Two-component injection moulding of thermoplastics with thermoset rubbers: Process development

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Two-Component Injection Moulding of Thermoplastics with Thermoset Rubbers: Process Development

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Abstract. Two-component injection moulding is a manufacturing process for combining polymers with different properties in a single injection moulding process. The process is typically used to combine thermoplastics with another thermoplastic or with a thermoplastic elastomer to create colour differences or hard and soft areas respectively. The present study aims at the development of a two-component injection moulding process for the combination of a thermoset rubber and a thermoplastic. Currently products that consist of those two materials (e.g. wheels, syringes and other products with gaskets) are made by assembling separate components. Implementing the two-component injection moulding technique for these products will result in better interphase properties, savings on rubber and avoiding costs related to the assembly process. A technological challenge is posed by the fact that injection moulding of rubbers and thermoplastics is fundamentally different. The injection moulding of a rubber requires a heated mould (140°C-180°C) whereas thermoplastics need a relatively cold mould (20°C-100°C) for the polymer to solidify. In this study a versatile two-component mould is proposed in which the mould cavities for the rubber and the thermoplastic are thermally separated and equipped with facilities to control the temperature of both cavities individually. The design of the mould also makes it possible to vary the sequence of injection. In this way it is possible to test several processes variations. Preliminary test results will be presented for specific rubber-thermoplastic combinations.

Keywords: Two-component injection moulding, thermoset rubbers, thermoplastics.
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INTRODUCTION

Several applications require a combination of parts with different characteristics like hard/soft, conductive/non-conductive or different colours. This diversity in requirements is only possible by combining different materials. Two-component (2K) injection moulding is a manufacturing process that allows to combine different polymers with different properties in a single injection moulding process. 2K injection moulding is often used to combine multiple thermoplastics with colour differences. In other applications, like in toothbrushes, a combination of a soft rubberlike material and a stiff material is required. In these cases the rubberlike material is a thermoplastic elastomer (TPE).

A large number of products combine thermoset rubbers with thermoplastics, e.g. wheels, syringes and other products with gaskets. Currently these products are made by assembling separate components. Implementing the 2K injection moulding technique for these products should result in better interphase properties and the avoidance of costs related to the assembly process. Furthermore it is expected that a redesign will result in savings on rubber. Such 2K process poses considerable challenges, since injection moulding of thermoplastics and thermoset rubbers requires fundamentally different process parameters. Thermoset rubbers are injected in a heated mould (140°C-200°C) to start the curing process whereas thermoplastics are injected in a relatively cold mould (20°C-100°C) to solidify the product [1,2]. High-end thermoplastics like polyamide (PA) can withstand high temperatures making it possible to insert the thermoplastic part in a completely heated mould and then overmould it with rubber [3, 4]. When this technique is applied with commodity thermoplastics like polyethylene (PE) or acrylonitrile butadiene styrene (ABS), it is expected that the thermoplastic part will deform under the high temperatures and pressures necessary for the injection moulding process of the thermoset rubber. This study aims at the development of a novel 2K injection moulding process that can be applied with commodity thermoplastics. Two possible solutions are proposed. In the first, deformation of the thermoplastic part is prevented by cooling the thermoplastic part during vulcanization of the rubber. This technique requires special moulds where the mould cavities for the rubber and the thermoplastic are thermally separated and equipped with facilities to separately control the temperature of both cavities. In the other solution, the thermoplastic material is injected after vulcanization of the rubber part.

MATERIALS AND METHOD

Material

For this research HDPE (Sabic, grade M80064) is selected as thermoplastic material. HDPE is a commonly used thermoplastic characterized by a rather low maximum service temperature (110°C-130°C) since it easily deforms at high temperatures. The thermoset rubber selected for this research is EPDM (Hercorub, grade 005K), a frequently used material for seals, gaskets, hoses, roofing and cable insulation. The selected EPDM rubber is a sulphur vulcanizing rubber that needs approximately 20 minutes of curing at 160°C.

Method

Injection moulding is conducted on an Engel ES330H/80V/80HL-F 2K injection moulding machine with a vertical rubber injection unit and a horizontal thermoplastic injection unit.

A versatile mould is required to enable both proposed 2K injection solutions. First of all it is designed in such a way that the injection sequence can be reversed. For this purpose, the mould is based on a movable core system. Instead of using a real moving core, a metal plate that can be manually inserted was used (figure 1). Moving the metal plate from one mould cavity to another is required to enable a different injection sequence. Secondly the mould cavities for the rubber and the thermoplastic are thermally separated and equipped with facilities to control the temperature of both cavities separately. In this way, it was possible to cool the thermoplastic during the in-mould vulcanization of the rubber. Thermal separation was achieved by using insulation and air gaps.

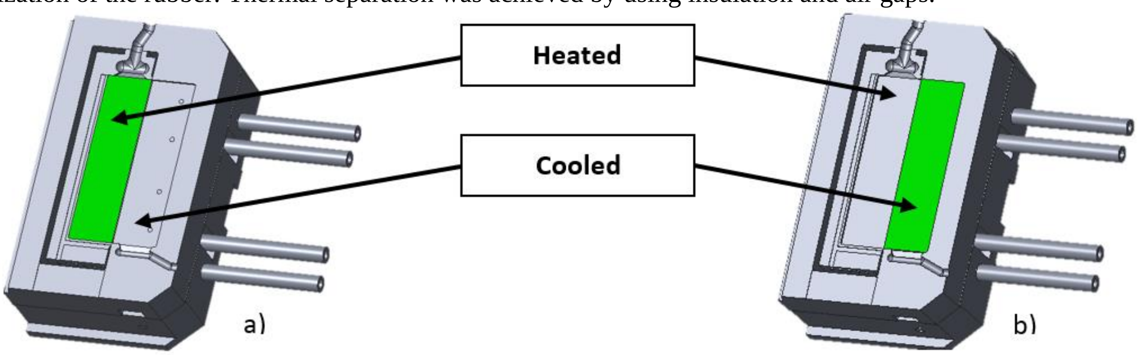


FIGURE 1. Mould system based on a movable core system. The metal plate, indicated in green, is used to change the order of injection: (a) shows the configuration where the thermoplastic is injected first followed by the rubber, (b) shows the configuration where the rubber is injected first. Both mould cavities are thermally separated. The left cavity is heated, the right cavity is cooled.

Pressurized water is used both for heating the mould cavity for the thermoset rubber and for cooling the mould cavity for the thermoplastic part. Design rules found in literature were used for the cooling channels [5] in order to obtain evenly distributed temperatures.

To achieve even more flexibility a combination of two temperature control units and a valve system is used to heat the mould cavity of the rubber (Figure 2). This set-up makes it possible to quickly cool the rubber after vulcanization. The same set-up is used for rapid heat cycling of the mould in injection moulding of thermoplastics to improve mouldability, strength of weld lines and surface quality [6].

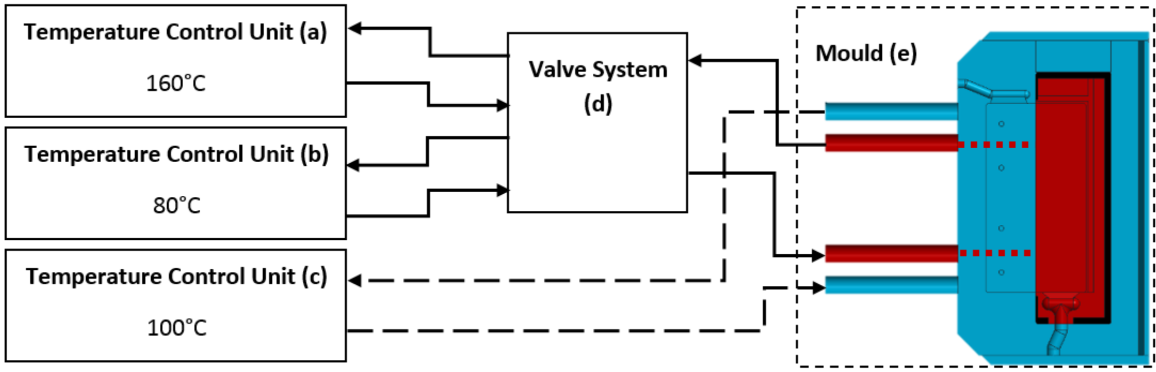


FIGURE 2. Temperature control set-up with possibility for rapid heat cycling on the mould cavity for the rubber. (a) and (b) are respectively temperature control units for the upper and lower temperatures of the mould cavity for the rubber. (d) is the valve system that switches between hot and cold water. (c) is the temperature control unit for the mould cavity for the thermoplastic part. (e) is the mould used in this study.

Temperature control units (a) and (b) determine respectively the upper and lower temperatures of the mould cavity for the rubber. The valve system (d) allows either the hot or the cold water to flow through the mould cavity for the rubber. In this way it is possible to vulcanize the rubber first and then quickly cool it to the temperature of the thermoplastic part. Temperature control unit (c) controls the temperature of the mould cavity for the thermoplastic part.

EXPERIMENTAL

Temperature Distribution Within the Mould

To verify thermal separation between the mould cavity of the thermoset rubber and the thermoplastic, an infrared camera (OPTRIS PI400) is used. Black adhesive tape with an emissivity of 0.95 is used in order to avoid reflection of the metal surface. The temperature control unit for the mould cavity of the rubber was set at 160°C. The temperature control unit for the cavity of the thermoplastic was set at 100°C.

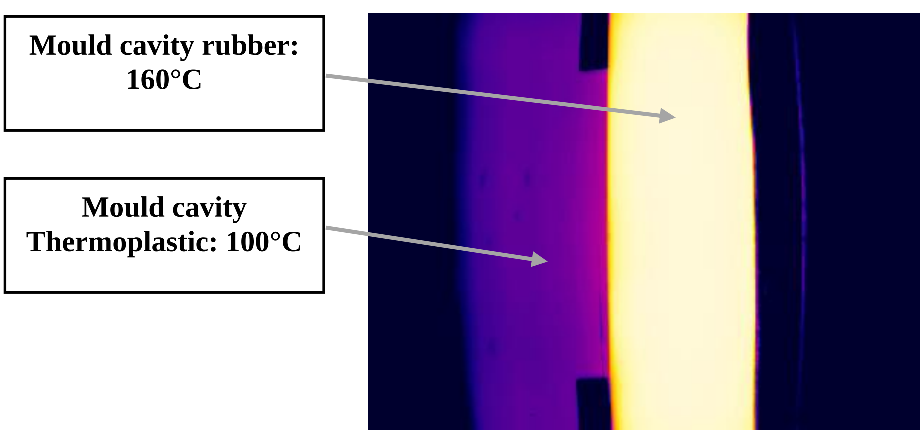
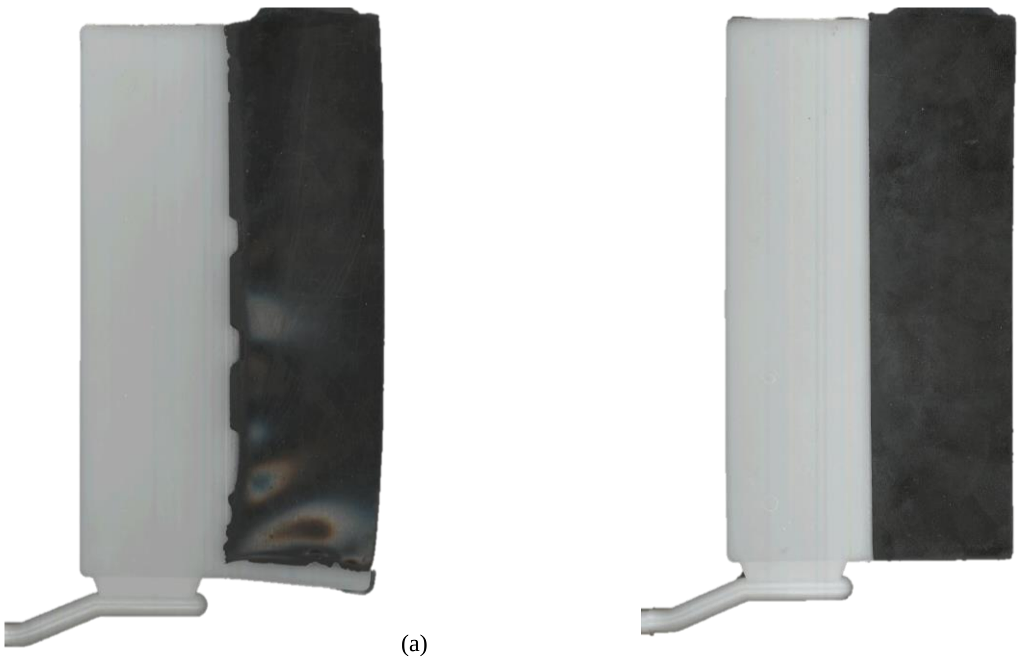


FIGURE 3. Thermal image of both mould cavities during heating and cooling. The left cavity is the colder cavity (100°C) for the thermoplastic part. The right cavity is the hot (160°C) cavity for the thermoset rubber.

At the left side of the thermal image is the cavity for the thermoplastic. It can be seen that the temperature of this cavity is successfully maintained at 100°C. At the right side of the thermal image is the cavity for the rubber. The temperature of this cavity is 160°C. The thermal image shows a uniform temperature distribution within the cavity for the rubber, which allows the rubber to vulcanize evenly and prevents warpage of the rubber part.

Rubber – Thermoplastic injection sequence

In this section the process of first injecting and vulcanizing the rubber is described. The rubber is vulcanized for 20 minutes. After cooling to a temperature of 40°C, the polyethylene is injected. Slow injection speeds (34 cm^3/s) and a low holding pressure (274 bar) were used for the polyethylene in order to minimize the deformation of the rubber part. In figure 4 (a) it can be seen that the rubber part is largely deformed during the injection of the polyethylene. The deformation is caused by the elastic behaviour of the rubber. Due to the deformation of the rubber, it is impossible to accurately control the dimensions of the finished product. Adhesion between the rubber and the polyethylene was found to be very poor. The stress within the rubber, caused by the deformation of the rubber, was large enough to break the adhesion.



(a) (b)

FIGURE 4. 2K injection moulded test samples of thermoset EPDM rubber and polyethylene. In (a) the thermoset rubber was injected first. Due to the elastic properties of the rubber, the rubber part is largely deformed. In (b) the injection moulding process started with the injection of the polyethylene.

Thermoplastic – Rubber injection sequence

In a second solution the thermoplastic part is moulded first and kept at a lower temperature during the vulcanisation process of the thermoset rubber. The result is shown in figure 4 (b). It is important to mould the thermoplastic part with minimal shrinkage by selecting optimal process parameters. Thanks to thermal separation between the two cavities, the cavity for the thermoplastic part can be kept at a lower temperature than the cavity for the rubber. When the thermoplastic part is smaller than its the cavity due to shrinkage, the interface between the rubber and the thermoplastic will be in the colder cavity. Because of the lower temperatures, the rubber at the interface will not vulcanize. The next step in the process is the moulding of the rubber part. It is important to keep the temperature of the thermoplastic part at an intermediate temperature during the moulding of the rubber part. The intermediate temperature should not be too high in order to prevent deformation of the thermoplastic part. On the other hand when the temperature is too low, the thermoplastic part will absorb heat at the interface resulting in an incomplete vulcanisation of the rubber at the interface. In this research it was found that for the specific type of polyethylene, 100°C is a good value for the temperature of the thermoplastic part. The rubber is now vulcanized for 20 minutes. After vulcanisation the rubber is quickly cooled down till 100°C using the valve system (d) in figure 2. The last cooling step of the rubber part is necessary for the solidification of the polyethylene at the interface. Without this cooling step the interface is weak and fails when ejected.

CONCLUSION

In this study a versatile mould is developed for 2K injection moulding of thermoset rubbers and thermoplastics. The sequence of injection is controllable by moving a metal plate. The cavities for the rubber and the thermoplastic are thermally separated in order to control the temperatures of both cavities separately. With the aid of a valve system it is possible to quickly cool the rubber after vulcanisation. Several 2K injection moulding variants have been tested. In this research it was found that the deformation of the rubber part is too large when the rubber is injected first. Adhesion between the rubber and the thermoplastic part was very weak for this injection sequence. By first injecting the thermoplastic it was possible to successfully make two-component products out of thermoset rubber and thermoplastics. In this process it was necessary to minimize shrinkage of the thermoplastic part by selecting optimal process parameters, in order to completely vulcanize the rubber at the interface. The thermoplastic part was kept at an intermediate temperature during the vulcanisation process of the rubber. After vulcanisation the rubber was quickly cooled down before ejection in order to solidify the thermoplastic at the interface. In future research this process will be optimized in order to maximize the adhesion and minimize the deformation. In order to further validate the proposed 2K injection moulding process, more combinations of different thermoset rubbers and thermoplastics will be tested.

ACKNOWLEDGMENTS

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REFERENCES

1. J.A. Lindsay, *Practical guide to rubber injection moulding*, London: Smithers Rapra, 2012.
2. T. Osswald, L-S Turng and P. Gramann, *Injection Molding Handbook*, Munich: Carl Hanser Verlag, 2008, pp. 65, 73.
3. D. Schneegans, R. Gattringer and Emmerich, *KGK Kautschuk Gummi Kunststoffe* **58**, 16-21 (2005).
4. D. Schneegans, R. Gattringer and R. Bauer, *GAK* **60**, 494-499 (2007).
5. W. Guilong, Z. Guoqun, L. Huiping and G. Yanjin, *Materials and Design* **31**, 3426-3441 (2010).
6. W. Guilong, Z. Guoqun and W. Xiaoxin, *International Journal of Heat and Mass Transfer* **78**, 99-111 (2014).