CHELSEA CENTER FOR RECYCLING AND ECONOMIC DEVELOPMENT

UNIVERSITY OF MASSACHUSETTS

Technical Report #16

Continuous Extrusion of Recovered Ultra-High Molecular Weight Polyethylene

January 2000

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January 2000

 This project was funded by EOEA through the Clean Environment Fund, which is comprised of unredeemed bottle deposits.

The Chelsea Center for Recycling and Economic Development, a part of the University of Massachusetts' Center for Environmentally Appropriate Materials, was created by the Commonwealth of Massachusetts in 1995 to create jobs, support recycling efforts, and help the economy and the environment by increasing the use of recyclables by manufacturers. The mission of the Chelsea Center is to develop an infrastructure for a sustainable materials economy in Massachusetts, where businesses will thrive that rely on locally discarded goods as their feedstock and that minimize pressure on the environment by reducing waste, pollution, dependence on virgin materials, and dependence on disposal facilities. Further information can be obtained by writing the Chelsea Center for Recycling and Economic Development, 180 Second Street, Chelsea, MA 02150.

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1. THE PURPOSE OF THE PROJECT

1.1 The purpose of the project is to develop a system that will efficiently and economically convert Ultra-High Molecular Weight Polyethylene (UHMWPE) waste into extruded sheet product. The product would be ¼, $^{3}/_{8}$, and ½ inch thick by 24 and 48 inches wide with a minimum recycled content of 50% for commercial use in high abrasion applications, the main area of use for UHMWPE products.

1.2 UHMWPE sheet has the most product versatility and presently enjoys the lion's share of the total market for UHMWPE products. Hence, the largest potential for acceptance of UHMWPE sheet with a high UHMWPE waste content.

2. BACKGROUND INFORMATION

2.1 UHMWPE is most noted for three desirable characteristics: very high abrasion resistance, self lubrication, and high impact strength, and it finds application where these characteristics improve the performance of the product for the intended purpose. At present it is estimated that domestically 80-100 million pounds of UHMWPE is converted to product per annum.

2.2 UHMWPE has a molecular weight of 5-7 million versus the PE in a milk jug that has a molecular weight of approximately 200,000. It is the very high molecular weight of UHMWPE that gives products of UHMWPE their three most desirable characteristics: abrasion resistance, lubricity, and impact strength. However, this very high molecular weight makes it difficult to convert to product by conventional means such as injection molding and extrusion. This is because UHMWPE in the melt-state is a solid and any mastication would break down the large molecules into smaller molecules, thereby severely diminishing the three desirable characteristics of UHMWPE. The primary conversion processes of compression molding and ram extrusion used today do not masticate the melt prior to forming the product, thereby preserving the desirable characteristics of UHMWPE in the final product.

2.3 While compression molding is employed to a small degree to mold finished products, the major product from compression molding is sheet 4 and 5 feet wide by 8 and 10 feet long in thickness of ½ inch and higher. Less that ½ inch sheet is skived from thicker sheet. A sheet molding system has a high capital cost (estimated at 3 ½ - 8 million dollars), is labor intensive, and requires high-energy consumption to maintain a continuous high pressure for the total cycle, and to both heat and cool the press platen over the course of a single cycle.

2.4 While ram extrusion is employed to a small degree to extrude finished products, the major products from ram extrusion are rod, board, and shapes that are subsequently machined to a final product. Compared to sheet molding, ram extrusion has a low capital cost (less than 1/10 for pound to pound output), is not labor intensive, and utilizes much less energy per pound of conversion. This is due to the fact that the force is applied to the least, rather than the largest, surface during processing; is applied intermittently rather than continuously; and the die platens are constantly heated (not heated and cooled) while the product is extruded. For years UHMWPE converters have recognized that ram extrusion would be ideal for producing sheet, not only from an economic point of view, but that high product fusion pressure can be achieve with a relatively small force versus compression molding. This is particularly important in the processing of waste UHMWPE.

2.5 A by-product of processing UHMWPE and finishing UHMWPE shapes (sheet, board, rod, and profiles) into finished product is waste UHMWPE. Processing generates approximately 5% waste, and machine finishing up to 30% waste. Industry in the local area generates approximately 400,000 pounds of waste from machining prime UHMWPE product, which is more than Dorchester Industry's present recycling needs. Some of the waste is converted but the greater amount is either burned or sent to a landfill.

2.6 UHMWPE resin is a powder with an average particle size of 500 microns. To process it into a product, the individual resin particles must be fused together. The more complete the fusion, the better the resultant product properties. There are a number of recommended conditions for optimum fusion. Since heat input is easily varied, the remaining critical input for optimum fusion is pressure. It has been found it that takes a higher pressure to obtain optimum fusion with a waste/virgin mix than with just virgin resin. Reducing the recovered UHMWPE to a small particle similar in size to virgin resin generates heat, which promotes oxidation on the surface of the resultant particle. The oxidized molecules do not fuse, and to ensure fusion of a high percent of non-oxidized sites, a much higher pressure is required and a percentage of virgin is added. The very high pressure is required to flatten the spherical shape of both virgin and waste particles, exposing the greatest number of sites for fusion, similar to squeezing two balls together forming a flat surface between them. The most suitable process to provide the very high force required to adequately fuse a waste resin-virgin mix of UHMWPE is ram extrusion. All previous attempts by other firms to ram extrude thin virgin sheet have failed, though the processing technique and reasons for failure are unknown to the author.

2.7 With Dorchester and its customers generating waste, Dorchester knowing of end uses for thin waste sheet product, and Dorchester being in the ram extrusion business with 30 years experience, the potential for success where others failed was good; hence the beginning of the project.

3. SCOPE OF WORK

The scope of the work is to convert a waste-virgin UHMWPE resin mix into a marketable sheet utilizing a proprietary, ram extrusion sheet system that has been in development since 1995.

4. DESCRIPTION OF WORK, WORK COMPLETED, AND RESULTS

4.1 The first step was to come up with the mix ingredients and their percentage of the mix to ensure the best results. The starter mix selected contained equal amounts of pulverized waste (20 plus mesh) generated from our prime product and pulverized by Pallman Pulverizer, Clifton, NJ, and virgin resin, 1% lubricant (calcium stearate), 0.05 pph antioxidant (Irganox 1010), and black colorant.

The second step entailed purchasing mix ingredients, and having 10,000 pounds of waste pulverized to a 20 plus mesh particle size.

4.2 The ingredients for the starter mix were mixed in a high intensity mixer to ensure optimum mixing.

4.3 The starter mix was successfully extruded, but being extruded as a sheet melt for ambient cooling, the resultant sheet had a dull surface, was much thicker in the middle than the outsides, and was off being flat by 1 plus inches over the 26 inch width. The physicals were tested and found to be satisfactory; i.e. within 90 % of the wear and impact resistance of prime UHMWPE.

4.4 To overcome the problems with the finish, a post extrusion-cooling fixture was added to the system downstream from the sheet die. After several test runs, a flat sheet with acceptable dimension tolerances and appearance was produced. However, subsequent testing showed the physicals to be satisfactory on the outer width dimensions but not in the middle portion of the sheet. This was attributed to the cooling fixture not providing an even pressure from the inside to the outer edges of the sheet. Modifications to the fixture to correct the problem have been made and new samples are yet to be made as of this writing.

5. SIGNIFICANCE OF SUCCESS

Since sheet extrusion is new, there is considerable domestic interest in the process, but the greater interest is with third world country UHMWPE converters that cannot afford the high cost of a sheet molding system.

6. FUTURE WORK

Future work will be focused on perfecting the system so that it will produce a sheet with a high content of waste resin that has both acceptable appearance and acceptable, uniform physicals.

7. CONCLUSION

Additional work is required but the goal is achievable.