Extrusion Calibrator Design:

Why Extrudate Cooling Analysis is Important!

April 28, 2004

M. Kostic
kostic@niu.edu Web: www.kostic.niu.edu/extrusion

Introduction

1. For optimal design of the profile extrusion calibrators, cooling bath and other cooling accessories, a comprehensive knowledge about the extrudate heat transfer (cooling) process, is necessary.

2. For the proper design of the calibrators and cooling equipment, it is very important to know the temperature fields inside the extrudate profile. However, in the case of a complicated profile it is almost impossible to imagine its inside temperature distribution.

3. To be able to comprehend the cooling process, a physical – mathematical model of heat transfer in the extrudate must be used and the temperature field simulated by an analytical or numerical method. Note that only some one-dimensional problems (not all) and very few two-dimensional problems can be solved analytically.

4. One critical variable in all heat transfer simulations is the heat transfer coefficient, important for the absolute results of the simulations. On the other hand, approximate, but realistic values of such heat transfer coefficients can cause some errors in the absolute temperature profiles, but will still show relative, but realistic temperature distribution across the profile.

5. In profile extrusion, any uneven cooling can cause undesirable shrinkage, bending, and twisting, including collapsing of the profile. Therefore, knowing the relative temperature distribution (which is possible) is almost equally important as knowing exact temperature values (which is not possible), since the former is usually sufficient to judge where the walls of the profile will miss-deform and where design corrections of the calibrator should be implemented.

Challenges in Modeling of Profile Cooling

1. The biggest challenge in modeling of profile extrudate cooling is to specify properly the boundary conditions in every local part of the cooling equipment.

2. It is possible to use a rough, heat transfer coefficient estimation or develop the values from experimental investigation.

3. It may be very difficult to estimate the heat transfer coefficient in a vacuum calibrator, because it is not possible to predict, without experimental verification, where the polymer has a good contact with the cooling wall and what is the influence of a thin layer of cooling water being sucked in from the cooling bath.

4. However, even estimated values can be used to get a good overall picture of the process, since the polymer materials have a fairly low thermal conductivity. Thus, the surface of the extrudate profile follows very quickly the imposed boundary conditions, but the heat from within is transported rather slowly because the extrudate has fairly high "internal thermal resistance."

5. Because of the uncertain values for the boundary conditions, the modeling of profile cooling doesn‘t provide exact information about the temperature fields inside the extrudate profile, but it is able to provide a very useful over-all relative picture of the cooling process.

6. Finally, knowing the relative temperature distribution (which is possible) is sufficient for scaling and sizing of the calibrators and other cooling equipment, and it can give the designer a warning about possible problems in cooling of some critical parts of the extrudate profile.

Summary

1. It is possible to model even complex extrudate-profile cooling during extrusion process.

2. The accuracy of the obtained results depends on the estimate of the heat transfer coefficients. This means that the obtained results are not exact, but they can be very useful for design.

3. It has been shown that there is a direct relation between the developed temperature profile and the profile deformation during the actual process, as well as that the predicted behavior can be related to real process results.

4. One way to improve the simulation is to better understand the conditions for estimating the heat transfer coefficients or to obtain them experimentally.

5. Another way to improve the simulation and calibrator design is to try to link the profile deformation closer to the calculated temperature profile and vice versa, and thus move the judging from qualitative to quantitative evaluation.

6. Therefore, the modeling and simulation of extrudate cooling is a useful tool for studying the profile extrusion cooling process, as well as for improvement of the calibrators and other cooling equipment design.
