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To the question of a process optimization of cast in a metal mould of automotive pistons made of grey cast iron and silumin

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ABSTRACT

A calculation of an optimal geometry of a gating system for cast in a metal mould of automotive pistons made of grey cast iron and silumin was performed. A conclusion about surface cast defects was given by the obtained three-dimensional models of the pistons castings. It is noted that the casting made of A356 silumin is cooled (is crystallized) uniformly throughout the volume, compared with the casting made of EN-GJL-300 grey cast iron.

Keywords *– a piston, cast, a metal mould, a gating system, silumin, grey cast iron.*

I. INTRODUCTION

A piston is one of responsible parts of an internal combustion engine of a car. The piston works under severe conditions and is subjected to variable loads of various kinds. For increasing of an operation period of the piston, it is necessary to reduce errors at manufacturing of the part, defects at manufacturing of a work piece and to increase durability of the finished part by hardening of working surfaces. Cast, and in particular cast in a metal mould, is one of manufacturing methods of the work piece of the automotive piston.

This method of cast is described in the works [1 – 10]. Metal melt cools rapidly and the remote mould cavities remain unfilled in a process of cast in the metal mould. Additional melt feeding allows to avoid premature crystallization of melt in the metal mould. Required melt feeding is determined after a calculation of optimal dimensions and the elements shape of a gating system of the metal mould. A computer simulation will provide a visual view of predicted incomplete fillings in castings at a designing stage of the technological process of cast in the metal mould of the automotive pistons.

II. MATERIAL AND METHOD

The process of gravity cast of the automotive pistons in the metal mould was implemented by the method of finite element modeling in the LVMFlow software environment.

The three-dimensional solid models of the pistons castings and the gating systems were built for the calculation. The grooves for the rings and the pin bore were provided in the castings models of the automotive pistons. The model of the gating system consisted of the pouring basin (for receiving of melt jet), the vertical downsprue (for melt supply in other elements of the gating system), the gas vent (for gases withdraw from the mould cavity and control of filling it by melt) and the slit gate (for melt supply in the mould cavity).

The castings of the automotive pistons were made of EN-GJL-300 grey cast iron and A356 silumin. Initial temperatures of melts of grey cast iron and silumin were 1290 °C (the liquidus temperature is 1196.791 °C) and 710 °C (the liquidus temperature is 617.848 °C), respectively. Alloys of grey cast iron and silumin have the same CLF down in liquid state. Melt of grey cast iron has the higher CLF up than melt of silumin. Initial grains growth rates in melts at cooling were changed from 5 to 200 times. The metal mould model was made of grey cast iron and was adopted by a perfectly rigid body.

Heating of the metal mould to the temperature of 200 °C for 5 s was provided at the calculation. The process calculation of cast in the metal mould was performed by the quasi-equilibrium model taking into account convection and without segregation. The friction factor of melts flow of grey cast iron and silumin in the metal mould was taken by 0.9.

III. Result and discussion

The calculated contours of thermal modulus on the three-dimensional models of the pistons castings are presented in the Fig. 1.

Color spectrum on the models characterizes cooling uniformity (crystallization) of melt in the metal mould. According to the scale located to the right of the model, crystallization of grey cast iron in the casting skirt is approximately twice as fast as in the crown. This suggests an uneven structure of the casting of the cast iron piston after cooling. Shrinkage of the casting made of EN-GJL-300 grey cast iron is not more than 1% of the entire volume. Crystallization of silumin melt in the metal mould is uniform. Almost the entire outer surface of the casting crown of the piston is subjected to shrinkage after cooling.

It is necessary to design the rational gating system for eliminating these cast defects. This will lead to uniform and complete filling of the entire volume of the metal mould cavities by melt.

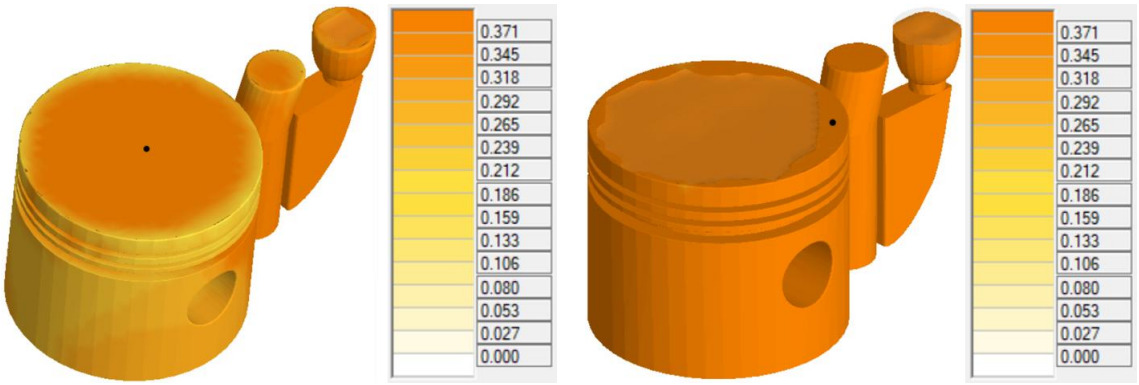

Fig. 1. The thermal modulus contours on the models of the pistons castings: *A* – EN-GJL-300 grey cast iron, *B* – A356 silumin.

The control points of the black color were set on the crowns surfaces of the castings models. A location of the control point on the crown surface of the piston casting was taken on the basis of predicted incomplete filling of the metal mould cavities by melt. Values of thermal modulus at the selected control points are the same.

The calculation results of the gating system for optimal cast in the metal mould of the cast iron and aluminium pistons are presented in the summary table I.

TABLE I. THE CALCULATION RESULTS OF THE GATING SYSTEM FOR OPTIMAL CAST IN THE METAL MOULD OF THE CAST IRON AND ALUMINIUM PISTONS.

Parameter	***Cast iron piston***	***Aluminium piston***
Alloy name	EN-GJL-300	A356
Alloy density, kg/m^3	7013.077	2425.751
Casting modulus, cm	0.522	0.544
Casting weight, kg	1.280	0.433
Pouring temperature, °C	1290.00	710.00
Minimum feed metal requirement, %	1.783	6.117
Minimum modulus ratio feeder/casting	1.200	
Feeder ratio height/diameter	1.500	
Modulus ratio neck/casting	0.800	
Feeder type	Cylinder	
Mould hardness	80.000	

Location	Top	
Minimum feeder modulus, cm	0.626	0.747
Actual modulus ratio feeder/casting	1.200	1.372
Feed metal requirement, cm^3	4.558	15.633
Feeder weight, kg	0.308	0.181
Modulus feeder neck, cm	0.418	0.435
Feeder neck dimension square, mm	16.706	17.414
Minimum feeder diameter, mm	33.412	39.829
Minimum feeder height, mm	50.118	59.743

The different volumes of melt of grey cast iron and silumin are required at the same dimensions of the pistons castings and the gating systems of the metal moulds. Melt feeding of grey cast iron in the amount of 4.558 cm^3 is required additionally for cast of the cast iron piston; melt feeding of silumin in the amount of 15.633 cm^3 is required additionally for cast of the aluminium piston. The cylindrical feeders are offered with the minimum diameters of 33.412 mm for melt supply of grey cast iron and 39.829 mm for melt supply of silumin in both cases. The ratio of the feeder height to its diameter for two designed gating systems of the metal mould was 1.5. The feeder weight in the gating system of the metal mould is reduced at cast of the aluminium piston.

IV. Conclusion

Thus, additional melt feeding of not less than 5% of the entire volume of the casting is required at cast of the aluminium pistons in the metal mould. Constancy of material properties of the piston casting is ensured by uniform cooling of silumin melt. Linear shrinkage of the casting of the aluminium piston was approximately 3.5%. Changing of the casting orientation of the piston in the metal mould (the crown is located at the bottom of the metal mould) allows to reduce linear shrinkage of material up to 0.5%. The cavities dimensions with allowance equal to the value of linear shrinkage of material must be provided at designing of the mould for cast of the aluminium pistons.

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