A Study of Ceramic Injection Molding of Watch Case Composed of ZrO_2 Powder

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Abstract

This study is focused on the manufacturing technique of powder injection molding of watch case made from zirconia powder. A series of computer simulation processes were applied to the prediction of the flow pattern in the inside of the mould and defects as weld-line. The material properties of melted feedstock, including the PVT graph and thermal viscosity flowage properties were measured to obtain the input data to be used in a computer simulation. Also, a molding experiment was conducted and the results of the experiment showed a good agreement with the simulation results for flow pattern and weld line location. On the other hand, gravity and inertia effects have an influence on the velocity of the melt front because of the high density of ceramic powder particles during powder injection molding in comparison with polymer's injection molding process. In the experiment, the position of the melt front was compared with the upper gate and lower gate positions. The gravity and inertia effect could be confirmed in the experimental results.

Keywords : Powder injection molding, computer simulation, Zirconia, weld-line, flow pattern

1. Introduction

This study is focused on the manufacturing technique of powder injection molding of watch cases made from zirconia powder. A series of computer simulation processes were applied to the prediction of the flow pattern in the inside of the mould, defects as weld line and to give a computational visualization in the injection molding process. The material properties of melted feedstock as like PVT properties and thermal viscosity had been measured to obtain the input data for computer simulation. An injection molding experiment has been conducted to evaluate not only the accuracy of analyzed material properties but also the accuracy of the simulation results for flow pattern, filling velocity and the location of the weld line.

2. Experimental Procedure

The zirconia watch case configured 3D shape is required to precision dimensions in addition to superior external appearance. The Experimental injection machine is used the NEX500 model, maximum injection pressure 255MPa made in NISSEI co. ltd.. The device is developed for using feedstock compound with ceramic or metal powder and binder. The anti-wear and corrosion-resisting surface treatment is conducted on the screw and cylinder, the parts of the injection machine.

Table 1. Injection molding conditions for the experiment and simulation

Injection pressure	Holding pressure	Injection temp.	Mold temp.	Injection time
900 [kgf/cm^2]	750 [kgf/cm^2]	200 [℃]	40 [℃]	1.07 [sec]

Table 1 shows the injection molding conditions used in the experiment. The conditions of table 1 are in accord with the conditions used in the simulation. The injection conditions of Table 1 are based on simulation results using material properties data of the zirconia feedstock. Figure 1 shows PVT graph measured from material property testing respectively.

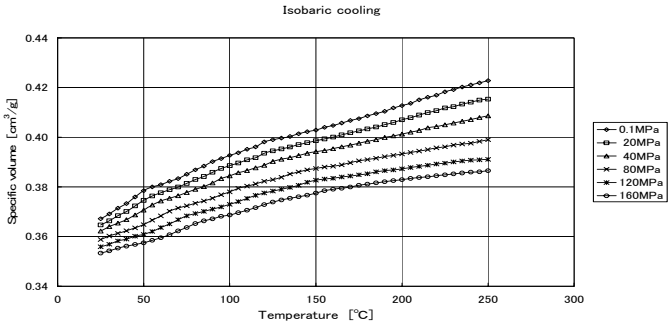

Fig. 1. PVTgraph measured by material property tests.

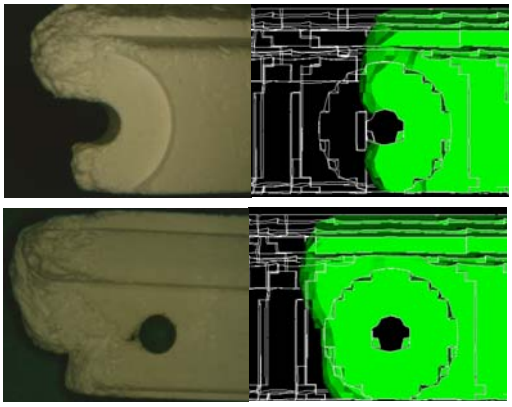

Fig. 2. Comparison with experiment and simulation results about flow pattern around hole for pin.

3. Simulation and Experimental Results

The 3D-Timon^{TM}, developed by Toray co. ltd., was used as a three dimensional analysis tool for powder injection molding simulation. The analysis of material flow, holding pressure, cooling and warpage process is accomplished after the creation of finite elements with hexa mesh type in the element creation module of 3D-Timon. In this section, we discuss on the simulation and experimental results predicted for flow pattern, location of weld line, shear stress distribution and so on. Also, the status of the melt front was made use of the observation of the gravity effect on flow pattern by means of changing the flow direction of the melting feedstock in both cases, down to up side and up to down side.

It has been introduced the experiment and simulation results for flow pattern of zirconia feedstock pass away the delivery system as like sprue, runner and gate. In the experiment, injection time could be adjusted by regulating the velocity-pressure converting position of the injection machine. Through the samples picked by regular step of injection time, the status of the melt front is observed. Fig. 4 shows the results for shear stress distribution calculated from the simulation. It is possible to make defects on surface of products if the shear stress becomes high when the melting feedstock goes into the cavity through the delivery system. The surface of samples was considered suitable because the maximum shear stress was 0.4MPa from the simulation results.

The flow pattern around the pin hole of the watch case has been compared with the experiment and simulation results. It could be confirmed that flow velocity on the upper side of the pin hole was faster than the lower side of the pin hole from both result(Fig. 2). From Fig. 2, it can be seen that the simulation results showed some discrepancy of velocity on both sides when compared with the experimental results.

The weld line often occur when melting feedstock joins again at the junction of the two flow of melting feedstock because the temperature of the melt front is lower than the temperature of inside the melting feedstock. Fig. 3 shows the location of the weld line predicted by simulation and experimental results. It is shown that the location of the weld line could be accurately predicted by using the computational simulation.

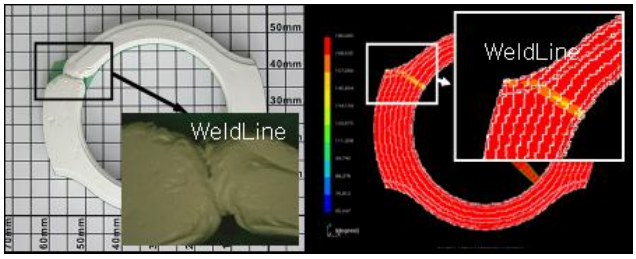

Fig. 3. Weld line location by experiment(left) and weld line location predicted by simulation(right).

It is known that powder injection molding is influenced by gravity or inertia on the filling process. An experiment has been also conducted to verify the gravity effect by utilizing the turnover of gate positions from the lower side to the upper side by means of a 180-degree turn of the mould in the injection machine. Fig. 8 shows the experimental results compared to the simulation results. The experiment shows that the upper gate fills first and then the lower gate.

4. Summary

1) An accurate prediction to ascertain the location of weld line, by using a computer simulation of the powder injection molding process, was made.
2) It has been confirmed that the experimental flow pattern was in good agreement with the results of the computer simulation.
3) It has been suggested that a gravity effect exists in the filliing process because of the discrepancy in the velocity of the melt front that was revealed in the experiment when the gate position changed from the upper to lower side.

5. References

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