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A Study on Feeding Technology of Motorbike Crankcase in Multidirection Squeeze Casting

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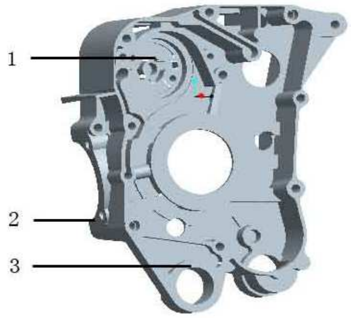
Abstract. The numerical simulation of squeeze casting to right motorcycle crankcase,as a object of study, has been performed， based on finite element analysis software on casting and orthogonal test method.Firstly,the three feeding technology parameters, feeding pressure,feeding delay and dwell time, were confirmed by calculation and analysis after the forecast of shrinkage defects location,then,orthogonal test and test program optimization to the parameters were completed. The results show that the deeding effect was the best when the parameter values , respectively,were 190Mpa,7.5s and 12s.

Introduction

Double squeeze casting,also known as partial feeding, is actually the combination of direct and indirect squeeze casting,absorbing the advantages of the two technology[1]. Multidirection Squeeze casting is another squeeze casting method,not only having the advantages mentioned above,but also can forge the casting in different directions,which achieves the shape and size control as Die-casting and improvement on strength due to plastic deformation and heat treatment[2].The range,deep and opportunity of squeeze can be adjusted due to repeated squeeze in multidirection squeeze casting, which is good for eliminating the defects of partial shrinkage and porosity[3].The most significant parameter among feeding process,playing a important role in the forming process of multidirection squeeze casting,is the feeding pressure.And the pressure from feeding pressure can only has an effect on nearby area of forging briquetting,so the defects of the location of casting need to be forecasted to find out the best feeding position.Besides the feeding pressure,the feeding delay and dwell time should be taken into account as well.

The Forecast of Shrinkage Defect

Modeling. Modeling of the crankcase takes these steps as follows,structural analysis,size measurement by Three-dimensional coordinate instrument,two-dimensional drawing, three-dimensional modeling,die sinking,meshing.



1- oil pump
2- cylinder hole
3- support hole

Fig..1 Three-dimensional Diagram of Crankcase

Numerical Simulation. The numerical simulation was performed in ProCAST , using the parameters of indirect squeeze casting from one foundry of YONGYUAN GROUP for Pre-analysis with squeeze pressure130Mpa,pouring temperature 710℃,mold temperature 250℃,filling speed 1.5m/s,and the material of casting is ACD12.

Analysis of Simulated Result. As it's shown in Fig. 2 to Fig. 5,the filling process of crankcase takes 0.63s.The liquid aluminum alloy was firstly pouring into the squeeze cylinder before squeeze, and gently flowing through pouring gate and then finally entering into cavity with the temperature of 628℃. As it's shown in Fig. 3 that most areas of the molding cavity have been filled with the liquid aluminum alloy with the temperature of 652℃ and good liquidity at 0.31s. As it's shown in Fig. 4 that the temperature of molten metal nearby the cavity surface apparently decreases and partial temperature comes close to liquidus temperature at 0.43s. As it's shown in Fig. 5 that,at 0.63s,the liquid aluminum alloy reaches the top of cavity where has been filled completely,the surface temperature of crankcase,at this moment, is about 560℃,the lowest temperature of the liquid alloy but still higher than liquidus temperature,and the highest temperature appears at the pouring gate where is also the final solidfied part.So the filling process is smooth,eliminating the defect of coldshut and incomplete filling.

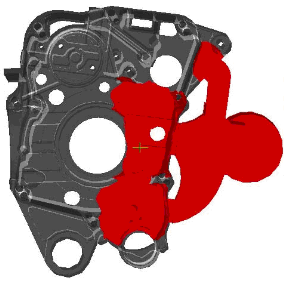


Fig. 2 0.16s' Status

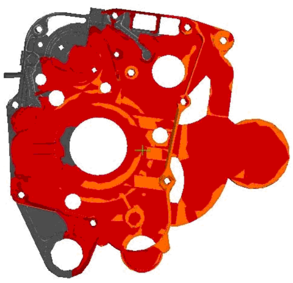


Fig. 3 0.31s' Status

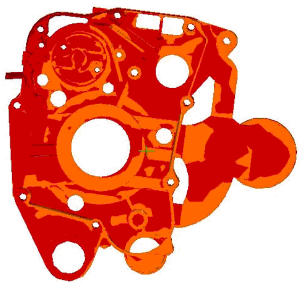


Fig. 4 0.43s' Status

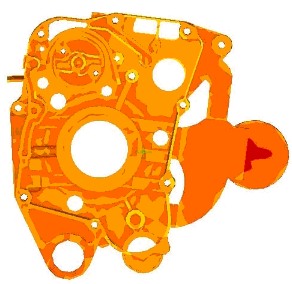


Fig. 5 0.63s' Status

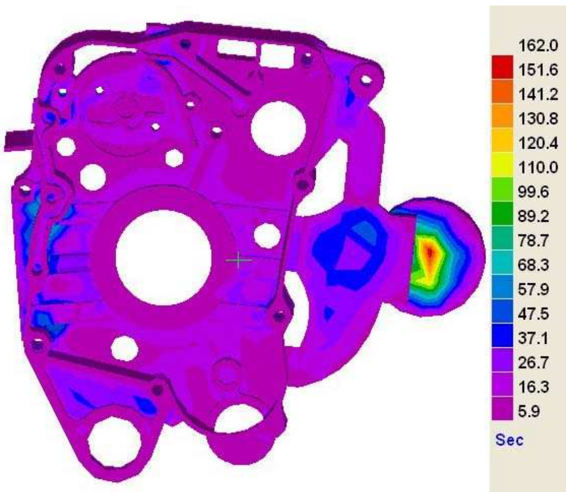


Fig. 6 Coagulation Time Figure

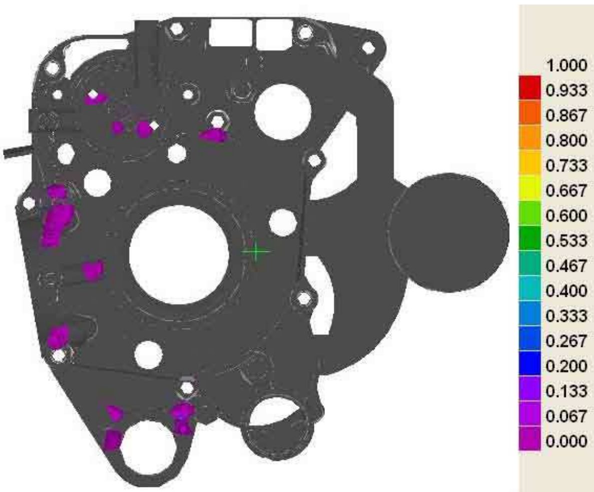


Fig.7 Shrinkage Position

The crankcase begins to solidify after filling process,the solidification rate is low at thin-wall area and high at thick-wall area,such as oil pump,cylinder hole and support hole in which the defect of shrinkage porosity is distributed,as shown in Fig. 6 and Fig. 7.

Feeding Position. The numerical simulation and analysis above show that the positions defect,also named the final solidfied part,are mainly concentrating upon cylinder hole,while the rest of those distritubuted at oil pump and support hole.The acreage of joint face and wall thickness of cylinder hole are 28.3cm^2 and 15mm,which are both the maximum value among the three position and meeting the requirements of feeding area selection[4].So the feeding position was put at the cylinder hole,the direction of feeding pressure is normal of the cylinder plane.

Structure Optimization Of The Lathe Beam

Feeding Pressure. Because of the low yielding limit of the material and the effect of frictional drag in feeding process,The value of feeding pressure,after taking all the influencing factors into account, was calculated by formula 1:

$$P=1.43\sigma_s A \tag{1}$$

Where σ_s is yielding limit of material at feeding temperature, A is the projected area of casting at the perpendicular direction of feeding pressure. σ_s is varied from 11Mpa to 15 Mpa while the temperature is 500℃,and the projected area of crankcase is 175.54cm^2 ,So the value of feeding pressure is varied form 157.3Mpa to 214.5Mpa.

Feeding Delay and Dwell Time. In order to obtain the precise feeding delay time and dwell time,one node 10295, was selected at the feeding area for Procast Fraction of Solid vs Time Results,as shown in Fig. 8.

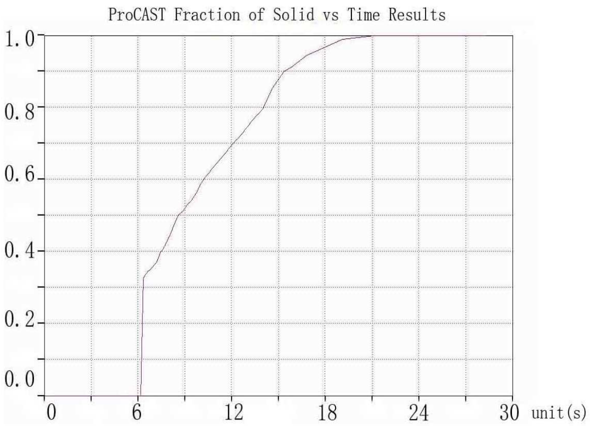


Fig. 8 Fraction of Solid vs Time Results

Table 1 Simulation Project Table

Plane num	The level of factor A		The level of factor B	The level of factor C	A Feeding pressure (Mpa)	B Feeding delay (S)	C Dwell time (S)
1	1	1	1	1	160	6	6.5
2	1	2	2	2	160	7.9	8
3	1	3	3	3	160	10	9.5
4	2	1	2	3	190	7.9	9.5
5	2	2	3	1	190	10	6.5
6	2	3	1	2	190	6	8
7	3	1	3	2	210	10	8
8	3	2	1	3	210	6	9.5
9	3	3	2	1	210	7.9	6.5

Generally,the semi-solid status is considered as the proportion,1:1, of solid phase with liquid phase.As it's shown in Fig. 8,it takes 8.5s to make liquid alloy keep the status of semi-solid,so the feeding delay is about 7.9s after cutting down the 0.63s of the filling time.The feeding pressure will not be stopped until the solid phase is 90%,so the dwell time inferred is 8s.

Structure Optimization Of The Lathe Beam

Orthogonal test plan. The equal level orthogonal table, $L_9(3^4)$, was established for three parameters, feeding pressure,feeding delay,and dwell time and the testing program was confirmed.Other parameters refer to the value of indirect squeeze casting technology of YONGYUAN GROUP. Factor and level table is established and used for orthogonal simulation test of feeding technology in multidirection squeeze casting as shown in table1.

Analysis of Simulated Result. Nine Orthogonal schemes were obtained by simulation,the result is shown in table 2 and Fig. 9 to Fig. 17.

Table 2 The Simulated Result of Each Scheme

Plan nun.	Factor				holistic marking
	A		B	C	
1	1	1	1	1	65
2	1	2	2	2	70
3	1	3	3	3	65
4	2	1	2	3	90
5	2	2	3	1	80
6	2	3	1	2	85
7	3	1	3	2	80
8	3	2	1	3	95
9	3	3	2	1	90
K_1	200	235	245	235	
K_2	255	245	250	235	
K_3	265	240	225	250	
rang	65	10	25	15	

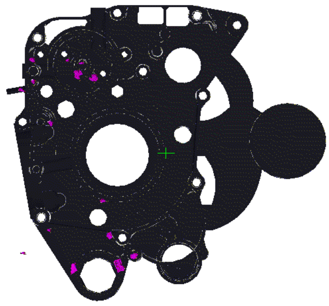


Fig. 9 Plan1

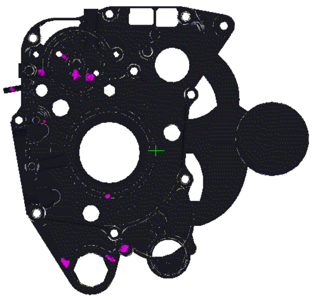


Fig. 10 Plan2

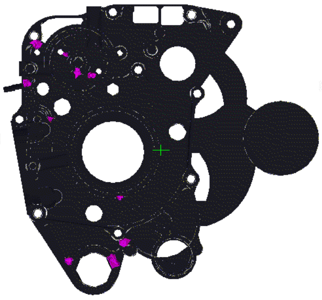


Fig. 11 Plan3

Fig. 12 Plan4

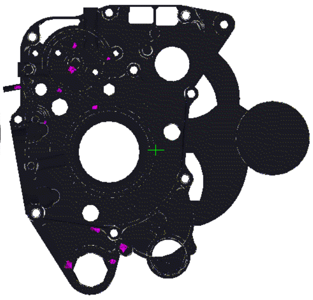


Fig. 13 Plan5

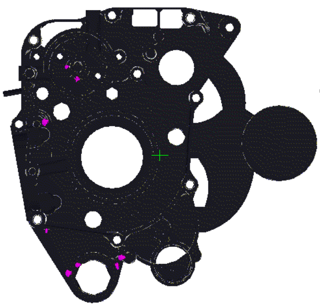


Fig. 14 Plan6

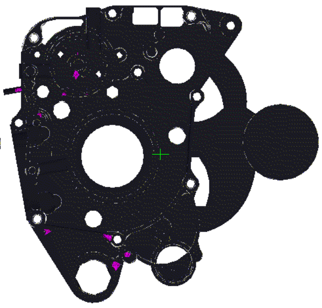


Fig. 15 Plan7

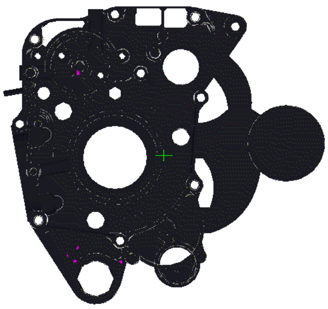


Fig. 16 Plan8

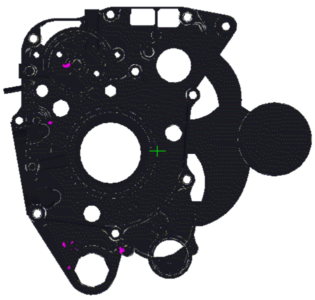


Fig. 17 Plan9

Comparing plan 1 to 3 of simulation results, it shows that their shrinkage region mainly concentrated in support holes and pump areas, comparing with indirect squeeze casting,the volume of shrinkage is significantly reduced, so it has obvious effect on reducing shrinkage porosity by enhancing feeding pressure.The larger volume of plan 1 to 3 show that even extending the dwell time, the effect of partial feeding will still be reduced if feeding delay is unsuitable.Comparing simulation results of plan 4 to 6 with plan1 to 3, the total shrinkage volume is obviously reduced, it shows that enhancing feeding pressure can effectively restrict the generation of shrinkage.Increased shinkage defects of plan 5 shows that the longer feeding delay does no good to partial feeding, the importance of choosing appropriate feeding delay has been proved once again, plan 4 has smaller area of shrinkage,showing that 7.9s feeding delay is appropriate. Comparing plan 4 and 6,it shows that sufficient dwell time can help to reduce shrinkage defect. The shrinkage defect of plan 7 to 9 is to some extend less than plan 4 to 6, but having less feeding effect than the moment feeding pressure coming up to 190Mpa from 160Mpa.Although it is an advantage to enhance feeding effect by increasing feeding pressure, but the pressure is not the higher, the better, the higher pressure can result in mold damage and reducing mold longevity. Plan 7 has more shinkage defect because of the wrong time for feeding delay, plan 8 has the better feeding effect because of the higher feeding pressure,the right time for feeding delay and longer dwell time. From nine simulation result figures, plan 8 is the best one , so,in order to decrease the shrinkage defect,it's necessary to choose higher feeding pressure, appropriate feeding delay and longer holding time.

Optimization. As it's shown in table2,the best technology scheme is $A_3B_1C_3$, different with the best calculated scheme, $A_3B_2C_3$.So the result of factors vs departure is discussed as Fig. 18.

As it's shown in Fig. 18,high feeding pressure is helpful to enchance the casting quality, but, with respect to the damage to mold and high pressure hydraulic machine needed,the departure value of 190Mpa is good enough to be selected .Factor B reach the highest departure at B2,7.9s,so it's appropriate for B to stay near 7.9s. The departure of factor C will be higher if the value of factor C is bigger than C3.Now,there are only two factors need to be considered.So the new test using comprehensive experimental method is rebuilt as table 3.The simulated result is as shown in Fig. 19 to Fig. 22.The best simulated result is plan 12,As a result,the defect of shrinkage has been removed.

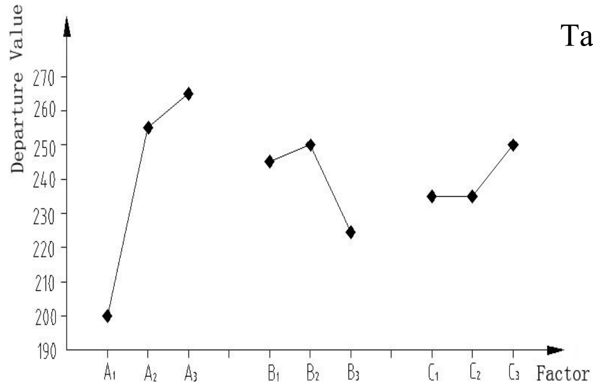


Fig. 18 The Result of Factors vs Departure

Table 3 Parameters Combination of Optimization

Plan num	Feeding pressure (Mpa)	Feeding delay (S)	Dwell time(S)
10	160	7	11
11	160	9	11
12	160	7	13
13	190	9	13

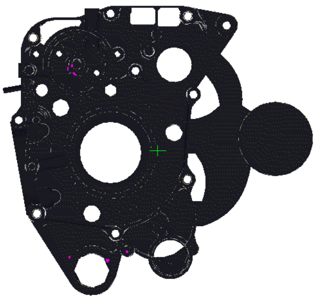


Fig. 19 Plan 10

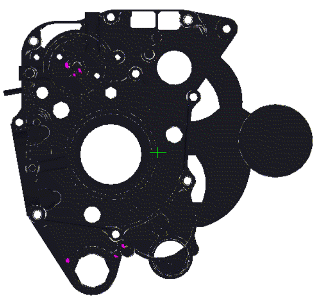


Fig. 20 Plan11

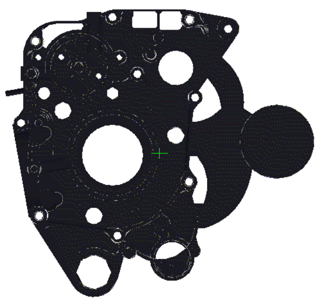


Fig. 21Plan12

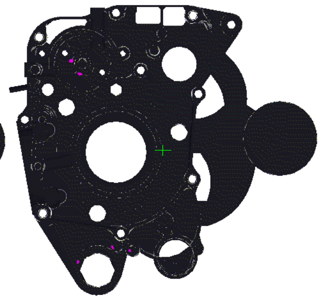


Fig. 22 Plan13

Summary

1）The distribution graph of shrinkage was obtained based on three-dimensional molding and defect analysis,corresponding to actual situation,thus comfirming the feeding position.

2）The three feeding technology parameters, feeding pressure,feeding delay and dwell time, were confirmed by calculation and analysis. Then,orthogonal test and test program optimization to the parameters were performed,eliminating the shrinkage defect.

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