Degradation Behaviour of Polyoxymethylene (POM)

Influence of Multiple-processing

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Polyoxymethylene (POM) tends to degrade during injection moulding. Its degradation behaviour is preferably characterised using thermal analysis methods as well as standardised material testing. It has thereby been possible to produce a quality control instrument near to production.

Polyoxymethylene is an engineering plastic and has a wide range of applications also in the motor vehicle industry. An important disadvantage of this material is its comparatively low processing stability. For this reason investigations of the influence of the processing conditions on its degradation behaviour and the structural and quality changes caused thereby are of particular importance in technical applications.

In order to understand this degradation quantitatively different materials were processed to produce injection moulded test specimens that were shredded and then reprocessed (up to seven times) and tested using different methods. In the following the influence of multiple-processing, ageing and UV radiation on the thermal and mechanical characteristics as well as the morphology of POM homopolymers and copolymers under different stabilisation conditions are discussed.

Different Reactions of the Indicators

The results on the influence of the number of the processing steps on the volume flow index MVR [1] shows that this procedure is suitable for the study in principle. However, the MVR is only one point of the viscosity curve.

An inverse relation between the MVR and the elongation in tensile test can be recognised in Fig. 1. Tensile tests [2] demonstrate that all materials behave similarly with respect to the modulus of elasticity and the tensile strength. The modulus of elasticity and the tensile strength do not change during the seven processing steps. In contrast it can be shown that the elongation at break is significantly more sensitive to the degradation than the other mechanical indicators. The elongation at break decreases with increasing number of processing steps. In addition, light-microscopic studies have been made to characterise the morphology of microtomed sections of the injection moulded test specimens. This showed that the average spherulite diameter decreases with increasing number of processing steps.

The results of the TGA investigation [3, 4] in oxygen atmospheres show that for purely thermooxidative treatment the light and heat stabilised products (homopolymers and copolymers) seem to be more resistant than the heat stabilised products (Fig. 2).

Fig. 3 shows degradation behaviour in an inert gas atmosphere of the materials after the first and the seventh processing of the granulate of heat and UV stabilised homopolymer. It is clear that the degradation begins already with the first processing step and is furthered during each subsequent processing step.

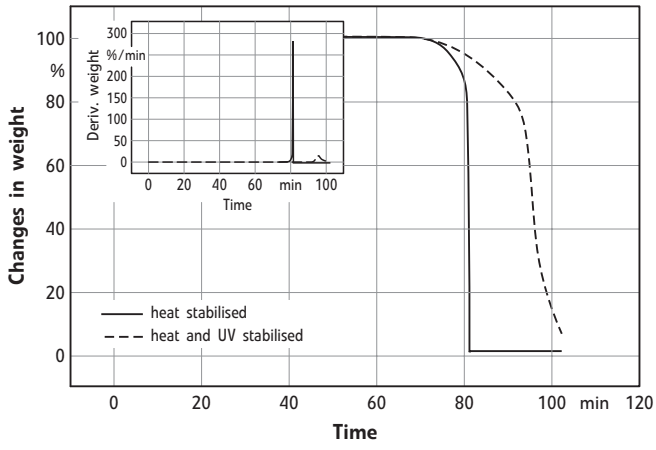

Fig. 2. Influence of the stabilisation states on degradation behaviour of POM copolymers (TGA measurements of copolymer 1)

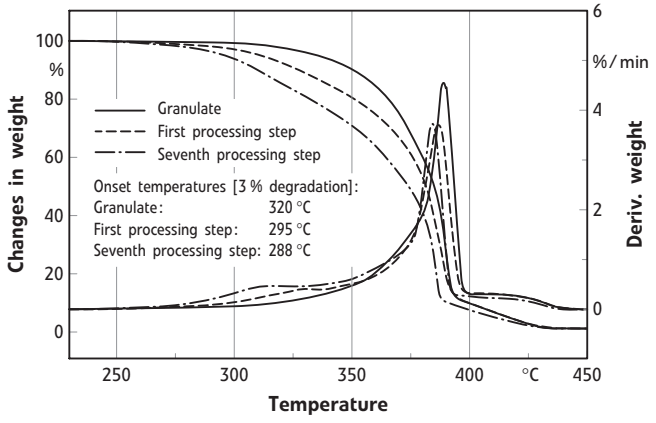

Fig. 3. Degradation behaviour of a POM homopolymer (heat and UV stabilised) in nitrogen atmosphere (TGA measurements)

Translated from Kunststoffe 91 (2001) 5, pp. 82–85

Accelerated Ageing Processes

A study of the long time stability of POM was made at a temperature of 140 °C [5]. After processing the long time stability clearly decreases depending on the stabilisation condition (Fig. 4). This is shown in the increase of the MVR with increasing treatment time and also as a clear decrease of the modulus of elasticity.

White deposits on the surface are a macroscopic characteristic of weathering in a xenon test (2 years/car indoor) [6]. DSC investigations [3] of the surface layer (Fig. 5) show a decrease of the melt enthalpy and a reduction of the melting temperature by about 10 K in comparison to the initial state. Both effects point toward chemical ageing processes, that is, molecular degradation.

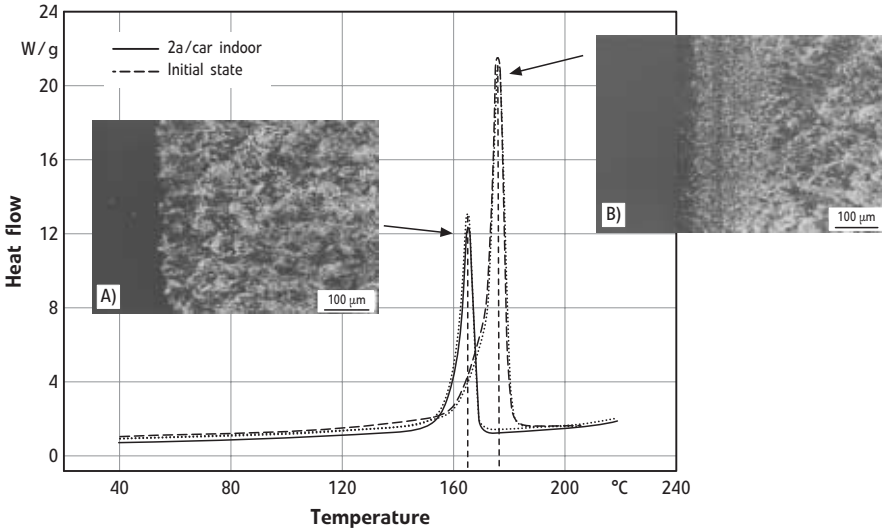

Fig. 5. DSC investigation of weathered test specimens (homopolymer, heat stabilised). A: Morphology of the edge region (homopolymer after weathering); B: Morphology of the edge region (homopolymer initial state, second run)

Tested Products

Ultraform W 2320 003
(manufacturer: BASF)
Ultraform W 2320 U03
(manufacturer: BASF)
Hostaform C 27021 nat
(manufacturer: Ticona)
Hostaform C 27021 LS nat
(manufacturer: Ticona)
Delrin 900 P natur
(manufacturer: DuPont)
Delrin 927 P natur
(manufacturer: DuPont)

Conclusions

From the above presentation it is clear that numerous systematic investigations are necessary to specify the factors that are influential in the degradation behaviour of polyoxymethylene and its long term behaviour. On the other hand the present results also show that each of the investigated materials has its own characteristics and that using present knowledge generalisation of the results can lead to misinterpretations.

Thermal testing methods are especially suitable for characterising the stabilisation condition of individual products. Integral measurement procedures (MVR, tensile tests) can be specifically applied to prove the existence of processing induced thermomechanical damage in POM. These can be simulated using accelerated ageing methods.

Acknowledgement

Developments within the framework of the present project were specially promoted and supervised by the Austrian Industrial Research Promotion Fund (FFF).

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Fig. 1. Influence of multiple processing on the MVR; dependence of the decrease of the elongation at break on MVR for example heat stabilised POM copolymers 1. A: Core morphology (copolymer 1, first processing step); B: Core morphology (copolymer 1, seventh processing step)
Verarbeitungsschritte = Processing steps; Reißdehnung = elongation at break

Fig. 4. Influence of the number of processing steps and the oven-storage duration on the modulus of elasticity (copolymer 1 heat stabilised)