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Optimised Design of Mould for Vehicle Throttle Body Bracket Based on CAE

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ABSTRACT:
The throttle body bracket is a structure to support and fix the throttle body. Its quality not only affects the performance of the throttle body, but also affects the running performance of car. Excellent mould is important guarantee for quality of the throttle body bracket. In this paper, mould of vehicle throttle body bracket is taken as research object. Methods combining structural design, simulation analysis with optimization design are adopted. First, process and structure of the bracket are analysed. Three plate mould structure and single-impression layout are determined. Based on mould flow optimization analysis, gate type and location are selected, structural dimensions of forming parts are calculated to design the side core pulling mechanism, remoulding mechanism and cooling system. Simulation analysis for filling time, weld line location, cavitation, cooling effect and warpage deformation are carried out by CAE to realise the optimal design of mould for the throttle body bracket.

KEYWORDS:
Vehicle; Throttle body; Bracket; Mould flow analysis; Mould; Optimization

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1. Introduction

Towards increased emphasis to environmental protection, energy shortage, energy conservation and other issues, the fuel consumption and exhaust emissions of vehicles have been given more and more attention by people. Low fuel consumption and exhaust emissions have become one of important factors that people consider when buying and using cars. In order to get this goal, vehicle companies have taken various measures, among which the most effective one is to realize lightweight vehicle. If the weight of whole vehicle is reduced by 100kg, the fuel consumption can save about 0.45L/100km and carbon dioxide emission can reduce 800-1100g/100km [1]. The lightweight vehicle can be realised using lightweight materials, body structure optimization design and manufacturing technology innovation [2]. Among them, the development of lightweight materials is overall demand of current vehicle industry. Plastic has become the preferred material for lightweight vehicle and the trend of "replacing steel with plastic" in vehicle industry is more and more obvious [3-4].

As an important part of vehicle, the throttle body bracket is mostly produced by injection moulding with high-quality plastic PPS. In the process of injection moulding, unreasonable mould design, improper moulding conditions and equipment selection often lead to defects, thus affects appearance quality and performance of the bracket. In order to prevent occurrence of defects and improve quality of the bracket, CAE technology is widely used in the design and manufacturing process of the bracket. In the design process, through CAE analysis, the defects of the bracket can be predicted in advance and solved through design optimization [5-8]. In this paper, through mould flow analysis, the gate type, side core pulling mechanism, demoulding mechanism and other structure forms of the vehicle throttle body bracket are determined using CAE. The possible defects in forming process are solved. The mould structure and shape design are completed and the optimal design of mould for vehicle throttle body bracket is realized.

2. Process analysis

The structure of throttle body bracket is shown in Fig. 1. The whole structure is symmetrically distributed along axial direction, relatively complex and small. Overall dimension is 90mm×79mm×95mm and the wall thickness is 4.5mm. Four bosses with threaded holes are symmetrically distributed at four corners. There are two side buckles on the sides of the bracket. The accuracy grade of the bracket is MT4. The mould accuracy is 2 levels higher than that of the bracket.

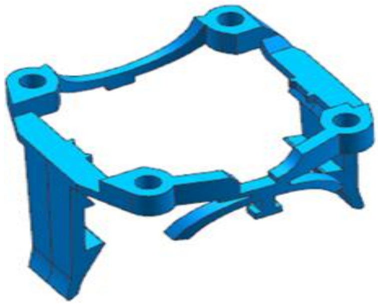

Fig. 1(a): Structure of throttle body bracket

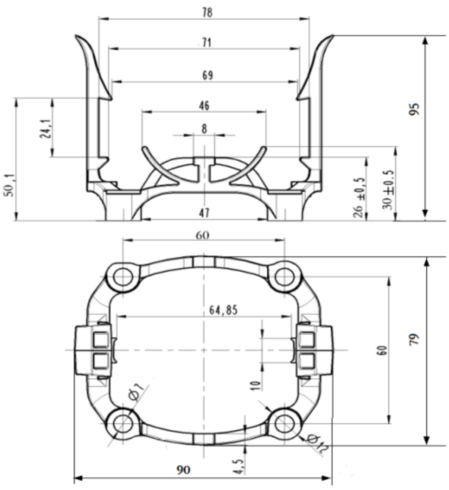

Fig. 1(b): Dimensions of throttle body bracket

The surface roughness of mould is 1 level higher than that of the bracket [9]. The bracket material is PPS. Shrinkage is 0.6% and density is 1.36g/cm^3. The unspecified fillet R is determined by design and draft angle of 0.5° - 2° is allowed. The bracket requires good surface quality, good dimensional stability and small deformation. From analysis of the bracket structure, the following difficulties are observed in the mould design:

(1) The bracket belongs to thin shell structure with uniform wall thickness, but because there are two relatively high claws and many corners, the loss of injection pressure and injection temperature is large, which will be difficult to fill the mould at the bracket end during injection moulding and wall thickness change at the corner is easy to produce cavitation [10].

(2) There are two side buckles with 25.1mm length on the side of the bracket and the side core pulling mechanism is required for the mould.

(3) The upper surface of the bracket is irregular, with both plane structure and arc structure and the height is inconsistent, so it is difficult to set the ejecting mechanism.

3. Mould design

The accuracy of the bracket is relatively high single-impression layout is selected considering production efficiency and bracket quality. The parting surface is selected at maximum profile, shown in Fig. 2. The design of feed system has a great influence on the plastic parts. Combining with structure, precision and demoulding characteristics of the bracket, the pin-point gate is selected as the gate type and the gate location is determined using Mouldflow. In Mouldflow, the analysis type is set as the best gate, material is PPS, melt temperature is 290°, mould surface temperature is 130°, injection machine selects 200T. Mouldflow result of the best gate position is shown in Fig. 3. Blue part and its vicinity are the best gate positions. Both the spur and runner adopt conical structure and the runner adopts a balanced layout as shown in Fig. 4. The bracket size is not large and the accuracy is relatively high, so the whole embedded cavity structure is adopted in cavity and a combined core structure is adopted in core as shown in Fig. 5. Since there are two side buckles with 25.1mm length on the side of the bracket, two side core pulling mechanisms are set on both sides of the mould, as shown in Fig. 6.

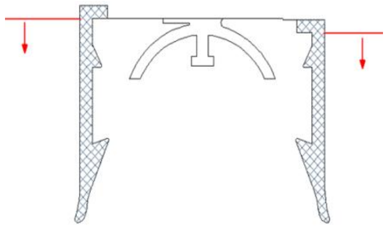

Fig. 2: Parting surface

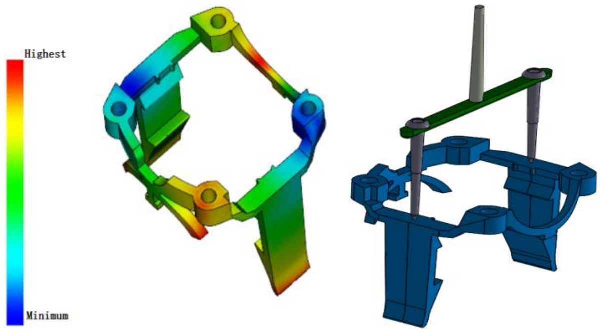

Fig. 3: Best gate positions

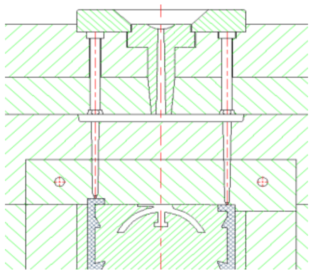

Fig. 4: Balanced layout runner

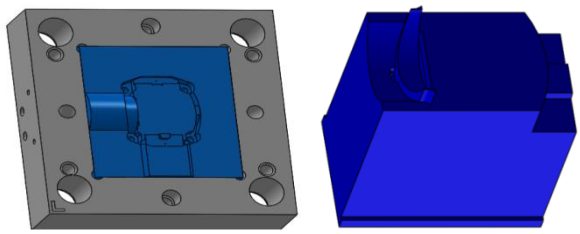

Fig. 5: Structure of cavity (left) and core (right)

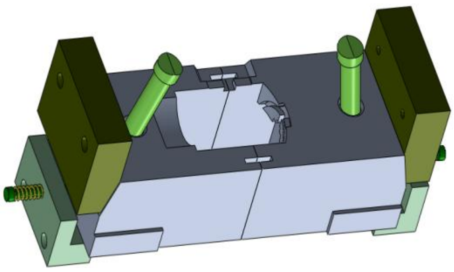

Fig. 6: Side core pulling mechanisms

In this design, mobile demoulding is adopted and the common ejecting pin shown in Fig. 7 is selected as ejecting mechanism. Generally, water or compressed air is used as cooling material because of its large specific heat capacity, convenient access and low cost. The cooling circuit can be arranged around the cavity. In order to keep the water in good flow state and stable in turbulent state at any time, the diameter of cooling circuit at fixed mould side is 6mm and at moving mould side is 14mm, which is cooled by a spray well. Structure of the cooling circuit is shown in Fig. 8.

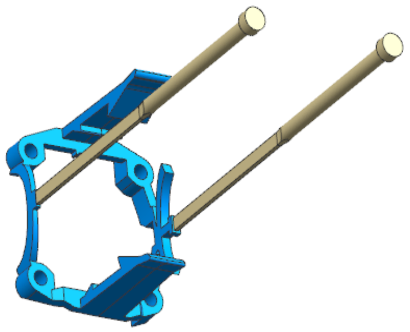

Fig. 7: Ejecting pin demoulding mechanism

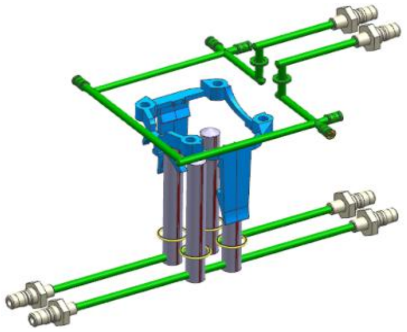

Fig. 8: Cooling system location diagram

4. Simulation analysis

By simulating the injection moulding process of the bracket by CAE software, filling, cooling of the plastic melt in mould cavity, shrinkage and warp age deformation of the bracket can be more accurately predicted. This way the potential moulding problems can be found as early as possible during the design, the mould structure can be modified in time, the mould trials can be reduced. This way, the quality of the bracket can be improved and the cost of mould design and manufacturing can be reduced. Mould flow filling time analysis results with 1.0mm gate is shown in Fig. 9. Blue area at the top is the part just at the start of the pouring, red area at the last is the part of final pouring. The filling time required is 1.021 sec, which meets the design requirements.

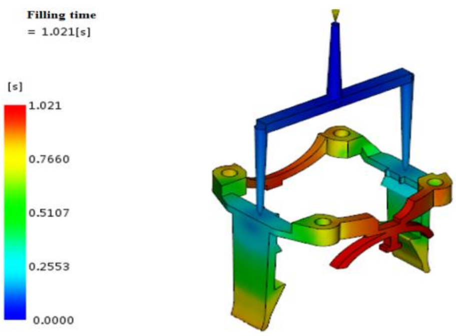

Fig. 9: Filling time analysis

For weld line analysis, surface defect caused by two melts meeting in different directions, which will have a certain impact on appearance and quality of plastic parts. From Fig. 10, it can be observed that most of weld line are located at the bottom of vehicle throttle body bracket. This is not too much (blue parts), which has little impact on the bracket, or even can be ignored. Therefore, according to analysis report of the weld line, the design scheme meets the design requirements. If excess gas is not completely removed and cooled in melt plastic, it will result in bubbles on plastic part. As shown in Fig. 11, cavitation is less and most of them are distributed on the edge of the throttle body bracket. This problem can be solved by fully drying the melt plastic, reducing the injection speed and increasing the back pressure.

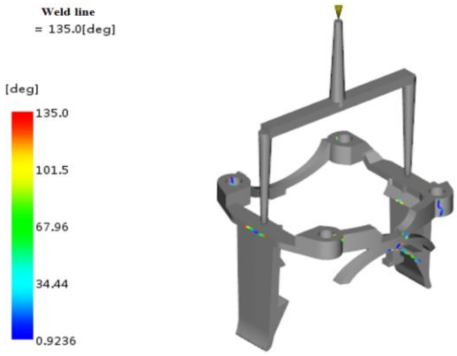

Fig. 10: Weld line analysis

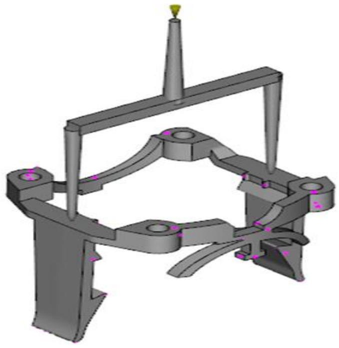

Fig. 11: Cavitation analysis

The cooling analysis results are shown in Fig. 12. The colour of bracket temperature is between green and blue, which is in a good state. This means that designed cooling circuit has a significant cooling effect on the bracket. So the design of cooling circuit meets moulding requirements of the bracket from the diagram. Generally speaking, the difference between the highest and lowest mould temperature should be kept at about 20℃. From mould temperature results in Fig. 13, the temperature is mainly distributed between the green and blue. According to legend, the mould temperature is relatively uniform and the minimum temperature is 35.73℃, the maximum temperature is 56.37℃, temperature difference is 21.64℃, which is small. Therefore, cooling circuit scheme meets the moulding requirements. Generally, temperature difference between water inlet and water outlet is not more than 3℃ when cooling water circuit is designed. According to temperature analysis of cooling water in Fig. 14, the maximum temperature is 25.37℃, the minimum temperature is 25.01℃ and temperature difference is 0.36℃. It is very stable, so it can be seen that the design scheme of cooling water circuit is more reasonable and meet s the moulding requirements.

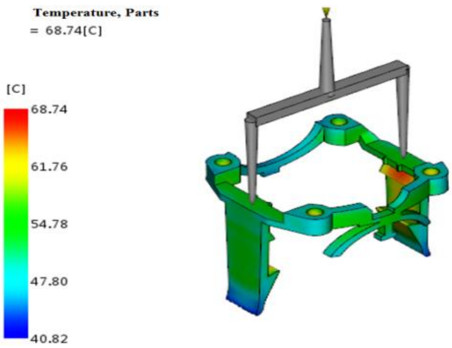

Fig. 12: Bracket temperature analysis

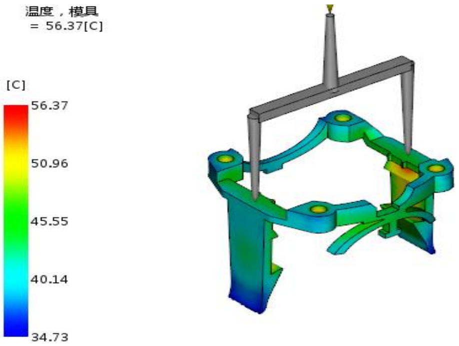

Fig. 13: Mould temperature

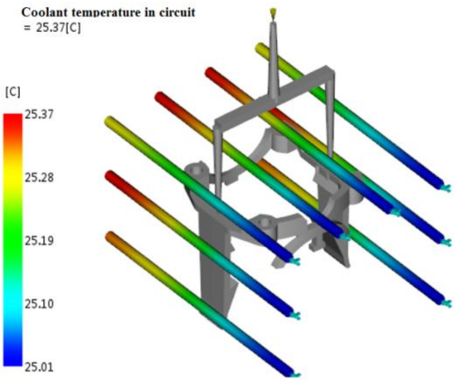

Fig. 14: Water temperature analysis in circuit cooling

Total deformation indicates deformation degree of each point of moulded plastic part compared with that of modelling. Total deformation of bracket is shown in Fig. 15. In general, total deformation degree of bracket is small, which meets the design requirements. As shown in Fig. 16, the cooling uneven deformation of the bracket is small. It can be concluded that the deformation is small and stable, so cooling uneven deformation meets the design requirements.

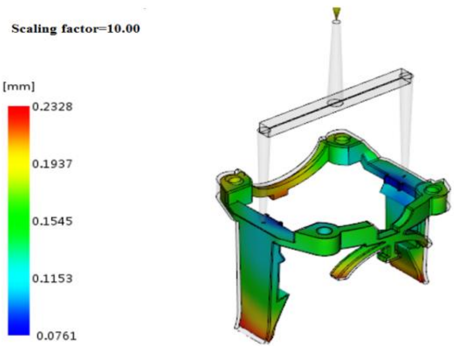

Fig. 15: Total deformation of the bracket

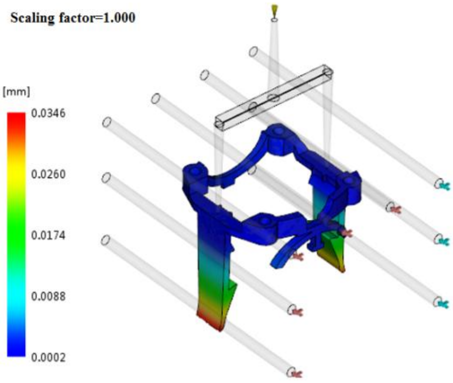

Fig. 16: Cooling uneven deformation of the bracket

Fig. 17 shows that the shrinkage uneven deformation of the bracket is small and the color is mostly distributed between blue and green, there is only small red at the mouth. It can be concluded that shrinkage deformation is small and stable and meets the design requirements.

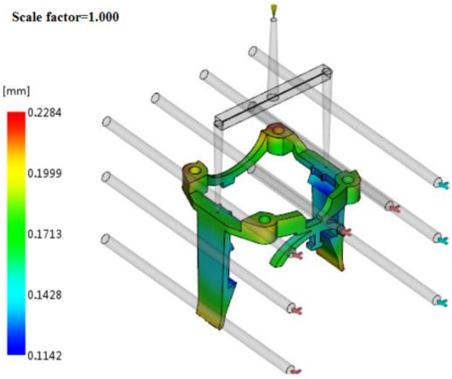

Fig. 17: Shrinkage uneven deformation

5. Conclusions

The parts of mould for vehicle throttle body bracket are designed and the optimal mould structure is determined based on the mould flow analysis. The symmetrical side core pulling mechanism setting on both sides of the mould ensures smooth opening and closing of mould, reduces mould deformation and completes reverse structure moulding on both sides of the bracket. The injection moulding process of the bracket is simulated by CAE software, the results show that during filling process, there are few weld lines and cavitation, most of which are produced at the bottom of the throttle body bracket, which have little impact on the bracket, even can be ignored. Cooling effect of cooling water circuit on bracket is significant, and warp age deformation of the bracket is good, which meets the design requirements.

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