Effect of Particle Size and Concentration of Fly Ash on Mechanical Properties of Polyphenylene Oxide Composites

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Abstract— In this study, the effect of the fly ash with different particle size and different filler concentration (5 to 20% by weight) on the mechanical and rheological properties of the polyphenylene oxide (PPO) composites were studied. The PPO Composites of fly ash were prepared by Haake Rheocord 9000 twin screw extruder machine. The standard test specimens were molded on Injection moulding machine. Mechanical and rheological properties were determined using these test specimens. It was found that with the addition of fly ash as filler in polyphenylene oxide, showed improvement in flexural strength and modulus with the increase in fly ash concentration whereas tensile strength, melt flow index and impact strength are found to decrease with increase in fly ash concentration.

Keywords— Polyphenylene oxide (PPO), Fly ash.

I. Introduction

THE reinforcing effect of mineral fillers for polymers has been recognized since the last few decades. Improving the mechanical, electrical, thermal, optical and processing properties of the polymer with the addition of filler materials has become a very popular research interest.. Utilization of fly ash (FA) as a filler in polymer composites has received increased attention recently, particularly for price-driven/ high volume applications. Incorporation of fly ash offers several advantages: it is the best way of disposing of fly ash, and as it is cheap and plentifully available, it decreases the overall cost of composites.

The flexural strength and modulus both were found to be increasing with the increase in the concentration of fly ash, for fly ash filled polypropylene composites. Gummadi Jitendra[1] et. al. It is also reported that the performance of fly ashcenosphere composite is the function of particle size, the dispersion and the interfacial interaction between the filler particles and the polymer matrix. The smaller particle size showed better properties in comparison with larger particle size for fly ash filled acrylonitrile butadiene styrene composites. M.B. Kulkarni[2] et. al. It has been found that the resultant strength and modulus of fly ash-epoxy systems increases considerably when fly ash is treated with a silane coupling agent. S. M. Kulkarni[3] et. al. It lower impact strengths with an increase in filler content fly ash filled epoxy Kishore[4] et. al. Fly ash can be incorporated in elastomers to get good properties at optimum concentrations which can be used for applications such as rubber buffer springs, rubber pads for ballast less track and industrial flooring . D. G. Hundiwale[5] et. al.

Tensile strength, flexural and modulus increased with the increase in fly ash concentration for fly ash filled HDPE composites. The tensile strength decreased drastically after 10 wt % loading of fly ash. Impact strength of the composite showed decrease up to 15wt % loading of fly ash and then remained almost constant. The smallest particle size of fly ash proved to be better in enhancing strength and relative elongation. Modulus and impact strength did not seem to depend much on particle size. Iftekhar Ahmad[6] et. al. The 30 and the 60% composites showed a faster degradation at a lower temperature, whereas, the 40 and the 50% composites showed a higher onset temperature. The activation energy was calculated following Broido's equation and was found to be lowered in all the composites compared to the unfilled resin. The residue increased in all the composites proportionately with the increase in the fly ash content. The temperature variation resistance of the unfilled resin, 30 and 60% filled composites were measured and all the samples showed semi conducting nature in 40–60°C temperature range. D. Ray[7] et.al.

N. A. N. Alkadasi[8] et. al. studied the effect of silane coupling agent on mechanical properties of fly ash filled Polybutadiene rubber. Properties of composite filled with treated and untreated Fly ash. Fly ash treated with silane coupling agents gave greater reinforcement than untreated. S. G. Pardo[9] et. al. studied Rheological, thermal, and mechanical characterization of fly ash-thermoplastic composites with different coupling agents. coupling agents containing amine and vinyl functional groups. materials with improved stiffness and strength. The Young's modulus seem to be related to the presence of the stiffer second phase and to the stiffness of the couplings. In the case of strength, however, the improvement was attributed to the higher degree of filler-matrix interaction promoted by these coupling agents. This was also confirmed from fracture surface analysis. Coupling agent had a vinyl-benzylamine group, no significant differences between the corresponding composite and the composite with untreated fly ash. material exhibited the most ductile behavior, even displaying yield before fracture. This behavior could be attributed to a change in particle dispersion in the matrix which would have been yielded induced from debonding of better dispersed ash particles. the effectiveness of the coupling

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agents in giving the best properties together with good process ability of the composites. K. T. Paul[10] et. al. studied Nano structured fly ash–styrene butadiene rubber hybrid nanocomposites. SBR composites filled with fresh fly-ash (FFA) carbon black (CB) and precipitated silica (PS). In general, SBR-NFA composites exhibit higher state of cure and higher strength properties as compared with HAF black-filled and fresh fly-ash-filled SBR composites at equivalent loadings. This may be attributed to the higher reinforcing ability of NFA. Tear strength and abrasion resistance of the SBR-NFA composites were superior to FFA-filled and precipitated silica-filled vulcanizates, but were inferior to carbon black- filled SBR vulcanizates. The SBR-NFA composites showed lower hardness as compared with both the carbon black-filled and silica-filled composites. Transmission electron microscopy and scanning probe microscopy studies revealed that the NFA particles are well dispersed in the SBR matrix. These results were further supported by fracture surface analysis under the SEM.

II. Experimental

A. Materials

Polyphenylene oxide was obtained from Rupal plastic pvt.Ltd, Mumbai. Fly ash was obtained from DIRK Mumbai Group under the brand name of Pozzocrete. The particle size used for the experiment was in the specific range of 30-50 µ, 120-140µ and160-180µ.

B. Compounding

Before blending, fly ash was preheated at 105^0 C in an air-circulation oven. The virgin polymer polyphenylene oxide was dried at 100^{o}C for 3 hours in an air-circulating oven. Polyphenylene oxide and fly ash were mixed as per required proportion in tumbler mixer. The pre-dried raw materials are dry blended in the required ratio (5, 10, 15, 20 wt%) before feeding in the counter-rotating twin screw extruder HaakeRheocord 9000 with 16 mm diameter and L/D 25:1 ratio. The extrudate is quenched in water at a temperature of about 20-30^0 C. The compounding is carried in twin screw extruder at 290^0C.

C. Fabrication of composite

The granules of the extrudate were injection moulded for preparing specimen to test for Impact, Flexural and Tensile properties. Test specimens were prepared as per ASTM standards. Dumbbell shaped for tensile test (ASTM D638M-91), notched Izod impact strength (ASTM 256) and rectangular bar for flexural strength measurement (ASTM 790M -92).

D. Measurement

MFI of the virgin polymer and composites is determined out by Extrusion Plastometer using Melt flow Index tester (Davenport, UK) according to ASTM D1258.Dumbbell shaped specimen were obtained by injection moulding. Tensile strength of the virgin polymersamples was evaluated according to ASTM D638 M-91using Universal Tensile Tester LR50K [Lloyd Instrument Ltd., U. K.] The crosshead jaw speed of 50mm/min was maintained for testing and a load cell of 5 KN was used. The flexural strength and flexural modulus was measured using universal testing machine [LR 50 K, LLOYD Instruments, U.K.] according to ASTM D790 M-92. Jaw speed of 2.8 mm/min was maintained for 3-point flexural strength and the span was 200 mm. Rectangular bars of dimensions 63×12×12 (length× width × thickness in mm were injection moulded. The notch was cut on rectangular bar specimen using a motorized notch-cutting machine [Polytest Model 1, Ray Ran U.K.]. Impact strength was measured using Avery Denison's pendulum type, Impact Strength Tester, [model 6709].The results reported are average values of at least 5 test specimens.

III. Results and Discussion

A. Melt Flow Index of untreated fly ash filled PPO composite.

Presents variation in melt flow index of fly ash filled polyphenylene oxide composites. It is seen that, melt flow index decreases with increasing concentration of fly ash, but the rate of change of melt flow index is ,higher in case of lower particle size as compared to higher particle size. The trend of variation in melt flow index is presented in **figure 1** indicates presence of agglomerate of smaller particle size fly ash and its effect on melt flow index. At 15% loading, the melt flow index of higher particle size is lowered as compared to, both the lower particle size, indicating the agglomeration of smaller particles of fly ash and thereby lowering the total surface area available for the interaction with the matrix. The phenomenon of agglomeration is also depicted by sinusoidal behavior of change of melt flow index of 30-50 µ fly ash filled composite of polyphenylene oxide composite as well as, at the higher concentration, melt flow index of all the three particle size polyphenylene oxide composite is almost same.

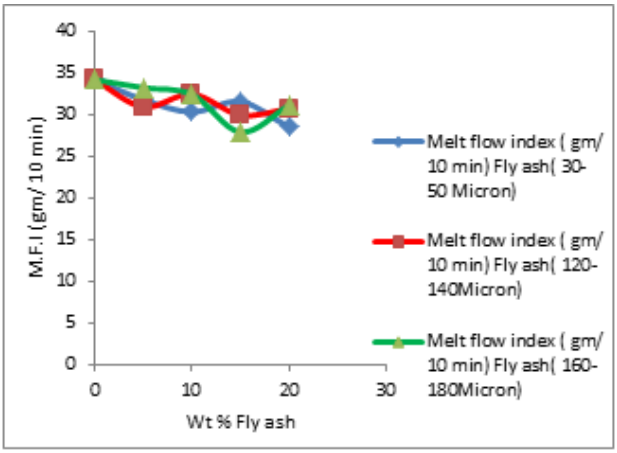


Fig 1. Variation of the melt flow index of polyphenylene oxide fly ash composite.

B. Tensile strength

Presents variation in tensile strength of fly ash filled polyphenylene oxide composite. It is seen that tensile strength increases initially with smaller particle size up to 10% loading

and, then decreases and attains minima at higher concentration, whereas the tensile strength remains almost unchanged for higher particle size fly ash indicating effect of particle size on tensile behavior and, thus lower particle size agglomerate at higher concentration, thereby reducing tensile strength as compared to coarse particle size fly ash. The dispersion level and agglomerate particle size changes with concentration, which is indicted by minima at 15% fly ash loading and increase in tensile strength thereafter, whereas for higher particle size, the tensile strength remain almost unchanged for all the concentration. The variation in tensile strength of fly ash filled polyphynylene oxide composite is shown in figure 2.

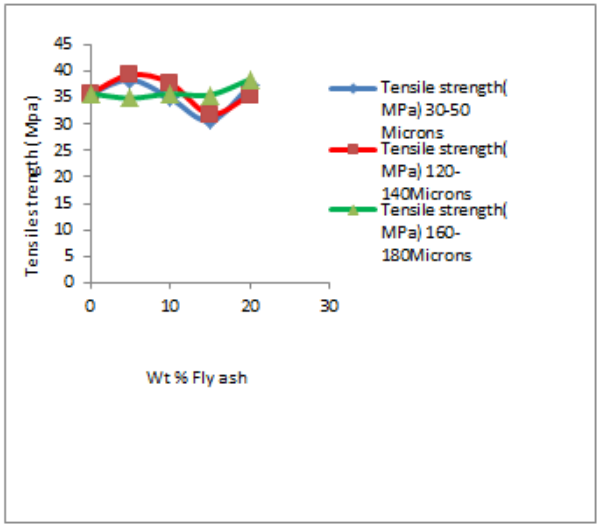


Fig. 2 Variation of the tensile strength of polyphenylene oxide fly ash composites.

C. *Elongation at break*

Presents variation in elongations at break of fly ash filled polyphenylene oxide composite. The agglomeration behavior of smaller particle size fly ash also supported by variation in percentage elongation of lower particle size as well as coarse particle size fly ash composite. It is seen that rate of change of elongation with respect to fly ash concentration is higher, for higher particle size, i.e. 160-180 µ, and remain almost same indicating formation of agglomerates at all the concentration up to 15% loading, having lower average particle size of agglomerate of smaller particle size fly ash as compared to individual coarse article size fly ash, thus the elongation behavior which is dependent on mobility of individual polymer chain is restricted to a limited extent, by lower particle size agglomerate as compared to higher particle size. At higher concentration the total surface area offered by higher particle size fly ash and agglomerate particle size of lower particle size fly ash become almost same, thereby offering same extent of restriction for immobility of polymer chain, thereby showing almost same percentage elongation. The variation in elongations at break of fly ash filled polyphynylene oxide composite is shown in **figure 3.**

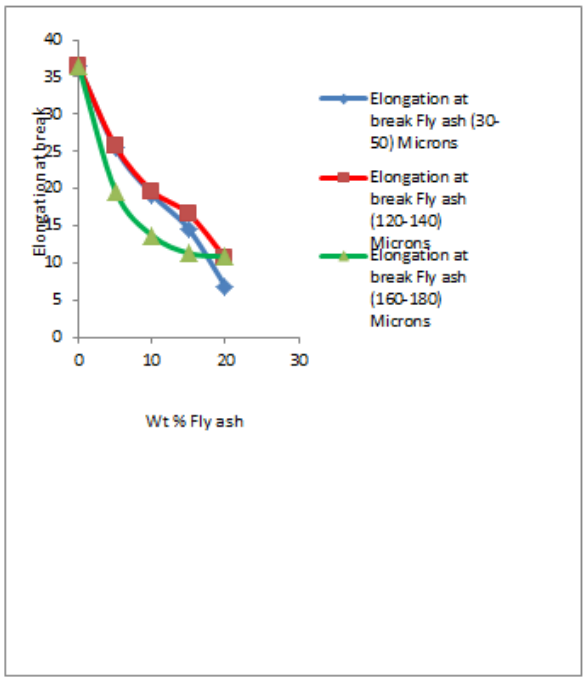


Fig. 3 Variation of the elongation at break of polyphenylene oxide fly ash composites.

D. *Flexural strength*

Presents variation in flexural strength of fly ash filled polyphenylene oxide composites. It is seen that flexural strength increases with increasing concentration of fly ash. The rate of increment of flexural strength remains almost same for all the particle size fly ash composite, except marginally higher flexural strength of 120-140 µ fly ash filled composite, indicating higher particle size agglomerate at higher concentration of fly ash, compared to lower particle size agglomerate, as well as higher particle size of individual particle of higher particle size fly ash. This also supports agglomeration behavior of lower particle size fly ash, and its response towards the applied stress on loss modulus and storage modulus of composites. The change in flexural strength is also controlled by the particle size of filler along with molecular weight, flexibility and surface properties of filler and matrix, thus at higher concentration effective particle size and interface interaction for all the particle size filled composite, become almost same, and there by showing marginal variation in lower particle, and higher particle size fly ash composites, where the molecular weight and other secondary forces offered by matrix remain same. The assumption of agglomeration of lower particle size is also supported by SEM photographs. The Variation in flexural strength of fly ash filled polyphynylene oxide composite is shown in **figure 4.**

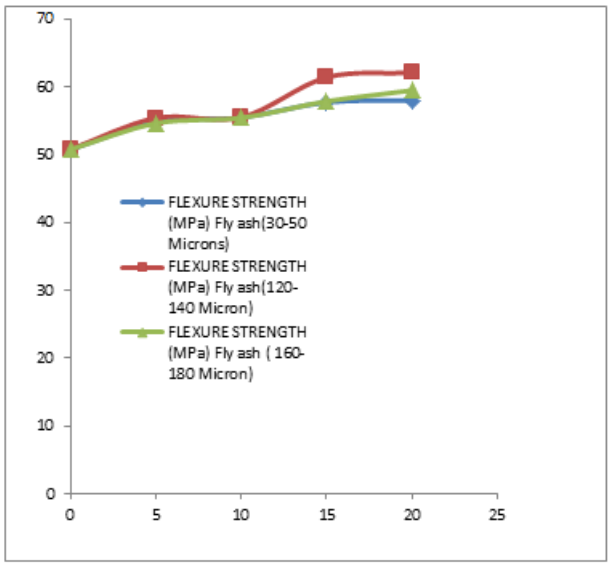


Fig. 4. Variation of the of the flexure strength of polyphenylene oxide fly ash composites.

E. Flexural Modules

Presents variation in flexural modules of fly ash filled polyphenylene oxide composite. It is seen that flexural modulus increases with increasing concentration of fly ash, in case of higher particle size as well as medium particle size fly ash, whereas the trend of rate of change of flexural modules of lower particle size indicates, occasional agglomeration of smaller particle size fly ash, thereby changing the availability of effective surface area for matrix. This assumption of change in effective area of interaction is also, observed in the rate of change of increments in, flexural modulus of higher particle size at lower and higher concentration. The rate of change of flexural modules is higher, at lower concentration as compared to higher filler concentration for higher particle size, whereas for 120-140 µ fillers, the rate of change of flexural modules remain almost same, at all the concentration of filler loading. The change in rate of change of flexural modules for smaller particle size at different concentration indicates the change in extent of dispersion, and change in agglomeration size at different filler loading. The observations of variation in flexural modulus support the earlier assumption of lower particle size. The variation in flexural modulus of fly ash filled polyphynylene oxide composite is shown in **figure5.**

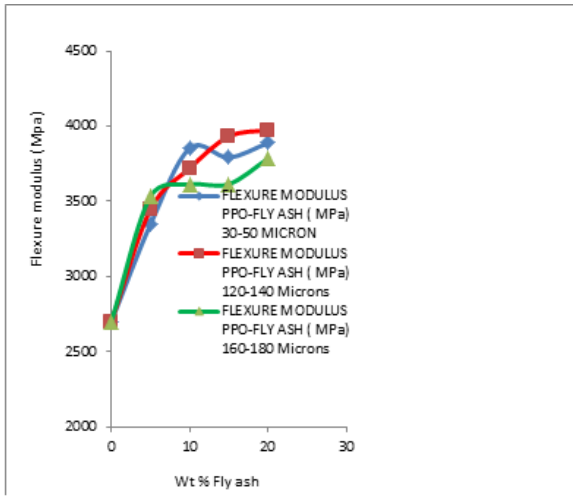


Fig. 5**.** Variation of the flexure modulus of polyphenylene oxide fly ash composites.

F. Impact strength

Present variation in impact strength of fly ash filled polyphenylene oxide composites. It is seen that impact strength decreases, with increasing concentration of fly ash. The rate of decrease of impact strength, with increasing concentration of filler, increases with medium particle size, compared to coarse particle size of fly ash, whereas the trend in variation in impact strength supports the phenomenon of agglomeration of lower particle size, as well as, the rate of change of reduction in impact strength of 120-140 µ and 160-180µ, at higher loading supports the agglomeration of smaller particle and thereby its effect on impact strength. The variation in impact strength of fly ash filled polyphynylene oxide composite is shown in **figure 6.**

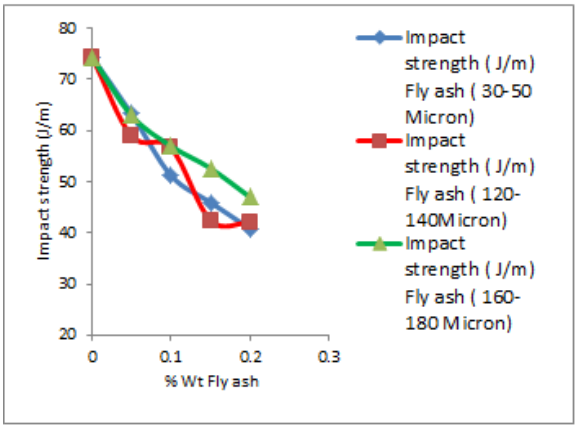
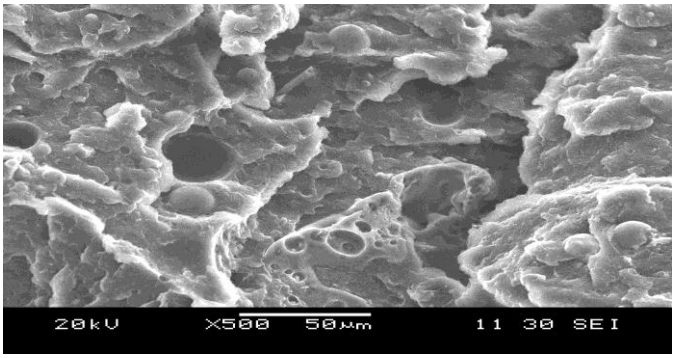


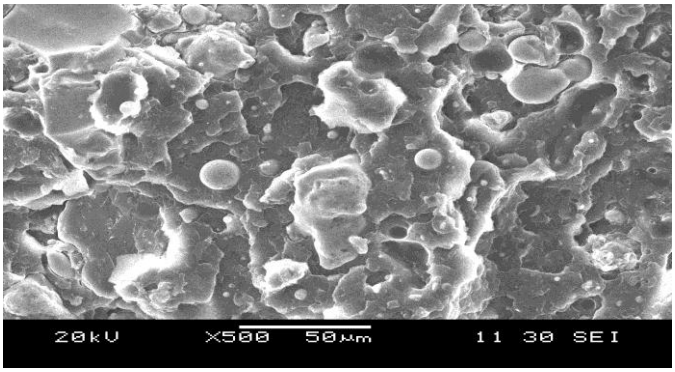
Fig. 6. Variation of the impact strength of polyphenyleneoxide fly ash composites.

G. Microstructure Characterizations

SEM is used to study the morphology of the composites. Fig.7. shows the SEM micrographs of the composites at 20 wt% composite with 125 micron. And of 15wt% fly ash with 53 Micron. represents the SEM micrographs of PPO/fly ash composites.



Fly ash filled polypropylene composites (53 micron, 15%).



Fly ash filled polypropylene composites (125 micron,20%)

V. CONCLUSION

Melt flow index, percent elongation and impact strength decreased with increasing concentration of fly ash.Tensile strength initially increased with increasing concentration of fly ash up to certain loading and thereafter decreased.Flexure strength and flexure modulus increased with increasing concentration of fly ash.

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