Re-Pelletizing Polycarbonate Scrap Prior to Injection Molding

A Risk-Based Technical Review

This technical review examines the processing tradeoffs between using irregular, dusty regrind and re-pelletized reclaim in polycarbonate injection molding. The discussion is grounded in peer-reviewed literature and established polymer processing principles, with an emphasis on process robustness, heat history, and defect-risk considerations in production and regulated environments.

What the document covers

- Effects of feed geometry and fines on solids conveying and melt stability
- Relationship between dust, degradation mechanisms, and black specks
- Comparison of direct regrind use versus controlled re-pelletizing
- Review of published data on molecular-weight degradation under repeated extrusion and injection molding heat histories
- Risk-based framing suitable for production and advanced engineering audiences

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This document reflects a technical review based on published literature and engineering principles. It is intended to support general engineering evaluation and discussion and does not represent a recommendation for any specific manufacturing operation.

Executive Summary:

Re-Pelletizing Polycarbonate Scrap Prior to Injection Molding – A Risk-Based Technical Review

This review assesses the processing tradeoffs between directly using irregular, dusty polycarbonate (PC) regrind and re-pelletizing it via controlled extrusion before injection molding. Grounded in peer-reviewed studies and polymer principles, it emphasizes impacts on process robustness, thermal stability, and defect risks in production and regulated settings.

Irregular regrind geometry reduces bulk density and frictional consistency, narrowing the processing window and increasing sensitivity to variability, as evidenced by reduced throughput and elevated melt temperatures (Thieleke & Bonten, 2021; Kneidinger et al., 2023). Dust and fines exacerbate degradation, promoting black specks through oxidative mechanisms in stagnation zones.

In contrast, in-line shredding, extrusion, and pelletizing homogenize material, vent volatiles, filter contaminants, and yield uniform pellets akin to virgin feedstock, enhancing feed stability and reducing defect risks. While adding heat history, controlled re-pelletizing causes modest molecular weight reduction—less severe than repeated injection cycles—when moisture, residence time, and temperature are managed (Pérez et al., 2010).

From a risk perspective, direct regrind heightens variability and intermittent defects, while re-pelletizing improves consistency and may extend material usability. **The review concludes that re-pelletizing mitigates risks with minimal thermal downside, meriting validation as a quality-enhancing strategy rather than a material alteration.**

1. Background and Objective

Polycarbonate (PC) scrap generated during medical device molding operations can be used to reduce material cost. One approach is to granulate the scrap and reintroduce it directly as regrind in the same or different product applications.

While this approach can be operationally feasible, published polymer-processing research indicates that the physical form of the reclaim material—pellets versus irregular regrind—plays a meaningful role in feeding behavior, thermal stability, and overall process robustness, independent of polymer chemistry. (1, 2)

The objective of this document is to summarize **peer-reviewed technical evidence** relevant to evaluating whether **re-pelletizing PC scrap prior to injection molding may support reduced process variability and defect risk**, while introducing **only minimal additional negative impact from added heat history when properly controlled**, subject to appropriate validation and quality controls.

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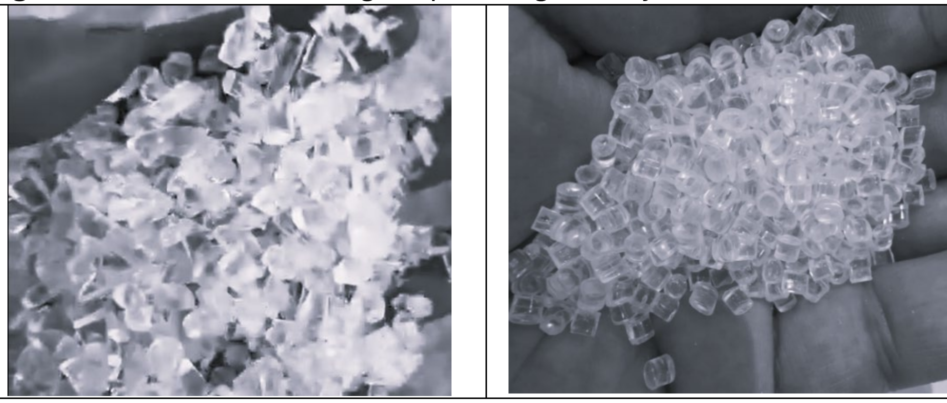
2. Effect of Regrind Geometry on Processing Behavior

2.1 Influence of Particle Shape and Bulk Density

Independent studies demonstrate that **raw material geometry alone significantly affects solids conveying, pressure development, and throughput stability** in single-screw processing systems, even when material composition is unchanged. (1, 2) Figure 1 illustrates the pronounced differences in particle geometry between polycarbonate regrind and uniform pellets that underpin these processing effects.

Figure 1. Pelletized versus regrind particle geometry



Representative examples shown to illustrate particle geometry differences between uniform pellets and irregular regrind.

Irregular or shredded feedstocks typically exhibit:

- lower and less consistent bulk density, and
- greater variability in frictional behavior during solids conveying.

These characteristics have been shown to reduce processing margins and increase sensitivity to local variations in residence time, shear, and heat generation (1, 2).

2.2 Processing Window Considerations

Published research indicates that **irregular or low–bulk-density feed materials tend to operate closer to the limits of the available processing window** for a given output and screw speed. (1)

This observation does **not** imply that higher temperature setpoints are required or used in practice. Rather, it indicates that **the process may become more sensitive to localized overheating, stagnation, or degradation mechanisms**, particularly when fines or dust are present.

From a quality and regulatory perspective, reduced processing margin increases susceptibility to variability rather than constituting an immediate or obvious processing failure.

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3. Dust and Fines as a Quality Risk Factor

Dust and fine particles exhibit:

- high surface-to-volume ratios,
- rapid thermal response, and
- increased susceptibility to oxidative and thermal degradation. (3)

When dusty regrind is introduced directly into an injection molding machine, fine particles may experience repeated exposure to high shear and regions of limited flow or stagnation. Over time, degraded material can accumulate in these regions and intermittently release into molded parts as dark inclusions or black specks.

This mechanism is widely recognized in polymer-processing literature and represents a **risk factor**, not a deterministic outcome.

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4. Process Implications of In-Line Shredding, Extrusion, and Pelletizing

An in-line shredder–extruder–pelletizer introduces a **dedicated, controlled melt step** designed for:

- homogenization,
- venting,
- melt filtration, and
- routine purging.

From a quality standpoint, this approach:

- concentrates degradation and contaminant removal in equipment designed to manage it,
- reduces dust content in the final reclaim pellets, and
- produces more uniform feedstock geometry for downstream injection molding.

Pelletized reclaim therefore tends to exhibit **feeding and melting behavior more consistent with virgin pellets**, which may support improved thermal uniformity and reduced localized degradation in the injection molding process.

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5. Added Heat History and Molecular Weight Considerations

5.1 Magnitude of Degradation from an Additional Extrusion Step

Peer-reviewed studies on polycarbonate reprocessing demonstrate that, when drying, residence time, and temperature are properly controlled, **early reprocessing cycles introduce only modest molecular-weight reduction**. (4) Reported observations include small changes in glass transition temperature, tensile strength and modulus remaining largely unchanged over multiple cycles, and degradation being strongly dependent on moisture and uncontrolled thermal exposure rather than the mere presence of an additional melt step.

These findings indicate that **the incremental negative effect of a single, well-controlled extrusion and pelletizing step is limited relative to typical injection molding thermal exposure**, provided that drying, residence time, and temperature are properly managed.

5.2 Comparison to Repeated Injection Molding Exposure

In contrast, when material is subjected to repeated injection molding cycles, higher melt temperatures, elevated shear rates, and prolonged residence in localized stagnation zones can contribute to more pronounced molecular-weight reduction. Peer-reviewed studies comparing extrusion-based reprocessing with injection molding reprocessing of polycarbonates show that **molecular-weight reduction during controlled extrusion occurs more gradually than during repeated injection molding cycles**, highlighting the importance of controlled thermal exposure rather than the number of melt histories alone. (4)

It is therefore important to recognize that **adding extrusion-based pelletizing cycles is not equivalent to adding injection molding cycles**, even though both involve melting the polymer. Injection molding typically exposes the material to higher peak temperatures, higher shear rates, and less uniform residence time distributions, which are known to accelerate molecular degradation. In contrast, **well-controlled pelletizing processes are designed to minimize shear, residence time, and thermal gradients**, resulting in a smaller incremental contribution to molecular degradation per cycle.

Accordingly, while the number of injection molding cycles that a material can tolerate is inherently limited by cumulative degradation, **the addition of pelletizing cycles does not translate directly into an equivalent reduction in allowable injection molding cycles**. When applied within a reasonable and controlled reprocessing strategy, re-pelletizing can improve feed consistency, melt stability, and overall processability, which in turn may reduce scrap generation during subsequent injection molding operations. From a process-risk perspective, these benefits can outweigh the modest additional thermal exposure introduced by controlled pelletizing steps.

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6. Risk-Based Comparison of Reclaim Approaches

From a process-risk perspective:

Direct use of dusty regrind may involve:

- reduced processing margin,
- greater sensitivity to localized degradation mechanisms, and
- increased risk of intermittent defect formation.

Re-pelletized reclaim may offer:

- improved feed consistency,
- reduced fines content,
- upstream filtration of degraded material, and
- enhanced process robustness.

Consistent with the mechanisms discussed in Section 5, the observed differences in processing behavior and defect risk between direct regrind use and re-pelletized reclaim arise not solely from the number of melt histories, but from **how thermal and shear exposure are introduced and controlled.**

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7. Conclusion

Published polymer-processing research supports the conclusion that re-pelletizing polycarbonate scrap prior to injection molding may support reduced process variability and defect risk, while introducing only minimal additional negative impact from added heat history when properly controlled. These outcomes reflect differences in **how thermal and shear exposure are applied and managed**, rather than simply the number of melt cycles alone.

From a regulatory and quality perspective, re-pelletizing can be considered a risk-mitigation strategy rather than a material change. Final implementation remains subject to internal change-control evaluation and appropriate process validation.

Endnotes

1. Thieleke, P.; Bonten, C. *Enhanced Processing of Regrind as Recycling Material in Single-Screw Extruders.* **Polymers**, 2021, 13, 1540.

This reference discusses reduced bulk density, reduced specific throughput, increased melt temperature, and narrowing of the processing window for irregular regrind materials.
https://doi.org/10.3390/polym13101540

2. Kneidinger, C.; Brunmayr, T. G.; Zitzenbacher, G. *Influence of Raw Material Shape on Single Screw Extruder Performance.* **AIP Conference Proceedings**, 2884, 040001 (2023).

This reference provides experimental analysis of how raw material shape and bulk density influence solids conveying behavior, pressure development, and throughput stability in single-screw extrusion, independent of polymer chemistry.
https://doi.org/10.1063/5.0168760

3. Polymer extrusion and injection molding defect-analysis literature consistently identifies fines and dust as contributors to black specks through oxidative degradation, dead-zone accumulation, and localized overheating under shear.

4. Pérez, J. M.; Vilas, J. L.; Laza, J. M.; Arnáiz, S.; Mijangos, F.; Bilbao, E.; Rodríguez, M.; León, L. M. *Effect of Reprocessing and Accelerated Ageing on Thermal and Mechanical Polycarbonate Properties.* **Journal of Materials Processing Technology**, 210 (2010) 727–733.

This reference compares molecular-weight evolution and property retention in polycarbonate subjected to repeated extrusion and injection molding reprocessing cycles, demonstrating more gradual molecular-weight reduction under controlled extrusion conditions relative to injection molding exposure.
https://doi.org/10.1016/j.jmatprotec.2009.12.009