ARKEMA

THE EFFECT OF FLUORINATED THERMOPLASTIC PROCESSING AIDS IN FILM PROCESSING OF RECYCLED POLYETHYLENE RESINS

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Abstract

Efficient mechanical recycling of post-industrial and post-consumer film remains a challenge in the industry today in part due to the variability of incoming film feed streams. This paper measures the effect that a Kynar® PVDF polymer processing and recycling aid (PPRA) has in improving the film processing of recycled polyethylene resins. Both melt fracture elimination and pressure reduction were observed when a Kynar® PPRA was added to a recycled polyethylene film process. This data suggests that film converters looking to increase recycled polyethylene output, or the percent of recycled polyethylene content in their process, can consider adding a Kynar® PPRA to increase their processing efficiency.

Introduction

The polyethylene industry is increasingly focusing on sustainable solutions. Mechanical recycling specifically is generating industry attention for its ability to extend the life cycle of plastics that were initially considered to be "single use." In the area of mechanical recycling, polyethylene film presents unique challenges when it comes to recycling. The challenges arise due to the variability in the composition of the feed streams, the need to wash and pretreat the film, and the possible degradation of the polyethylene from additional heat histories. Polymer processing aids (PPA) have been proven to increase processing efficiency in various polyethylene base resins by eliminating melt fracture, and increasing output (by reducing extruder pressure).[1,2,3,4] Prior to this study, to the knowledge of the authors, no technical analysis on PPA performance in recycled polyethylene base resins had been conducted. The objective of this study was to determine if a Kynar® PPRA maintains its effectiveness in improving processing efficiency when added to a recycled resin.

Experimental Procedure

Four different polyethylene samples were analyzed in this experiment. A 1.0 melt index (MI) linear low density polyethylene was used as the control resin. The three other samples were provided courtesy of Polykar Inc., an innovative, world-class manufacturer of sustainable packaging solutions in North America. These materials are commonly used in applications such as trash bags and octabin liners, for example. The samples from Polykar included the following: 1) white pigmented recycled LLDPE 2) natural color recycled LLDPE (no color pigment) and 3) gray pigmented recycled LLDPE. Figure 1 shows the three recycled samples, in pellet form.

The four samples were first analyzed using a parallel plate rheometer, Fourier Transform Infrared (FTIR), and thermogravimetric analysis (TGA). The parallel plate rheometer provides curves of melt viscosity as a function of shear rate. FTIR was used to identify the components present in each recycled LLDPE product. The TGA was also used to identify components in the recycled resins by measuring weight loss as a function of temperature. Different components present in the resins can affect the thermal stability of these resins, and these variations can be detected by TGA.

Figure 1. Three recycled polyethylene resin samples provided by Polykar from left to right: white, natural, gray.

The second part of the study that was conducted on the four samples was to measure the processing efficiency with the addition of a Kynar® PPRA. Previous technical work has shown that Kynar® PPRA performance on a lab scale, flat die extruder can be correlated to the expected results on an industrial scale, blown film line.[5] The four samples were run on a 1¼ inch Davis Standard extruder with a 50 mm flat die at a range of temperatures from 155°C – 170°C, and a shear rate ranging from $300s^{-1}$ – $500s^{-1}$. Figure 2 summarizes the flat die experimental setup. The melt pressure was recorded, and pictures of the film extrudate were taken throughout the experiment. Once each sample reached steady state, a Kynar Flex® 5301 PPRA masterbatch (using a LLDPE carrier resin) was added to the process. A timer was started once the PPRA was added, and the evolution of the film surface over time was captured by camera at 5 minute intervals. The melt pressure was also recorded throughout the duration of each test. After the conclusion of the test, the extruder was emptied and purged to remove any remaining PPRA from the die wall. Then, the next sample was added to the extruder hopper.

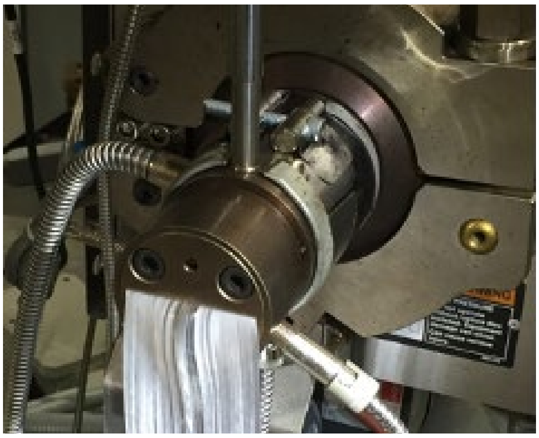

Figure 2. The flat die extruder used for the melt fracture elimination and melt pressure reduction studies.

Results and Analysis

Figure 3 shows the rheological curves for the four samples. The data suggest that while the materials have similar rheology, there is some variability within the different resins particularly at lower shear rates.

This finding supports the hypothesis that the incoming recycled feed streams present an inherent potential for some variability in the properties of the final recycled film. This hypothesis was supported by the FTIR and TGA findings. The FTIR spectrum of the white recycled sample is shown in Figure 4. The data generated from the three recycled samples are all similar, but there are some small peaks observed that are unique to each resin and may have contributed to the presence of certain additives based on the source of the feed stream. The analytical techniques conducted on the three recycled resins supported the idea that mechanical recycling introduces inherent variability due to the nature of different feed streams.

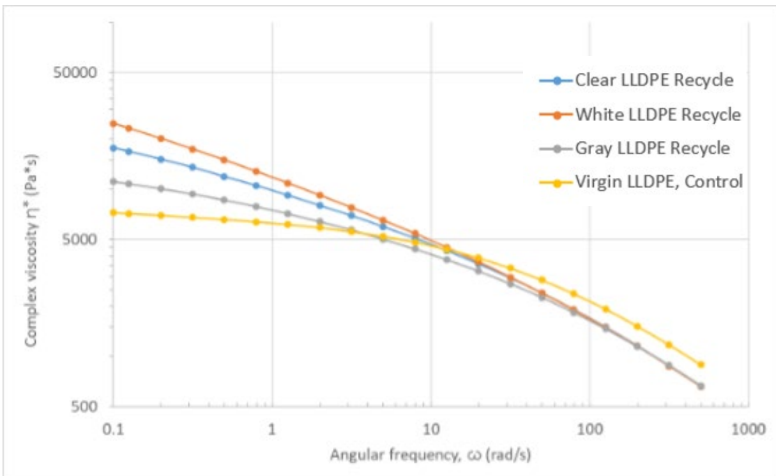

Figure 3. Rheological curves for the four experimental samples.

The melt fracture elimination curves of the three recycled resins are shown in the graph in Figure 5. Pictures at the beginning and the end of each sample test are located in Figures 6, 7, and 8. The white recycled resin with the addition of Kynar® PPRA showed the fastest time to melt fracture elimination, eliminating melt flow instability and creating a higher gloss surface in about 10 minutes. The natural recycled sample with the addition of Kynar® PPRA showed an elimination of melt fracture in about 15 minutes, and it also showed reduced die build-up collecting at the extruder die lip. With the addition of the Kynar® PPRA, the natural recycle sample film's surface was visibly smoother after 15 minutes than at the beginning of the test. The final, gray recycle sample containing Kynar® PPRA eliminated melt fracture in a linear fashion, achieving a smoother, glossier surface in around 30 minutes. The different recycled streams each took a different amount of time to eliminate melt fracture, but for each sample, elimination of melt fracture was achieved with the addition of Kynar® PPRA. One hypothesis to explain the different times required for melt fracture elimination can be attributed to the different additives that are present in each resin. Different recycled feed streams may contain certain additives, or higher concentrations of additives, which can interact differently with the performance of the PPRA.

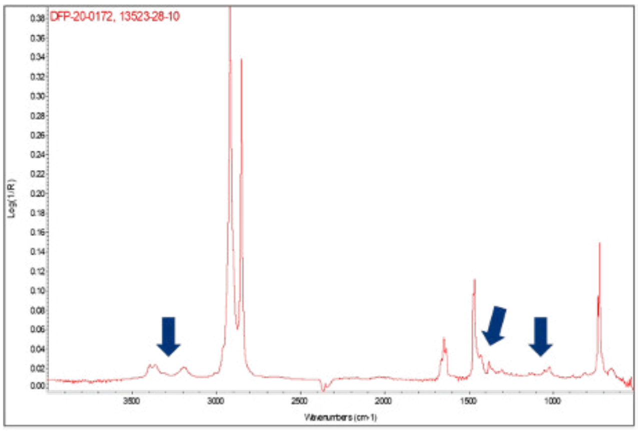

Figure 4. The FTIR spectrum of the white recycled resin. Blue arrows indicate areas of slight variability between the three recycled resin samples.

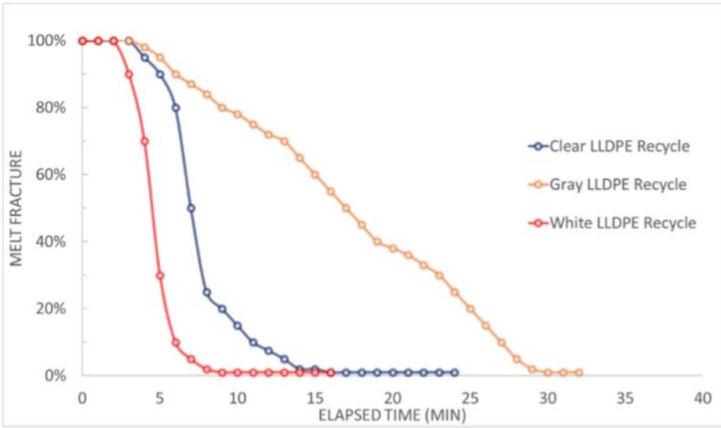

Figure 5. The melt fracture elimination curves of the three recycled samples.

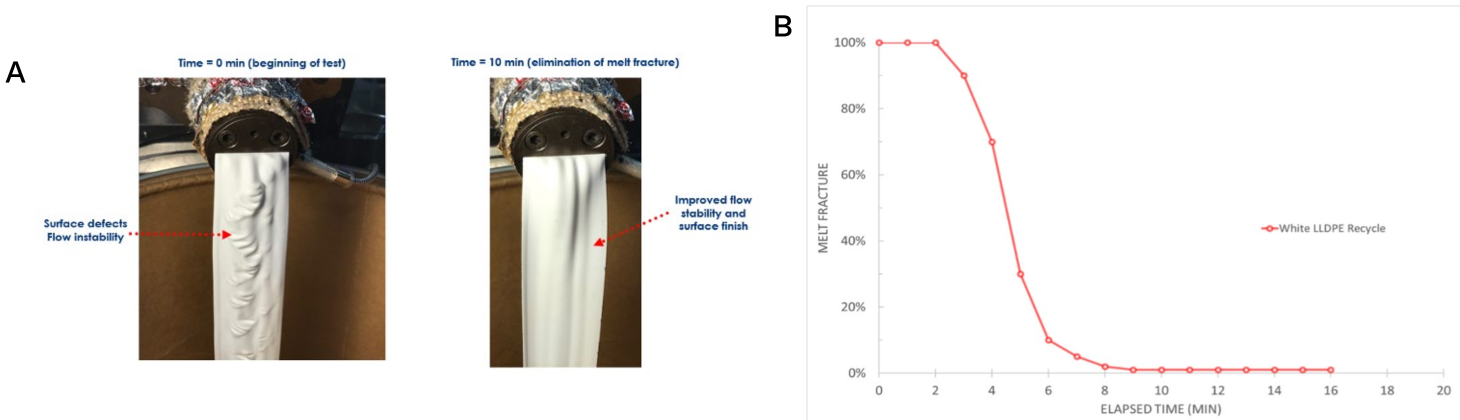

Figure 6 (A) The white recycled resin (left) before the addition of Kynar® PPRA and (right) 10 minutes after the addition of Kynar® PPRA. (B) The melt fracture elimination curve of the white recycled resin.

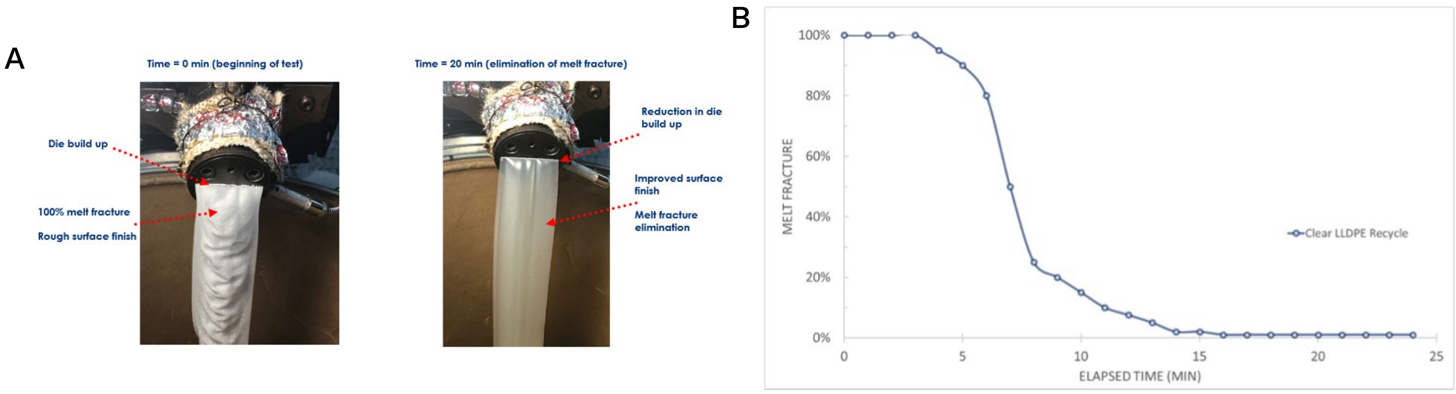

Figure 7 (A) The natural colored recycled resin (left) before the addition of Kynar® PPRA and (right) 20 minutes after the addition of Kynar® PPRA. (B) The melt fracture elimination curve of the natural recycled resin.

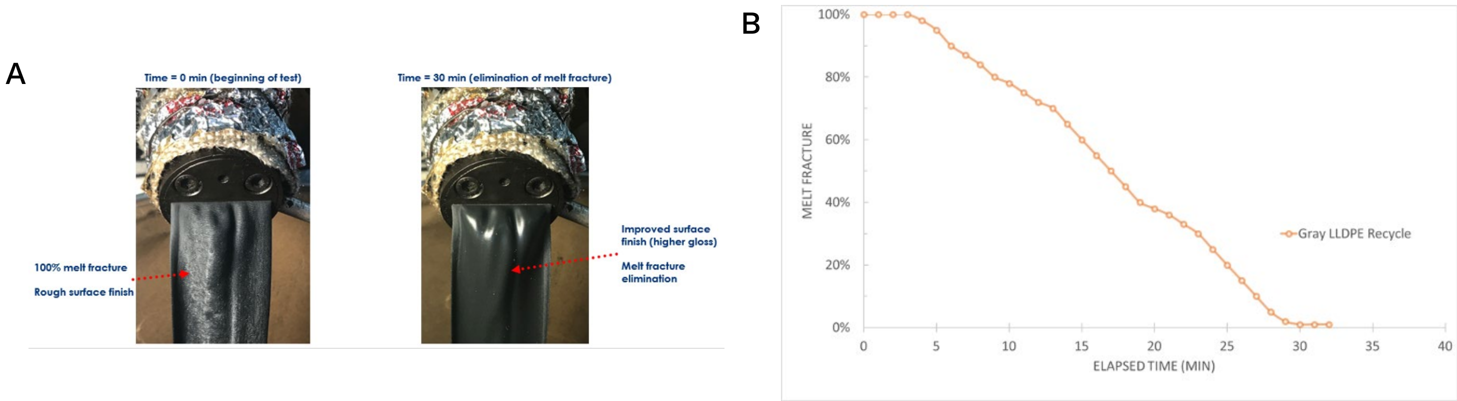

Figure 8 (A) The gray pigmented recycled resin (left) before the addition of Kynar® PPRA and (right) 30 minutes after the addition of Kynar® PPRA. (B) The melt fracture elimination curve of the gray recycled resin.

Each sample also experienced a reduction in extruder pressure after the addition of Kynar Flex® 5301 PPRA. Figure 9 shows the melt pressure reduction for all three recycled samples. The natural recycled resin had the greatest pressure drop, a delta of around 400 psi from the beginning to the end of the flat die test. Each sample had a different starting pressure at the beginning of their respective test, this was likely caused by the slight variations between the sample feed streams. In the case of the natural recycled sample, after the addition of a Kynar® PPRA, a pressure drop of around 20% was observed.

The reduction in extruder pressure means a film converter who was previously restricted in production capacity due to pressure limitations on their extruder, can consider increasing their output of total product by adding a Kynar® PPRA.

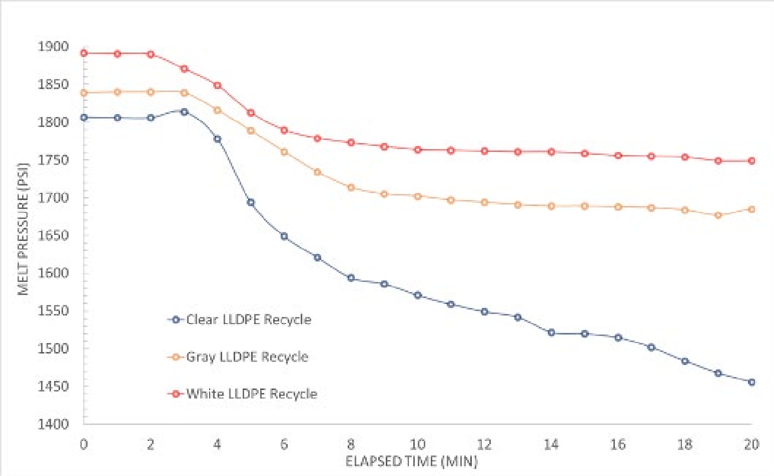

Figure 9. The melt pressure reduction curves for all three recycled resins.

Due to the variability of recycled feed streams, not all recycled resins, whether pigmented or natural, may behave in the exact same manner, as the samples tested above. The goal of this paper is not to suggest that a natural recycled resin outperforms a pigmented recycled resin (as an example) because each resin may have different additive packages and physical properties which are dependent on the recycled feed streams.

Conclusion

The addition of a Kynar® PPRA increased the processing efficiency of three different recycled polyethylene samples. Processing efficiency was measured by the elimination of melt fracture, and the reduction in extruder die pressure. These conclusions suggest that film converters wishing to run more recycled polyethylene content may have more processing options available to them than initially thought. Kynar® PPRAs can help increase the total output for a film converter so they can run more material on the same equipment without the need to invest in additional processing equipment. Additionally, if converters are blending recycled polyethylene content with virgin polyethylene, they can consider increasing the ratio of recycled to virgin resin, and still produce a product that meets the performance requirements of a given application.

The findings from this paper introduce several options for continued research. For example, the effect of different Kynar® PPRA grades in a given recycled base resin, the performance of a Kynar® PPRA in variable ratios of recycled to virgin polyethylene base resin content, and the impact of the number of recycled processes (heat histories) on Kynar® PPRA performance are all potential topics for further study.

References

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