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THERMAL CHARACTERISATION OF RECYCLED HDPE REINFORCED WITH AL_2O_3

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Abstract: Plastic solid waste is one of the major crises in today's scenario. In this study, an effort has been made to recycle one of the commercial wastes through reinforcement. Melt flow indices (MFI) of different proportions of recycled High density polyethylene (HDPE) with different sizes of aluminium oxide (Al_2O_3) are calculated. Some researchers have highlighted the use of reinforced composite wires but hitherto no work has been reported on the effect of Single particle size (SPS), Dual particle size (DPS), Triple particle size (TPS) of Al_2O_3 (as reinforcement) in HDPE matrix . Further, thermal analysis has been performed using Differential Scanning Calorimetry (DSC-Mettler Toledo) technique.

Keywords: Al_2O_3, Plastics, melt flow index, HDPE, differential scanning calorimetry, thermal analysis.

1. INTRODUCTION

Plastics are artificially manufactured long chain polymers. These are broadly utilized, cost-effective polymers exhibiting incredible versatile behaviour properties, and offer easy fabrication. Generally, plastics are exceptionally steady and do not get promptly corrupted in the ambient environment, thereby posing a severe environmental pollution threat. A survey carried out by United States (US) Environmental Protection Agency in 2003 revealed that, plastic waste (PSW) contributed to 11.3% of total municipal strong waste (MSW) in the preceding year. Of this total waste, only a marginal amount could be recycled through soft drink and other bottles, thereby calling for disposing the significantly remaining plastic waste. With an increasing trend towards use of plastics materials in our daily routines, causing generation of huge PSW, thereby necessitating higher emphasis on recycling and reusing [1]. PSW disposal in landfills causes significant environmental deterioration, thereby calling for need for development and deployment of biodegradable plastics and biodegradation of conventional PSW [2]. Some researchers have investigated the recycling of PSW by deploying metallic powder reinforcements using rapid prototyping (RP) applications. Most RPT equipment deploys a layer-by-layer production technique to manufacture three dimensional products [3]. Fused deposition process can be deployed for producing intricate casting patterns for investment casting process [4]. The study additionally gave a few pilot exploratory information about MFI of plastic materials with metal powder that can be appropriately deployed for future research. This residual composite matrix can be effectively deployed as filament for fused deposition modelling (FDM) setup.

Further, few researchers have utilized sawdust as filler in polymer and proportionate results were found as far as the tensile and flexural properties [5]. Ahmadinia et al. (2011) have also reported that significant favourable results can be obtained by using plastic bottle waste as a part of stone mastic asphalt [6]. It was also observed that better results were obtained as far as stability and mechanical properties when maleated polypropylene (MAPP) was included [7].

The literature reveals that plastic waste polymers can be effectively recycled up to certain degree. Literature survey reports that many studies have been reported related to recycling and reusability of PSW polymers. The proposed research work endeavours to device a mechanism to recycle PSW polymer materials by appropriately reinforcing it with metallic powder to produce a filament wire for FDM setup using RP technique

2. PLASTIC RECYCLING AND ITS USES

Plastic recycling means recovering and reprocessing scrap or PSW to manufacture practicable components and commodities that may be similar to or entirely distinctive their original state. Since majority of PSW is non-biodegradable, thus the nations across the world have to work aggressively to devise mechanisms of PSW recycling to mitigate the ill effects of plastic waste stream for effectively tackling enormous plastic pollution.

2.1. Conservation of resources and energy

Recycling plastics significantly addresses the global environmental concerns about minimizing the use of energy and natural resources (such as water, petroleum and natural resources) required for producing virgin plastic.

2.2. Waste reduction

Due to shrinking landfill areas and non-favourable conditions towards biodegradation in landfills, PSW reclamation facilitates in effectively utilizing landfill areas to be effectively managed for other purposes.

2.3. Easy recycling

Due to increasing awareness amongst masses in developed countries, PSW segregation programs have facilitated efficient PSW management.

2.4. Environmental protection

The studies have confirmed that the production of virgin plastics causes generation of significant amount greenhouse gases (GHG) (CO_2), thereby adversely affecting environment through global warming effect. Whereas, the PSW recycling process requires less energy and fossil fuels, and also emits significantly less GHG, thereby protecting environment.

2.5. Decreased Pollution

It is observed that burning or fires at many landfills lead to blazing of plastics thereby erupting toxic pollutants causing severe air pollution. PSW recycling besides significantly reducing GHG emissions also minimizes air and water pollution.

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3. MELT FLOW INDEX

Melt flow index (MFI) is widely accepted as one of the crucial rheological property [8] that determines the basis of running in-house developed FDM filament in the machine. MFI is generally expressed in terms of weight (in gm) of polymer which will flow per 10min of time period (i.e. gm/10 min.). It is to be worth noted that the present study has been performed by taking MFI as a crucial base property among other rheological properties as because it is very convenient and cost effective method used in field applications. The present work is focused on effect of reinforcement of various combinations of sizes (SPS, DPS, TPS) of Al_2O_3 and SiC in HDPE matrix. It should be noted that the SPS represents single particle size (of either 300, 400, 500 grade), DPS

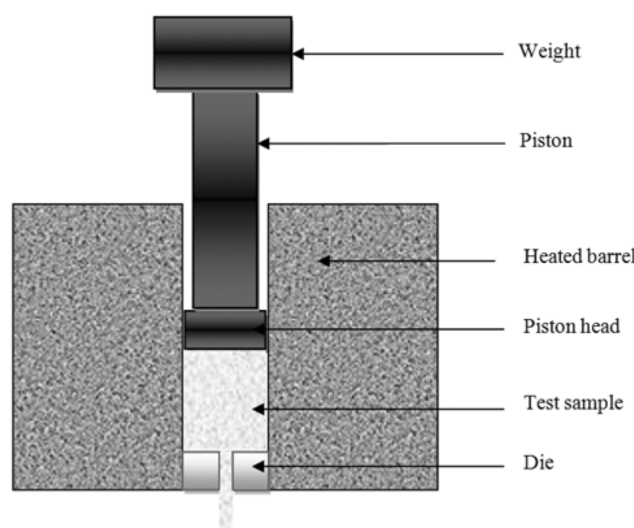

Figure 1: Schematic of MFI tester [9]

represents two particle sizes in equal proportion by weight (of combination of either of two from 300,400,500 grade) and TPS represents three particle sizes in equal proportion by weight (of 300, 400 and 500 grade).It has been observed that in reported literature, researchers have studied only the effect of SPS and very less exploration is done in the field of study of MFI's considering DPS and TPS. The above stated sizes of Al_2O_3 are taken, considering the commercially availability of these.

Fig. 1 shows a basic schematic of MFI tester.

4. DIFFERENTIAL SCANNING CALORIMETRY (DSC)

DSC is a thermoanalytical technique used to calculate the amount of heat required to increase the temperature of sample and refernece in terms of temperetaure. Bothe sample and refernece are maintained at nearly same temperature throughout the study. The temperature module for DSC is designed such that the sample crucible temperature increases linearly with time.

During analysis, sample is heated using a controlled temperature gradient with a defined heating rate, thereby heat flow difference is measured by comparing sample to reference[10] .This technique is very useful for small amount of samples (3 to 8 mg) [11].

5. EXPERIMENTATION

Various combinations of HDPE granules along with reinforcement of Al_2O_3 as per pilot experimentation were mechanically mixed and placed in electric oven to eliminate any type of moisture present. It is to be noted that recycled HDPE has been taken as matrix material. The mixture is then put into the pre- heated barrel of MFI tester. The weight as per the ASTM standard (D 1238-95) is put on the piston to expel the molten material from barrel and thereby made to exit out of die opening as extrudate and weighed to find MFI in terms of gm/10min. Table 1 shows MFI values of different set of composition with HDPE as parent material and Al_2O_3 as reinforcement. Furthermore, different sizes of Al_2O_3 i.e. SPS, DPS and TPS are also considered for pilot experimentation.

Table 1
Mfi Values of Different Set of Composition With Hdpe As Parent Material And Al_2o_3 As Reinforcement

HDPE (wt%)	Al_2O_3 300-G (wt%)	Al_2O_3 400-G (wt%)	Al_2O_3 500-G (wt%)	MFI (gm/10min)
50	0	0	50	9.24
50	0	50	0	10.605
50	50	0	0	10.788
50	0	25	25	11.58
50	25	25	0	12.87
50	25	0	25	14.565
50	16.67	16.67	16.67	16.595
60	0	0	40	18.22
60	0	40	0	24.95
60	40	0	0	22.55
60	0	20	20	21.73
60	20	20	0	17.03
60	20	0	20	12.55
60	13.33	13.33	13.33	14.185
70	0	0	30	20.98
70	0	30	0	21.56
70	30	0	0	20.36
70	0	15	15	22.55
70	15	15	0	24.85
70	15	0	15	25.88
70	10	10	10	13.95
80	0	0	20	22.54
80	0	20	0	22.92
80	20	0	0	20.48
80	0	10	10	17.59
80	10	10	0	23.55
80	10	0	0	27.82
80	6.67	6.67	6.67	12.25
90	0	0	10	22.55
90	0	10	0	24.58
90	10	0	0	25.75
90	0	5	5	25.85
90	5	5	0	25.44
90	5	0	5	27.15
90	3.33	3.33	3.33	10.02

Note: G represents grade of abrasives.

From Table 1, it was found that a certain trend was there between various composition sets for SPS, DPS,TPS particles of Al_2O_3. As, in case of TPS reinforcement, all the sizes of Al_2O_3 were contributing towards change in MFI of parent material (HDPE), so, considering TPS as case study, MFI values for TPS is selected from table 1 and are shortlisted as in Table 2.

Further, thermal analysis of above TPS samples were done using Differential scanning calorimetry technique on Mettler Toledo- DSC. Fig. 2 shows 3D view of Mettler Toledo DSC apparatus.

Table 2
Selected Mfi Values Of Tps From Combinations Of Hdpe-al_2o_3

S. No.	*HDPE (wt%)*	*Al_2O_3 300-G (wt%)*	*Al_2O_3 400-G (wt%)*	*Al_2O_3 500-G (wt%)*	*MFI (gm/10 min)*
1	50	16.67	16.67	16.67	16.595
2	60	13.33	13.33	13.33	14.185
3	70	10	10	10	13.95
4	80	6.67	6.67	6.67	12.25
5	90	3.33	3.33	3.33	10.02

The thermal plot for first sample is shown in Fig. 3.

Figure 2: Mettler Toledo DSC apparatus

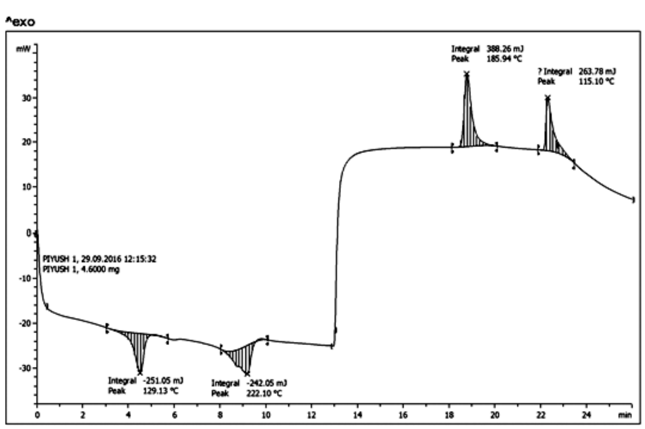

Figure 3: DSC results of sample 1.

6. CONCLUSIONS

From study of data generated from MFI's (Table 2), it can be seen that value of MFI decreases as the percentage of reinforcement in HDPE increases. This can be due to fact that Al_2O_3 has high thermal conductivity (38.5 W/m.K) and high density (3.98 g/cm^3) due to which it can accumulate high energy in form of heat as compared to HDPE. Also, HDPE being a polymer is non-conducting in nature will ultimately change its phase to semi molten state due to transfer of energy from reinforcement, thus flowing out of MFI tester barrel in lesser amount of time yielding high values of MFI. This phenomenon as explained as Fig. 4. Let there be x gm of particles of HDPE (black ovals) and there be y gm of Al_2O_3 particles (red circles) in a MFI tester barrel. On heating, Al_2O_3 particles will take up the energy and will transfer to surrounding HDPE particles due to HDPE particles will start changing their phase from solid to liquid there by coming out of barrel in liquid form. More the no. of reinforcements particles, more will heat stored and will be transferred to HDPE particles thereby yielding high MFI values.

Also, after analysing graphs obtained (Fig. 2) from thermal analysis on DSC for heating and cooling, two peaks each for heating and cooling cycle were obtained. The reason for this is that HDPE material used for the study may have previous history due to which there may be pre-stresses in the material. This peak also signifies that HDPE may have stresses due to aging phenomenon ensuring that it is recycled one.

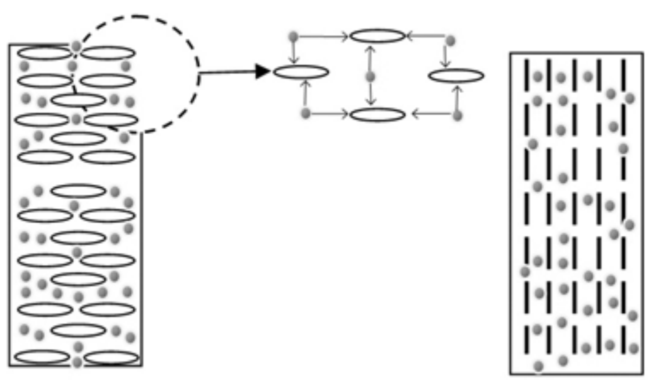

Figure 4: Heat transfer bw Al_2O_3 and HDPE

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