"Effect of Fly-Ash on Thermal & Mechanical Properties of Polystyrene Fly-Ash Composites"

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Abstract— Replacement of conventional materials by polymeric composites with improved mechanical performance is of immense importance for modern technology. The Tensile test (stress, strain and young's modulus), Micro-hardness and Differintial Scanning Calorimetry (DSC) of composites were investigated. Fly-ash reinforced polystyrene composites have been prepared with solution casting method. Concentration of fly-ash was varied from 3% to 8 % by weight. Tensile properties were found to decrease with fly-ash addition, however, the Micro-hardness was found to increase with increasing fly-ash concentration. The DSC test gives good indication of improvement in thermal properties..

Key words: Micro-hardness, Tensile properties, DSC,PS, FA.

I. INTRODUCTION

Expending industrial activities demand materials that are expected to satisfy increasing requirements of strength, modulus and reduction in cost. This demand has given a big scope for the use of polymeric composite materials. Polymer composites are very important as they are widely used in large number of applications due to their light weight , ease of fabrication and variety of other properties (Singla et al. 2010; Chauhan et al. 2010). With increasing demand of high technology areas such as air frame, jet engines, space shuttles and atomic energy field. The need for light weight materials with high strength and stiffness has led to the development of flyash based composites (Kishore et al. 2002)

A composite is a material that consists of two or more constituents that are combined at a macroscopic level and are not soluble in each other. One constituent is called the reinforcing phase and other one in which it is embedded is called the matrix((Dobrzański et al.2006).The composite material generally possesses characteristic properties such as stiffness,strength, weight, high temperature performance and hardness that are not possible with the individual component of composite (Ayatollahi et al.2011). The fly ash is produced as industrial by product from the combustion of coal in thermal power plant and properties of fly ash depend primarily on the type of coal burned, the type of combustion of equipment used and the type of fly ash collection mechanism (Celik Ozlem et al. 2008). The major component of the fly ash is silica and alumina and oxides of iron, calcium, magnesium along with elements like Ti, carbon, Mg. etc. (Singla et al. 2010). Fly ash can increase the strength and make these light weight composites very desirable for the automotive , aircraft , aerospace industries (Abdullah et al. 2010) and also various house hold applications.

The strength of the composite material depends on the nature of polymer and reinforcement material such as particle's shape and size, morphology, concentration of filler viscoelastic behavior of matrix and dispersed phase .in case of irregularly shaped spherical particle fillers , the strength of composite may decrease due to inability of the filler to hold the local stress from the matrix in the absence of binding(Nath et al.2010) .The purpose of the present study is to investigate the effect of FA – which is new kind of filler on thermo mechanical properties of PS composite.

II. EXPERIMENTAL

A. *Materials:*

For the preparation of the polymeric composite films ,the commercially available polymer Polystyrene obtained from- Research lab Fine chemical industries, Mumbai and fly ash in powder form was procured from thermal power plant, Singrauli (M.P.) used without further purification.

B. *Preparation Of Specimen:*

Fly ash in different concentration was added to the polystyrene to yield the composite of required concentration and labeled as Pure polystyrene(PS),Pure fly ash (FA), 3% FA & PS, 5%FA & PS, and 8%FA & PS for 3, 5 and 8 weight percentage concentration of fly ash .

The solution-casting method has been utilized to prepare the composite films of pure polystyrene(PS) and fly ash based composite films. 1, 2 Dichloro-ethane has been taken as solvent. Fly ash and polystyrene were mixed in solvent 1,2 dichloro-ethane with the help of magnetic stirrer at 600C for 6 h. A known quantity of homogeneous solution poured in glass mould of size 5x5 cm2 was kept in the oven at 700C to sufficient time to cool down (nearly 24 h). Samples of 4x2 cm2 size were cut from the pellets and kept in the air tight polyethylene bags

C. *Thermal And Mechanical Properties:*

1) *DSC Study:*

In present investigation the DSC study of pure PS and FA reinforced PS composites have been carried out using DSC instrument DSC 2910 (Instrument from TA Instrument Inc., USA) at UGC-DAE consortium for Scientific Research, Indore.

2) *Microhardness Measurement:*

The microhardness studies has been carried out on pure polystyrene and fly ash reinforced polystyrene composite films with the help of mhp 160 microhardness tester, equipped with the Vicker's diamond pyramidal indenter having a square base and 1360 pyramidal angle attached to the Carl Zeiss NU2 universal research microscope.

The Vicker hardness number (Hv) was calculated using the relation

$$Hv = (1.854 \times L)/d2 \text{ kg/mm2},$$

where L is the load (in kg) and d is the length of the diagonal of indentation (in mm).Indentation at each load were obtained in replicate number and average hardness number was calculated.

3) Tensile Properties:

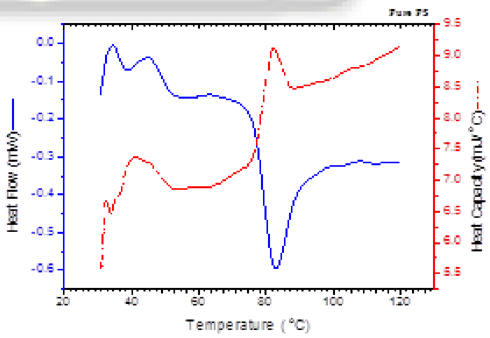
The Tensile strength (stress & strain) and Young's modulus studies were carried out using Instron 3369 (UTM) with extension rate 5 mm/min carried out at Department of Material science, IIT-BHU, Varanasi.

III. RESULTS AND DISCUSSION:

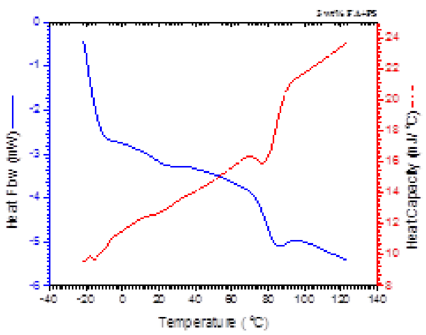
A. DSC Study:

DSC measures the amount of energy absorbed or released by a sample when it is heated or cooled, providing quantitative and qualitative data on endothermic and exothermic processes. The DSC profiles for pure PS and FA reinforced PS composites are observed. In present system, the DSC measurements are carried out in order to investigate the effect of varying filler concentration (3-8wt% FA) on thermal characterization of the polymer composites. The glass transition temperature of the pure PS is found to be 82.8390C. The DSC thermograms of various FA reinforced PS composites are shown in fig.1. It is evident that as the concentration of FA is increased to 3 weight percent (3wt% FA + PS), the glass transition temperature increases to 85.7600C.On further increasing the concentration of FA , the glass transition temperature successively increases to 87.7810C for specimen with 5wt% FA and 87.8180C for 8 wt% FA.

The increase in glass transition temperature with increase in the wt% of FA in PS composites shows the increase in crystallinity with developed morphology of composite.The increase in Tg of composites also suggests improvement in thermal stability. Such variations observed in the DSC scans of the composite may be due to interaction amongest the composite constituents (between PS and FA). The maximum value of Tg obtained for the composite sample with 8 wt% FA in PS which exhibits the maximum crystallinity.



(a)



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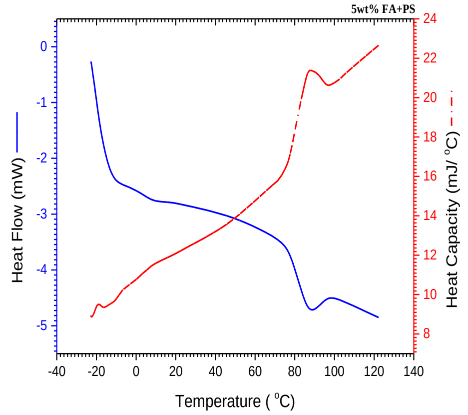

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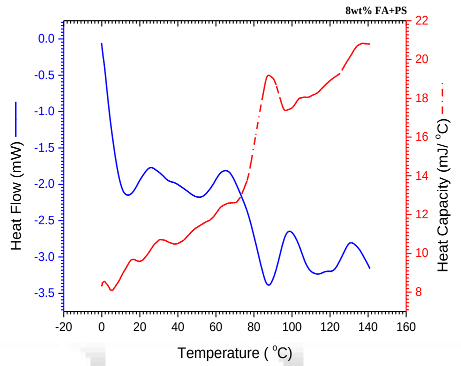

(d)

Fig. 1: DSC Thermograms of (a) pure PS,(b)3% FA and PS composite,(c) 5% FA and PS compositeand (d)8% FA and PS composite

S.No.	Sample	T_g (in ^{0}C)
1	Pure PS	82.839
2	3% FA+ PS	85.760
3	5% FA+ PS	87.781
4	8% FA+ PS	87.818

Table 1: Glass Transition Temperature Of Various Polymer Composites Of Polystyrene And Fly Ash.

B. Microhardness Measurement:

Microhardness testing is widely used in industry and laboratory as a useful tool for determining the mechanical properties of materials because it provides an easy, inexpensive and non destructive method of characterizing properties. Fig.2 shows the variation of microhardness (Hv) of pure polystyrene and fly ash reinforced polystyrene composites. The value of Hv is minimum for pure polystyrene and increases with increase in concentration of fly ash . The graph shows that the value of Hv increases curvilinear with increasing load (10 - 80 g) for different samples.

The increase in Hv with load is due to the strain hardening in the specimen. It is also noticed that the rate of strain hardening is greater at lower load and lower at higher loads. The strain hardening phenomena in polymers can be explained on the basis of spectrum of micromodes of deformation in the polymer chain (Rabinowetz and Brown 1967). When sufficient number of micromodes becomes active, large scale plastic deformation begins.On applying load, the polymeric specimen is subjected to the strain hardening and as the load is increased , the specimen is subjected to the greater strain hardening and hence Hv increases. The final saturation value of Hv observed due to permanent deformation caused by chain – chain slipping in polymer composites. Vander Waals forces and relatively high molecular forces between the individual macromolecules are known to contribute to the strength of polymer (Bajpai and dutt 1986).

The Hv attains a limiting value beyond the load at 50g for pure PS, 60g for 3%,5% and 8% FA reinforced polystyrene composites. The different values of the microhardness at saturation for the pure PS and various incorporation of fly ash indicate the changes in macromolecular structure and morphology. On applying the load the polymer is subjected to strain hardening, when Hv value tends to become constant the polymer is completely strain hardened. The rate of strain hardening in various sample is related to weight percentage ratio of fly ash within the composite.

Fig.3 shows the effect of load on the variation of diagonal size of pure PS, 3%FA and PS ,5%FA and PS and 8% FA and PS. The size of diagonal decreases with increasing concentration of fly ash within PS matrix, which represents the increasing plasticization effect due to incorporation of fly ash powder.

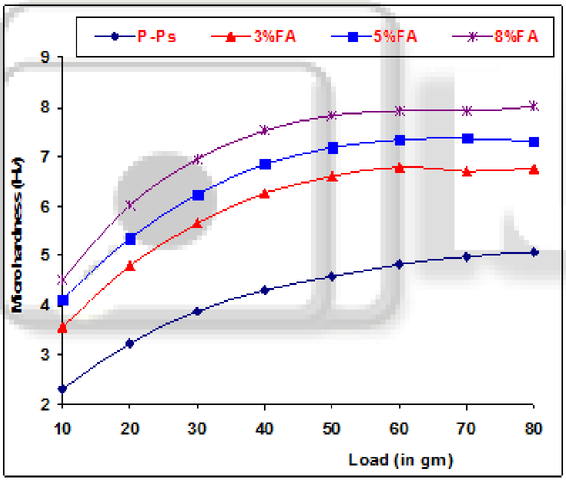

Fig. 2: Effect of load on the microhardness of pure PS, 3%FA & PS, 5 % FA & PS and 8%FA & PS.

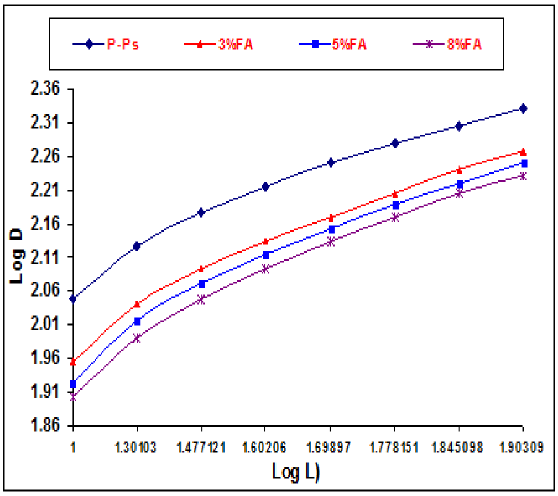

Fig. 3: Effect of load on the variation of diagonal size of pure PS, 3%FA & PS, 5% FA & PS and 8% FA & PS

C. *Tensile Properties:*

Tensile stress v/s fly-ash concentration curves were plotted and depicted in fig.(4). Fig.(4) shows the variation in tensile stress with varying concentration of fly-ash. It is observed that tensile stress gets reduced by 2.76% for 3 wt.% flyash concentration, 10.92% reduction for 5 wt.% fly-ash concentration and 38.75% reduced for 8 wt.% fly-ash concentration .

Fig.(5) shows variation in tensile strain with varying concentration of fly-ash .It is observed that tensile strain is reduced by 2.03% for 3 wt.% fly ash concentration then it increases to 4.53 % for 5 wt.% fly-ash concentration. The tensile strain reduced 22.10% for 8wt% fly ash concentration. The percentage increase in tensile strain upto 4.53% for sample with 5wt% FA suggests the increase in elastic characteristic of composite. However, for sample with 8wt% FA the strain percentage reduces to 22.10% suggesting the decrease in elastic characteristic enhancing the brittleness in the material.

Fig.(6) shows variation in Young's modulus with varying concentration of fly-ash. It is observed that modulus increase by 2.34 % for 3 wt.% fly-ash concentration and thereafter the modulus was decreases 7.15% for 5 wt.% fly-ash concentration and 11.78% for 8 wt.% fly-ash concentration. The decrease in modulus of elasticity shows plasticity increases as the FA concentration increases

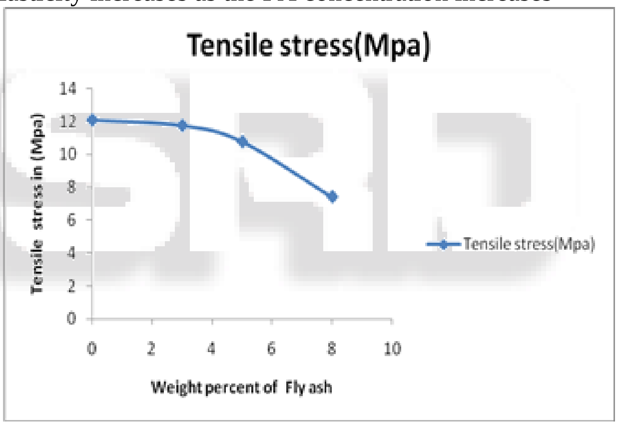

Fig. 4: Variation of Tensile stress with different Fly-ash wt. % concentration

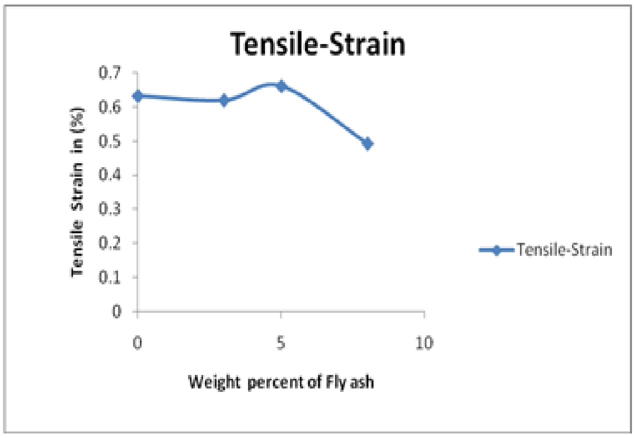

Fig. 5: Variation in Tensile strain with different Fly-ash (wt.%) concentration

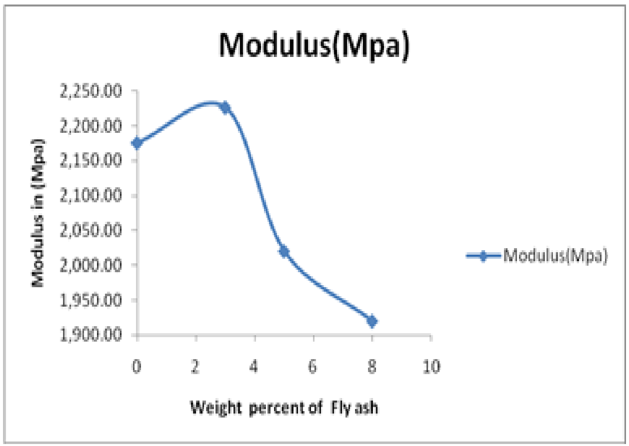

Fig. 6: Variation in Young's modulus with different Fly-ash (wt.%) concentration.

IV. Conclusion

The outcome of the studies undertaken for thermal and mechanical behavior of fly ash reinforced PS composites can be formed.

1) The DSC studies indicates the addition of FA in PS increases the glass transition temperature (Tg) ,that increases the thermal stability and improved crystalline property. The improved crystalline property increases the mechanical property of the composite.
2) The microhardness studies of pure PS and prepared composites reveals that the addition of FA leads to significant changes in the micromechanical properties due to modification of structure by interlocking of the chains on the surface and within the FA particles. the microhardness increases with increasing concentration of fly ash in composites However the fly-ash filled composite may find application in making low cost product .
3) The tensile studies indicates that the decrease in tensile stress, strain and young's modulus of FA reinforced PS composites leads the increase in plasticity of the prepared composite.

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