Melt Index Mysteries Unmasked

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Melt index. We buy materials, set conditions and sell our products all based on this number, which has been around for over 50 years.

But it's not so simple. First of all, melt index (or MI, or melt flow index, or MFI) is a measure of *melt viscosity*, but it's the inverse of real viscosity – that is, a resin with low viscosity (soupy, easy flow) has a high melt index, and vice versa. There are correlation charts if anyone wants to get viscosity in MPa or centipoises from a melt index number, but hardly anyone uses them in industry.

Either term is a measure of how big the molecules are, which affects flow: the bigger, longer or more branched molecules get tangled up more, and therefore they flow (slide over one another) with more difficulty. The size of a molecule is sometimes referred to as *molecular weight*, so we can say that the higher the molecular weight, the higher the viscosity, and because viscosity is *push over flow*, that means more force is needed to push them through a passage such as a die or screw channel. If viscosity is push over flow, its inverse, melt index, is *flow over push*, or the amount of flow for a given amount of push, and a low melt index means a resin that flows with more difficulty, and therefore needs more power, may run hotter, but yields a stronger product.

A melt indexer is a capillary rheometer, a tube (capil-lary) in which the amount of flow (rheo-) is measured (-meter) under specific conditions (temperature, force). The size of the tube is standardized at 0.083" diameter and 0.250" length, but the conditions can be varied, so that different materials may have different test conditions, and comparisons must be made at the same conditions. An illustration of a simple melt indexer, plus additional information, is available on the web, at http://www.bpsolvaype.com/na/upload/techpub_n14.pdf.

For polyethylenes, by far the most common conditions are 190 C and 2.16 kg force, which correspond to Condition E in ASTM test D1238. For polypropylene, the temperature is 230 C, and for some polyethylenes the load is increased to 21.6 kg, which is called the High Load Melt Index, or HLMI. This is typically used for very low-flow materials, to reduce the test error and get more manageable numbers. Unfortunately, it has become common to cite the ratio of the two melt indices as Melt Flow Ratio (MFR) instead of the two numbers. This is a nice example of the "disease" of ratiosis: two very different materials can still have the same ratio – e.g., if normal melt index is 2.0 and HLMI is 20, and if normal is 0.3 and HLMI is 3. The ratio is 10 for both of these, yet they are very different.

The unit of melt index is grams per 10 minutes, or decigrams per second. This unusual unit is often omitted, which doesn't cause much problem because no-one uses any other units.

The basic problem with melt index is that the test is slow, much slower than actual extrusion, and viscosity of a melt is dependent on its speed of flow as well as temperature and basic molecular characteristics. This dependence may be expressed as the power law factor, which can vary between 1.5 and 4 (or the reciprocal, 0.25 to 0.67, depending on how the power law equation is written). For a resin with a melt index of 1, the shear rate at the exit is around 2 reciprocal seconds, while in extrusion, the shear rates are about 100 in the screw channels, 200-500 in the die lips, and well over 1000 in the flight-to-wall clearances where much frictional heat is generated! Thus, two materials with the same MI may behave quite differently in an extruder if their power-law factor is different.

It is useful to know melt index because it gives some indication of how much power is needed, and thus how much heat will be generated in extrusion, but a plot of viscosity vs shear rate (or even two or three melt indexes at different loads) is much better. Such information clearly shows why LLDPE needs more cooling, as its power law factor is down below 2, while regular LDPE is around 2.5, which give more flow for the push, or less frictional heat for a given production rate.

Melt index also is a measure of product strength (lower = better) and environmental stress-cracking resistance (again, lower is better). Unfortunately, lower melt index also means a greater tendency to show melt fracture, which is one reason why processing aids are sometimes used as an alternate or adjunct to blending with LDPE to allow cooler melt and thus higher production rate.