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PARTICLE FILLED POLYETHYLENE COMPOSITES USED IN THE TECHNOLOGY OF ROTATIONAL MOULDING

Peter BÚTORA[1], Antonín NÁPLAVA[2],
Martin RIDZOŇ[2], Jozef BÍLIK[2], Viktor TITTEL[2]

Abstract

The submitted article discusses rotational moulding technology and filled plastics. For testing, linear low density polyethylene filled with talc was used. The materials tested varied way of mixing the filler into the polymer. For the prepared samples were evaluated by tensile, elongation, melt flow index, density, Shore hardness and Vicat softening temperature. Experiments showed that, in principle, it is possible to produce rotational moulding technology filled thermoplastics.

Key words

rotational moulding, low-pressure, open-moulding, plastic-forming, particle composite, LLDPE, talc

Introduction

Development of basic types of plastics is virtually complete. New development of plastics is not expected mainly for economic reasons. Therefore, future development will be focused on improving the existing plastics' properties and processing technologies. One way to achieve this goal is the possibility of developing composites with inorganic fillers and increasing their share while maintaining reasonable mechanical and rheological properties. The aim of our research was to verify the rotational moulding technology and its use in the processing of thermoplastic composites. We tried to assess the impact of the dispersion of inorganic filler - talc in polyethylene on mechanical properties.

[1]Peter Bútora, MSc. Eng. - Plastika, a.s., Nitra
[2]Antonín Náplava, Assoc. Professor, Ph.D., Marián Ridzoň, Ph.D., Jozef Bílik, Assoc. Professor, Ph.D., Viktor Tittel, Assoc. Professor, Ph.D. - Institute of Materials Science, Faculty of Materials Science and Technology in Trnava, Slovak University of Technology Bratislava, J. Bottu 25, 917 24 Trnava, Slovak Republic, peter.butora@stuba.sk, antonin.naplava@stuba.sk, marian.ridzon@stuba.sk, jozef.bilik@stuba.sk, viktor.tittel@stuba.sk

Theoretical principles

Process description

Rotational moulding is a high-temperature, low-pressure, open-moulding plastic-forming process that uses heat and bi-axial rotation to produce hollow, one-piece parts (1). To rotationally mould a roll-out refuse container, a mould that defines the shape of the part to be produced is mounted on the arm of a moulding machine (Fig. 1). The machine is capable of bi-axially rotating and moving the mould through the four phases of the process. A predetermined amount of plastic material, in the form of a liquid or a powder, is then placed in the mould's cavity (Fig. 1a) The machine then simultaneously rotates the mould in two directions and moves the mould into the heating chamber or oven (Fig 1b). In the oven, the mould becomes hot and all the plastic material adheres to and sinters onto the inside surface of the cavity. While it continues to rotate, the machine moves the mould out of the heating chamber and into the cooling chamber, where the plastic is cooled so that the formed plastic part will retain its shape (Fig. 1c). The machine then moves the mould to the open station, and the mould stops rotating. The mould can then be opened and the moulded part removed (Fig. 1d).

The mould is then recharged with plastic material and the process can be repeated (1).

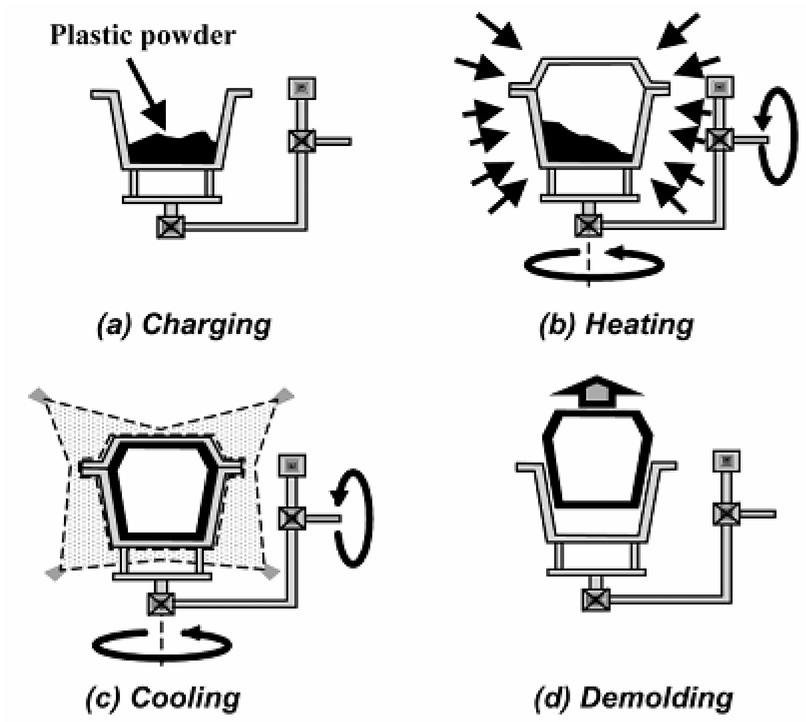

Fig. 1 *The four steps of rotational moulding process (2)*

Attributes of the process

Rotational moulding technology has always been regarded as ideal for producing large reservoirs (tanks). This process is, however, capable of producing many types of parts (Fig. 2), (1).

Fig. 2 *The typical array of RTM products (1)*

Like all other manufacturing processes, rotational moulding has advantages and disadvantages.

Advantages:

- low-pressure process,
- can produce complex shapes,
- light-duty moulds and machines,
- low post-mould warpage,
- walls can be extremely thin in relation to their overall size ability to produce two-color or two-material parts without multiple moulds or sophisticated machines,
- parts are free of weld-lines.

Disadvantages:

- can produce small quantities,
- no cores inside the hollow parts,
- the process requires the heating and cooling of not only the plastic material, but of the mould too.

Rotational molding materials

More than 80 % of all the materials used is from the polyethylene family: cross-linked polyethylene (PE), linear low density polyethylene (LLDPE), and high density polyethylene (HDPE). Other compounds are PVC plastisols, nylons, and polypropylene.

Order of materials most commonly used by industry:

- Polyethylene,
- Polypropylene,
- Polyvinyl Chloride,
- Nylon,
- Polycarbonate (1, 2).

Methods

Stage 1 was the preparation of samples. Stage 2 was measuring the mechanical and rheological properties. The samples were fitted from sewerage pipes.

Step 1: Preparation of samples consisted of seven steps:

1. We drew four samples of 2 kg.:
   - sample No. 1 content 100 % LLDPE ICORENE 4-3545;
   - sample No. 2 content 100 % LLDPE RESIN RX103 NATURAL;
   - sample No. 3 content 90 % LLDPE ICORENE 4-3545 + 10 % Talc;
   - sample No. 4 content 90 % LLDPE RESIN RX103 + 10 % Talc;
2. Preparation of samples:
   A) Samples No. 1 and Nr. 2 was mixed by small mixer for concrete
   B) Sample No. 3 was mixed by a small fluid mixer.
   C) Sample No. 4 was prepared mixing the talc into the melt polymer on double-screw homogenization equipment Bresdorff Φ 45mm.
3. We inserted the prepared samples to the two-part aluminium mould. Fitting the mould on three-arm carousel rotational moulding machine.
4. The mould was heated during rotation up to 285 °C for 23 minute.
5. Then the mould was cooled during rotation up to 23 °C for 20 minute.
6. After cooling, the product was selected from the mould.
7. Preparation of testing samples from the functional parts of the product.

Stage 2 was measuring the mechanical and rheological properties.

We measured the following properties: tensile property, melt flow index, density, Shore hardness and Vicat softening temperature (3).

Results

The knowledge gained showed that compared with the mixing of dry powder mixture to a fluid mixer, the intensive mixing of filler in the melt reaches better dispersion, which resulted in better mechanical properties of the final product. Measured values of properties are shown in Table 1.

MEASURED VALUES OF PARAMETERS (3)

Table 1

Sample No.	Yield stress (MPa)	Elongation (%)	Melt flow index (g/10 min)	Density (g /cm^3)	Shore hardness (°Sh)	Vicat softening temperature (°C)
1	18.86	172	3.4	0.923	53	114
2	20	132	3.8	0.939	59	123
3	10.7	0	3.2	0.972	50	114
4	15.6	10	3.7	0.993	57	121

Discussion

Evaluation of production technology

Sample No. 1 consists of 100 % LLDPE ICORENE 4-3545 has a smooth surface, the layers are compact and without undesirable colour degradation. The wall of the manufactured product is strong and solid.

Sample No. 1 consists of 100 % LLDPE RESIN RX 103 NATURAL has a smooth surface, the layers are compact and without undesirable colour degradation. The wall of the manufactured product is strong and solid.

Sample No. 3 consists of 90 % LLDPE ICORENE 4-3545 and 10 % talc has a rough, leathery finish. By the tool is smoother than the inside. Compact layer is formed. De-moulding took place without difficulty.

Sample No. 4 consists of 90 % LLDPE RESIN NATURAL RX 103 and 10% talc and an outer smooth surface as seen in Figure 3, layers are compact, rugged inner surface is as shown in Figure 4 Compact layer is formed. The product had the form of a charge for the use of power, while not necessarily undermining its unity as shown in Figure 5 De-moulding is difficult due to different shrinkage and the fulfillment of basic material.

Fig. 3 *Smooth outer surface of the product*

Fig. 4 *Rough inner surface of the product*

Fig. 5 *Deformed shape of the product after de-molding*

Evaluation of mechanical and rheological properties

Tensile strength and elongation

Tensile strength at yield is the sample No. 1 18.86 MPa at 172 % elongation. Sample No. 2 has 20 MPa at 132 % elongation. Sample No. 3 exhibits lower strength values than sample No. 1, composed of pure LLDPE ICORENE 4-3545. Tensile strength at yield is 10.7 MPa at 0 % elongation. In contrast, sample No. 4 shows the decrease of strength properties versus sample number 2 to 15.6 MPa at 10 % elongation.

Tensile strength at yield of Rezin NATURAL RX103 has a smaller decrease in value compared with the raw material, which is achieved through more complete dispersion of filler particles incorporated into the basic matrix intensive homogenization effect double-screw extruder. Decrease in ductility is due to better dispersing the filler in the polymer.

Density

The density of sample No. 1, composed of 100 % LLDPE ICORENE 4-3545 has a value of 0.923 g/cm^3 and sample No. 3 with 10 % addition of talc has a value of 0.972 g/cm^3. Sample No. 2, composed of 100 % LLDPE RESIN NATURAL RX 103 has a value of 0.939 g/cm^3 and sample No. 4 with 10 % addition of talc has a value of 0.993 g/cm^3. Higher density fillers are very influenced by the overall density of the product versus the product of pure LLDPE and is proportional to the concentration of filler.

Hardness Shore

The hardness value is dependent on the modulus, which depends on the relative weight of the material. The relatively low modulus of LLDPE and soft particles of talc, and also an imperfect connection matrix polymer filler, we reached the small differences of hardness of the samples. Hardness of sample No. 1 is 53 °Sh and sample 2 is 59 °Sh. For samples with 10 % talc is 50 °Sh in sample No. 3 and 4 57 °Sh.

Vicat softening temperature

Typically, the softening temperature using reinforced filler increases. The number of samples 1 and 3 reached the same value of 114 °C. For sample, in No. 4 we even noticed a decrease compared to sample No. 2 with primary LLDPE 2 °C to 121 °C, which is likely to be associated with different degrees of filler dispersion, which affects the thermal conductivity of the composite.

Melt flow index

Sample No. 1 has a value of 3.4 g/10 min and the sample No. 3 with the same LLDPE + 10 % talc has a lower value 3.2 g/10 min. Sample No. 2 has a value of 3.8 g/10 min and the sample No. 4 with the same LLDPE + 10 % talc has a lower value 3.7 g/10 min. A lower value for ITT samples with the addition of talc is caused by an increase in viscosity due to the addition of filler to polymer and the subsequent narrowing of the capillary flow (3).

Conclusion

Experiments showed that, in principle, it is possible to produce rotational moulding technology filled thermoplastics. However, it is necessary to choose optimal parameters of the polymer filler and the size of the particles, their dispersion and density. To increase the adhesion of the polymer matrix and filler and thus the increased compactness of the final product, we focused attention on improving the dispersion of filler in the polymer used double screw homogenization equipment used in the manufacturing of thermoplastic composites with conventional particulate filler.

The results obtained suggest that it will be filled with more efficient production of plastics: reduced price while maintaining the required mechanical properties.

Further experiments will focus on increasing the filler content. Mould modifications were due to different shrinkage of the base material and filler.

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Reviewers:

Ján Grom, Assoc. Professor, Ph.D. – VÚSAPL, a.s., Nitra

Ľubomír Jahnátek, Professor, Ph.D. – National Council of the Slovak Republic, Bratislava

Ernest Gondár, Professor, Ph.D. – Faculty of Mechanical Engineering, Slovak University of Technology, Bratislava