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Injection molding. Influence of process parameters on mechanical properties of polypropylene polymer. A first study.

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Abstract

This paper shows the first study results of the mechanical characterization of a commercial polypropylene (PP) polymer. Before testing, a mold for injection molding process has been designed and realized. Three different specimens can be produced, for three different tests: tensile, Charpy and Hopkinson bar. In-cavity pressure and temperature sensors are installed next to the molded item to have direct information about process phases. After the description of the instrumentation, the correlation between injection molding input parameters and mechanical behavior of the material has been assessed. In particular, tensile tests have been carried out to investigate the influence of: melt temperature, mold temperature, packing pressure and cooling time. A Design of Experiment plan has been set up to establish the tests to be performed. Results show the influence of mold temperature and holding pressure on mechanical strength of the polymer.

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1. Introduction

Polypropylene is a common thermoplastic polymer, largely used in industrial applications for the number of its properties, which make it versatile. PP components are semi-rigid, translucent, fatigue and heat resistant, tough and

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chemically durable. The main manufacturing processes of polypropylene parts are extrusion and injection molding (IM). Through these technologies a numerous kind of products are available: buckets, bowls, crates, toys, medical components, washing machine drums, battery cases, bottle caps, etc.

In the large-scale industrial production world, plastic injection molded parts are getting a key role, because of their affordability and lightness, especially when there are no mechanical requirements. Although the process optimization focuses often on the reducing of cycle time (in accordance with dimensional and aesthetic specs), more and more frequently it's fundamental that the manufactured parts have mechanical performances. These last can be affected by process parameters, which can induce residual stresses to the component due to deformation at high shear rates, temperature and pressure. A right combination of these parameters can optimize the properties of the component.

In general, research activity on injection molded polymers' characterization by process parameters has been developed by several groups and different approaches have been carried. Typically, IM input parameters are: injection speed, melt temperature, mold temperature, packing time, packing pressure, cooling time.

An early study on PP properties was conducted by G. Kalay and M.J. Bevis (1997). They studied the influence of holding pressure, cooling time, melt temperature and injection speed on different molded parts (via conventional or SCORIM process). They reported the substantial increase in Young's modulus of moldings produced by SCORIM and the mechanical behavior about stiffness and impact resistance. Then, recent works concerning PP filled with calcium carbonate have been made by D. Kusić and A. Hančič (2016). Their aim has been the optimization of six molding conditions (melt temperature, packing time, cooling time, injection speed, packing and injection pressures) to reduce the shrinkage and warpage of a standardized test specimen, through the statistical Taguchi method.

In some cases, the research has been carried out controlling only one input parameter, as showed by M. Feldmann (2016). A polypropylene with a man-made cellulose fiber material was molded and mechanically tested, as well as SEM analyzed for a fiber length study. Results show an independence of Young's modulus from melt temperature, instead of tensile and Charpy (notched) impact strength.

Meanwhile, some researchers reported the influence of processing conditions for different polymers than PP. For example, U. A Dar et al (2016) made a study about the behavior of polycarbonate linked with injection velocity, packing pressure, cooling time, mold temperature, and melt temperature. They showed that the tensile stress increases with melt temperature and mold temperature, which helps the polymer to set a higher molecular orientation and have lower residual stresses. The higher is mold temperature, the lower is cooling rate: this condition increases part performances. Packing pressure and injection speed are not much significant to the polymer strength.

From the point of view of the analysis of experimental results, researchers have made use of different statistic approaches in order to investigate the correlation between molding conditions and part properties. In this study, a design of experiments (DoE) has been carried out to investigate the trend of mechanical strength of a commercial PP. The work approach is similar of the study made by Natalini et al (2013).

For the aim of the research, a mold for polymeric specimens has been manufactured, to carry out quasi-static and dynamic standard tests. Pressure and temperature sensors are installed next to the cavity mold, for the direct monitoring of filling and packing phases (in addition with the information of IM machine sensors). In this study, the controlled input parameters are: mold and melt temperatures, packing pressure and cooling time. From the effects analysis, it is possible understand which part properties are mostly dependent from IM parameters, for the specific polymer. In this paper, tensile test is the only mechanical test applied.

Nomenclature

PP	polypropylene
IM	injection molding
DoE	Design of Experiment
MT	melt temperature
MdT	mold temperature
Pp	packing pressure
Ct	cooling time
V/P	Switchover point