is the yield strength and the corresponding strain and then, fracture which occur in a sudden, brittle manner or through fatigue [7].

For the suggestion of future work of this research, the research is about correlation of mechanical and structural properties of fly ash filled-isotactic polypropylene composites said that there are limitation of Fly Ash (FA) content in the composites to make sure the linear elastic fracture is acceptable. According to [11], exceeding 20% of FA content in the composites may reduce the intimate contact between the surface of FA and PP lessening the interfacial interaction. Thus, since FA has few similarity with CBA, the analysis of the limitation can be followed as reference. However, there must be expanded limitation of CBA content up to 80 wt% in the composites to analyze the limitations of tensile properties in details as to know the exact percentage limitation of CBA content in the composites that can be accepted. Therefore, further study of this research recommends on more details of the mechanical properties when CBA content is increasing in the composites including the difference temperatures (25, 50, $70^{o}C$ for example) when tensile test were conducted.

IV. CONCLUSION

The coal bottom ash filled with polypropylene composites (CBA-PP) becomes a plastic molding when injection molding process is done. To get the standard characteristics of plastic molding, the optimum temperature zones are determined and other parameters such as injection pressure (60 bar), cycle time (67.35 sec) and mold temperature ($33^{o}C$) are set at fixed value. The temperature zones identified to be 200, 210, 215, 215 and $240^{o}C$ for zones of 1, 2, 3, 4 and 5 respectively. Then, the experiment was continued to tensile test of the plastic molding. The analysis for composites with pure PP (PP100), 5% of CBA content (CBA5PP) and 10% of CBA content (CBA10PP) were determined based on the stress-strain graph. The tensile strength of PP100 followed by CBA5PP and CBA10PP with value of max stress (MPa) of 315.28, 292.26 and 282.00 MPa respectively. The yield percent (%) of tensile properties for PP100, CBA5PP and CBA10PP are 17.39, 16.01 and 14.56 % respectively. Based on the result, the analysis of the plastic deformation highest, the fracture point by the strain axis is longest, the necking region is longest, and the tensile strength is highest when the composite is pure PP (PP100 sample). The addition of CBA content in the composites slightly decreases the stress and strain analysis.

Future research plan recommends to be increase the CBA content up to 80% and analyze the exact limitation percentage of CBA content as a filler for the tensile properties that can be considered as acceptable range when comparing with pure PP of plastic molding. In conclusion, CBA can be utilized in other application including plastic industry which are apart from construction industry as an alternative.

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References

[1] Rafieizonooz, M., Mirza, J., Salim, M. R., Hussin, M. W., & Khankhaje, E. (2016). Investigation of coal bottom ash and fly ash in concrete as replacement for sand and cement. *Construction and Building Materials*, 116, 15-24.

[2] Ramme, B. W., & Tharaniyil, M. P. (2004). Coal combustion products utilization handbook.H. Poor, (2013). *An Introduction to Signal Detection and Estimation*. Chapter 4. New York: Springer-Verlag.

[3] Malhotra, V. M., & Ramezanianpour, A. (1994). *Fly ash in concrete*: Canmet.

[4] Das, A., & Satapathy, B. K. (2011). Structural, thermal, mechanical and dynamic mechanical properties of cenosphere filled polypropylene composites. *Materials & Design*, 32(3), 1477-1484.

[5] Jaturapitakkul, C., & Cheerarot, R. (2003). Development of bottom ash as pozzolanic material. Journal of materials in civil engineering, 15(1), 48-53.R. J. Vidmar, (1992). On the Use of Atmospheric Plasmas as Electromagnetic Reflectors. *IEEE Trans. Plasma Sci. 21(3).* 876-888.

[6] Kumar, B. B., Doddamani, M., Zeltmann, S. E., Gupta, N., & Ramakrishna, S. (2016). Data characterizing tensile behavior of cenosphere/HDPE syntactic foam. *Data in Brief*, 6, 933-941.

[7] Ebewele, R. O., & Ebewele, R. O. (2000). *Polymer science and technology* (Vol. 1): CRC press Boca Raton, FL.
[8] Huang, X., Hwang, J., & Gillis, J. (2003). Processed low NOx fly ash as a filler in plastics. *Journal of Minerals and Materials Characterization and Engineering*, 2(01), 11.
[9] Milisavljevic, J., Ćirić, I., & Mančić, M. *Tensile Testing for Different Types of Polymers.* Paper presented at the 29th Danubia–Adria Symposium.
[10] Kumar, B. B., Doddamani, M., Zeltmann, S. E., Gupta, N., Ramesh, M., & Ramakrishna, S. (2016). Processing of cenosphere/HDPE syntactic foams using an industrial scale polymer injection molding machine. *Materials & Design*, 92, 414-423.
[11] Shubhra, Q. T., Alam, A., & Quaiyyum, M. (2013). Mechanical properties of polypropylene composites: A review. *Journal of thermoplastic composite materials*, 26(3), 362-391.
[12] Gummadi, J., Kumar, G. V., & Rajesh, G. (2012). Evaluation of flexural properties of fly ash filled polypropylene composites. *Int J Mod Eng Res*, 2(4), 2584-2590.