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STUDY OF INJECTION MOULDING USING POLYPROPYLENE H200MK GRADE-1

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Abstract

Injection molding is one of the most versatile and important manufacturing processes capable of mass-producing complicated plastic parts in net shape with excellent dimensional tolerance. Injection molding process and quality control has been an active research area for many years, as part quality and yield requirements become more stringent. This paper reviews the state-of-the-art research and development in injection molding control. It organizes prior studies into four categories, namely, process setup, machine control, process control, and quality control, and presents the distinction and connection of these different levels of control. This paper further reviews and compares the typical variables, models, and control methods that have been proposed and employed for those control tasks. Strictly speaking, real online quality control without human intervention has yet to be realized, primarily due to the lack of transducers for online, real time quality response measurement, and a robust model that correlates the control variables with quantitative quality measurements. Based on the research progress to date, this paper suggests that the different levels of control tasks have to be integrated into a multilevel quality control system, and that the quality sensor and the process and quality model are the two most important areas for further advancement in injection molding control.

Key words: Injection Modeling, Polypropylene, robust model, process setup, machine control, process control, and quality control.

1. INTRODUCTION

1.1. History

Propylene was first polymerized to a crystalline isotactic polymer by Giulio Natta as well as by the German chemist Karl Rehn in March 1954. This pioneering discovery led to large-scale commercial production of isotactic polypropylene by the Italian firm Montecatinifrom 1957 onwards. Syndiotactic polypropylene was also first synthesized by Natta and his coworkers. Polypropylene is the second most important plastic with revenues expected to exceed US$145 billion by 2019. The demand for this material was growing at a rate of 4.4% per year between 2004 and 2012.

1.2. Polypropylene

Polypropylene (PP), also known as **polypropylene**, is a thermoplastic polymer used in a wide variety of applications including packaging and labeling, textiles (e.g., ropes, thermal underwear and carpets), stationery, plastic parts and reusable containers of various types, laboratory equipment, loudspeakers, automotive components, and polymer banknotes. An addition polymer made from the monomer propylene, it is rugged and unusually resistant to many chemical solvents, bases and acids. The global market for polypropylene had a volume of 45.1 million tonnes, which led to a turnover of about $65 billion (47.4 billion).

2. CHEMICAL, PHYSICAL & MECHANICAL PROPERTIES

Most commercial polypropylene is isotactic and has an intermediate level of crystalline between that of low-density polyethylene (LDPE) and high-density polyethylene (HDPE). Polypropylene is normally tough and flexible, especially when copolymerized with ethylene. This allows polypropylene to be used as an engineering plastic, competing with materialssuch as ABS. Polypropylene is reasonably economical, and can be made translucent when uncolored but is not as readily made transparent as polystyrene, acrylic, or certain other plastics. It is often opaque or colored using pigments. Polypropylene has good resistance to fatigue. The melting point of polypropylene occurs at a range, so a melting point is determined by finding the highest temperature of a differential scanning calorimetry chart. Perfectly isotactic PP has a melting point of 171 °C (340 °F). Commercial isotactic PP has a melting point that ranges from 160 to 166 °C (320 to 331 °F), depending on atactic material and crystallinity. Syndiotactic PP with a crystallinity of 30% has a melting point of 130 °C (266 °F).

The melt flow rate (MFR) or melt flow index (MFI) is a measure of molecular weight of polypropylene. The measure helps to determine how easily the molten raw material will flow during processing. Polypropylene with higher MFR will fill the plastic mold more easily during the injection or blow-molding production process. As the melt flow increases, however, some physical properties, like impact strength, will decrease.

2.1 Mechanical Properties

The mechanical properties of semi-crystalline polymersstrongly depend on the degree of crystallinity, the crystallite size and the concentration of tie-chains. The tie-chains connect the adjacent crystals (lamellae). In addition, the (average) molecular weight and the molecular weight distribution (MWD) also affect the mechanical properties. Nucleating agents can reduce the cycle time in the injection moulding process, increase the stiffness, increase the tie-chain concentration, improve the clarity, promote the β phase etc. Single crystals (lamellae) are highly anisotropic because of the nature of bonding between atoms and molecules, strong covalent bonds along the chain vs. weak Vander Waals interaction etc between chains, Random formations of spherulite structure in the 3D space create an isotropic composition. Therefore, even if the individual crystals are anisotropic, the differences in the properties tend to average and, overall, the material is isotropic. Note that the degree of crystallinity and molecular orientation are affected by the fabrication process that could lead to anisotropic mechanical response in solid polymers.

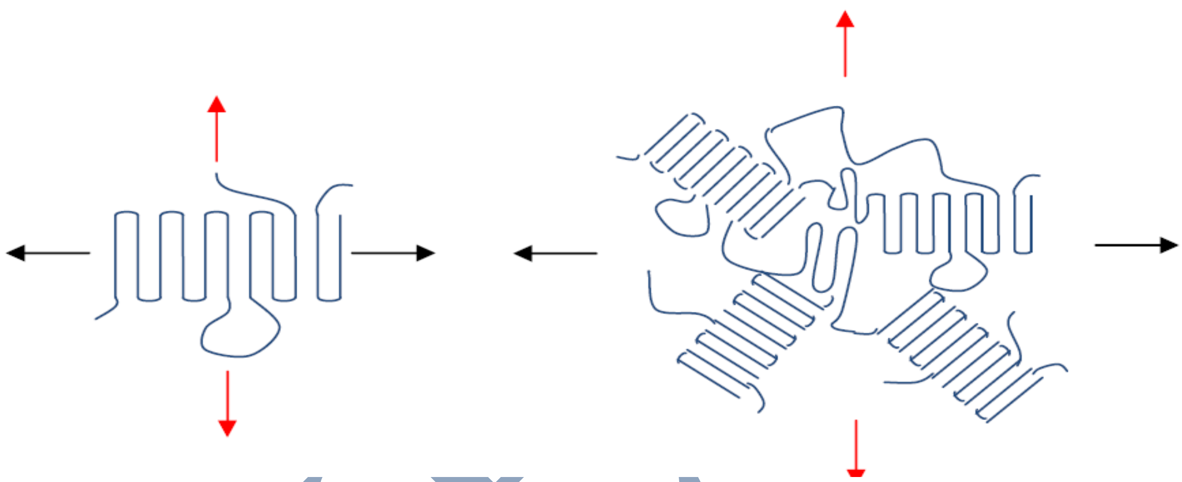

Figure 2.1: Molecular Orientation of polypropylene

3. DEGRADATION

Polypropylene is liable to chain degradation from exposure to heat and UV radiation such as that present in sunlight. Oxidation usually occurs at the tertiary carbon atom present in every repeat unit. A free radical is formed here, and then reacts further with oxygen, followed by chain scission to yield aldehydes and carboxylic acids. In external applications, it shows up as a network of fine cracks and crazes that become deeper and more severe with time of exposure. For external applications, UV-absorbing additives must be used. Carbon black also providessome protection from UV attack. The polymer can also be oxidized at high temperatures, a common problem during molding operations. Anti-oxidants are normally added to prevent polymer degradation.

3.1 Synthesis

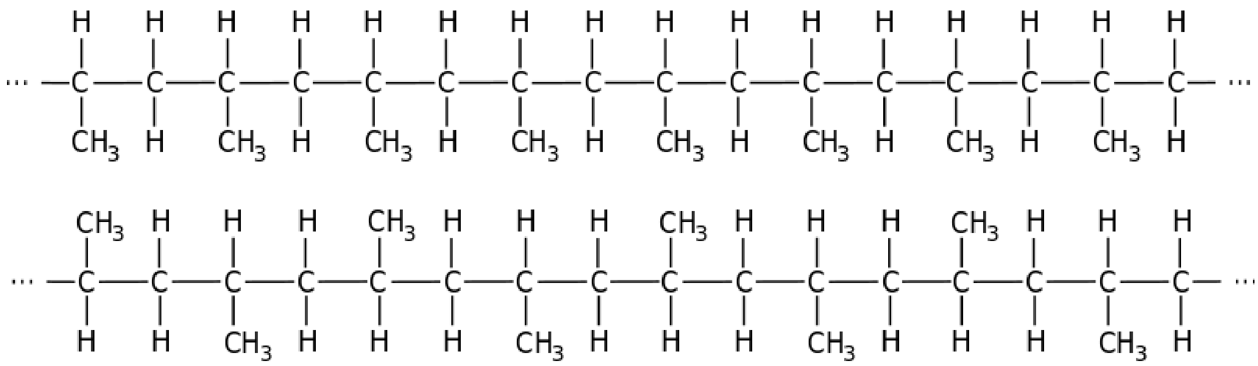

Figure 3.1: Chemical structure of polypropylene

An important concept in understanding the link between the structure of polypropylene and its properties is tacticity. The relative orientation of each methyl group (CH3 in the figure) relative to the methyl groups in neighboring monomer units has a strong effect on the polymer's ability to form crystals. A Ziegler-Natta catalyst is able to restrict linking of monomer molecules to a specific regular orientation, either isotactic, when all methyl groups are positioned at the same side with respect to the backbone of the polymer chain, or syndiotactic, when the positions of the methyl groups alternate. Commercially available isotactic polypropylene is made with two types of Ziegler-Natta catalysts. The first group of the catalysts encompasessolid (mostly supported) catalysts and certain types of soluble metallocene catalysts. Such isotactic macromolecules coil into a helical shape; these helices then line up next to one another to form the crystals that give commercial isotactic polypropylene many of its desirable properties.

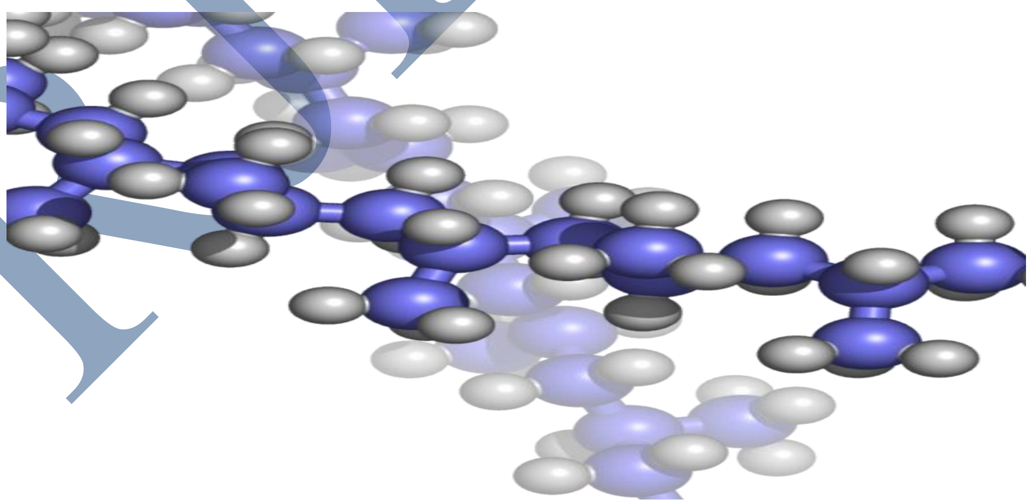

Figure 3.3: Atomic structure of polypropylene

3.2 Industrial Processes

Traditionally, three manufacturing process are the most representative ways to produce polypropylene. Hydrocarbon slurry or suspension: Uses a liquid inert hydrocarbon diluents in the reactor to facilitate transfer of propylene to the catalyst, the removal of heat from the system, the deactivation/removal of the catalyst as well as dissolving the atactic polymer. The range of grades that could be produced was very limited. (The technology has fallen into disuse).

Bulk (or bulk slurry): Uses liquid propylene instead of liquid inert hydrocarbon diluents. The polymer does not dissolve into diluents, but rather rides on the liquid propylene. The formed polymer is withdrawn and any unreacted monomer is flashed off. Gas phase: Uses gaseous propylene in contact with the solid catalyst, resulting in a fluidized-bed medium.

4. MANUFACTURING

Melt processing of polypropylene can be achieved via extrusion and molding. Common extrusion methods include production of melt-blown and spun-bond fibers to form long rolls for future conversion into a wide range of useful products, such as face masks, filters, nappies (diapers) and wipes. The most common shaping technique is injection molding, which is used for partssuch as cups, cutlery, vials, caps, containers, housewares, and automotive partssuch as batteries. The related techniques of blow molding and injection-stretch blow molding are also used, which involve both extrusion and molding. The large number of end-use applications for polypropylene is often possible because of the ability to tailor grades with specific molecular properties and additives during its manufacture. For example, antistatic additives can be added to help polypropylene surfaces resist dust and dirt. Many physical finishing techniques can also be used on polypropylene, such as machining. Surface treatments can be applied to polypropylene parts in order to promote adhesion of printing ink and paints.

4.1 Biaxially Oriented Polypropylene (BOPP)

When polypropylene film is extruded and stretched in both the machine direction and across machine direction it is called biaxially oriented polypropylene. Biaxial orientation increasesstrength and clarity. BOPP is widely used as a packaging material for packaging productssuch assnack foods, fresh produce and confectionery. It is easy to coat, print and laminate to give the required appearance and properties for use as a packaging material. This process is normally called converting. It is normally produced in large rolls which are slit on slitting machines into smaller rolls for use on packaging machines.

4.2 Development Trends

With the increase in the level of performance required for polypropylene quality in recent years, a variety of ideas and contrivances have been integrated into the production process for polypropylene. There are roughly two directions for the specific methods. One is improvement of uniformity of the polymer particles produced using a circulation type reactor, and the other is improvement in the uniformity among polymer particles produced by using a reactor with a narrow retention time distribution.

5. APPLICATION

Polypropylene is used in the manufacturing piping systems; both ones concerned with high-purity and ones designed for strength and rigidity (e.g. those intended for use in potable plumbing, hydronic heating and cooling, and reclaimed water). This material is often chosen for its resistance to corrosion and chemical leaching, its resilience against most forms of physical damage, including impact and freezing, its environmental benefits, and its ability to be joined by heat fusion rather than gluing.

Polypropylene is widely used in ropes, distinctive because they are light enough to float in water.[dead link] For equal mass and construction, polypropylene rope issimilar in strength to polyester rope. Polypropylene costs less than most other synthetic fibers.

Polypropylene is also used as an alternative to polyvinyl chloride (PVC) as insulation for electrical cables for LSZH cable in low-ventilation environments, primarily tunnels. This is because it emits lesssmoke and no toxic halogens, which may lead to production of acid in high-temperature conditions.

Polypropylene is also used in particular roofing membranes as the waterproofing top layer of single-ply systems as opposed to modified-bit systems. Polypropylene is most commonly used for plastic moldings, wherein it is injected into a mold while molten, forming complex shapes at relatively low cost and high volume; examples include bottle tops, bottles, and fittings.

It can also be produced in sheet form, widely used for the production of stationery folders, packaging, and storage boxes. The wide color range, durability, low cost, and resistance to dirt make it ideal as a protective cover for papers and other materials. It is used in Rubik's Cube stickers because of these characteristics. The availability of sheet polypropylene has provided an opportunity for the use of the material by designers. The light-weight, durable, and colorful plastic makes an ideal medium for the creation of light shades, and a number of designs have been developed using interlocking sections to create elaborate designs.

Polypropylene sheets are a popular choice for trading card collectors; these come with pockets (nine for standard-size cards) for the cards to be inserted and are used to protect their condition and are meant to be stored in a binder.

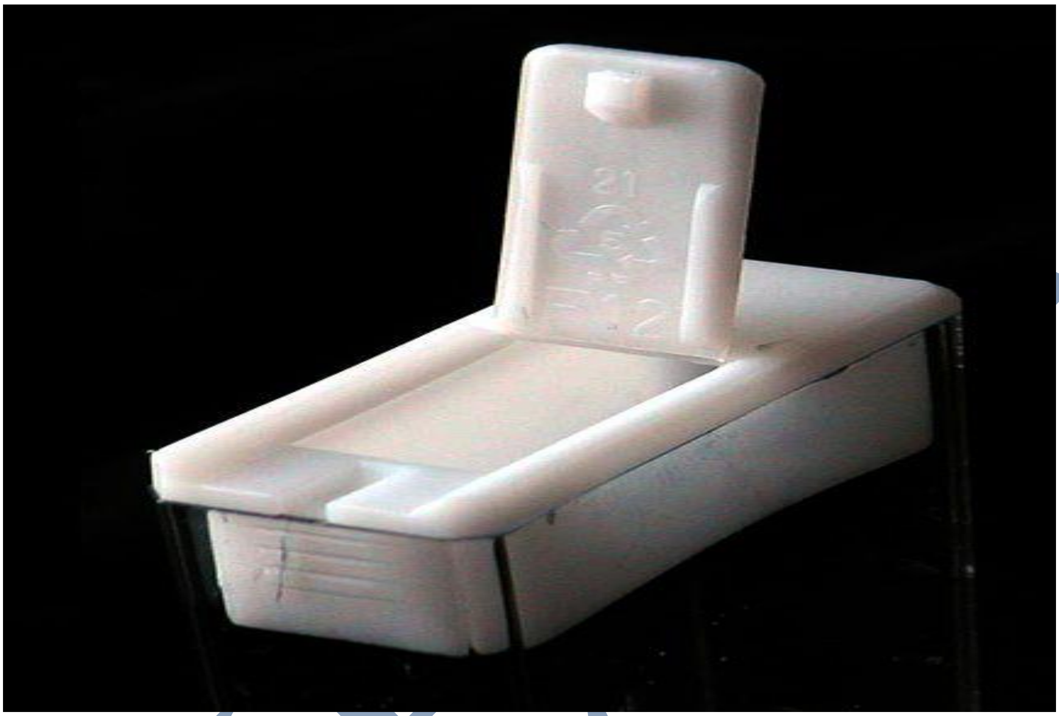

Figure 1.4: Specimen of polypropylene

5.1 Clothing

Polypropylene is a major polymer used in nonwovens, with over 50% used [citation needed] for diapers or sanitary products where it is treated to absorb water (hydrophilic) rather than naturally repelling water (hydrophobic). Other interesting non-woven uses include filters for air, gas, and liquids in which the fibers can be formed into sheets or webs that can be pleated to form cartridges or layers that filter in various efficiencies in the 0.5 to 30 micrometre range. Such applications could be seen in the house as water filters or air-conditioning-type filters. The high surface area and naturally oleophilic polypropylene nonwovens are ideal absorbers of oil spills with the familiar floating barriers near oil spills on rivers.

The material has recently been introduced into the fashion industry through the work of designers such as a nosh Waddington, who have developed specialized techniques to create jewelry and wearable item from polypropylene.

5.2 Medical

Its most common medical use is in the synthetic, non absorbable suture Prolene, manufactured by Ethicon Inc. Polypropylene has been used in hernia and pelvic organ prolapsed repair operations to protect the body from new hernias in the same location. A small patch of the material is placed over the spot of the hernia, below the skin, and is painless and rarely, if ever, rejected by the body. However, a polypropylene mesh will erode over the uncertain period from days to years. Therefore, the FDA has issued several warnings on the use of polypropylene mesh medical kits for certain applications in pelvic organ prolapse, specifically when introduced in close proximity to the vaginal wall due to a continued increase in number of mesh erosions reported by patients over the past few years. Most recently, on 3 January 2012, the FDA ordered 35 manufacturers of these mesh products to study the side effects of these devices.

5.3 Epp Model Aircraft

Since 2001, expanded polypropylene (EPP) foams have been gaining in popularity and in application as a structural material in hobbyist radio control model aircraft. Unlike expanded polystyrene foam (EPS) which is friable and breaks easily on impact, EPP foam is able to absorb kinetic impacts very well without breaking, retains its original shape, and exhibits memory form characteristics which allow it to return to its original shape in a short amount of time. In consequence, a radio-control model whose wings and fuselage are constructed from EPP foam is extremely resilient, and able to absorb impacts that would result in complete destruction of models made from lighter traditional materials, such as balsa or even EPS foams. EPP models, when covered with inexpensive fibre glass impregnated self-adhesive tapes, often exhibit much increased mechanical strength, in conjunction with a lightness and surface finish that rival those of models of the aforementioned types. EPP is also chemically highly inert, permitting the use of a wide variety of different adhesives. EPP can be heat molded, and surfaces can be easily finished with the use of cutting tools and abrasive papers. The principal areas of model making in which EPP has found great acceptance are the fields of:

- Wind-driven slope
- Indoor electric powered profile electric models
- Hand launched gliders for small children

5.4 Market

Following the slumping recession period and the slow revival state during the post-crisis years, the global market for polypropylene isseeing considerable demand increase as the key end-use fields expand production volumes. The total polypropylene market is not expected to witness complete and bashing downs in the coming 5 years: the polypropylene price is high and consumer are looking more rigidly for the material substitutes.

CONCLUSION

The mechanical response of thermoplastic polymer materials is strongly related to their microstructure. Due to the complexity of the molecular and composite structure of these polypropylene compound, making an accurate simulation requires highly well-defined material models. It means the material model should be able to describe the most important features of the material behavior, e.g. for mechanical strain rate, tensile strength, modulus, extension and for thermal heat deflection temperature. It should be noted, however, that with this rather complex material behavior it is often difficult to separate the effect, but however experimental results shows the change with respect to the variation in all the parameters

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