

# Re-visiting extrusion scale-up

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Scale-up in materials processing can be viewed as the action of defining the geometry and/or the operating conditions of a given machine/manufacturing sequence that replicate the working conditions of a different equipment of the same type but distinct size, processing the same material. In the case of polymer extrusion, scale-up rules are used quite frequently in R&D, for example to extrapolate to laboratorial equipment the conditions leading to the occurrence of problems observed in the production plant, whose origin and resolution can then be investigated at lower costs. Subsequently, scale-up rules must be utilized again to apply the solution found back to the production equipment. Surprisingly, most scale-up rules consist of simple power-type relations that were derived from analytical expressions describing individual steps of the plasticating extrusion sequence. Thus, it is not surprising that their application can lead to unbalanced solids and melt conveying rates, or excessive viscous dissipation.

A more performing scaling-up approach is therefore essential, namely one capable of using the available accurate descriptions of flow and heat transfer inside the extruder. It is also important to consider simultaneously several process criteria, to allow for flexibility in their selection, and to use either single values (e.g., average shear rate) as well as functions (e.g., axial shear rate profile). To achieve this, extrusion scale-up was regarded as a multi-objective optimization problem, where the aim is to define the geometry/operating conditions of the target extruder that minimize the differences between the criteria values for the reference and target extruders.

The methodology was tested in a number of increasingly more complex problems, demonstrating its effective capacity. Obviously, the larger the number of criteria, the more compromises are required between conflicting criteria. A way of minimizing this is to merge various criteria related to heat and flow into a few others associated to material morphology and homogeneity. Of course, this requires the availability of more comprehensive process models, which are also briefly discussed.