Technology Introduction

Technological Development of Mass Production of Injection-Molding Worm Wheel

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1 Introduction

Pinion type Electric Power Steering System (hereafter referred as EPS) is the EPS, which assist mechanism on the pinion shaft. The output torque from an electric motor is increased by a gear reducer and transmitted to pinion (output shaft). Worm wheel is used for this reduction gears (Photo 1). The resin material is used for making tooth of worm wheel in order to reduce the gear meshing sound.

A worm wheel is engaged with the worm in each steering, the contact stress was caused on the tooth base, creating friction on the tooth surface. If a gear is deformed or worn out, the backlash of worm and worm wheel will be increased, causing gear meshing sound. Therefore, excellent strength and wear resistance are required in worm wheel.

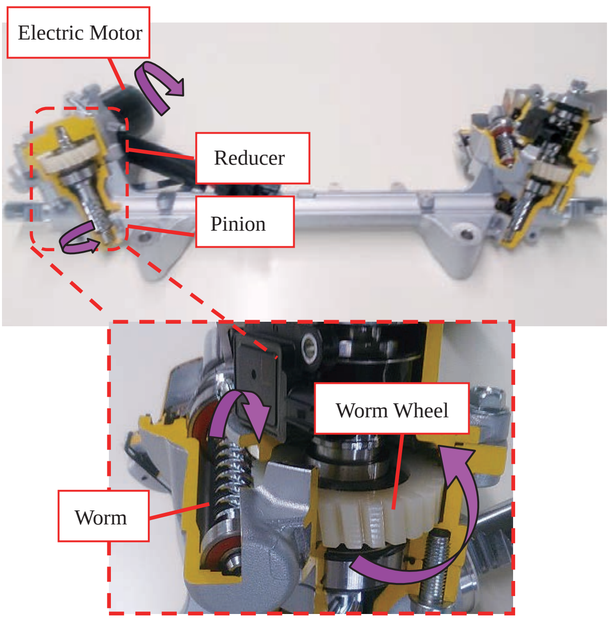

Photo 1 EPS Structure

As well as high product quality, the improvement of the productivity must be ensured to meet demands for cost reduction these days.

Therefore, this section introduces the innovative production line, which was developed to satisfy high quality requirements while ensuring the high productivity.

2 Purpose

Establish a mass production that satisfies all the elements required for functional components, including high strength, durability, and productivity.

3 Objectives

(1) Inner defect rate 0%
(2) Ensure resin material properties that meet required strength.
(3) Operational Availability 85 % or greater

4 Description of Applicable Product

The worm wheel, which is object of this project, consists of a resin made tooth and a metallic core bar (Fig. 1).

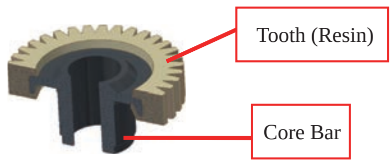

Fig. 1 Cross Section of Worm Wheel

5 Overview of Production Line

5.1 Process Flow

Process flow developed for Injection molding line is shown in Fig. 2.

In order to achieve high quality and productivity, the

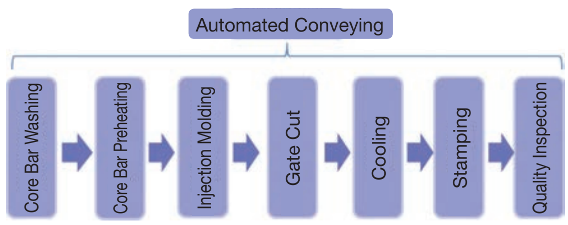

Fig. 2 ProcessFlow

production line was developed based on the fundamental philosophy described as follows.

5.2 Quality

(1) Defect occurrence prevention
Determine the manufacturing control conditions that can ensure the targeted quality.

(2) Defect outflow prevention
When defect occurs, automatically dispose the defective parts, avoid decision making by an operator, and prevent the defect outflow.

(3) Traceability System Development
The traceability system should be developed, which enables tracking the impact range in a short time when defects occurs after market introduction.

5.3 Productivity

(1) Automation
A self-driving robot is used to convey workpieces between presses in order to reduce conveyance loss and variation.

(2) Multi-product manufacturing
Measures effective to reduce change-over time should be taken to ensure the operational availability thorough multi-product manufacturing.

The description and result of development is partly described as follows.

6 Descriptions and Results of Development

6.1 Thermal stability of core bar

When changes in resin filling properties occurs due to fluctuations in core bar temperature, there will be a possibility of dimensional variation. Therefore, the relationship between the temperature of the core bar during molding and its quality was examined, and the temperature range wherein the variation in dimensional change is suppressed (Fig. 3).

In order to maintain the core bar temperature within the targeted range, a preheater, which offers the low-frequency induction heating method was installed. Thereby, a rapid and uniform heating were also achieved. This method can be used for a core different in shape by changing the heating conditions, and the need of changing set-up, such as coil exchange, was eliminated.

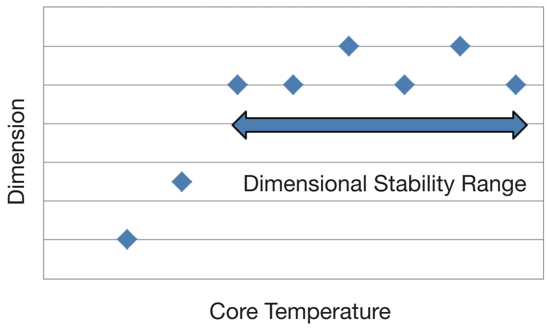

Fig. 3 Relationship Between Core BarTemperatureand Dimension

6.2 Injection Molding

Injection molding is a manufacturing process whereby the molten resin is injected into a mold, and then cooled and solidified. It is suited for high volume production of complex shaped parts. Injection molding machine is shown in Photo 2.

The molded products by injection molding vary in their size, appearance, and strength due to differences in melting temperature, injection speed, and injection pressure.

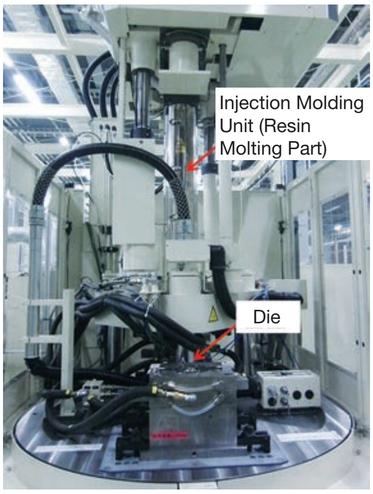

Photo 2 Appearance of Injection Molding Machine

6.2.1 Balancing Inner Defect Prevention and Cycle time

Earlier in development, air bubbles were formed in the resin. The temperature profile during injection was examined, using flow analysis in order to determine the cause of air bubbles (Fig. 4).

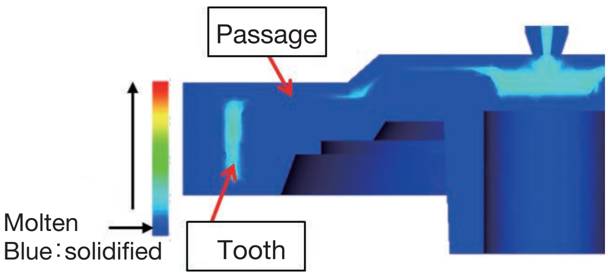

Fig. 4 Temperature Profile During Injection

Since a resin was first solidified in a flow passage half way to the tooth, the sufficient resin was not filled into the tooth, causing air bubbles. The injection molding condition was optimized in order to delay the solidification in the flow passage, and the delay of the solidification in the flow passage was confirmed by the temperature profile (Fig. 5). When manufacturing under optimum molding conditions, the air bubbles were prevented.

The multistage control of the injection speed and injection pressure enables the air bubble prevention and shorter cycle time.

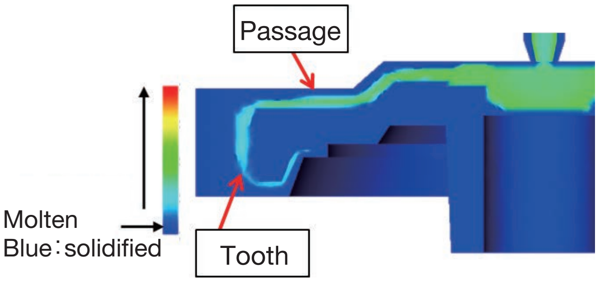

Fig. 5 Temperature Profile During Injection (After Injection molding conditions optimized)

6.2.2 Management of Quality Requirements

The injection molded products vary in their strength and size due to differences in the temperatures of resin and dies even if the same material is used. This is similar to the metallic materials, which vary in their mechanical properties after their system and crystal structure are changed in the processes of machining and heat treatment. Considering the above, the correlation between molding conditions and the overall quality is clarified, centering the resin material properties. The schematic chart is shown in Fig. 6.

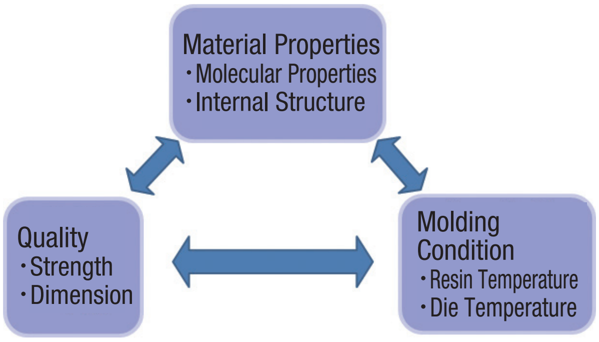

Fig. 6 Schematic Chart of Injection Molding

Determination method for the control value of molding condition which can meet the required strength is described in this report.

First, the relationship between strength and material properties is examined to determine the material properties that can meet the required strength.

Then, the impact to the material properties upon changes in the molding condition was observed to determine the control value of conditions, which satisfies the target value. Example of resin temperature is shown in Fig. 7.

The control items such as the resin temperature are monitored for each mold shot during production. If values do not go beyond a given control range, the product will be disposed into NG chute automatically by a self-driving robot. This can prevent prevent the defect outflow.

Moreover, the serial numbers associated with the above mentioned control item data was stamped on each molded product. This allows confirmation of each molding conditions.

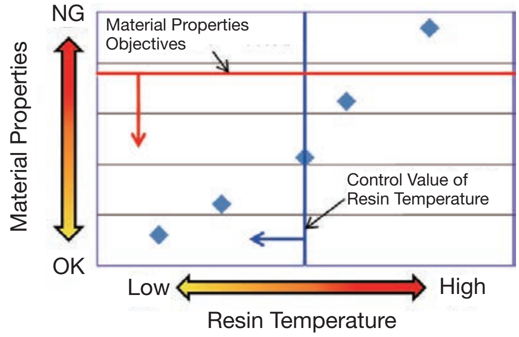

Fig. 7 Relationship Between Material properties and Resin Temperature

6.2.3 The reduction of time and material loss after stoppage of equipment

Once the equipment stops, the molten material inside injection unit will be deteriorated by heat, resulting in the strength reduction of the molded product . In such case, the deteriorated resin is typically purged by test shot. However, excessive test shooting may cause the decrease in operational availability and material loss.

The level of strength resulting from machine downtime was examined to determine the downtime that would not adversely affect strength and a required purge resin amount.

In the event of an abnormal stop, the downtime measurement will be automatically started. A mechanism was developed for, when a downtime exceeds the specified time period, automatically purging an amount of resin that was determined from the total amount of downtime, and then starting re-operation.

Thereby, an accidental outflow to a subsequent process of a mold product, which contains the deteriorated resin and excessive test shooting were eliminated and both high quality and operational availability were achieved.

6.3 Development in Gate Cut Method

The gate cut method wherein a gate portion (Fig. 8) is cut and removed after molding would cause an equipment abnormality due to resin chips, blade wear, and variations of shape generated during machining process. A highly reliable gate cut method was newly developed.

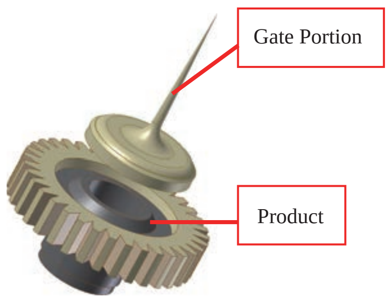

Fig. 8 Gate Cut Portion

By step-feeding, Note 1) resin chips which were generated during machining process were sequentially parted into more fine chips, and recovered by air blowing and vacuuming in order to prevent winding of the chips on a blade.

Note 1) The feeding method that enables a blade moving back to the mouth of hole after cutting a certain amount.

By monitoring the load torque of a shaft, the points of blade contact on the core during machining process was detected, and the detection signal was utilized as an operation completion signal (Fig. 9). Thereby, the variations in work dimension and in shape, which is resulted from blade wear were eliminated to prevent the stoppage of equipment caused by the gate remaining. Moreover, the blade wear was mitigated by reducing the core cutting portion.

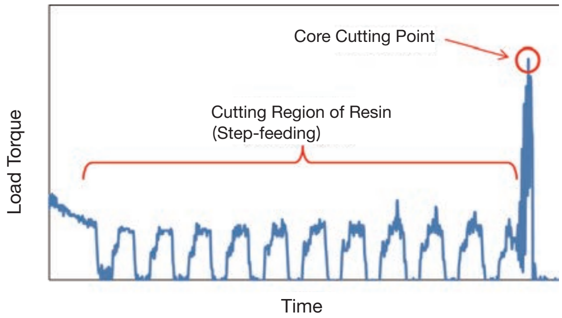

Fig. 9 Load torque of Shaft During Gate Cutting

6.4 Change-Over Time Reduction in Multi-Product Manufacturing

In order to achieve high productivity in multi-product manufacturing, the change-over time must be reduced.

Measures used to reduce the change-over time are described as follows:

(1) Reduce die changing time

For an injection molding machine, a die exchange is required based on the product shapes. The die structure that enable the shortening of the exchange time was developed, and the setup time was significantly reduced.

(2) Commonize parts shape

By using a part with a same shape, where technically feasible, during design phase, the setup work involved in die exchange for each product shape was minimized as far as possible.

(3) Incorporate into equipment and process specifications

In order to reduce setup time losses, the method and equipment that can be utilized only by changing machining condition, and the system wherein data, typically machining condition, is automatically changed under communication between robots and controlling facilities were incorporated as new features in specifications.

7 Achievements

(1) Inner defect rate 0%

(2) Determination of manufacturing conditions, which can ensure the material properties.

(3) Operational availability 88%

8 In Closing

The mass production line of resin mechanical component where high strength is required was successfully developed. The automated line that enable the multi-product manufacturing, and the facilities that provide the determination of abnormality and recovery system controlled by facilities are developed, achieving the high quality.

I would like to make continuous effort to contribute in improvement of resin processing technologies, that allows the weight reduction by using resin product for metal replacement, and the achievement of higher function and lower cost.

At last, I would like to take this opportunity to express my sincere gratitude to the relevant parties for their cooperation for this project from the start to the end.

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