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Design of Rubber Injection Molding Mold for Windshield in High-Speed EMU

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Abstract

This paper takes the rubber parts of the wind shield inside the high-speed train as the research object. Through the in-depth analysis of structure of the rubber parts of the wind shield inside the high-speed train, the rubber materials are reasonably selected, and the overall structure, pouring system, cooling system, demould mechanism, the selection of parting surface and the sequence of mold opening of the injection molding die are set. Four injection schemes with the number of injection ports of 12 14, 16 and 18 are designed. In order to achieve balanced filling and minimize defects, the design scheme with 16 injection ports is selected as appropriate scheme. The gate position of the mold is determined. The qualified rate of the rubber parts of the inner wind shield is improved, and the reliable technical guarantee is provided for the of the rubber parts of the inner wind shield of the high-speed train.

Keywords

High-Speed Railway EMU, Inner Windshield, Rubber Injection Molding, Mold Design, Process Parameters

1. Introduction

High-speed railway is one important mode of modern transportation, with its high-speed, efficient, comfortable and other features, the rubber inner wind shield is part of the flexible connection of the high-speed train body, and the product quality is strictly required. The main structure of the rubber inner windshield is a circular rubber part with a U-shaped section opening inward, which has higher requirements for the molding process. At present, there are two kinds of molding methods: compression molding and injection molding. However, it is very easy to appear bubbles, lack glue and uneven quality in the production of large parts by compression molding, so the injection molding is mainly used to produce large

and complex parts. In our country, the technology injection molding for large and complex rubber parts is less studied, especially the research of injection molding dies. Therefore, the design and research of the inner windshield rubber injection molding mold of high-speed rail EMU is of great practical significance for improving the production quality and efficiency of the inner windshield rubber parts and ensuring the safety and comfort of high-speed rail operation [1]-[7].

Therefore, this paper takes the rubber inner windshield injection molding mold of high-speed train as the research object, Pro/E software is used to carry out three-dimensional structure design of the rubber injection mold, Moldflow software is used to analyze the Moldflow, and its injection parameters are optimized by combining computer simulation technology and orthogonal experiment method. To determine the optimal injection molding scheme, Moldflow software was employed for simulation and verification. This study provides a reference for advancing the molding technology of large and complex parts [8]-[13].

2. Analysis of Rubber Parts of the Wind Shield inside the High-Speed Rail EMU

2.1. Analysis of Rubber Parts of Inner Windshield

During the operation of high-speed rail EMU's, the rubber parts of the inner windshield need to withstand a variety of complex working conditions. When running at high speed, the inner windshield should be able to effectively block the intrusion of external air flow, ensure the stability of the air pressure in the carriage, and avoid the discomfort of passengers due to air pressure fluctuations (**Figure 1**) [14]-[18].

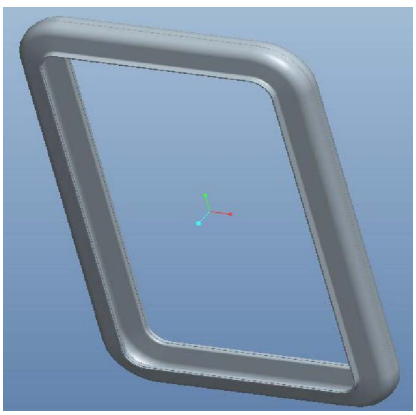

Figure 1. Three-dimensional diagram of the inner wind shield of the high-speed EMU.

From the performance point of view, the rubber parts of the inner windshield should have excellent weather resistance, and can be used for a long time under different climatic conditions without aging, cracking and other phenomena. At the same time, it should have good wear resistance and tear resistance to cope with frequent friction and stretching during train operation. In addition, the elastic and compressive permanent deformation properties of rubber parts are also crucial,

and should be able to maintain a stable sealing performance during a long time of use, so according to the requirements to judge the material performance has the following parameters: temperature −40˚C - +40˚C; The flammability grade of the main material is S3 the smoke grade is SR2, and the droppability grade is ST2; its hardness (A)is 65 + 5; Tensile strength(MPa) ≥11.8; Elongation at break (%)≥450.

2.2. Selection of Rubber Materials

Based on the functional and performance requirements of the inner windshield rubber parts, and considering the characteristics of various rubber materials, EPDM was finally as the manufacturing material for the inner windshield rubber parts. EPDM has the following excellent performance characteristics:

1) Weather resistance: Excellent resistance to ultraviolet rays, ozone and climate change, it can be used for a long time in harsh outdoor environments without obvious aging phenomena. The operating temperature is −40˚C - 40˚C, theammability rating is S3, and the smoke rating is SR2.

2) Chemical corrosion resistance: It has good tolerance to most chemicals and can effectively resist the erosion chemical substances such as acid and alkali. The dripping rating is ST2.

3) Elasticity and compression permanent deformation performance: It has good elasticity and low permanent deformation, and can maintain stable sealing performance during long-term compression and stretching. Its hardness (A) is 65 ± 5, tensile strength (MPa) ≥11.8; elongation at break (%) ≥450.

4) Processing performance: EPDM has good processing performance and is suitable for by injection molding process, which can meet the requirements of large-scale industrial production.

3. Injection Molding Mold Design

3.1. Overall Mold Structure Design

In view of the complex structure and production requirements of the windshield rubber parts, the mold adopts a double-separation surface injection mold structure (a double separation surface injection mold structure can complete the forced demoulding of undercuts, automatic separation of gates, and multi-stage push-out control, which is suitable for complex plastic parts). The locking device connects the upper mold of the mold to the casting system, and the cold runner is separated by an insulator plate, and the precise positioning is realized a trapezoidal block and a core mold, and the heating pipe hole is evenly distributed in the upper mold, and the mold is heated through an electric heating pipe during rubber molding. There are 20 U-shaped blocks evenly distributed on the upper and lower sides of the upper mold, which can be firmly connected with the upper hot plate and lower mold through bolts, which is convenient for installation and commissioning. The gate is evenly distributed on the outside of the inner windshield, and the rubber is uniformly injected from the symmet center of the outside of the inner windshield during injection molding (**Figure 2**).

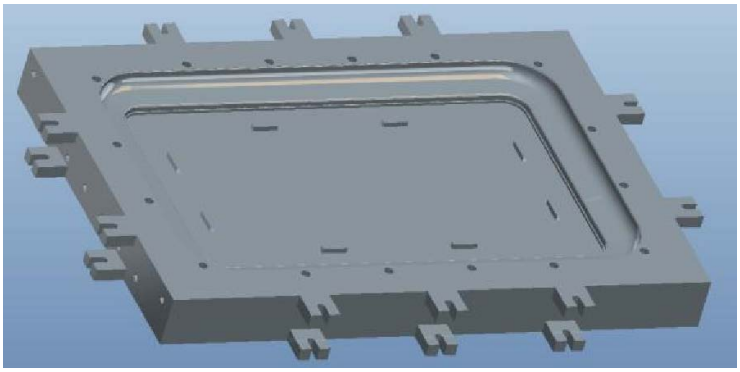

Figure 2. Overall structure of the upper die of the mold.

The lower die of the mold is connected to the lower hot plate by a locking device during injection molding, and is precisely positioned between the trapezoid block and the mandrel. The hole of the heating tube is evenly distributed in the lower die, and the electric heating tube is used to heat the mold during rubber injection molding. The upper and lower sides of the lower die are distributed with 20 U-shaped blocks, which can be closely connected with the lower hot plate and the upper die by bolts, convenient installation and debugging. There are 8 channels uniformly arranged in the inner cavity of the lower die. When opening the die, the top rod will top the core die through the form of a ladder shaft in this channel.

To realize the separation of the lower die and the mandrel (**Figure 3**).

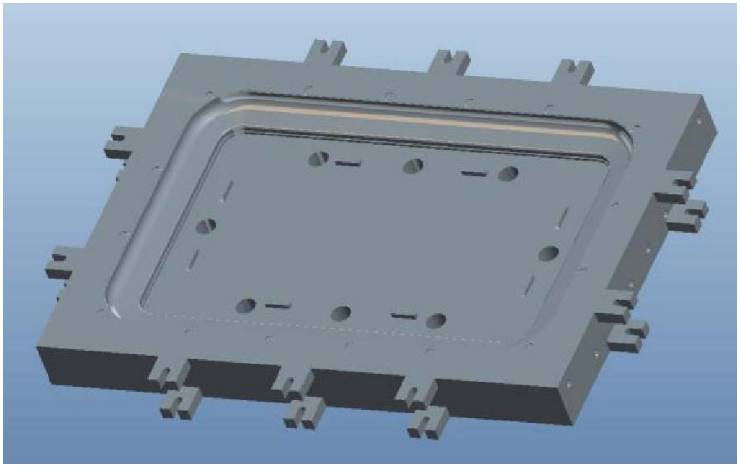

Figure 3. Overall structure of the lower die.

A lateral core-pulling mechanism is used in the mold to form the lateral holes and grooves on the rubber parts of the inner windshield. The lateral core. pulling mechanism is composed of a slide block, a inclined guide post and a wedge block. In the process of mold opening, the inclined guide column drives the slider to move along the side direction to realize the side core-pulling action; In the process of closing the mold, the wedge compact block will tightly press the slider to prevent the slider from displacing during the injection process (**Figure 4**).

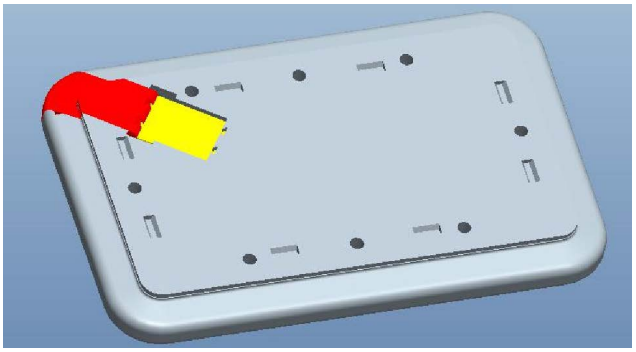

Figure 4. Overall structure of the mandrel.

3.2. Gating System Design

The design of pouring system is the key to ensure that the rubber material can fill the mold cavity evenly and quickly. The casting system of the mold adopts the suspension nozzle of the cold flow channel to insert the mold pouring mouth precisely, and the rubber material enters the pouring channel from the bottom groove. During injection molding, the rubber material is injected from the center of the product symmetry, evenly filled to both sides until it is full of cavity, mainly including the main channel, hot runner plate, diverter channel, gate and cold hole and other parts. The main channel adopts a conical structure, and its taper is 3˚ - 5˚ to reduce the resistance of rubber materials in the flow process. A heating device is arranged inside the hot runner plate, which can maintain the temperature of the rubber material in the flow process and avoid the solidification of the rubber material in the flow channel (Figure 5).

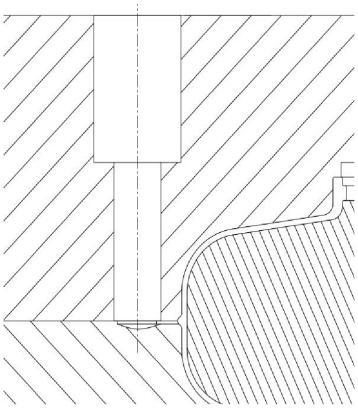

Figure 5. Design of pouring gate.

4. Moldflow Analysis of Gate Position

4.1. Moldflow Analysis Before Processing

1) Click on the new project in the Moldflow software, and import the 3D model of the windshield inside the high-speed train. The grid tool that comes with Moldflow was used. The matching rate of the surface mesh model is not less than 85% after meshing according to the requirements.

2) Mesh division, click the mesh division tool in Moldflow, select the double-layer mesh, set the global mesh side length to 20 mm, and set the combined tolerance to 0.5mm.Check the matching grid and calculate the thickness of the double-layer grid, open the grid statistics after the division, see the basic situation of the grid, the initial grid aspect ratio is relatively large, so it should be repaired.

3) Click [Grid]--[Grid repair wizard], forward to select the target aspect ratio, enter 6, click repair. Then repair manually, by merging nodes, moving nodes, etc., until the satisfactory result is obtained.

4.2. Determining the Range of Process Parameters

After determining the value range of the injection process parameters of the rubber inner windshield, it can be convenient to optimize the injection process parameters later. The recommended mold temperature of EPD rubberP127T910 produced by CSA Lillebonne company selected in this paper is 195˚C, and its temperature range is 185˚C - 205˚C. The melt temperature of EPDM rubber of P127T910 is 65˚C - 75˚C, and the melt temperature of this topic is temporarily set at 70˚C.

4.3. Determining the Location of the Gate

According to the structure of the rubber inner windshield, this topic proposes to open the injection port of the inner windshield at the symmetrical center of the U-shaped section of the inner windshield, and fill the two sides of the U-shaped from the middle. According to the volume of the rubber inner windshield and the injection parameters of the rubber injection molding machine, four kinds of gate arrangement injection schemes are preliminarily set up. The number of injection gates is 12, 14, 16 and 18 respectively. Each scheme adopts the principle of uniform distribution, so that each gate is around the product for a week, and the product is evenly divided.

4.4. Simulation of Injection Scheme

After the gate position is designed, the simulation results of the four design schemes are analyzed, so as to compare the advantages and disadvantages of each scheme, and determine the optimal choice of the number and position of the gate under the same process parameters.

1) Filling time: After the injection time is set to 100 s, the injection molding system will adjust the injection rate according to the injection time. After 100 s, the rubber material may not fill the mold cavity, and the injection pressure needs to be maintained to make the rubber material completely fill the mold cavity. The time that the glue material can completely fill the mold cavity is called the filling time. Due to the possibility of glue burning, blockage will be formed in the mold cavity, and the mold cavity will not be filled. Maintaining the injection pressure will make the pressure in the mold cavity continue to rise. until the pressure in the mold cavity exceeds the set maximum clamping force of the injection molding

machine, the filling stage will end, and the filling time will be recorded. And this inability to fill the situation also represents the unreasonable design of the program, need to be excluded.

2) Cavitation is a very common defect in the rubber injection molding process. Air pockets will directly affect the quality of injection molding products, so preventing the generation of air pockets and reducing the number of air pockets is an important work in the design of injection molds. Due to the huge volume of the rubber inner windshield, multiple sprue must be injected at the same time during injection molding, which improves the overall injection rate and also increases the probability of air pockets.

3) Fuse connection

Due to the huge volume of the rubber inner windshield, multiple gates must be injected at the same time when injection molding, which improves the injection rate of the whole body but also increases the number of fuse lines. The rubber material flowing into each gate will be cut at the junction, resulting in a change in temperature, and resulting in a change in the mechanical properties of the rubber material at the position, which affects the fusion of the rubber material and forms a fuse wire, so that the texture of the molded product is not uniform. The position of the fuse wire is also the most prone to surface defects in the injection molding products.

According to grid division, material selection, process parameters setting, simulation analysis, etc. According to the principle of uniform distribution, four kinds of gate position arrangement schemes are preliminarily designed. After the gate position is determined, the Moldflow analysis is carried out, and the filling time and the number of cavitation generated in the injection molding process are analyzed, and the pros and cons of the four schemes are judged. the best scheme is selected, and the optimal choice of the number and position of the gate is determined under the same process parameters. According to the results of Moldflow analysis, the final choice of 16 injection port design scheme.

5. Summary

This paper analyzes the shape and size of rubber products, and determines the required injection pressure, clamping force, and the size of the hot plate etc. Through the analysis of the specific structure of the inner windshield of the rubber, the product material and the various parameters of the material are determined, and the parting surface is determined; the structure of the rubber injection molding die is designed, etc. The main structure of the mold is divided into upper mold, lower mold and core mold. And the of the mold core is innovatively designed to solve the problem of difficult demoulding of the product after molding. According to the structure of the inner windshield of the rubber, gate layout schemes are designed, and the Moldflow software is used to perform mold flow analysis on the injection process of the inner windshield of the rubber. According to the results of the flow analysis, the four gate layout schemes are compared. 16

gate design fill time of 103 s material filled the mold cavity is more reasonable, the number of flash is small, the quality of the product is good, and the position of the weld line is reasonable. Thus, the design scheme of 16 injection ports is selected the most appropriate scheme.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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