WHAT PART OF "REGRIND" DON'T YOU UNDERSTAND?[1]

Thermoforming is burdened by two serious economic albatrosses. First, thermoforming is considered a secondary process. That is, it is a process that takes place *after* the primary process of extrusion, used to produce the sheet that represents our incoming material. And second, thermoforming never, ever uses the entire sheet that we purchase from the extrusion house. In fact, it is strongly believed that thermoforming cannot exist as a major, growing process without extensive methods of recycling its non-product, called web, skeleton, edge trim or selvage (but *never, ever* **scrap**!). This tutorial looks at that part of the sheet that never, ever produces money for the thermoformer. And in fact, costs the thermoformer dearly. The subject is regrind, that is, taking the non-product, chopping it or chipping it, and feeding it to the hopper of the extruder, along with a proper amount of virgin polymer.

Let's bound the problem first. For the most part, heavy-gauge thermoformers use cut sheet. The mold cavity is smaller than the mold frame, so a portion of the sheet resides on the mold frame and not in the mold cavity. Then the edges of the sheet must be held in a clamping fixture. This portion of the sheet also does not participate in the final part. Because the heavy-gauge thermoformer can get sheet cut to size, his/her trim is usually around 20% of the original sheet for single mold cavities. But, if the mold contains more than one cavity, the plastic between the cavities adds to the trim fraction. Usually the trim sections are large enough to be reground and reprocessed into sheet. But if the formed part requires machining, routing, or drilling, the polymer that is cut away may simply be dust or shavings. This trim is not normally reprocessed. The trim for a complex part with many slots and cutout holes may be as much as 40% of the original sheet.

The trim in thin-gauge forming is usually greater than that for heavy-gauge forming. This is particularly true for axisymmetric or round parts such as cups. Keep in mind that the thin-gauge former must also hold the sheet and must also provide mold metal around the cavities. The plastic in these regions becomes trim. In most thin-gauge operations, the mold cavity layout is rectangular. In technical vernacular, this is called a *square pitch*. This allows the maximum number of cavities on a rectangular mold frame, such as 6 across by 8 deep. Surprisingly, the square pitch does not yield the minimum amount of trim. An *equilateral triangular pitch* yields the minimum amount of trim. But a triangular pitch requires a parallelepiped mold frame. And asking for that mold frame will cause your local mold maker, your setup man, and the guy doing make-ready on the trim press to question your sanity. So thin-gauge thermoformers live with trim or skeleton or web, up to 65% or more.

So what is the big problem with reprocessing trim? Very little if a few cardinal rules are followed. First, the amount of trim needs to be determined. Relatively accurately. Then the allowable amount of reground trim in the incoming sheet needs to be determined. This time, very accurately. Obviously if the maximum allowable amount of regrind is determined to be 20%, say, and the thermoformer generates 30%, say, something must be done with the rest. The extruder and former must agree on the amount of regrind to be used, to plus-or-minus 5%, say. And this agreement must remain in place, regardless of the ebb and flow of regrind availability.

And second, the thermoformers biggest concern when dealing with the regrind stream is contamination. Contamination from the original extrusion process, including black specks and gel, from the thermo-forming process, including oil and grease, from the regrind process, including cross-contamination from other polymers, and from the handling process in general. Production facilities, shipping, warehousing, all generate detritus. And most polymers are easily statically charged, thereby attracting airborne "stuff." And moisture is readily absorbed [meaning the water resides on the surface] or absorbed [meaning that water is drawn completely into the polymer]. If molded parts are rejected for contamination, they must **never** be tossed into the regrind stream. Doing so will ensure an accumulation of contamination and hence an ever-increasing fraction of rejected parts.

Most reprocessing operations are steady state. That is, the regrind is mixed with virgin polymer at the extruder in a constant ratio, say, 50%, for this example. Consider the implications of steady-state reprocessing. A virgin polymer molecule has a 50% chance of becoming regrind. And a 25% chance of becoming regrind a second time, 12% a third time, 6% a fourth time, 3% a fifth time. In fact, it has a small but finite chance of going around for years. Consider what happens to the molecule if it loses 10% of its strength, say, each time. It maintains only about half its strength on the fifth pass. In fact, for this example, the entire polymer sheet at steady-state processing, as delivered to your thermoforming machine, has only 80% of the strength of the virgin polymer. Similar analyses are available for color change, fire retardancy, even fiber length. Physical property loss is an important consideration when designing plastic parts that contain regrind.

Certain polymers can be reprocessed many times without apparent property loss. This is true for most polyethylenes. Polypropylene on the other hand loses some important additives such as odor suppressants, antioxidants, and crystallizing enhancers. Funky smell and increased haze may follow. PVC exhibits color deterioration and increased flow resistance. Flexible PVC may lose plasticizers, leading to loss of flexibility and decreased texture retention. PET is extremely moisture sensitive and even when carefully dried will lose molecular weight. This can lead to haze generation and loss in impact strength. ABS and HIPS will yellow after many recycles. Most polymer suppliers have run extensive recycle tests on their thermoformable polymers. It is your obligation to exploit the results of these tests.

Keywords: regrind, contamination, steady-state, scrap

[1] Readers please note that there is an Industrial Practice article on regrind, by Bill McConnell, also in this issue.