Study on Properties of High Density Polyethylene Doped Recycled Plastics

Yanling Wang[1], Aoxue Dong[2], Zhimin Ren[1], Zhuoyi Ren[2], Qian Gao[3], Song Zhao[2,*]

[1] Hebei Institute of Product Quality Supervision and Inspection, Shijiazhuang 050227, Hebei, China

[2] Department of Agriculture and Food Science, Shijiazhuang University, Shijiazhuang 050035, Hebei, China

[3] Hengshui Comprehensive Inspection and Testing Center, Hengshui 053010, Hebei, China

*Corresponding author: Song Zhao

Abstract

High density polyethylene (HDPE) is widely used in the fields of packaging, piping and medical devices because of its high tensile strength, impact resistance and chemical corrosion resistance. In recent years, the quality requirements of high density polyethylene plastics are also increasingly high. The composition of polyethylene recycled plastics is complex, which has potential safety problems. Therefore, the detection of polyethylene plastics doped with recycled plastics has gradually become the focus of attention. In this study, the effects of different melt extrusion processing times and the mass ratio of doped recycled plastics on the properties of HDPE were carried out. The main research contents include: the mechanical properties of HDPE were tested by universal testing machine, and the thermal properties were tested by melt flow rate meter and differential scanning calorimeter. The results showed that with the increase of melting processing times, the elongation at break of HDPE decreased, the tensile strength increased slightly, the melt flow rate increased, the melting temperature increased slightly. While the oxidation induction time shortened. With the increase of doped recycled plastics in HDPE mass ratio, the elongation at break, tensile strength and melt flow rate decreased, the melting temperature decreased slightly, and the oxidation induction time shortened significantly. The development of this study provides technical support for plastic recycling and energy conservation and emission reduction.

Keywords

High density polyethylene, doped recycled plastics, mechanical properties, thermal properties.

1. Introduction

High density polyethylene (HDPE) is a high crystallinity, non-polar thermoplastic resin with a density of 0.940-0.976g/cm^3. Its appearance is milky white or translucent[1]. The compact molecular structure of high-density polyethylene gives it excellent hardness, tensile strength, wear resistance, impact strength and creep resistance, as well as wear resistance, electrical insulation, heat resistance and cold resistance[2, 3]. High density polyethylene (HDPE) has outstanding chemical stability and is resistant to acid, alkali and salt corrosion at room temperature, but has weak resistance to oxidizing acids, aromatic hydrocarbons and halogenated hydrocarbons. High density polyethylene is a thermoplastic with linear molecular structure, and its crystallinity is as high as 80%-90%, which gives high strength, wear resistance and chemical corrosion resistance, but the heat resistance is poor[4]. It is widely used in pipeline system, impermeable membrane, packaging containers and other fields, especially the impermeable membrane is the core material of environmental protection engineering because of its excellent waterproof performance and anti environmental stress cracking ability. Therefore, HDPE has a good development prospect and irreplaceable role.

With the continuous growth of the use of HDPE, waste plastics have become a serious environmental problem and a potential renewable resource with good recycling potential[5]. Polyethylene is the most consumed material in the plastic industry, and the number of waste produced by it has reached an alarming level. Due to its structural characteristics, it is difficult to be degraded, which makes the environmental pollution problem caused by polyethylene plastic more and more serious, and the recycled plastic has complex components and potential safety problems[6]. In view of the fact that petroleum, coal and other resources are non renewable and increasingly scarce, and waste plastics can regain their use value after effective collection, classification and scientific treatment, so as to realize recycling, it is an important direction to explore and develop methods, technologies and equipment for waste plastics recycling from the perspective of saving resources and promoting recycling[7, 8] at present, countries around the world are actively paying attention to the recycling of waste plastics and committed to developing relevant key technologies[9, 10]. Since the beginning of the 21st century, China's plastic recycling industry has ushered in a period of rapid development. Enterprises of all sizes have sprung up like mushrooms and are gradually forming an environmental protection industrial cluster based on market demand and price mechanism regulation[11] due to the structural and performance changes of high-density polyethylene in the processing process, temperature, pressure and processing environment, the quality ratio of polyethylene doped recycled materials is of great significance to its recycling. Therefore, this study focused on the influence of melting processing times and recycled plastic doping on the performance of high-density polyethylene, aiming to provide effective detection means for the utilization and detection of recycled plastics, and play a role in energy conservation and emission reduction.

2. Experimental

2.1. Materials

The main raw materials used in this study are as follows: high density polyethylene resin (FHC7620, China National Petroleum Corporation), and linear polyethylene plastic particles are used as recycled materials.

2.2. Instruments

Twin screw extruder(S07020, Keqiang chemical equipment company of China Blue Chenguang Chemical Research Institute); Plastic injection molding machine （JN88-E, Zhenxiong machinery (Ningbo) Co., Ltd）;Vacuum drying oven(DZF-6050, Shanghai Yiheng Scientific Instrument Co., Ltd); Differential scanning calorimeter: DSC200-F3, Netzsch, Germany); Universal testing machine(UTM-1422, Chengde Jinjian Testing Instrument Co., Ltd); Simply supported beam impact testing machine: KXJJ—5M, Chengde Kebiao Testing Instrument Manufacturing Co., Ltd); Melt flow rate meter: MFI-1211, Chengde Jinjian Testing Instrument Co., Ltd); Plastic pelletizer: PQ-50, Keqiang chemical equipment company of China Blue Chenguang Chemical Research Institute.

2.3. Characterization

Tensile strength was tested according to GB/T1040.2-2006, and the tensile speed is 50mm/min; The melt flow rate was tested according to GB/T3682.1-2018, the experimental temperature was 190℃, and the load was 5kg; The melting temperature is determined by DSC according to the provisions of GB/T19466.6, the nitrogen flow rate is 50ml/min, the rising and cooling rates are both 10℃/min, and the temperature range is 20℃-200℃; The oxidation induction time was conducted by DSC according to the provisions of GB/T19466.6, the nitrogen flow rate was 50mL/min (1±10%), the oxygen flow rate was 50mL/min (1±10%), the heating rate was 20℃ /min, and the test temperature was 200℃.

2.4. Preparation of High Density Polyethylene Samples

High density polyethylene (HDPE) samples were melt extruded by twin-screw extruder. HDPE samples with different processing history and HDPE samples doped with different recycled plastic content were prepared respectively. The polyethylene particles were dried at 60 ℃ for 12h in the blast drying oven, and then injected into the plastic injection molding machine to prepare the sample for testing.

3. Results and discussions

3.1. Effect of Processing History and Recycled Plastic Content on Mechanical Properties of High Density Polyethylene

The tensile strength and elongation at break of HDPE spline were tested by universal testing machine. The results are shown in Figure 1.

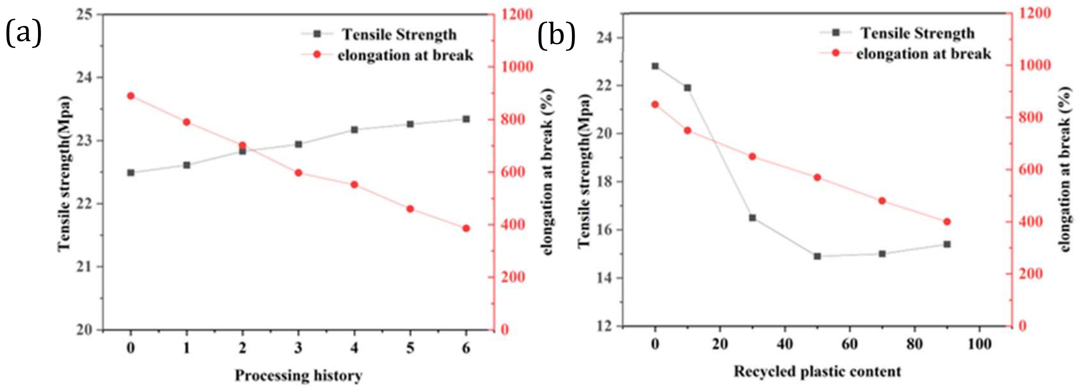

Figure 1. Tensile strength and elongation at break of HDPE: (a) different melt extrusion times, (b) recycled plastic doping amount

Figure 1 (a) shows the effect of different melt extrusion processing times on the tensile strength and elongation at break of HDPE spline. It can be seen from the figure that with the increase of melt extrusion processing times, the tensile strength of HDPE is gradually increasing, while the elongation at break is gradually decreasing. This is due to the increase of processing times, the polymer forms a shorter molecular chain, which can better transfer stress, and the ductility is reduced due to the fracture of the molecular chain. Figure 1 (b) shows the effect of recovery ratio of 0%, 10%, 30%, 50%, 70% and 9% on the tensile strength and elongation at break of HDPE. It can be seen from Figure 2 (b) that the tensile strength of HDPE gradually decreases with the increase of doping recycled materials, which may be due to the destruction of the original molecular chain arrangement of HDPE due to the doping of different recycled materials, resulting in the reduction of tensile strength. With the increase of doping content, the elongation at break of HDPE gradually decreases. This reflects that when the material is subjected to external force, the molecular chain breaks, and its ductility gradually becomes worse.

3.2. Effect of Processing History and Recycled Plastic Content on Melt Flow Rate of High Density Polyethylene

The melt flow rate of HDPE was tested with a melt flow rate meter. The results are shown in figure 2.

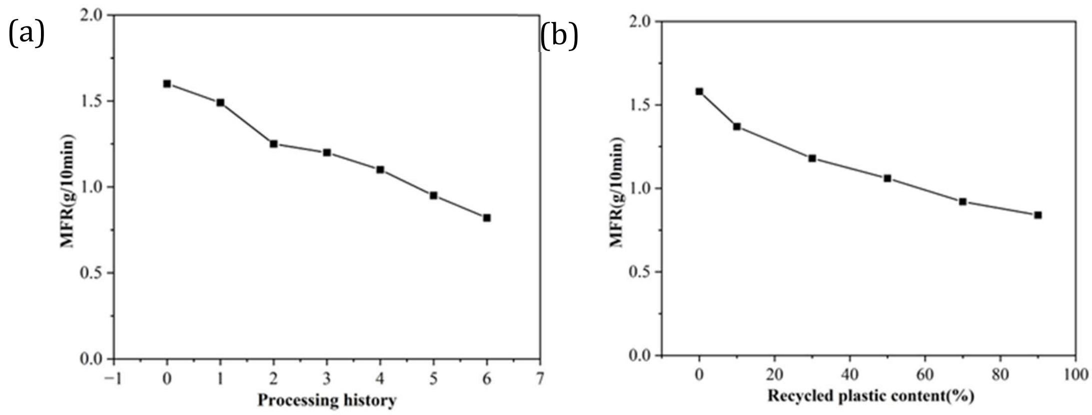

Figure 2. Melt of flow rate of HDPE: (a) different melt extrusion times, (b) recycled plastic doping amount

It can be seen from Figure 2 (a) that the melt mass flow rate of HDPE gradually increases with the increase of melt extrusion processing times. The melt mass flow rate of HDPE decreased from 1.60g/10min to 0.82g/10min from 0 to 6 times. This indicates that the increase of processing times leads to the increase of molecular weight of HDPE and the decrease of melt fluidity of HDPE. It can be seen from figure 2 (b) that as the mass ratio of recycled materials increases from 10% to 90%, the melt mass flow rate decreases from 1.58g/10min to 0.76g/min, possibly because the crosslinked structure will form a three-dimensional network structure between molecular chains, limiting the movement of molecular chains; Branched molecular chains will also hinder the free flow of molecular chains due to the steric hindrance effect, resulting in a decrease in the fluidity and melt index of the whole system.

3.3. Effects of Processing History and Recycled Plastic Content on Melting Temperature and Oxidation Induction Time of High Density Polyethylene

The melting temperature and oxidation induction time of HDPE were measured by differential scanning calorimeter. The results are shown in Figure 3.

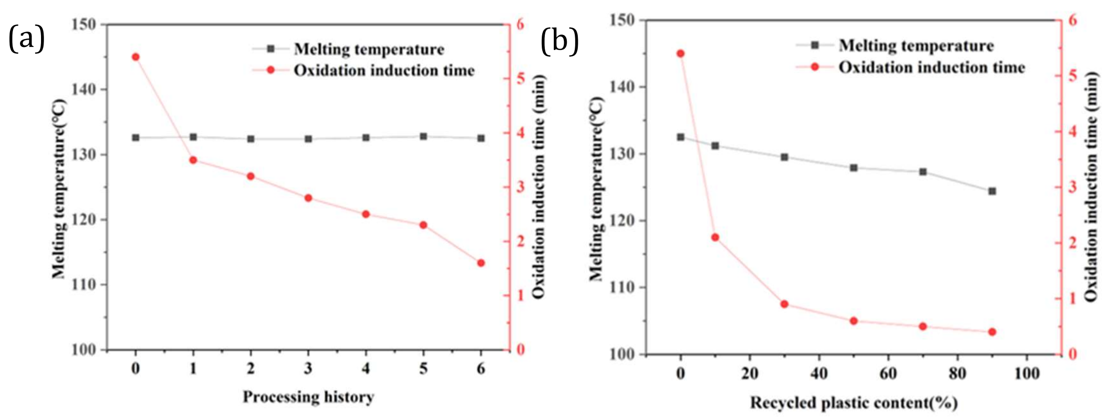

Figure 3. Melting temperature and oxidation induction time of HDPE: (a) different melt extrusion times, (b) recycled plastic doping amount

According to the analysis in Figure 3 (a), the melting temperature of HDPE has little change as the number of melt extrusion processing increases. This shows that the melting temperature of HDPE is slightly affected in the range of 0-6 processing times, while the oxidation induction time of HDPE decreases with the increase of processing times. The oxidation induction time from 0 to 6 times was 5.4min, 3.5min, 3.2min, 2.8min, 2.5min, 2.3min and 1.6min, respectively. From 5.4 minutes to 1.6 minutes. This indicates that the oxidation resistance of HDPE is gradually weakened, and it is more susceptible to oxidative degradation. It can be seen from figure 3 (b) that the melting temperature of 0% to 90% of the Recycled HDPE dopants shows a decreasing trend. When the mass ratio of recycled plastics in HDPE increases, it contains low molecular weight degradation substances. The low molecular weight part acts like a plasticizer here, weakening the interaction between molecules and making the molecular chain easier to move. At a lower temperature, the molecular chain can overcome the interaction force and enter the melting state, leading to the reduction of the melting temperature. With the doping of recycled materials, the oxidation induction time was 5.4min, 2.1min, 0.9min, 0.6min, 0.5min, 0.4min respectively, and the oxidation induction time showed a downward trend. This shows that the oxidation resistance of HDPE is gradually weakened in both cases, and it is more susceptible to oxidative degradation.

4. Conclusion

In this paper, the effects of melt processing and recycled material content on the properties of HDPE plastics were studied by using mechanical property analysis and thermal analysis, respectively. The results showed that with the increase of melt extrusion processing times, the elongation at break of HDPE decreased, the tensile strength increased slightly, the melt flow rate increased, the melting temperature remained unchanged, but the oxidation induction time decreased. With the increase of HDPE mass ratio, the elongation at break, tensile strength and melt flow rate decreased, the melting temperature was slightly lower, and the oxidation induction time decreased significantly. Therefore, the processing times of melt extrusion and the amount of recycled materials have different effects on the mechanical properties and thermal properties of the materials. It is necessary to select the appropriate process and amount according to the demand in practical application. The significance of this study is to study the possibility of plastic recycling, which plays a role in energy conservation and emission reduction.

Acknowledgments

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