Technical University of Denmark

Effects of moulding and environmental conditions on the mechanical and surface properties of injection moulded santoprene rubber

Islam, Aminul; Ruby, Tobias M.; Jessen, Rikke L.

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Effects of moulding and environmental conditions on the mechanical and surface properties of injection moulded Santoprene rubber

SONION

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Advisor Aminul Islam - Course responsible S ren Hvilsted and Hans N rgaard Hansen

DTU

Introduction

This project was carried out in cooperation with the company, Sonion. Sonion specializes in manufacturing miniature components mainly for use in hearing aids or medical instruments. Recently Sonion has developed a hearing aid that calls for the need of a miniature sealing ring to protect the electronics inside from environmental hazards (Image 1 & 2). The sealing ring is injection moulded in Santoprene – a thermoplastic vulcanizate consisting of Polypropylene and highly vulcanized EPDM rubber (Ref 5). The scope of the project was therefore to investigate the properties of Santoprene and make an immediate evaluation of whether Santoprene is appropriate for use under the conditions, to which it will be subjected being a part of a hearing aid used on a daily basis.

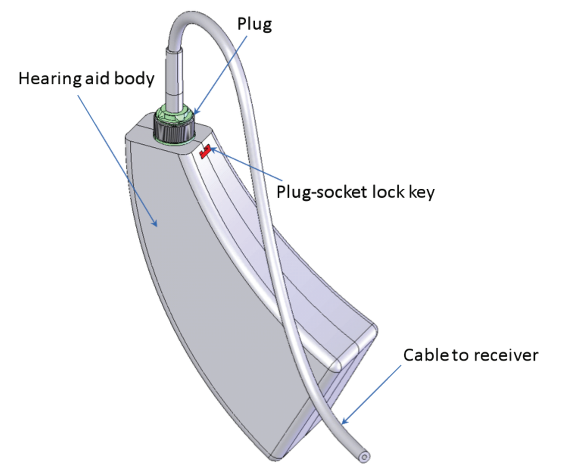


Image 1 - The hearing aid in which the sealing ring is placed.

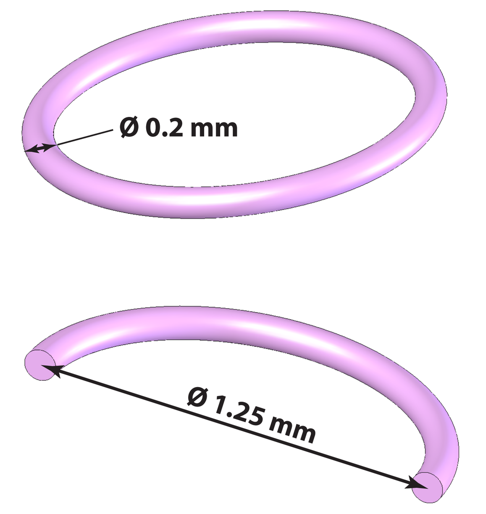


Image 2 - The sealing ring which Sonion wish to mould in Santoprene rubber.

Experimental plan

This project will analyse whether different moulding or environmental conditions will have an effect on the mechanical properties of the Santoprene rubber material.

Moulding conditions

A number of sample specimens simulating the sealing ring were injection moulded and needed to base the investigation of Santoprene upon. Changing different parameters from one specimen to another during the moulding process enabled a later determination of the influence of the manufacturing conditions on the mechanical characteristics of the specimen. The parameters that were changed from sample to sample was the following

Either a high mold temperature (50°) or a low mold temperature (32°)
Either a high material mass temperature (300°) or a low material mass temperature (260°)
Either a high injection speed (400 mm/s) or a low injection speed (200mm/s) (Ref 3 & 4)

By combining each of these six parameter settings a total of eight different specimens were molded. Each specimen was made in a batch of four, so later testing of the samples is not based on a single specimen but calculating the average of four is allowed. Additionally 21 sample specimens with the optimal settings of the described manufacturing parameters according to the producers of Santoprene were made. The manufacturing conditions of the nine different specimens are listed in Table 1.

Specimen [#]	Opt	I	II	III	IV	V	VI	VII	VIII
Mold Temperature (Tm) [°]	32	32	50	32	50	32	50	32	50
Material Mass Temperature (Tme) [°]	280	260	300	300	260	260	300	300	260
Material Mass Temperature (Vin) [mm/s]	300	200	200	200	200	400	400	400	400

Table 1 - The average weight compared to the melt temperature.

Environmental conditions

The optimal sample specimens were subjected to different environmental conditions the sealing ring might have to be able to withstand when used in a hearing aid to test if the strength of Santoprene is affected by these.

Sweat

When used in a hearing aid the sealing ring will be regularly be subjected to human sweat. To test whether human sweat had a negative effect on Santoprene, a chemical solution was created to simulate sweat and the specimens were placed in the solution for 24 hours before the strength was tested (Ref 1).

Corrosion

Five optimal specimens were also placed in an corrosive acid solution for 24 hours consisting of 10% H_2SO_4 and 90% H_2O to test the resistance to acids of Santoprene material.

Temperature Cycle

Another batch of the optimal specimen was also subjected to an extreme temperature elevation followed by an extreme temperature lowering. For 12 hours they were kept at a constant 60° followed by 12 hours at -18°.

Results

For analysing a change in mechanical properties because of different mould and environmental conditions the following tests and measurements have been made. The results are as following.

Mass

When weighed, the average mass of the nine different specimen types slightly differed, as shown by Chart 1. This is a direct result of the differing moulding conditions and more precisely the T_{me}.
Because of the higher temperature the material will experience more thermal expansion and there will then fit less material in the cavity.

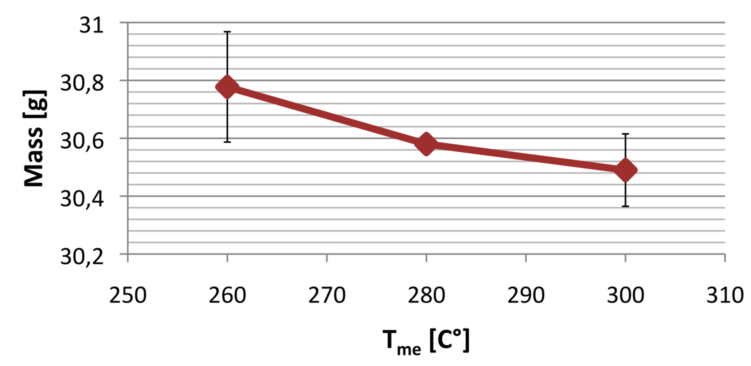


Chart 1 - The average mass compared to the melt temperature.

Roughness

To evaluate the roughness of the different samples two tests were made. Microfocus measurement and Contact angle.

3D Surface Profilometer

To evaluate the quality of the specimens it is important to look at the surface roughness. This is an important parameter for both mechanical and visual properties. The roughness analysis was done with an advanced optical 3D measurement device, which is able to create a 3D representation of any surface area and determine the average roughness in that specific area.
Measurements were done on the two extreme, I and VI, and the optimal sample specimens and the results are presented in Chart 2 below and are averages based on five measurements.

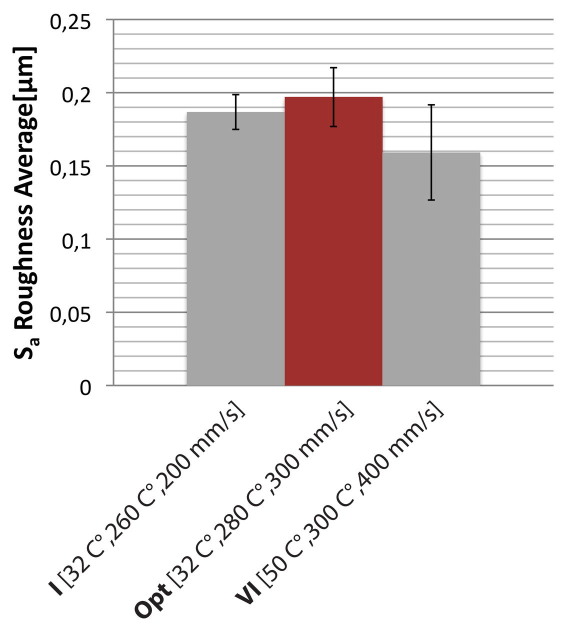
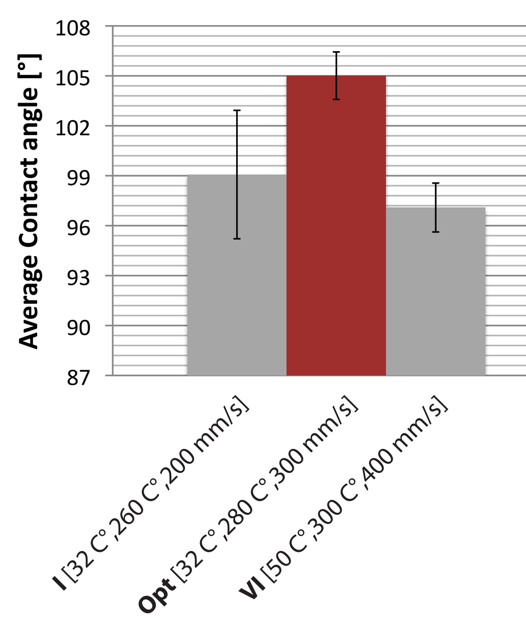


Chart 2 - The average roughness of the extreme moulding scenarios compared with the optimal.

These results are difficult to explaing because there is no knowledge about the mould roughness. The **VI** looks to have a smoother surface when compared to the **I** but the difference is very small and therefore it is impossible to destinguish between them.

Contact Angle

The surface properties were further analyzed by the Sessile drop technique (Image 5). A known liquid droplet is placed on the tested specimens and the resulting contact angle is defined by the surface properties of the material. Generally a larger contact angle occurs with greater roughness.
The results as presented in Chart 3 also show us inexplainable results. The reasons for this are the same as for the Microfocus measurement.



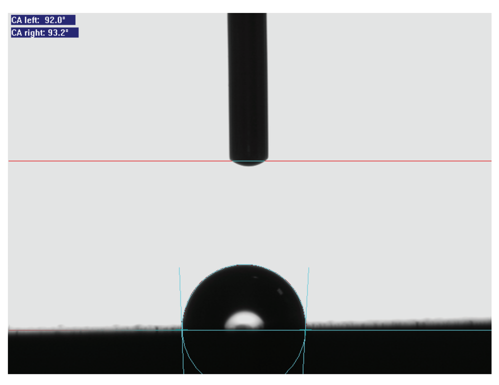


Image 5 - A screenshot of a contact angle measurement.

Chart 3 (Right) - The average contact angles of the extreme moulding scenarios compared to optimal.

Hardness

The hardness of specimens was also investigated by conducting hardness tests in accordance with the relevant ISO standards. The test shows the specimen's ability to withstand compression by another object.
The results as listed in Chart 4 shows the hardest sample to be the Opt which is the closest to the suppliers 60 Shore A specification.

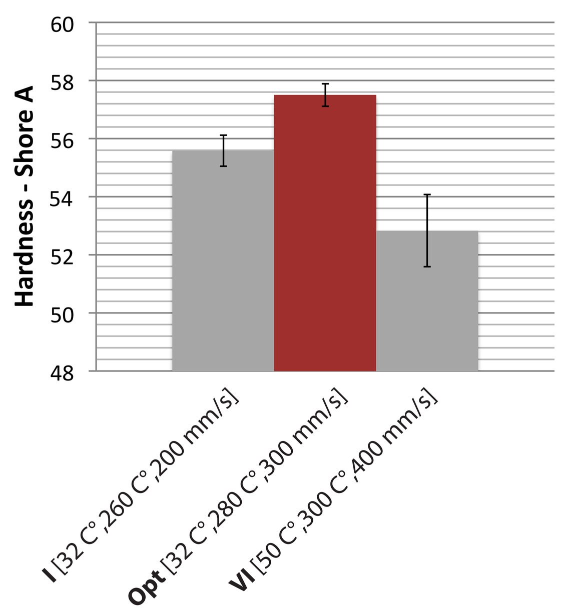


Chart 4 - The average hardness of the extreme moulding scenarios compared to optimal.

Tensile strenght

By tensile testing, in accordance to ISO 37, every specimen it could be determined how specific moulding or environmental conditions influences the tensile strength of Santoprene (Image 6 and 7) (Ref 2).

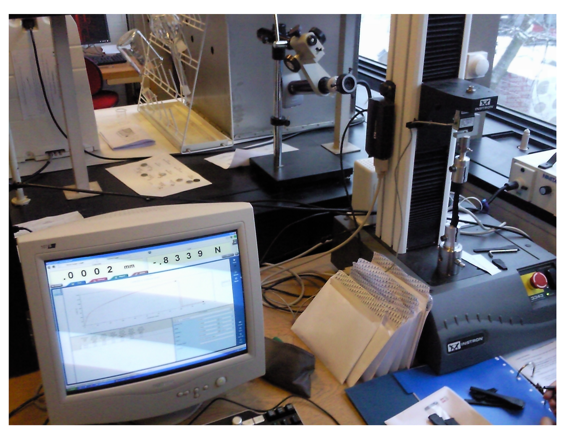


Image 6 - The tensile test setup.

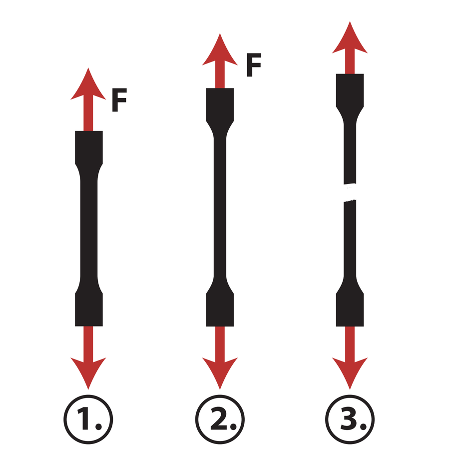


Image 7 - The three figures show how the material behaves during a tensile test.

For each specimen type a visual presentation of the load and extension relationship was made. These show how elastomeric properties of the polymer relate to the load and are important in analyzing the mechanical properties. An example is Chart 4 which is the presentation on the six optimal specimens tested.

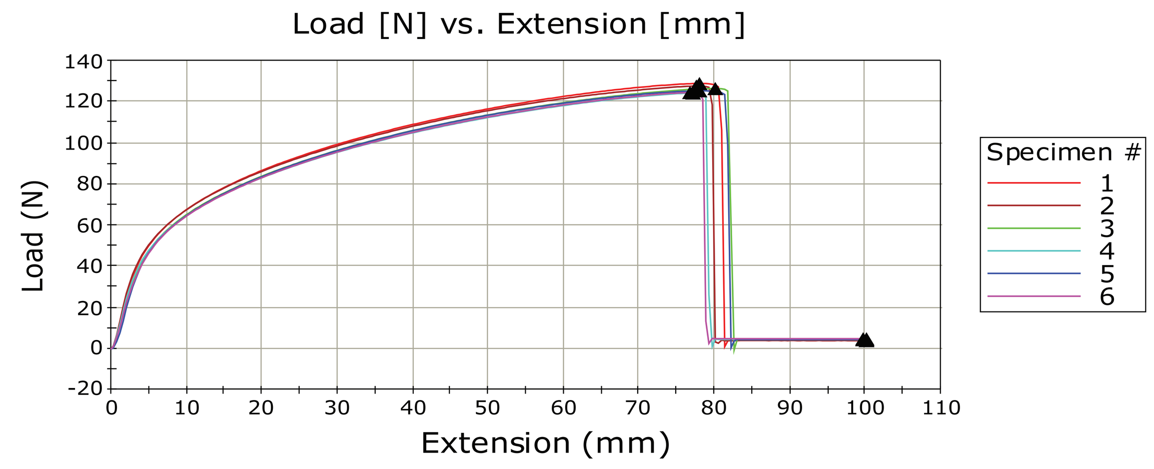


Chart 5 - Load vs. Extension graph of the optimal samples.

The results retrieved from the tensile tests are the average maximum load before break, calculated on basis of four tensile tested specimens. See chart 5 for the moulding scenarios and chart 6 for the environment scenarios.

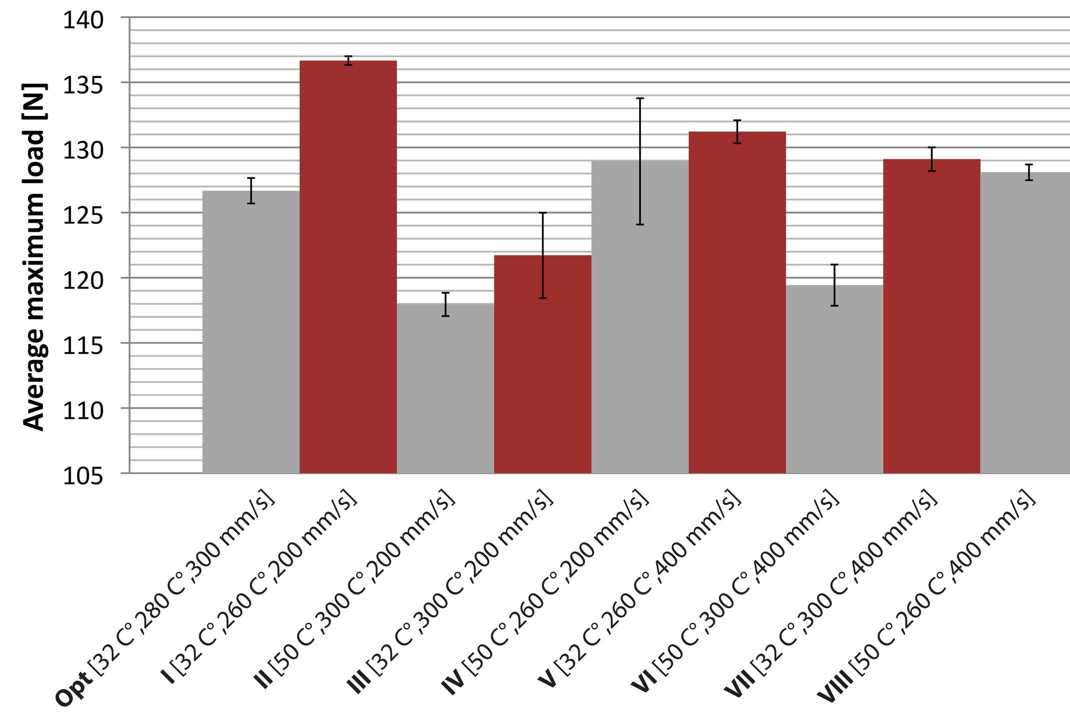


Chart 7 - The average maximum load of each moulding scenario.

Specimens moulded at high material mass temperature are generally weaker because of the lesser material mass in the specimen caused by thermal expansion. This is consistent with the tendency in our results considering all the specimens with high material mass temperature (II, III, VI) except one (VII) are the weakest.
In general the effect of high injection speed is a stronger specimen, but in this project both the slow and fast injection speed would normally be regarded as relatively high. Therefore it is difficult to conclude anything specific from the results regarding injection speed.

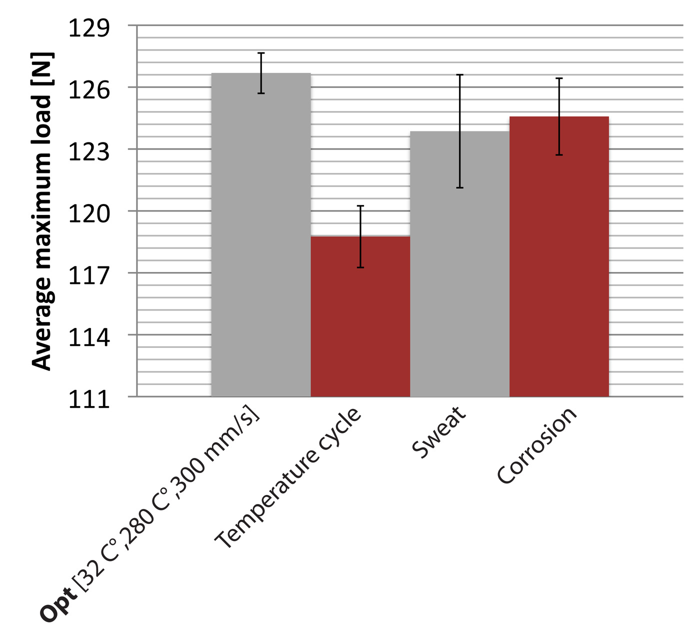


Chart 6 - The average maximum load of each environmental scenario.

Comparing the strength of the optimal specimen with the specimens exposed to sweat or corrosion nothing can be concluded, since the standard deviations are overlapping. Considering the temperature cycle test a clear deterioration in the strength of the specimen is observed.

Conclusion

When argumenting whether Santoprene is an appropriate material for use in the hearing aid, it is firstly important to realize that this project only is a guideline on the matter. The results cannot directly be translated to the miniature sealing ring in reality, since the dimensions and mass of the used specimens will have severe significance. In micro moulding many other parameters are crucial. Other than that many of the mechanical properties of Santoprene are satisfactory in relation to the desired and the material does not seem to be significantly affected by sweat or corrosive solutions. The manufacturers should though be aware of the effect on the strength, when exposed to radical temperature changes over a longer period of time (Chart 6).

Sources of errors

During the execution of this projects a numerous list of either equipment, environmental conditions or human related sources of errors have affected the results. To systematically state them all here would be irrelevent.

Acknowledgements

Throughout this project many people have helped us along. Therefore we would hereby like to thank Sonion for entrusting us with this project. DTU MEK, DTU Chemistry, DTU Management and The Danish Polymer Center for lending us their equipment. Hans Nørgaard Hansen and Søren Hvilsted as our lectors. Aminul Muhammad Islam as our helpful and very capable advisor. Lastly Christian Ravn, Reinholdt Koch, Steffen S. Munch and Kim Chi Szabo for helping us with conducting the different tests.

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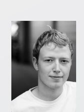
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Rikke Lichinger Jessen - s061995