ISSN 2321-807X
Volume 12 Number17
Journal of Advances in chemistry

Effect of Inorganic Fillers on the Friction Properties of Polyamide 66

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ABSTRACT

Organic materials are those which have carbon elements in them and the inorganic materials are those which do not have carbon elements and those obtained from earth materials such as minerals and the atmosphere. The inorganic materials have advantages such as high thermal stability, chemical stability etc. Fly ash and silica fume are inorganic industrial wastes which are produced in large quantities during production of power and silicon respectively. These are the sources of land pollution and this pollution could be minimized if they are successfully reused in appropriate applications. . The polymer composites are becoming suitable alternative materials for metals in various tribological applications and so wear and friction studies of these materials gain significance. Polyamide 66, also known as Nylon 66 are engineering polymers used in such applications. Nylon was reinforced with these fillers in 5 to 25 % weight fraction increasing in steps of 5%, using a twin- screw extruder. The friction tests were carried out under dry sliding conditions in a pin-on-disc type friction and wear monitoring test rig at different normal loads and at a constant sliding distance and velocity. Friction coefficient of both composites have found to be decreased than pure Nylon. The friction coefficient of fly ash reinforced Nylon is lesser than the silica fume filled nylon at all the tested conditions.

Indexing terms/Keywords

Inorganic Materials, Fly Ash, Silica Fume, Nylon 66, Friction coefficient

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Academic Discipline And Sub-Disciplines

Mechanical Engineering, Chemistry, Composites

SUBJECT CLASSIFICATION

Polymer Composites

TYPE (METHOD/APPROACH)

Experimental Analysis and Charectarization

1. INTRODUCTION

Polymer composites are found to be suitable alternatives for metals in components such as gear, cams, bearings etc in order to reduce weight, energy consumption and cost. Most of the polymers are targeted to work in tribological environment and hence wear and frictional properties of these materials become prominent area to be researched. Various investigations have been made in the recent past for enhancing the tribological properties of various polymers by reinforcing them with different fibres and particles. Particulate reinforcement helps to increase the wear resistance of a material [1]. The wear resistance of PTFE was increased by adding alumina nano particles to it [2]. Friction coefficient decreased and maximum wear reduction was achieved when 20% weight fraction of titanate whiskers were added to PTFE [3]. Zinc oxide particles and whiskers were added to Nylon 1010 and was found that both enhanced the tribological properties but the shape of reinforcement did not have any effect [4]. Compatabalizer was found to have a good effect in reducing the wear rate of PA46/HDPE polyblends and affected adversely in the transfer film formation when it was used excessively [5]. Friction coefficient of Nylon 6 nano composite was found to be lesser than that of neat Nylon and this was due to the ability of nanofiller to form uniform tenacious transfer layer on the counter surface [6]. Coefficient of friction, temperature rise and specific wear rate of Nylon 66 was found to be reduced when it was reinforced with glass and carbon fibre [7]. Rice bran ceramics were reinforced in Nylon 66 matrix and friction coefficient was found to be highly reduced [8]. SEBS-*g*-MA particles were able to reduce the wear rate and friction coefficient of Nylon 66 [9] The coefficient of friction of Nylon 66 was found to increase when impregnated with graphite but it got reduced when impregnated with oil [10]. The addition of nano SiO_2 and short carbon fiber together into epoxy was able reduce the friction coefficient and wear rate than reinforcing them individually [11]. Likewise when nano SiO_2 and graphite was added together in basalt fabric reinforced phenolic resin, friction and wear behavior was greatly improved [12]. Glass fibre reinforced PTFE showed 20 and 366 times better friction and wear charecteristics than carbon reinforced PTFE and pure PTFE respectively [13]. The incorporaton of carbon fibre into PA6 showed different results. It either decreased or increased the friction coefficients depending upon the testing conditions [14]. When SEBS-g-MA and organ clay were used to reinforce Nylon 66, it showed best wear resistance at a normal load of 200N [15]. PTFE showed low coefficient of friction when reinforced with bronze and subjected to normal loads upto 30 N.But after that there was no significant variation between the composite and pure PTFE [16].

Recent trend in filler reinforcement has shifted from the conventional materials to wastes and by products.Fly-ash is the final waste collected from thermal power plants resulting from combustion of pulverized coal in the furnace [17]. Fly ash, has been considered as a problematic solid waste until now and so attempts are made to build value added products using flyash. The conventional disposal methods of fly ash was land filling but it lead to degradation of arable land and contamination of the ground water [18]. However nowadays flyash has become good filler material, particularly in mechanical and civil engineering domains. The wear characteristics of the vinylester matrix has been increased by the addition of flyash [19]. Flyash was able to decrease the wear rate in the hybrid reinforcement of graphite and flyash to aluminium matrix [20]. When flyash was mixed along with glass fibre in MC Nylon, the friction coefficient decreased 57% than that of pure Nylon [21].

Likewise, silica fume is a byproduct of silicon and ferrosilicon industry. The main constituent of silica fume is non-crystalline silica. Like flyash, silica fume is also disposed by land filling but nowadays they are used to as substitute for Portland cement [22].

The literature survey reveals that enhancement of frictional properties is essential if a suitable polymer has to be developed for replacement of metals, depending on the applications. Also, various polymers have been reinforced with different particles for this purpose and their characteristics were studied, but investigations on fly ash and silica fume filled Nylon is not adequate. To acquire a thorough knowledge on frictional properties of these composites, studies were conducted and findings are reported.

2. Materials and Methods

2.1 Materials used

The matrix material Nylon 66 was purchased from Radici Group Plastics, USA and the fly ash was collected from the Mettur Power Plant, Tamil Nadu, India. Silica fume was bought from Meridian Sciences and Technologies, Karur, Tamil Nadu. The main constituents of fly ash and silica fume are given in Table 1. Fly ash and silica fume were mixed with Nylon 66 in 5 to 25 % weight fraction increasing in steps of 5%. This weight fraction was selected on the basis of previous study [23]. The other materials added to the mixture are additive, heat stabilizer and compatabalizer

TABLE 1 Main Constituents Present in Flyash and Silica Fume

Element	Weight % in Fly Ash	Weight % in Silica Fume
Al_2o_3	27	1.75
Fe_2o_3	4.77	0.89
SiO_2	60.12	95.37

2.2 Sample Preparation and Experimental Procedures

The composite granules were prepared by using a twin- screw extruder (make Berstroff.) The temperature profiles were maintained from 260^0 C to 275^0C in the barrel from hopper to die in 8 stages. The extrudate was passed into water bath and cooled before being chopped into small pellets by a chopper. The cylindrical specimens of dimensions 8 mm diameter and 40 mm length for conducting friction tests were prepared using an injection molding machine (M/s L&T) of 60 ton capacity in which the temperature range of 270^0C to 290^0C was maintained from feed pit to nozzle. The injection pressure was 105 MPa and holding pressure was 90 MPa with holding time 3 seconds. The friction tests were carried out under dry sliding conditions in a pin-on-disc type friction and wear monitoring test rig (TR20 LE model supplied by DUCOM) as per ASTM G 99. The counter disc used was EN31 hardened steel disc. The specimens were polished using a fine grade SiC emery paper and cleaned with acetone and dried before testing. The tests were conducted at various normal loads of 20 N, 40 N, 60 N at sliding velocity of 3 m/s and at a sliding distance of 5000m. The coefficient of friction was measured directly from the data acquisition system incorporated in the machine along with necessary software.

3. Results and Discussion

3.1 General Observations

In general, run- in- friction precedes the steady state friction for all composites as found in previous investigations [7]. The friction coefficient gets stabilized within 5 minutes in the given test conditions for fly ash filled Nylon composites, while it does not as such in silica fume filled composites. This is clear from Fig. 1 and Fig. 2. An overview of all the results reveals that different contact chemistries prevail at the specimen-counter face junction which is still more different for the two types of reinforcements due to their different physical properties [7], [24] & [25].

ISSN 2321-807X
Volume 12 Number17
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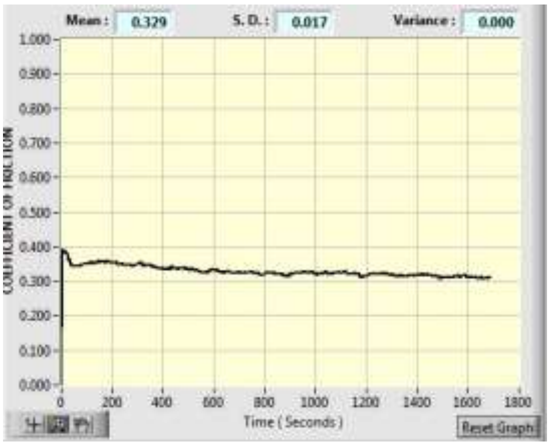

Fig.1. Friction Coefficient Graph of Flyash Filled Nylon Composite

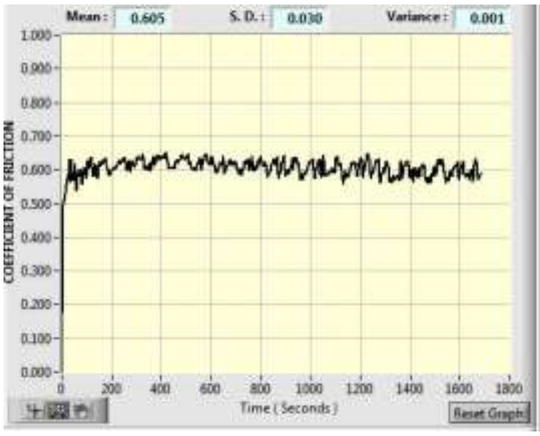

Fig.2. Friction Coefficient Graph of Silica Fume Filled Nylon C

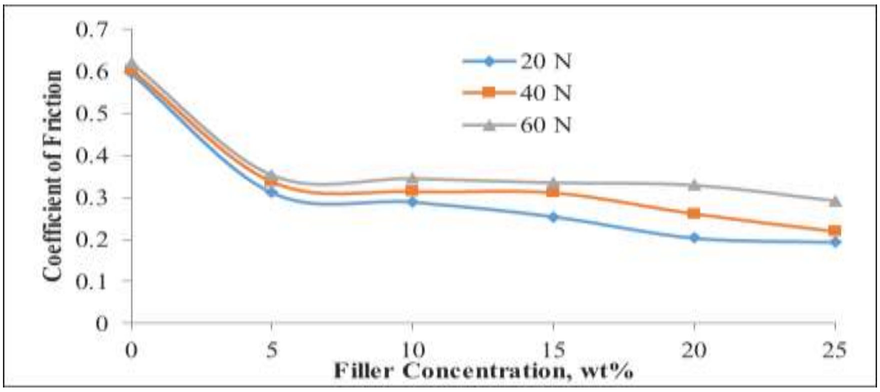

Fig. 3 Effect of Fly Ash Concentration on Coefficient of Friction

3.2 Effect of Fillers' Concentration on the Friction Coefficient

The effect of fly ash concentration on the coefficient of friction of the composites is shown in Fig. 3 and that of silica fume is presented in Fig.4 at different loads. For both nylon–fly ash and nylon–silica fume composites, the incorporation of the filler has great impact on the friction coefficient.. With the increase in the filler content, the coefficient of friction decreases in both the composites. The increase in the heat distortion temperature of both the composites is the cause for the reduction in the coefficient of friction. The ability of withstanding the heat has increased so that softening of the polymer matrix is avoided due to which formation of rough asperities is avoided[6]. This has made the sliding of the pin on the counter face smooth due to which the friction coefficient gets reduced with the increase of the filler content. This is evident from the coefficient of friction values of unfilled nylon in various test conditions. All those values are far higher than those of the composites. This is due to nylon being weak conductor of heat, as discussed in previous studies[9]. Furthermore, at the higher concentration, the fillers get debonded from the nylon matrix due to agglomeration by which they themselves have acted in formation of the transfer film and reduced the coefficient of friction [23] & [25]. The coefficient of friction of nylon–silica fume composites being in higher range than that of nylon–fly ash composites can be attributed to the composition of the filler particles and their characteristics.

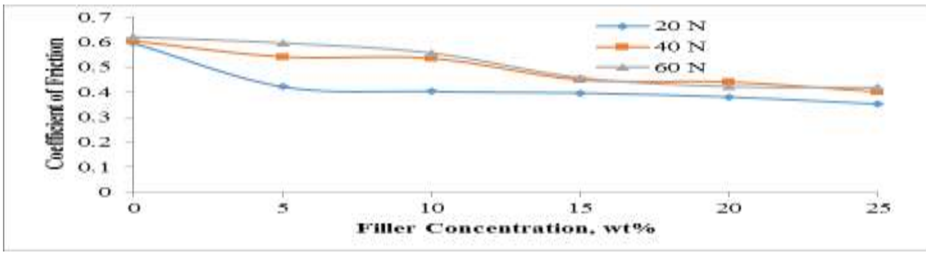

Fig. 4 Effect of Silica Fume Concentration on Coefficient of Friction

4. Conclusion

Nylon was reinforced with fly ash and silica fume separately in 5 to 25 % weight fraction increasing in steps of 5%, and friction tests were carried out under dry sliding conditions in a pin-on-disc type friction and wear monitoring test rig at different normal loads at 3 m/s sliding velocity and at a constant sliding distance of 5000m. The findings are as below.

- The inorganic fillers fly ash and silica fume reduced the friction coefficient of Nylon.
- Friction coefficients of fly ash filled Nylon composites stabalized within five minutes of sliding but the friction coefficient of silica fume filled Nylon composites did not stabalize as that of flyash filled Nylon composites
- Friction coefficients of fly ash filled Nylon composites are lesser than friction coefficients of silica fume filled Nylon Composites.
- By effective reusage of these inorganic industrial wastes, the wastes could be properly managed and value added products could be manufactured at very low cost.

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