PVC Testing

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Stephen J. Redline, of Plexco, asks the following question:

Please consider the following question for your Newsletter: What characteristics of PVC resin could be measured by a well equipped scientific laboratory which would provide meaningful information to the custom profile extruder on the "Processability" of plasticized PVC compound? We have never been able to see any significant differences in the generally measured characteristics between "good" and "bad" resin. The "bad" resin generally exhibits itself in poor quality of surface finish and/or reduced output due to requirements for excessive screw cooling in an effort to improve surface finish.

The answer was provided by Z. Todmor, Israel Institute or Technology, Haifa, Israel.

PROCESSABILITY OF POLYMERS

Mr. Redwine's question deals with the very important and difficult problem of "processability," that is associated with most polymer processing operations (not only extrusion), and is certainly not limited to the quality of surface finish. The following brief comments, taken from a forthcoming book (1), while not answering the question, will perhaps outline the source of difficulty in defining and measuring "processability."

The main source of difficulty in pro viding a simple measure of "processability" is that in all processing operations it depends on the ability of the polymer to respond to any of the phases of the complex and diverse temperature and deformation history the polymer experiences from the hopper all the way to the finished product. This leads to two conclusions:

(a) "processability" is the interactive result of polymer properties (rheological, thermal, physical), machine design (screw, die, etc.) and operating conditions. Clearly, not even a "good" polymer will perform in a poorly designed or poorly run ma chine;

(b) "overall processability" is the combined result of "processabilities" of the interdependent phases of the whole operation. In the case at hand there is a "processability" associated to the processes occurring in the screw extruder (sol ids conveying, melting, mixing, and pumping); a "processability" associated to the flow of the polymer melt in the shaping die, that could be termed "extrudability" (the latter as indicated in the question is not independent from the former); and "processability" associated to the post-shaping operations (cooling, orientation, etc.) A full laboratory characterization of any of these "processabilities" is not a simple task.

Let's take "extrudability" as an example. It is assumed that die design is "good" and inlet conditions (temperature, homogeneity in composition and temperature, and pressure) are satisfactory. The dominant physical properties related to. the. shaping step or the flow of polymer in the die are rheological, such as the "flow curve" (i.e. the non-Newtonian viscosity as a function of shear rate); the flow activation energy (that reflects the temperature dependence of the viscosity); and the primary and secondary normal stress difference functions that are closely related to extrudate swelling. Normal stress difference functions, like the viscosity, are shear rate and temperature dependent. To this growing list of theological properties, the elongational viscosity must also be added because the elongational flow patterns in certain sections of the die.

Among all these usually only the flow curve is measured (or only the melt index which reflects a point on the flow curve) and this is done in steady viscometric flows. In the die, however, the deformations are imposed on the polymer suddenly. The polymer, being a viscoelastic fluid, responds differently to suddenly applied stresses, exhibiting strong transient behavior. This for example may lead to the "stress overshoot" phenomenon. Therefore, the viscosity, the normal stress functions, and the elongational viscosity, must also be measured under transient

conditions (stress growth experiments). However, there is yet another difficulty involved. In most existing laboratory instrumentation rheological properties are measured in relatively simple (viscometric) flows under isothermal conditions, whereas flow in the die is by and large nonisothermal and nonviscometric. Now, if we super impose on these difficulties, (a) the interaction with die design and operating conditions, (b) the processability in the extruder itself (that is a function of a whole new set of variables), and (c) "processability" in operations following the die, it is clear why there is no simple quantitative measure to determine a priori the "processability" of a given polymer in a given operation.

A well documented case in demonstrating the difficulty in measuring "processability" is the IUPAC report (2) on low density polyethylene (LDPE). In this report a cooperative effort of a number of laboratories is documented. The purpose was to understand theologically why three LDPE samples that are practically identical (equal: densities, melt indices, intrinsic viscosities, molecular weights, lR data, linear viscoelastic behavior, and flow curves) behave quite differently in processing (e.g. film blowing) and end use behavior.

(1) L Tadmor and C. C. Gogos "Principles of Polymer Processing," Wiley, New York. In press.

(2) J. Meissner, "Basic Parameters, Melt Rheology, Processing and End Use Properties of Three Very Similar Low Density Polyeethylene Samples," Report of the IUPAC working party on structure and properties of commercial polymers, 1973.

See also:

- Extrusion of thermoplastic foams
- PVC gels
- On line quality analysis
- Performance of twin screw extruders
- Precision profile extrusion
- Structural changes in PVC due to extrusion

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