The Material Cascade: An Alternative Form of Regrind Utilization

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In the plastics industry, and in particular the injection molding industry, regrind is a natural offshoot of most processes. Regrind, as defined by ASTM D5033, is "a product or scrap, such as sprues and runners, that has been reclaimed by shredding and granulating for use in-house, and that may be dry blended by the molder with the same grade of virgin material" [1]. Regrind is the product of conventional runner systems, as well as reject parts from both conventional and hot runner systems.

This regrind material, which can range in molding jobs from a few percent to over 50%, can cause many problems in a processing plant. First, many cosmetic problems in a molding facility can be correlated to a poorly planned or executed regrind strategy. Second, regrind stockpiles often become excessive and unmanageable due to misconceptions and interpretations of third party certification standards. One such example is the assumption held by many molders that only 25% regrind may be used in Underwriters' Laboratory recognized and listed components. In fact, the standard reads that as much as 25% regrind can be used without further testing[2]. There is no limitation on the amount of regrind which may be used in UL approved components if further testing indicates that the material remains within specification limits.

These types of problems bring to light a very important concept. By understanding regrind flow throughout the process and incorporating a well prepared regrind strategy, a molder can improve reject levels, increase profits, and use resins which would otherwise be discarded. This concept, along with a proposed alternative method for regrind utilization is the topic of this presentation. Experimental evidence will also be presented to support the alternative method's viability. Even if a molder elects not to use the alternative approach, being aware of its feasibility will provide greater insight into regrind issues when attempting to analyze the flow of regrind through the operation.

The Current Approach to Regrind Utilization

The standard method for utilizing regrind can be referred to as a continuous regrind loop. Virgin plastic from the supplier is blended by percentage with regrind generated during previous manufacturing, either by proportional loading at the machine, or by blending in a central material preparation room. Regrind is typically proportioned by percent, based on recommendations from material supplier's literature or on third party certification standards. Let's take a look at what happens in this type of regrind loop.

Figure I follows the flow of material through a continuous 20% regrind loop. At the start of the process, virgin material is fed into the machine. Here, 100 Kg of the first-pass virgin material is fed into the hopper, with 80 Kg becoming good parts and 20 Kg returning to the hopper as regrind. Of this 20 Kg, 20%, or 4 Kg, will remain in the regrind loop after the next pass through the machine. The amount of first-pass material remaining in the regrind will become less and less after each pass through the machine, but will never be completely removed from the system unless the entire regrind system is purged and restarted. Over a very short period of time, one can see that there will be a number of molecules represented in the material mix which will have passed through the molding machine for several heat histories. And while polymer molecules are generally stable with respect to heat history, polymer degradation is a time-temperature phenomenon. Eventually, polymer molecules exposed to many heat histories begin to break down.

Proponents of this blending technique would point out that the number of old molecules are quite small and therefore would tend to be insignificant. Numerous regrind studies show that, when conducted in a laboratory setting, the material in such a regrind loop will maintain its integrity, especially with respect to physical properties and flame retardant capabilities. However, a major problem which is often overlooked is the probability of contamination in the processing environment. This is a variable which is not easy to duplicate in a material supplier's laboratory setting, and is generally not accounted for. Yet, even traces of a few parts per million of some incompatible materials can render perfectly fine virgin material utterly useless.

Further, if the material is subject to hydrolysis, processing even only a small amount of the material while wet and introducing it into the regrind loop can have a severe impact on parts made after the hydrolysis occurs. When this occurs, it is extremely difficult to get this material out of the loop unless the complete system is purged.

If a continuous regrind loop is to be implemented, it is imperative that the processor make a diagram of how the regrind flows through the facility. An at-the-press regrind loop is the simplest of all. However, when using central regrind systems, which typically handle multiple lots of a variety of materials, the extremely complex flow of materials makes lot-to-lot material accountability virtually impossible.

Hence the problem of the continuous regrind loop. It is impossible to account for all material in the system, including trace amounts, unless it is discarded after each batch use and the regrind equipment thoroughly cleaned. As a result, determination of specifications for regrind from a continuous regrind loop becomes virtually impossible. How much "inbreeding" of contaminants can the specification include? How can traces of foreign objects, such as floor sweepings, be accurately included into a regrind study? How can a worst-case scenario be predicted and evaluated?

An Alternative Approach for Regrind Utilization

An alternative to the continuous regrind loop is the cascading regrind system, illustrated in Figure II. Here, regrind from the first-pass virgin run is stored until the virgin resin has been completely used up. Next, this first generation 100% regrind is processed. The second generation regrind is also stored, and run as soon as the first generation regrind has been used up. This process can continue until the regrind has been almost entirely utilized. It is important to realize that regrind isn't necessarily good or bad material. However, it is different material than the virgin resin. Therefore, it becomes necessary to identify regrind with respect to its heat history, and to determine how many heat histories the material can experience while remaining within specification limits.

In order to keep track of a material's heat history, a suffix notation would be used, after its lot number, which would record the number of processing steps the resin had passed through. To maintain the consistency of this procedure, filled and/or compounded material could be clearly labelled by the material supplier, indicating the number of processing steps the material had been exposed to after emerging from the reactor. This characterization could be carried on into recycling applications by implementing in-mold markers, which would allow reclaimers to know how many heat histories recycled materials had been through. This could be a significant aid in allowing further separation of material for future use.

Testing of the various generations of regrind would also need to be conducted. Regrind would be saved, ground up, and resubmitted into the machine. Some parts would be kept for testing, while others would be further reground. As will be shown later, generally only five generations need to be tested, and if only 20% of the material used is regrind, only three heat histories need to be represented in the study. This is shown in the table in Figure II.

With worst-case parts now available, material tests could be conducted using third party compliance standards (UL type), standard ASTM type or actual component use tests. These tests can be used to prove the viability of the various regrind generations in end-use application parts. Once material suitability is established for, say, fourth generation material, then it could be readily concluded that parts made from materials having heat histories equal to or less than the generation tested would be suitable for the application. With this test criteria firmly established, the cascading system could be easily implemented into production.

For example, we will examine the use of a production part where 50% of the material produced in a shot is sprue and runner, which is fed back into the system using a cascading regrind approach. This means that when a virgin part is made, an equal amount of regrind will be produced. Let's also assume that we need 980 kg of good parts, with 1000 kg of virgin material to make them. This example is highlighted in Figure II.

The 1000 kg of material is placed in the machine and 500 kg of good parts are produced. The resulting 500 kg of sprues and runners are ground, but instead of being fed in with the virgin resin, they are placed into a separate container. All grinding takes place while virgin material is still being molded. When the 1000 kg of virgin resin has been used, the system is switched to the first generation regrind lot. The grinder is emptied and cleaned, and the further sprues and runners begin to be ground, producing a second generation regrind material which is labelled as such. When the 500 kg of first generation material is used, 250 kg of good parts have been produced, along with 250 kg of second generation regrind. The process is repeated, successfully producing 125 kg, 62.5 kg, 31.2 kg, and 16.1 kg of parts at each successive generation through number five. Having molded parts only through 5 generations of regrind, 980 kg of parts are produced, with four pounds to spare. As a by-product of the process, 16 kg of 6th generation material will be produced as well. This material is probably still good material, and could be used in other less demanding applications.

There are many benefits to the cascading regrind approach.

- Heat histories: The number of heat histories which a material has passed through is a known variable. Molecules are not allowed to stay in the system long enough to degrade and thereby cause resulting problems.

- The system is self cleaning: Any contamination entering the regrind stream, a major problem in real-world processing environments, is removed from the system as soon as the regrind is used up. In this way, contamination affects only a minimum number of parts.

- Simplified coloring: Color is introduced along with the virgin material only, and does not need to be proportioned to account for pre-colored material.

- Blending systems: No systems are necessary for blending regrind with virgin material.

- Regrind value: Even if not directly utilized, regrind has a higher value, since it can be classified and tested. Thus it can be characterized as a material type, rather than simply as a "regrind" with unknown properties.

- Worst-case testing: A worst-case scenario is much easier to predict and test when using the cascading system. Molders benefit from reduced potential liability. Designers are supplied with more accurate worst-case specifications.

- The system is simpler: While at first the approach may seem complex, companies who have adopted the cascading system have universally agreed that it is easier to implement. It simply requires different kinds of disciplines.

Experimental Regrind Study

A laboratory scale cascading regrind study was conducted in order to illustrate the feasibility of the cascading regrind approach. Physical properties of three different polymer types were examined at each of the first three regrind generations. The materials tested included two high impact polystyrenes from different material suppliers, ignition resistant polystyrene, and polycarbonate. Injection molding was completed on two different types of machines: a 150 ton HPM using a six cavity ASTM test part mold, and a 100 ton DEMAG using a seven cavity ASTM test part mold. Molding conditions were based upon material supplier recommendations, and were conducted using the Systematic Molding Procedure[3] outlined by John Bozzelli.

Parts were produced through the third generation of the cascade, providing a total of four generations of parts. All parts were tested using the following ASTM and Underwriters' Laboratories test methods:

ASTM D256-87 Notched Izod Impact
ASTM D638-87b Tensile Properties
ASTM D1238-86 Melt Flow Rate
UL 94 Flammability Tests
Capillary Rheology
Differential Scanning Calorimetry
Thermal Gravimetric Analysis
Average Molecular Weight by Gel Permeation Chromatography

The results of the molecular weight, flammability, tensile strength and notched Izod tests are presented below. All results, except for those of the flammability tests, are plotted as percent change in properties with respect to virgin parts.

These are plotted versus the number of regrind generations the materials have passed through.

The most direct indicator of polymer degradation is average molecular weight. Graph I plots the percent change in weight average molecular weight after the processing of virgin resin and third generation regrind. The error bars indicate the standard deviation for this test method. No significant reduction is noted for any of the materials after three processing steps, indicating that little molecular degradation has occurred.

Table I illustrates the percent change in UL 94 Flammability Test results versus number of regrind generations. The burn times for all generations of the high impact polystyrenes and ignition resistant polystyrene remained comparable to those of the virgin material.

Graph II illustrates the percent change in tensile strength versus number of regrind generations. The error bars indicate the average standard deviation at each generation. All four materials show no significant degradation in properties.

Graph III shows percent change in notched Izod impact properties versus number of regrind generations. The error bars indicate the average standard deviation at each generation. Again, none of the materials show significant property degradation. The results for polycarbonate are particularly encouraging, since its notched Izod properties are very dependent upon thermal degradation. While a slight decrease is noted, the notched Izod value after the third generation is still within the standard deviation of the value for the virgin material.

The remainder of the tests showed the same general trends: part properties did not change significantly after being exposed to three regrind steps.

The data from these tests for these particular materials shows that property retention can be quite good, even after several regrind generations. While independent testing of actual end-use parts is required for each type of resin system, the results shown here are very encouraging. Upon reviewing the results of this study, combined with numerous studies provided by material suppliers, molders should have enough data to help them decide how many regrind generations are appropriate, at a 100% regrind level, for their applications.

Conclusions

A new, viable regrind strategy has been developed which offers many advantages to molders:

- The cascading regrind approach is very simple.

- Processes are made more robust.

- Product integrity is easily evaluated in worst-case scenarios.

- Even in high percentage regrind applications, a maximum of five generations are generally necessary to utilize all process regrind.

- Contamination is continuously flushed from the system by avoiding regrind circulation.

- Only one lot of material is ever present in one part.

- Regrind value is optimized.

Many molders may decide not to implement this type of system. However, the issues surrounding regrind utilization must be understood by all molders who wish to remain profitable and state-of-the-art in a competitive environment.

Acknowledgements

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References

1 Underwriters Laboratories Inc. Standard for Safety UL 746D; "Polymeric Materials - Fabricated Parts", Paragraph 2.9, Underwriters Laboratories Inc. , March 6, 1990

2 Underwriters Laboratories Inc. Standard for Safety UL 746D; "Polymeric Materials - Fabricated Parts", Underwriters Laboratories Inc. , March 6, 1990

3 John Bozzelli, The Dow Chemical Company; "Systematic Molding for Accurate Comparisons: Part to Part, Resin to Resin, Plant to Plant, and Lot to Lot", Paper presented at the 1991 Society of Plastics Engineers ANTEC Conference

Table I: UL 94 Burn Times for Polystyrene
(Standard Deviation = ± 2 sec)

GENERATION	HIPS A	HIPS B	IRPS
VIRGIN	2 min 24 sec	2 min 28 sec	1 sec
FIRST	2 min 25 sec	2 min 26 sec	0 sec
SECOND	2 min 20 sec	2 min 23 sec	1 sec
THIRD	2 min 21 sec	2 min 19 sec	0 sec
TEST:	UL 94 HB	UL 94 HB	UL 94 V-0

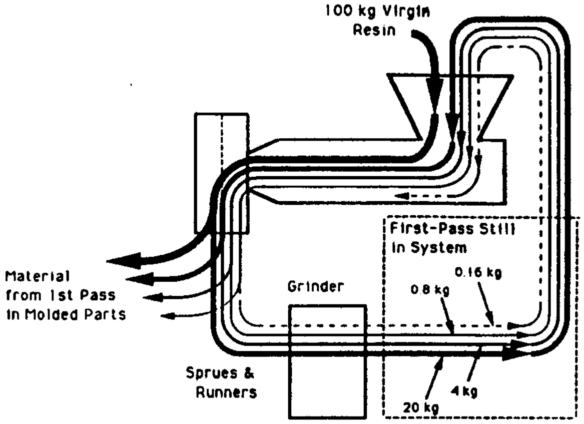
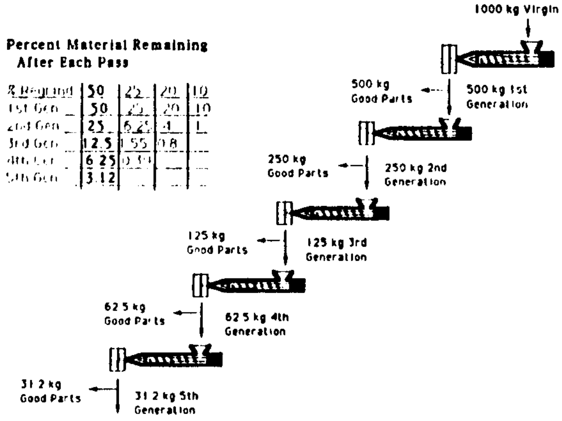


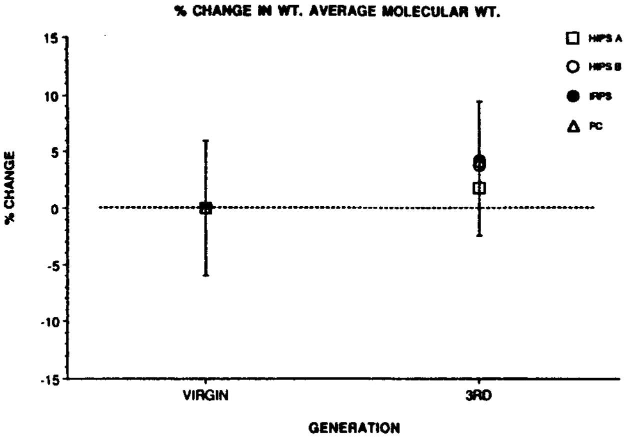
Figure I: The Continuous Regrind Loop
Resin from the 1st pass never completely leaves the system



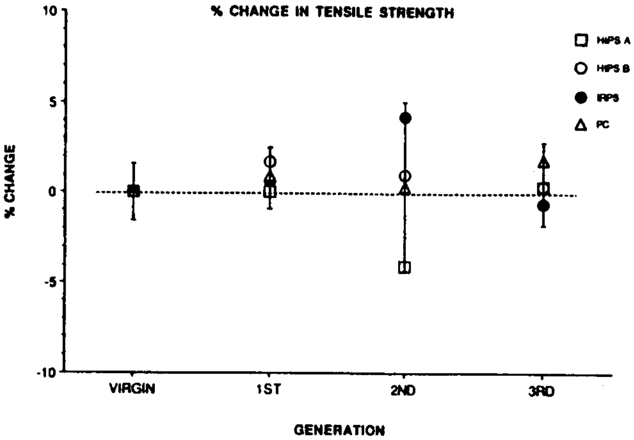
Percent Material Remaining After Each Pass

% Regrind	50	25	20	10
1st Gen	50	25	20	10
2nd Gen	25	6.25	4	1
3rd Gen	12.5	1.55	0.8	—
4th Gen	6.25	0.39	—	—
5th Gen	3.12	—	—	—

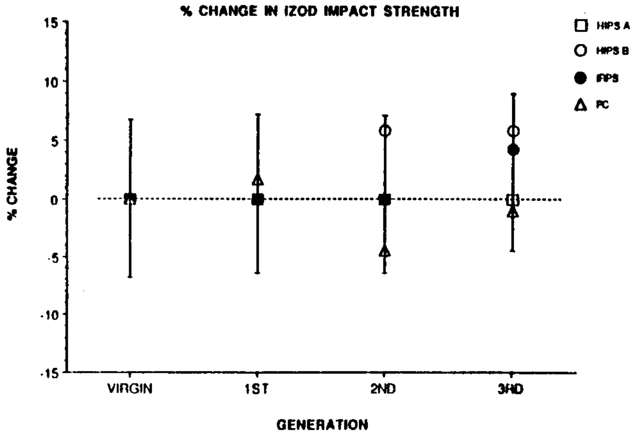
Figure II: Cascade Method for Utilizing Regrind
50% Regrind Example



GRAPH I: AVERAGE MOLECULAR WEIGHT AFTER PROCESSING OF VIRGIN & THIRD GENERATIONS

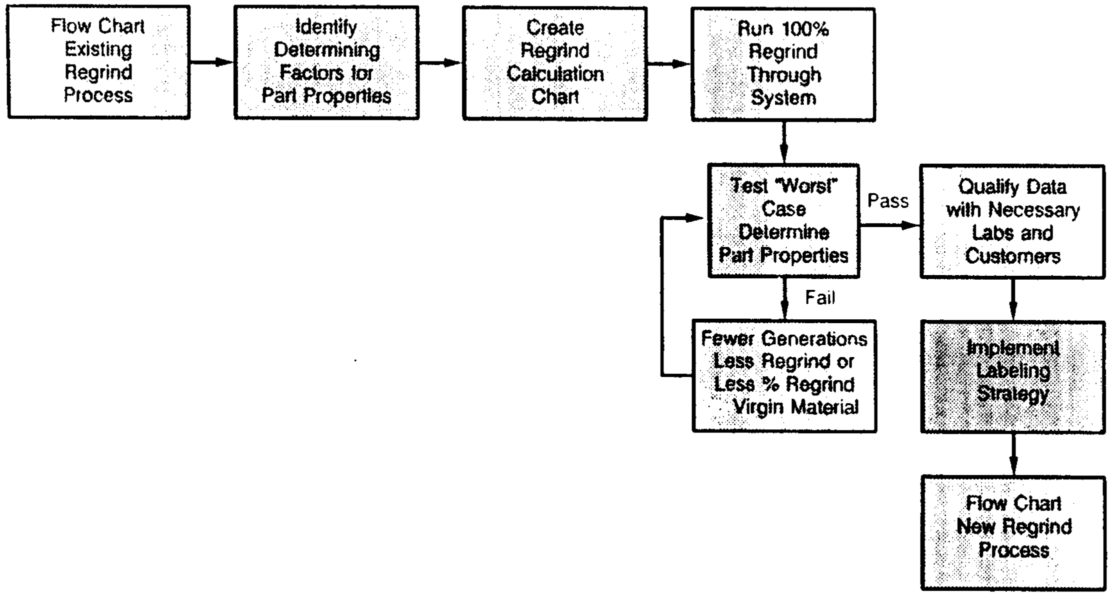


GRAPH II: TENSILE STRENGTH vs. NUMBER OF REGRIND GENERATIONS



GRAPH III: NOTCHED IZOD IMPACT PROPERTIES vs. NUMBER OF REGRIND GENERATIONS

Implementation of Cascading Regrind Approach



Flow Chart Existing Regrind Process

Identify Determining Factors for Part Properties

Create Regrind Calculation Chart

Run 100% Regrind Through System

Test "Worst" Case Determine Part Properties

Pass

Qualify Data with Necessary Labs and Customers

Fail

Fewer Generations Less Regrind or Less % Regrind Virgin Material

Implement Labeling Strategy

Flow Chart New Regrind Process