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Evaluation of thermal and mechanical stability of circular discs made of waste HDPE and PP

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ABSTRACT

Plastic waste is a well-known threat to the ecosystem. Many countries are exploring ways to mitigate the threat. In the present study, the waste plastic bottles made of Polypropylene (PP) [and High-Density Polyethylene (HDPE) was converted to circular disks. The discs would be used as an electric circuit breaker. Additives, namely $CaCO_3$ and HPMC, were used as a filler and binder, respectively, during casting. The response surface methodology (RSM) was adopted during disk preparation in order to investigate the influence of process parameters, namely casting temperature (100 °C to 200 °C), hydraulic pressure (120 to 170 psi), composition (0 to 20 %), and grain size (1.4 to 2mm). Fabricated disc characteristics such as tensile strength, thermal conductivity and melt flow index (MFI) were evaluated. It was observed that on increasing the casting temperature from 100 to 200 ° C, tensile strength of casted disk increased from 653 to 1064 MPa, 775 to 1172 MPa, & 879 to 1396 MPa for recycled PP, whereas 713 to 1242 MPa, 818 to 1327 MPa, & 990 to 1478 MPa, for recycled HDPE. Similarly, it was evident that MFI increased from 2.637 to 5.617gm/ 10 min, 3.125to 5.979 gm/ 10 min, and 3.998 to 7.06 gm/ 10 min for recycled PP and HDPE, respectively, on increasing the temperature from 100 to 200 °C. The thermal conductivity of HDPE is found to be higher as compared to PP under the same operating conditions.

Keywords: ***Polypropylene, High-Density Polyethylene, Marble slurry, HPMC, Tensile strength, Melt flow index***.

1. INTRODUCTION

Plastic wastes are known as "the material for the 21st century" due to their many useful properties and widespread application in modern society (Abeykoon, 2018; Abeykoon et al., 2021).Plastic is a material consisting of a wide range of synthetic or semi-synthetic organic compounds that are malleable so that they can be molded into solid objects. Plastic products have become an integral part of our daily life. As a result, the polymer is produced on a massive scale worldwide. According to projections, the value of the worldwide plastic wastes marketplace will increase from $533.6 billion in 2019 to $838.5 billion in 2030. (ReportLinker,2021). Its broad applications include packaging films, wrapping materials, shopping and garbage bags, fluid containers, clothing, toys, household and industrial products, and building materials. Approximately 70% of plastic packaging products are estimated to be converted into plastic waste quickly. Approximately 9.4 million tonnes per annum (TPA) plastic waste is generated in India, which amounts to 26,000 tonnes per day (TPD) (CPCB, 2019). Of this, about 60% is recycled. Recycling rate in India is considerably higher than the global average of 20% (CPCB, 2019), there is still over 9,400 tonnes of plastic waste, either land filled or polluting streams or groundwater resources. While some kinds of plastic do not decompose at all, others could take up to 450 years to break down. Analyzed the recycled polypropylene Granules; PP will be used in the LDPE application field, especially in the automotive and packaging industry. Different concentrations of micron-sized glass fibres, talc, and $CaCO_3$ are added to the polymer to improve the properties (physical and thermal) of RPP polymer and give near or more excellent quality to the original PP features (Findik et al. 2017). A few researchers including R. S. Chen et al. (2014) have studied the composite effect of recycled plastic on mechanical and thermal properties. Another study on thermal and mechanical properties of product composed of waste plastic was carried out by H. Zhang et al. (2007). Furthermore, Kulkarni P. et al. (2022) studied the mechanical properties of HDPE/PP with an ultimate load carrier of 191.35 kN at a displacement of 18.40 mm. Madi

N. (2012) studied the thermal and mechanical properties of blends comprising recycled HDPE and virgin PP. The blend of HDPE/PP varying from 95/5 up to 80/20 showed better thermal and mechanical stability. Erkendirci O. (2016) represents mechanical and thermal properties of carbon fibre and HDPE composite. The temperature varies from 100- 350 ℃ for blend preparation due to high thermal resistance offered by carbon fibre. In terms of mechanical strength, the platens were able to withstand up to 22 kN of force. In this study, the polymer wastes such as high-density polythene (HDPE) and polypropylene (PP) were recycled using a sheet casting process. Efforts were made to convert these wastes into value-added product, namely, fabricated circular disk. Various additives such as HPMC and waste marble slurry were used as a binder to enhance the mechanical property. Moreover, the effects of process parameters such as average heating plate's temperature, hydraulically gauge pressure of sheet casting, grain size and composition on sheet casting fabricated circular disks were carried out for better understanding the sheet casting process. Most of the earlier studies had not considered the effect of grain size in processing, however, grain size plays an important role in the sheet casting process due to the involvement of chemical interaction and morphology. Therefore, in the present study, the effect of polymer grain size on tensile strength, melt flow index and thermal conductivity were also taken into account.

2. MATERIALS AND EXPERIMENTAL METHODS:

This section describes the mechanical properties, thermal properties and plastic waste, sheet casting processes in detail.

2.1 Materials

Various substances used in this study could be defined under the following categories: polymer waste of HDPE and PP, additive as hydroxy-propyl-methyl- cellulose (HPMC), and marble waste in the form of marble slurry ($CaCO_3$). A nonlinear polymer HDPE and PP were collected from the laboratory container waste. Whereas marble slurry of 100 and 200 mesh size was purchased from Rankem, India, and HPMC was purchased from ASES Chemical Works Jodhpur, India.

2.2 Experimental Procedure for Sheet Casting

The sheet casting process is also a thermal fabrication process where a polymeric substance turns into a desirable formation. The sheet casting machine was purchased from KANT Plastology, Gujarat, India. The sheet casting is a single-step manual procedure Figure 1, where the raw material is filled into a mold at a required temperature (100-200 ˚C) and pressure (120-170 psi) for a specific interval of time (15 minutes). The polymer was shredded with the help of shredder SP Industry, Delhi, India, and was categorized based on mesh size (100-200 mesh). The additive (HPMC and $CaCO_3$) was taken in the 0-20% range by weight. The Mould (thickness 2mm, dia. 9.8 cm) is removed from the machine and then placed in a water bath to retain the product (circular disc) shape and structure.

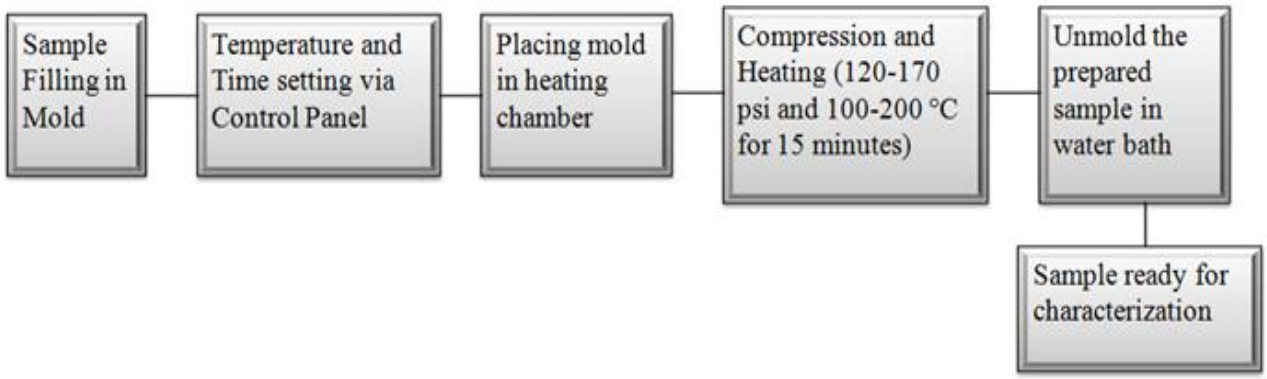

Figure 2 Sheet casting flow diagram

3. RESULT AND DISCUSSION:

In this section, the effect of process parameters on fabricated circular disks of HDPE/PP by sheet casting process is discussed in detail. Moreover, the effect parameters of the experiment were conducted to determine each parameter on disk properties such as tensile strength, melt flow index, and thermal conductivity.

3.1 Effect of Process Parameters on Fabricated Circular Disk Properties:

The effect of process parameters such as heating plate temperature, hydraulic pressure, additive concentration, and grain size as fabricated circular disk properties made up of HDPE and PP recycled waste material such as tensile strength, melt flow index, and thermal conductivity.

3.1.1 Effect of Average Heating Plate's Temperature on Tensile Strength (HDPE/PP)

The effect of the average heating plate's temperature on the casting sheet as the tensile strength of fabricated circular disk by a sheet casting process is shown in Figure 2(a). It is evident from Figure 2(b) that as increasing the average barrel temperature from 100 to 200˚C, the tensile strength increased from 653 to 1064 MPa, 775 to 1172 MPa, & 879 to 1396 MPa for recycled PP, whereas 713 to 1242 MPa, 818 to 1327 MPa, & 990 to 1478 MPa, for recycled HDPE at 120, 145 & 170 psi hydraulic pressure psi respectively under constant 10 (1.70 mm) grain size and additive concentration ratio 10% (CaCO3 (8%) & HPMC (2%)) as an additive (R Chaudhary et al, 2021). The reason for this increment as increasing the heating plate's temperature may be because increased temperature enhanced the proper mixing of additive with recycled polymer intermolecular linkage. As a result degree of compatibility increased, which may create a single-phase structure in the morphology of the fabricated circular disk with superior characteristics. The same is attributed to the SEM image Figure 1 & 2 of recycled HDPE & PP at 100 & 200˚C, respectively. The SEM image shows that mixing at 200˚ is constant to 100˚C during sheet casting (L Techawinyutham et al., 2021).

Similarly, the effect of the heating plate temperature on the melt flow index and thermal conductivity of recycled circular disks fabricated by the sheet casting process is depicted in Figures 3(a), it is illustrated that on increasing the heating plate's temperature from 100 to 200˚C the melt flow index increases from 2.637 to 5.617gm/ 10 min at 100˚C, 3.125to 5.979 gm/ 10 min at 150 ˚C, and 3.998 to 7.06 gm/ 10 min at 200 ˚C for recycled PP. A similar behaviour in properties like TS, MFI and TC was shown by recycled HDPE at 120, 145 & 170 hydraulic pressure psi, respectively, under constant grain size of 10 (1.70 mm) 10% (CaCO3 (8%) + HPMC (2%)) as an additive (R Chaudhary et al, 2021). The probable reason for the increment of the melt flow index with the heating plate's temperature may be that the polymer's viscosity decreases with temperature increases. As a result, MFI decreases since the melt flow index and viscosity are inversely related. Figure 3(b) shows that as the heating plate's temperature increased from 100 to 200˚C the thermal conductivity (k) increased from 0.0645 to 0.201 W/mk at 100˚C, 0.108 to 0.262 W/mk at150˚C, and 0.254 to 0.434 W/mk at 200˚C for recycled PP. A similar behaviour in properties like TS, MFI and TC was shown by recycled HDPE at 120, 145 & 170 psi hydraulic pressure, respectively, under a constant grain size of 10 (1.70 mm) 10% (CaCO3 (8%) + HPMC (2%)) as an additive. In summary, the thermal conductivity of HDPE and PP polymers is influenced by various factors, including the degree of crystallinity, the presence of amorphous regions, and the molecular structure of the polymer. Both waste polymers generally exhibit an increase in thermal conductivity with increasing temperature up to a certain point.

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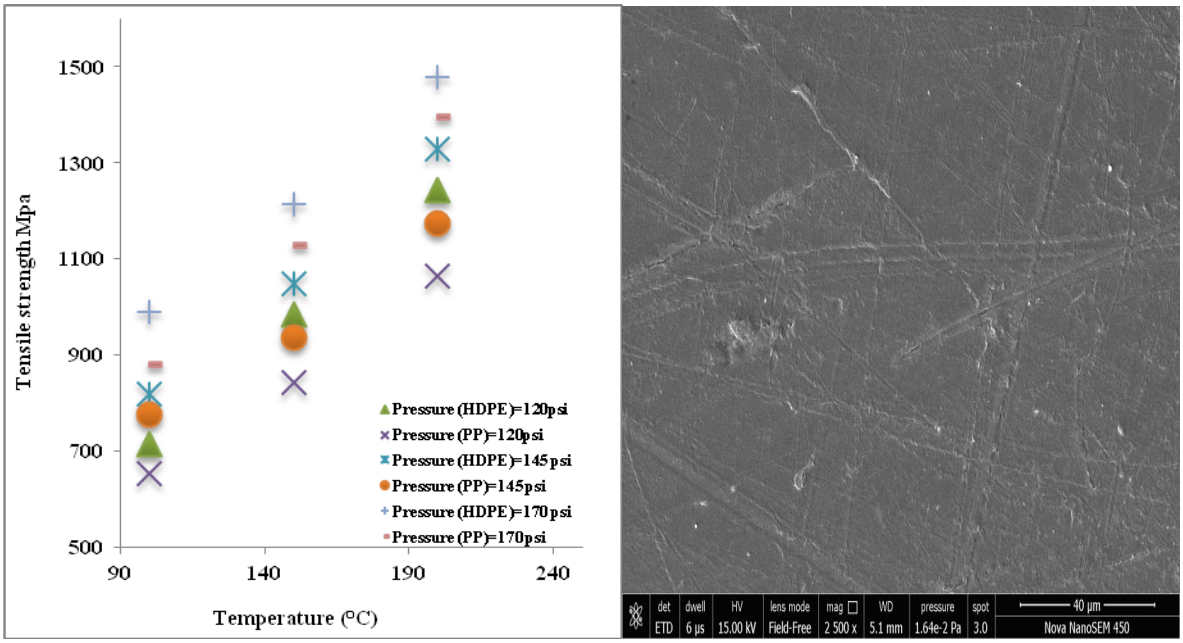

Figure 2(a) Effect of average heating plate temperature on tensile strength (b) SEM image of circular disc obtained at optimized conditions

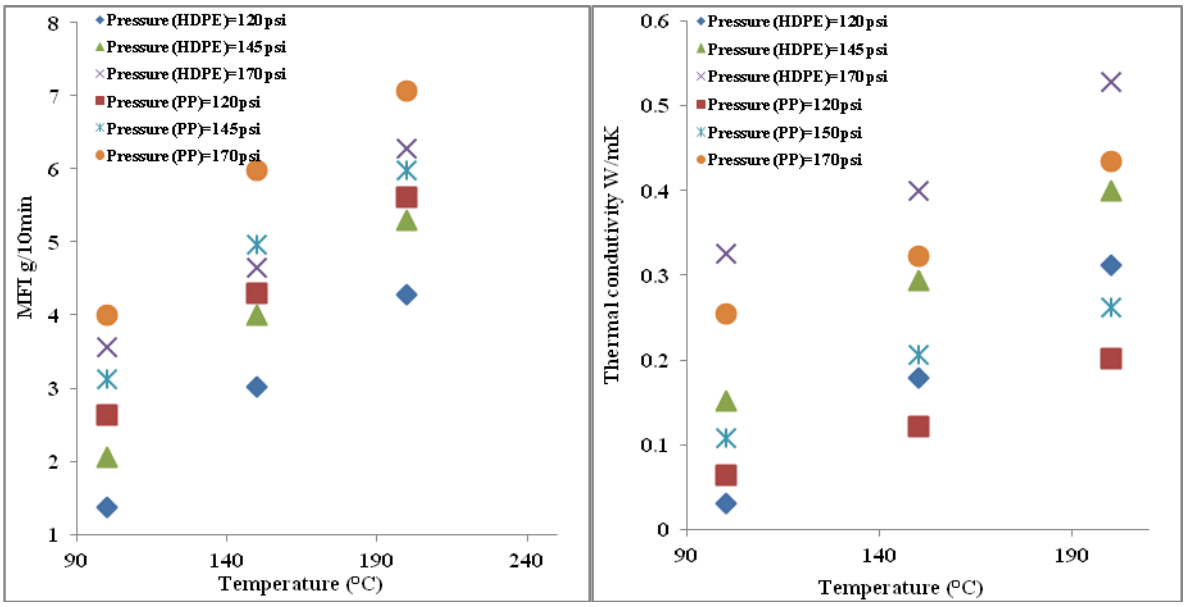

Figure 3:Effect of average heating plate temperature on (a) melt flow index amd (b) thermalconductivity.

4. CONCLUSIONS:

Experimental studies of wastes plastic fabricated circular disk properties composite blends. The effect process parameters such as average heating plate's temperature, hydraulic gauge pressure, the grain size of feed and feed composition were studied systematically on the sheet casting process on tensile strength, melt flow index and thermal conductivity of recycled HDPE and PP synergy from a gauge pressure highly instrumented sheet casting. It was found that the fabricated circular disk shows exponential increment on increasing the heating plate's temperature. However, linear increment in tensile strength was encountered with hydraulic gauge pressure. The probable reason for the increment of the melt flow index with the heating plate's temperature may be that the

polymer's viscosity decreases [μ] with temperature [T] increases. As a result, MFI decreases since the melt flow index and viscosity are inversely related. In case of thermal conductivity and temperature is a positive one, with thermal conductivity generally increasing as temperature increases, because depends on crystalline of polymers. Moreover, at higher hydraulic gauge pressure and heating plate's temperature, the exponential increment in tensile strength, melt flow index and thermal conductivity were envisaged whereas linear increasing temperature. The synergistic effect of HDPE/PP with additives was also studied and revealed that the tensile strength was higher than individual polymers as well as while using additives with individual polymers on increasing the heating plate's temperature, which clearly proclaims the waste utilisation of marble slurry in the fabrication of value-added product.

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