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Multicomponent Injection Molding Of Thermoplastics And Liquid Silicone Rubber (LSR) – Either Cured By Heat Or UV Light

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Abstract

For processing thermally curing liquid silicone rubber (LSR) as well as UV light curing LSR for multicomponent injection molding with thermoplastics in an comparable way a processing center was designed and set into operation.
For the production of the multicomponent specimens a modular tool was designed. In there a thermoplastic plate gets molded on the one side, then gets transferred automatically by a robot system and gets overmolded by the silicone on the other side. The complete silicone side of the tool is easily changeable from a heated cavity, which is more or less state of the art, to a transparent cavity, wherein the UV LSR gets cured by according LEDs.
In first studies tests have been carried out concerning the adhesion between several thermoplastic materials and different LSR types, cured by heat as well as by UV light. The adhesion has been tested according to VDI 2019.
The used injection molding technique makes an intermediate treatment like surface activation of the thermoplastic plate possible before it gets overmolded. Therefore exemplarily different surface treatments and their effects on the adhesion strength of the material composite were evaluated.

Introduction

By the use of different materials various properties can be integrated in according areas of multicomponent parts. In these applications for example there are hard components used providing the required stability and soft components, which function as sealing or shock absorbing elements.
For thermoplastic components these processes are well established. One of the most common applications are probably tooth brushes, which are made of a hard solid body overmolded with a softer thermoplastic material for a better grip. [1, 2]
If it comes to technical applications with higher requirements thermoplastic elastomers (TPEs) reach their limits. For those requirements silicones show several properties like a high reversible elastomeric behavior, good temperature resistance, flexibility at temperatures down to -50°C, high resistance against chemicals, weather conditions and aging. Furthermore silicones are harmless from a physiological point of view, what makes them very interesting for medical applications. [3, 4]
Parts consisting of thermoplastic and silicone components can be produced by multicomponent injection molding techniques. There are several variations of multicomponent techniques with different pros and cons. [5] One possibility is the overmolding of previously inserted parts. This approach provides the opportunity to separate each injection molding step and to include for example a pretreatment of the thermoplastic part before it gets overmolded with the second component. [6]
The overmolding of thermoplastic parts with heat curing LSR is state of the art. But due to the fact that there is heat needed for curing the silicone, there are severe restrictions on the thermoplastic partner regarding thermal stability. LSRs curable by UV light make new material composites with thermoplastics possible, which need not to be that stable against high temperature. [7]

Objectives

There are several challenges for producing injection molded parts with UV curing LSR. The biggest hurdle to clear is how to get the UV light into the cavity. Therefore transparent cavities needed to be designed. When it then furthermore comes to multicomponent parts, wherein UV light curing LSR is used there are still some more obstacles. A big challenge for producing such parts is the adhesion between the thermoplastic and the UV cured silicone partner. Therefore the adhesion between several thermoplastic materials and different LSR types, as well cured by heat as by UV light, were tested. Furthermore the effects of different surface activation techniques like plasma or silicatization on the adhesion strength of the material composites have been evaluated.

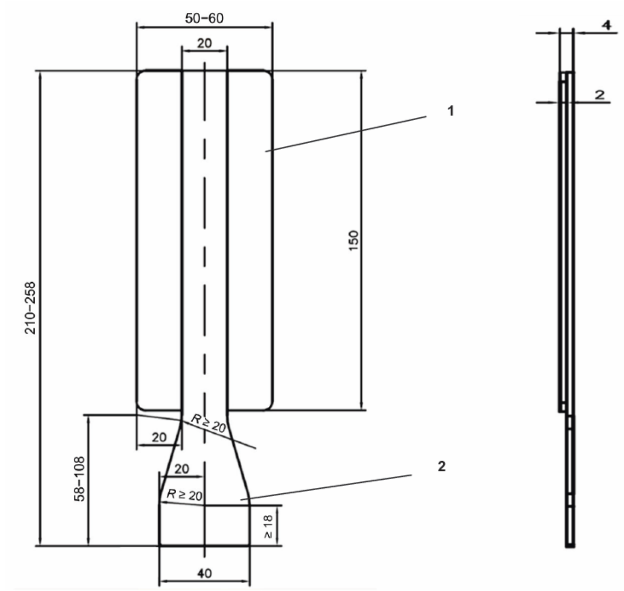
Experimental

In the following chapter the overall approach including the tooling and machinery setup as well as the used materials are described.

Test method

For testing the material composites made of thermoplastics and LSR the approach of VDI 2019 "Testing the adhesion of thermoplastic elastomers (TPE) on injection-moulded substrates" [8] was chosen.

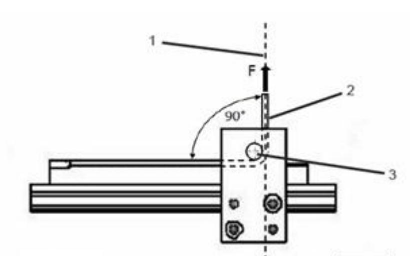
VDI 2019 describes testing of multicomponent specimens consisting a hard and an elastomeric part made by injection molding. Other standards like DIN ISO 813 or DIN EN 1464 deal with material composites made by gluing or other joining techniques. [9] Although VDI 2019 originally deals with thermoplastic elastomers, it is well applicable for injection molded parts with liquid silicone rubber.
Figure 1 shows the peel test specimen described in VDI 2019. It consists of a hard thermoplastic plate, that gets overmolded with the elastomeric component for peeling. As it has a flap for clamping it in the according testing machine, the length of the flap depends. The thickness of the hard as well as the elastomeric component is 2mm.



1. *hard component*
2. *soft component*

Figure 1: Drawing of peel test specimen according VDI 2019 [8]

According VDI 2019 the adhesion strength between both components gets quantified by a peeling test.



1. *tensile axis*
2. *free end of the soft component*
3. *guide pulley*

Figure 2: Specimens clamping arrangement of VDI 2019 [8]
Figure 2 shows the clamping arrangement the specimen is tested with. Therefore the device is put in a tensile testing machine and the flap of the soft component is clamped in the testing machine.

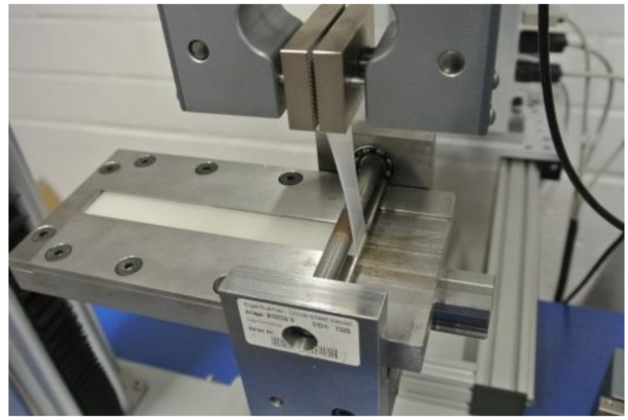


Figure 3: Multicomponent peeling test according VDI 2019

As one can see in Figure 3 the force of the tensile axis gets transmitted by the guide pulley. Due to that and to the moving slide where the hard component is fixed in, the peeling angle between hard and soft component is always 90°.

Overmolding Technique

The overview in Figure 4 shows available overmolding technologies for producing multicomponent parts. Transfer molding has been chosen, with a transfer from one cavity to another in one single mold on one machine. The transfer of the hard thermoplastic plate to the LSR cavity is done fully automatically by a robot system.

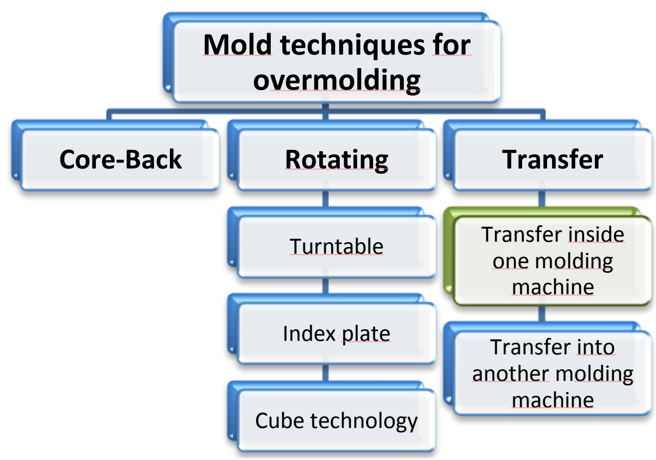


Figure 4: Overview about overmolding techniques [10]

Figure 5 shows the fully electrically driven Arburg Allrounder 370A 600-70/70 in L position with a linear robot for creating the multicomponent test specimens by transfer molding.

Figure 5: Arburg Allrounder 370A 600-70/70 multicomponent injection molding machine with robot system

Multicomponent TP-/LSR-IM Tool For Heat And UV Light Curing

For processing both materials, i.e. thermoplastics and liquid silicone rubber, in parallel in one process step a special tool was designed. The tool is furthermore equipped with a changeable LSR side, so that thermally curing LSR can be processed as well as LSR to be cured by UV light.

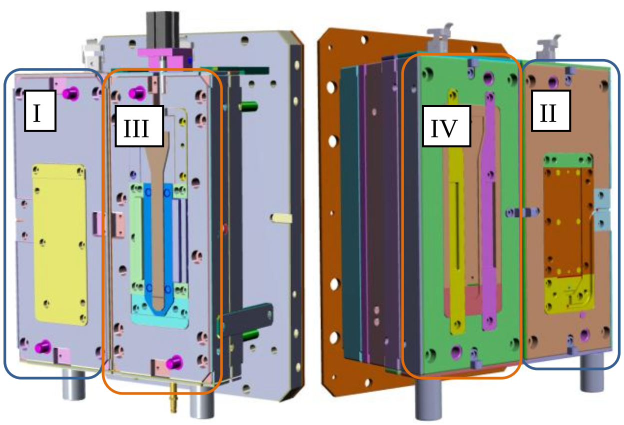


Figure 6: Multicomponent TP-/LSR tool

Figure 6 shows the setup of the injection molding tool schematically. The areas I and II are cooled areas for the thermoplastic component. The areas III and IV are for the silicone component, while the whole block of area IV is changeable.
Figure 7 gives a view inside the tool. The left side shows the heated LSR cavity for accordingly curing LSR, with its ejector bars. The picture on the right side shows the transparent cavity with its UV light LEDs. The tool was designed and manufactured in close collaboration with the company of EDEGS[1].

1 EDEGS Formenbau GmbH, Daimlerstraße 12, 71691 Freiberg - GERMANY

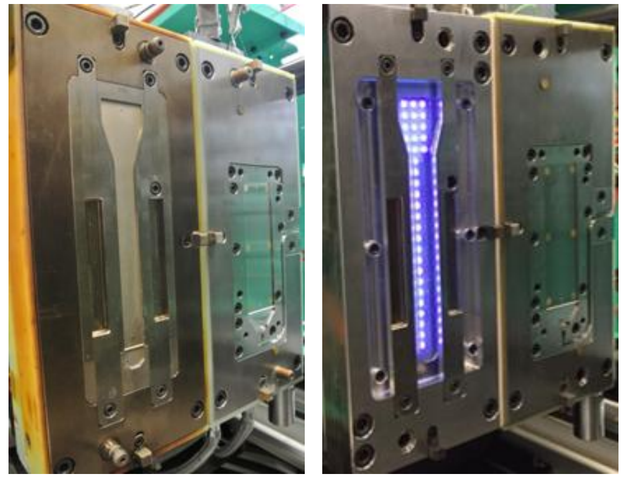


Figure 7: left: heat curing LSR cavity right: UV light curing cavity

Surface Pretreatment Of Hard Thermoplastic Component

The transfer technique makes it possible to do an intermediate treatment step of the thermoplastic component of the specimen before it gets overmolded with the silicone. Therefore the thermoplastic plate is transferred outward the injection molding machine by the robot system. Then a surface treatment can take place and afterwards the pretreated plate is transferred inward the machine again by the robot.

Figure 8: Magazine for pretreated thermoplastic plates

Figure 8 shows the magazine for storing the pretreated thermoplastic plates. The robot takes one freshly molded thermoplastic plate at each cycle and inserts a pretreated plate from the magazine at the same cycle for overmolding.
To achieve an appropriate bonding between the two components a certain type of UV light pretreatment was applied to the thermoplastic plate. The details of the pretreatment are confidential at this time. The length of the

exposure time was adjusted in steps between 0s (no pretreatment) and 300s to fit the cycle time of the injection molding process.

Materials

For the tests with heat curing LSR thermoplastic plates made out of the commercially available polycarbonate grade Calibre MegaRad 2081 by Dow Plastics were overmolded with four different also commercially available liquid silicone rubber types. Silopren LSR 2040 from Momentive Performance Inc., QP1-40 from Dow Corning GmbH and Silpuran 6000/40 from Wacker Chemie AG, these non self bonding grades were evaluated. Furthermore as a self bonding grade Silopren 2740 from Momentive Performance Inc was used.
For testing the composites consisting UV light cured silicone as the elastomeric component different commercially available thermoplastics were used. There were tests performed with MABS (Terlux 2902 from Styrolution), PP (575P from Sabic) and PC (Calibre MegRad 2081 from Dow Plastics). For these tests Silopren UV LSR 2030 by Momentive Performance Inc was used, as it is currently the only UV light curing LSR for injection molding, that is commercially available.

Results And Discussion

Figure 9 shows the resistance to peeling of material composites made of polycarbonate and different heat cured LSR types. Furthermore there were specimens tested with a pretreatment of the PC plate before overmolding and without.

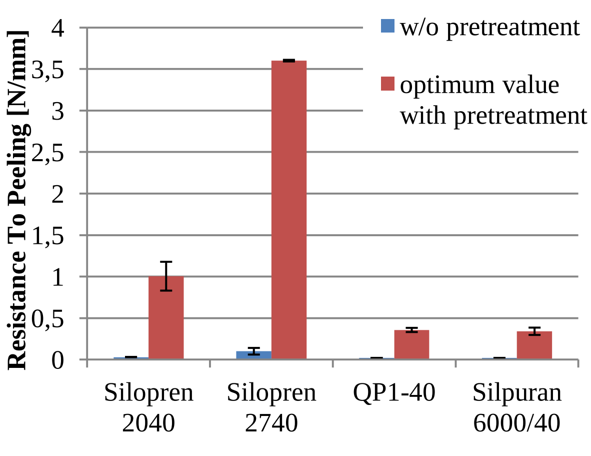


Figure 9: Results of peeling tests of heat curing LSR on PC with and without pretreatment

Two different effects can be identified. There is a big influence of the pretreatment. The values change from close to 0 up to 1N/mm for the non self bonding grades or 3,5N/mm for the self bonding one.

Figure 10 shows the results of the peeling tests with hard components made of different thermoplastics overmolded with the UV light curing LSR. To realize a bonding a pretreatment of the thermoplastic plates is necessary, else there is no adhesion at all. The thermoplastic plates were treated by silicatization and afterwards two different primers were used. The details about the primers are confidential.

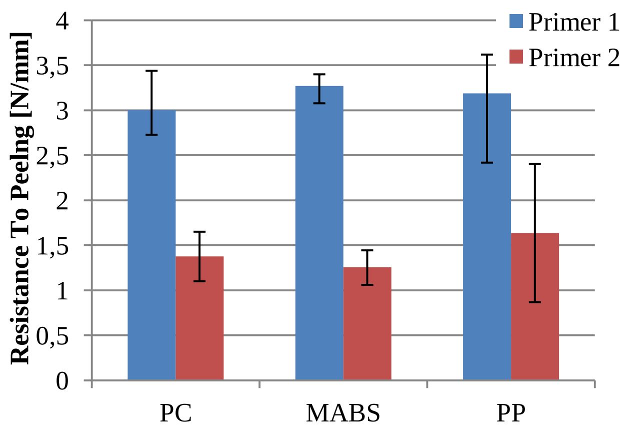


Figure 10: Results of peeling tests of Silopren UV LSR 2030 on different thermoplastics with different primers

Even with Polypropylene acceptable values of the resistance to peeling have been achieved. Furthermore there is a big influence of the used primer. The values for resistance against peeling for the samples treated with primer 1 are more than 100% higher than the values for the samples with primer 2.

Conclusions

For theses studies a multicomponent injection molding process for composites of thermoplastics and heat curing as well as UV light curing LSR including the according tooling technology was designed and set into operation.
In first tests with heat cured LSR it could be shown that a pretreatment with really short processing times leads to a significantly and sharply improved composite quality. Even with non self bonding LSR types the resistance to peeling was high enough, so that it could work for examble as a fixation for sealing elements until the next assembly step is done in production.
First tests with composites of thermoplastics and UV light cured LSR show, that it is generally possible to reach a certain resistance to peeling. But the necessary pretreatment steps still require relatively high effort.
It should be the aim of further investigations to find appropriate techniques to improve the bonding quality of composites made of thermoplastics and LSR cured by heat as well as by UV light.

Acknowledgements

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