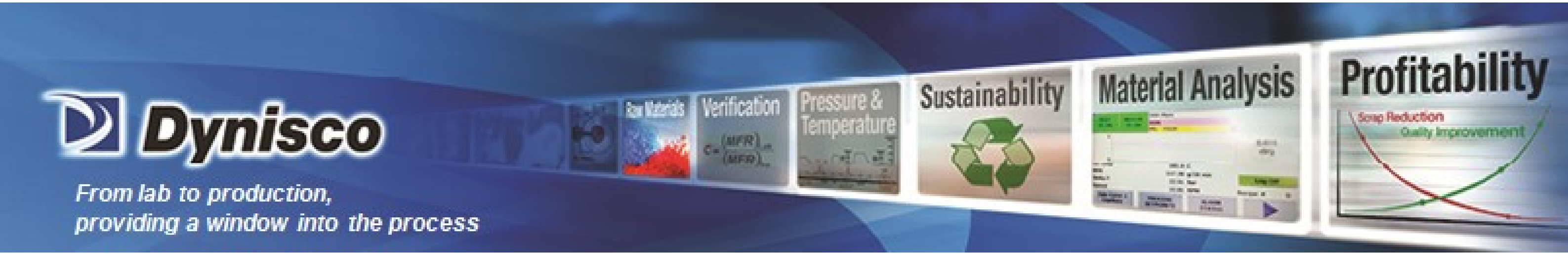


# Melt Processing of Thermoplastics for Extrusion and Injection Molding

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## Table of Contents



## Introduction

Extrusion and injection molding are the most important conversion techniques used by the thermoplastics processing industry. Certain factors need to be considered before a thermoplastics material is processed, regardless of whether it is injection molding or extrusion molding that is used.

These factors include the granule characteristics, the hygroscopic behavior of the material (whether it picks up water), the flow properties, the thermal properties (such as thermal stability and heat transfer), shrinkage, crystallization behavior, and molecular orientation.

## Hygroscopic Behavior

If a polymer compound contains water, or any other material with a low boiling point, then the heat required for processing can increase its temperature above the boiling point. When the pressure decreases, visible bubbles will then develop within the thermoplastic material, such as when it evolves from the die of an extruder.

It is said that when the processing temperatures is higher, the quantity of water that can be tolerated is lower. The reason is higher temperatures will produce a larger volume of steam from the same amount of water. Typically, commodity thermoplastics do not suffer from water-related issues to the same extent as the engineering thermoplastics.

Some of these materials, for instance Nylon and PET absorb water i.e. they are hygroscopic and have to be carefully dried before processing. In addition, additives contain plenty of water which may cause water to be introduced into the system.

## Granule Characteristics

Processes such as extrusion molding, injection molding, and blow molding frequently use material in granular form as the feed. Feeding issues will arise if the material is available in more than one feed form. In terms of feeding efficiency, spherical granules (of roughly 3 mm (0.125”) diameter) are considered the most efficient, while fine powder is considered the worst.

Regranulated material can be nearly as bad as it may contain a variety of particle sizes. Although cube cut granules are a better choice, lace cut granules are even better as they are produced by chopping strands with a circular cross-section. Due to the feeding differences of a variety of granulates, the machines have to be fed with a consistent raw material blend. This particularly applies to masterbatch mixes.

## Thermal Properties and Heat Input

Thermoplastic materials need large heat inputs to increase their temperatures to those required for melt processing. They also vary greatly in the amount of heat energy required to bring them up to processing temperatures.

These differences are not merely due to the varied processing temperatures required, but also due to the fact that varied plastics materials have varying specific heats. (The amount of heat needed to increase the temperature of a specific weight of a material by 1 °C or °F).

Different quantities of heat are required by different materials to increase their temperature to a fixed number of degrees; for instance, when melt processing a semi-crystalline, thermoplastic material, heat has to be supplied to melt the crystal structures. In the case of an amorphous resin, this additional heat input is not required.
However, both types of material will need a large quantity of heat to be quickly added into the material. This leads to issues because plastics are poor conductors of heat and can have limited thermal stability at the processing temperatures used. As plastic materials are poor thermal conductors, the elimination of large quantities of heat needed to solidify a part also creates major problems if rapid production needs to be maintained.

## Thermal Stability

Thermoplastic materials vary extensively in their thermal stability. For instance, UPVC is highly unstable even when stabilized and can only be maintained at processing temperatures (175 ºC/347 ºF) for a few minutes (Unstabilized PVC will exhibit some degradation in boiling water).

In contrast, polysulfones need melt temperatures in the range of 400 ºC/752 ºF, where they are stable. A material's thermal stability is controlled not only by the temperature, but also by the residence time at that temperature, the materials in contact with the plastics material, and the atmosphere surrounding the material (inert or oxygen).

For instance, polypropylene (PP) is rapidly decomposed or degraded by copper. Therefore, copper cleaning pads must not be used to clean the rheological equipment used to examine this material. Overall, the decomposition products from plastics must be viewed as being potentially destructive and any gases evolved should be appropriately vented.

## Flow Properties

Due to thermal stability issues, the processing temperatures used for thermoplastics are often limited to fairly low values. This indicates that melt viscosities are typically high. Process melt viscosities are not even and vary from one grade of the same material to another grade, and from one material to another.

While these variations could be the result of intrinsic differences in the nature of the polymers, they may also be influenced by molecular weight and by temperature. Generally, viscosity

reduces with an increase in temperature and as the molecular weight is reduced. This is the reason for the increased interest in flow testing of thermoplastic materials. It Slight variations of molecular weight, molecular weight distribution, and temperature can result must also be noted that since the viscosity decreases with an increase in output rate, via in large differences in melt viscosity. This influences quality and output in both injection and a given die, the energy used per unit output is likely to decrease as the extrusion rate is extrusion molding. Therefore, stringent control over both the processing conditions as well as increased. the material fed to the machine should be employed.

## Thermal Properties and Cooling

Large heat inputs are required by thermoplastic materials to increase their temperatures to those required for melt processing. As these materials are good thermal insulators, removing large amounts of heat can create major problems for high-speed production. Variations in the cooling rate may have a distinct effect on the product’s crystalline morphology and on factors such as molecular shrinkage and orientation.

## Crystallization and Shrinkage

Once cooled from processing temperatures, all polymeric products generally shrink. The shrinkage of polystyrene (PS), an amorphous thermoplastic material, is relatively less than that for a high-density polyethylene (HDPE) - a semi- crystalline thermoplastic (for PS, the amount of shrinkage may be 0.6%, while for HDPE it may be up to 4%).

This is because when polymer molecules crystallize, they are likely to pack more efficiently than when they are in the disorganized amorphous state. With thick-sectioned extrusions and moldings, the cooling rates will vary from the outer edges to the center.

This causes differences in the degree of crystallinity across the entire part. This explains the reason for always quoting the shrinkage range for each material. This shrinkage range is always higher for a semi-crystalline thermoplastic material when compared to an amorphous one. For instance, the shrinkage of PS is listed as 0.02 to 0.08%, while that of HDPE is 1.5 to 4%.

Molecular Orientation

During melt processing, polymer melts are extensively deformed. The hot material is then cooled rapidly to realize the high output rates required. The shearing processes cause the molecules to take up an oriented, or deformed, shape and the fast cooling leads to this deformed shape being frozen-in the product.

This orientation, which causes the product to have different properties in different directions, is referred to as anisotropy. In several cases orientation is unwanted, but in some cases, orientation is enhanced or introduced to improve the product's properties. The process of intentionally orienting extrudates is used in the development of fibrillated tape, in the extrusion blow molding of bottles, and many different types of fibers.

This information has been sourced, reviewed and adapted from materials provided by Dynisco.

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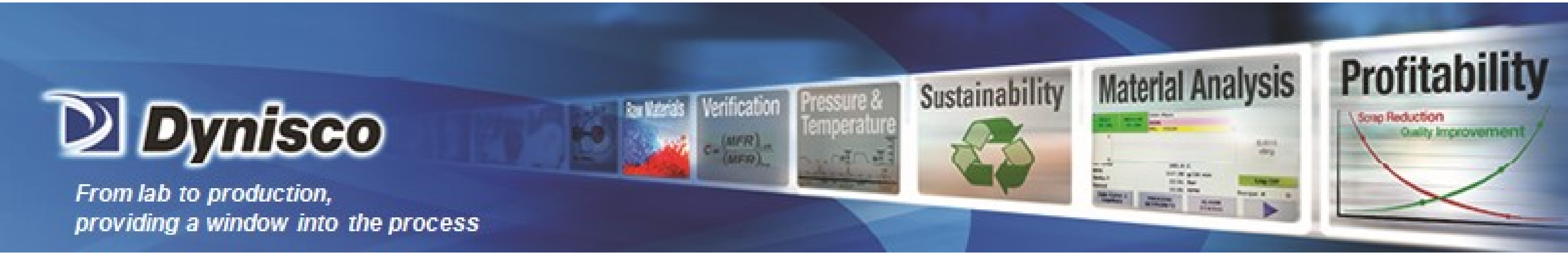


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