23rd Stuttgarter Kunststoff-Kolloquium

Stuttgart, Germany
March 6 – 7, 2013

The Institut für Kunststofftechnik (IKT) and the Institut für Polymerchemie (IPOC) hosted the 23 rd Stuttgarter Kunststoffkolloquium from March 6th to March 7th, 2013. The plenary speakers were Prof. Ernst Schmachtenberg and Prof. Ernst Ulrich von Weizäcker spoke about the meaning of engineering and science for the German and European industrial sector and presented his visions about sustainable prosperity by exploring the possibilities of energy savings in our society, thus continuously reducing the dependence on non-regenerative natural resources. In about 50 oral presentations, chosen experts in the field of polymer science from the University of Stuttgart and other research facilities spoke to over 200 guests. The field of polymer rheology was part of five oral presentations that are summarized subsequently.

In the first topic the rheological behavior of thermoplastic polyurethane was discussed. In this study, different types of thermoplastic polyurethanes were being investigated, using thermal and rheological characterization techniques. Two conventional thermoplastic polyurethanes and three bio-based thermoplastic polyurethanes were analysed. Via DSC thermograms it was shown that the bio-based types show a different melting behavior compared to the conventional ones. During processing of TPU the molecular weight of the material decreases, which has an impact on their rheological behavior. This behavior can be analyzed in oscillatory rheometry via a time sweep, in which the complex viscosity decreases with time until a plateau value is reached. To calculate the flow activation energy, it is necessary to consider these degradation phenomena. The true activation energy can be calculated with a model under consideration of binding and dissociation mechanisms of the urethane bonds. Next to the decrease, some materials, surprisingly, also showed a time-shifted increase of the complex viscosity over the course of the time sweep. Another model describing this was proposed and has yet to be validated by further investigations.

In another oral presentation, the different rheological behavior of polypropylene melts and their impact on the pellet shape during underwater pelletizing was investigated. Underwater pelletizing has gained high importance within the last years among the different pelletizing technologies, due to its advantages in terms of throughput, automation, pellet quality and applicability to a large variety of thermoplastics. The resulting shape and quality of pellets, however, differ widely, depending on material characteristics and effects not fully understood yet. In two sets of experimental runs, pellets of different volumes and shapes were produced and the medium pellet mass, the pellet surface and the bulk density were analyzed in order to identify the influence of material properties and process parameters. Additionally the shaping kinetics at the die were filmed with a specially developed camera system. It was found that rheological material properties correlate with process parameters and resulting particle form in a complex way. Higher cutting speeds were shown to have a deforming influence on the pellet shape, leading to less spherical forms and lower bulk densities. More viscous materials, however, showed a better resistance against this influence. Generally, the viscous properties of polypropylene proofed to be dominant over the elastic ones in regard to their influence on pellet shape. It was also shown that the granule shapes filmed at the die opening and the actual form of the granules after a cooling track did not always correlate, indicating a significant influence of thermodynamic properties during the cooling.

Another investigation dealt with the rheological behavior of a polyamide 6 block copolymer blend with a flow restriction behavior. In this study, a blend based on a polyamide 6 and a block copolymer (BC) had been compounded and its rheological behavior was analyzed systematically. The BC was produced from a polyether polyol and a polyamide 6 via reactive extrusion in a twin screw extruder. It shows an elastomeric behavior, for which it can be used as a notch impact strength modifier. In a second compounding process the PA 6 BC blend was produced with different weight fractions of BC. The dynamic rheological behavior was studied for each sample with a stress controlled rheometer using a parallel plate geometry. All tests were performed within the linear viscoelastic regime at a temperature of 260°C under nitrogen atmosphere. The complex viscosity shows a strong dependence of the BC weight fraction. The unmodified polyamide 6 in this study has a common shear thinning behavior whereas the block copolymer shows a typical rubber-like flow. Within the investigated shear rate range the blends show a characteristic flow behavior that can be divided

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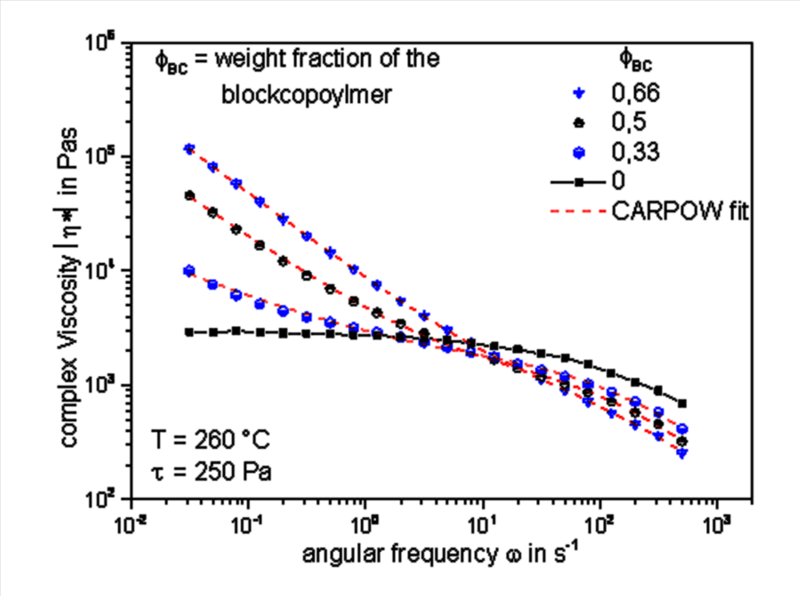

Figure 1: CARPOW approach compared to experimental results.

into three flow regimes. To describe the flow properties over a broad range of shear rates a new empirical approach was created, based on the Carreau equation and the Osswald de Waele equation (see Figure 1 and Equation 1). IKT calls it CARPOW approach.

$$\eta(\omega)=\eta_{zäh}\left(\frac{\omega_{We}}{\omega}\right)^n+\frac{a}{(1+b\omega)^c}$$

The approach shows very good accordance with experimental results. The parameters can be explained physically and show strong dependence of the BC concentration. In the terminal regime the storage modulus increases with increasing BC content. The slope in the terminal regime reveals a characteristic jump as a function of the BC concentration that can be referred to the rheological percolation threshold. From the viscosity data the same rheological threshold can be determined as well and coincides well with mechanical and morphological results.

Further presentations dealt with the rheology of polymers and their simulation. A numerical analysis of the flow in a wedge slit with plane walls was presented for fluids with pseudo plastic flow behavior. Additionally to this analysis, the flow in a combined wedge/rectangular slit system was calculated. Shear, elongation and resulting total deformation at the wedge slit exit was quantified with specific numbers. The calculated residential time in the wedge slit allows the determination of the elongational rate and the Deborah number in order to characterize the entropy elastic state of melt particles.

The CARPOW equation was used in investigations of mixing processes as well as the influence of viscosity models on the flow calculations. Distributive mixing plays an important role in polymer processing, especially for shear-sensitive materials. Many materials with very high filler contents or partly cross-linked materials show a rheological yield point, which makes mixing of such materials very difficult. Due to this fact it is very important to predict the mixing behavior before expensive mixing devices are manufactured or production suffers from insufficient product quality. Besides the mixing quality both, pressure drop and dissipative heating are important quality criteria for mixer geometries. The CARPOW equation is capable to describe the flow behavior of materials with a rheological yield point, depending on the shear rate and the temperature. The implementation of this fluid model in the open source CFD toolbox OpenFOAM® and the combination with a particle tracking approach allow to predict the mixing behavior of such materials in distributive mixing devices. Numerical calculations were done with two mixer geometries and two material systems in order to investigate the influence of the selected viscosity model on the calculation results.

The next Stuttgarter Kunststoff-Kolloquium will be taking place in the spring of 2015. Current informations are available online:
www.stuttgarterkunststoffkolloquium.de

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