Glossary

Injection Molding of Fiber-Reinforced Plastic

Refer to “Research on Strength Prediction Technology for Fiber-Reinforced Plastic Injection-Molded Products” (page 20)

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1 What is Injection Molding?

Injection molding is a process for forming parts by heating resin and injecting the molten material into a mold. This process enables the stable production of parts of complex geometry at a high-speed cycle. Plastic parts manufactured by this process are used in a variety of fields.

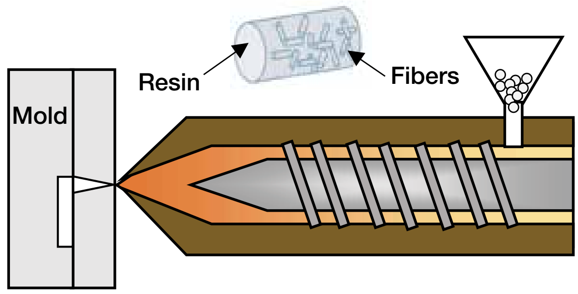

Fig. 1 Schematic of injection molding

2 Features of Injection Molding of Fiber-Reinforced Plastic

The plastic used for structural members is reinforced with glass or carbon fibers to be fiber-reinforced plastic (hereinafter “FRP”) with improved physical properties. Injection-molded FRP is made from resin pellets mixed with three-dimensionally distributed fibers of a length of about 100 μm. Like normal plastic, FRP can also be formed into complex geometries by injection molding (Fig. 1). However, FRP injection-molded parts have fiber orientations (fibers positioned in different orientations) that depend on how the molten resin flowed during the molding process (Fig. 2). FRP is more reinforced in the direction of fiber orientation. This means that the physical properties in the direction parallel to the fiber orientation are different from those in the direction perpendicular to the fiber orientation. This is called “anisotropy of physical properties” and makes it difficult to predict the final quality of parts.

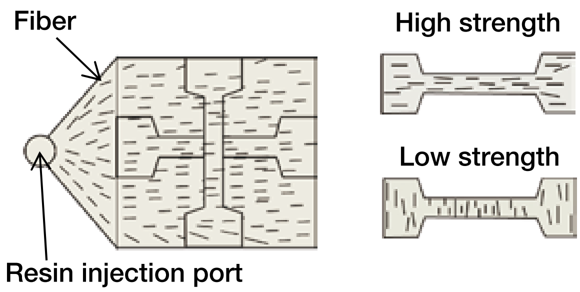

Fig. 2 Overview of anisotropic physical properties

3 Prediction of Anisotropy of Physical Properties

To predict the physical properties of a composite of resin and fibers, an approach called “homogenization” may be used. Homogenization can be used to predict the physical properties of a composite from the physical properties and geometry information of the individual materials, i.e., fibers and resin in this case. Homogenization is thus a concept necessary for predicting the quality of composites. Furthermore, for composites containing a number of distributed short fibers, as seen in injection-molded products, it is necessary to define how many fibers exist in which directions. To this end, a concept called “fiber orientation tensor” is used. Fiber orientation tensor is expressed in three major directions of fiber orientation and the ratio of fibers oriented in the respective directions. For example, a fiber orientation tensor closer to one (1) along an axis indicates that more fibers are oriented aligned along that axis. Thus, fiber orientation tensors can be used to quantitatively define the orientation of a number of fibers distributed in the plastic, thereby enabling the prediction of anisotropy of physical properties of FRP injection-molded parts.

Glossary

PMSM[1)]

Refer to “Characteristic Analysis of High-efficiency Hydraulic System” (page 10)

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1 What is PMSM?

1. 1 Acronym and Structure/Operation

PMSM is an acronym for Permanent Magnet Synchronous Motor. This is a motor that uses magnetic field flux created by permanent magnets to run in synchronization with an alternating-current (AC) power source. PMSMs are classified as AC motors.

1. 2 Classification by Configuration

PMSMs can be divided by magnet arrangement into Surface-mounted PMSM (hereinafter “SPM”) and Interior PMSM (hereinafter “IPM”). These types of PMSM deliver different characteristics from each other depending on the combination with current control methods as described below.

The SPM is suitable for low-speed, large-torque design and can smoothly run with low torque ripples Compared to the IPM, the SPM can deliver liner torque responses against a current and be more easily controlled.

With its higher degree of geometry design freedom, the IPM can be designed to provide specific characteristics tailored to the application. The range of speed at which the IPM can be rotated is higher than that of the SPM.

1. 3 Characteristics

PMSMs can commonly deliver high power efficiency over a wide operating range and output a high power even with small-sized designs. On the other hand, they requires microcomputers and permanent magnets that use rare earth elements, which make PMSMs more expensive than the induction motors widely used in industrial applications. Therefore, PMSMs are suited to applications where downsizing and efficiency enhancement are needed.

2 Varying Properties Depending on Control

2. 1 Control Methods

The PMSM control methods can generally be divided into V/f control (open-loop control) and current vector (hereinafter just “vector”) control (closed-loop control). The former is used in cost-oriented applications and the latter used in performance-oriented ones. This section describes the latter control method.

2. 2 Current Vector Control

On the plane of the d-axis corresponding to the direction of magnet flux (≈ physical angle of the magnets) and the q-axis orthogonal to the d-axis, current components of a three-phase motor are regarded as a vector. A method of controlling the magnitude and angle (= current split ratio between the d-axis and the q-axis) of these components is vector control. The vector can be determined by several approaches including MTPA control and weak field control described in the following.

2. 3 Maximum Torque Per Ampere Control

MTPA control determines the current split ratio so as to achieve the highest possible torque on the assumption that the vector is constant (= constant motor current). This is a basic motor control strategy applied to cases with no limited by voltage or current.

2. 4 Weak Field Control

In a high range of revolutions, the reverse induced voltage increases to reduce available current. Then, a negative d-axis current can be used to cancel the magnet flux, lowering the reverse induced voltage. This expands the range of speeds to drive the motor. This weak field control strategy is applied to cases in the presence of voltage limit.

Reference

1) MORIMOTO Shigeo, INOUE Yukinori: “Basics and Design Method of Drive System for Energy Saving Electric Motors” Kagakujyoho Shuppan Co., Ltd. (November 4, 2019)