

Compounding of Blends

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Mixtures

When two or more polymers are mixed, several factors should be considered from the outset. One is whether or not the phases are ultimately miscible, thermodynamically. In most cases where the phases are immiscible, which is predominantly the case with polymers, the minor component(s) become the dispersed phase(s) and the major one the so-called matrix or continuous phase. Therefore, another relevant factor is the ultimate desired phase morphology (spherical, lamellar, co-continuous, etc.). Other important factors include the order of feeding (mixing protocol), the thermal (T_g , T_m) and rheological (viscosity, melt elasticity) properties of each polymer, whether the feed streams are solids or melts, or both, the average stress levels, and number of flow reorientations experienced by the melts, and the anticipated phase stability of final morphology (resistance to coalescence) with respect to subsequent flow and heat histories downstream of the extruder mixing elements (pins, gears, pineapples, kneading paddles, pelletization operations, injection molding, and static mixers).

Mixing

When feed streams consist of separated bulk phases, irrespective of whether they are miscible or not, mixing processes in general, and extrusion compounding of polymers in particular, involve two basic mechanisms: one is size reduction (break-up into smaller "regions") and the second is spatial rearrangement (uniform distribution of these regions). These are commonly termed dispersive and distributive mixing, respectively.

When all feeds are particulate solids, of course, a gross distributive mixing is partially built in from the outset, which is an advantage. In this situation, attention must be paid to which component melts first and what its melt viscosity will be.

Generally speaking, in melts, dispersive mixing is enhanced by high stress levels (narrow gaps, converging channels, etc.), distributive mixing by stream splitting and recombination, and both by stretching and folding motions. This is the reason that polymer mixing and compounding machines are usually twin screw continuous or batch devices, where extensional flows, stretching and folding are predominant. Single screw extruders, by contrast, are characterized by shear, non-reorienting flows, which may result in slow, incomplete and inhomogeneous distributive and dispersive mixing. Specialized mixing elements incorporated onto single extruder screws ameliorate this problem. Still, single screw extruders are better pumps than they are mixers.

The most favorable conditions are when the properties (viscosity, melt elasticity) of the dispersed and continuous phases are comparable at processing conditions (temperature, shear rate) - or when the dispersed phase is slightly "weaker." The inverse is a much more difficult situation.

In summary, it is prudent to remember that the rheological/mechanical properties of all polymers are time rate-dependent (stress increases with strain rate) when attempting to predict the potential effect of extruder geometries and operating conditions on dispersed-phase break-up and "homogenization".

Some general, introductory references are: "Principles of Polymer Processing" Z. Tadmor and C. G. Gogos, Chapters 7 and 11, John Wiley and Sons, New York (1979)

"Mixing in Polymer Processing", C. Rauwendaal Ed., Marcel Dekker, New York (1991)

"Mixing and Compounding of Polymers", I. Manas-Zloczower and Z. Tadmor, Eds. Hanser Publishers, Munich (1994)

"Two-Phase Polymer Systems", L. A. Utracki, Ed., Hanser Publishers, Munich (1991)

The following institutions are actively involved in the area of compounding of blends: - The Polymer Processing Institute at Stevens Institute of Technology, Hoboken, New Jersey

- Institute of Polymer Engineering, University of Akron, Akron, Ohio

- Department of Chemical Engineering, Case Western Reserve University, Cleveland, Ohio

- Mechanical Engineering Department, University of Maryland, College Park, MD.

- Department of Chemical Engineering, University of Minnesota Minneapolis, MN.

- National Research Council of Canada, Industrial Materials Institute, Boudeauville, Quebec, Canada

See also:

- Distributive mixing and energy distribution in twin screw extruders
- Downstream mixing in twin screw extruders
- Extrusion evaluation through pressure and melt temperature analysis
- Mixing myths
- Single screw mixing

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