AN APPROACH TO OPTIMIZING A FOUNDRY TECHNOLOGY BY MEANS OF COMPUTER SIMULATION

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A common approach to optimizing casting technologies is presented. The approach is illustrated by means of an example of the technological solution for the formation of automotive wheel using gas Counter Pressure Casting (CPC) method, but it could be applied with success in Low Pressure Die-Casting (LPDC) or in die-casting too. For this purpose the latest version of the world-famous software package MAGMAsoft – MAGMA5.3.1 of MAGMA GmbH based in Aachen, Germany, is used. The method consists of a series of purposeful changes in the geometry of the casting or moulds, as well as the cooling channels that leads to the reduction of the defects in the casting registered with the tools of the software. The process starts with a heuristic solution of technology and after a series of iterations leads to a technological solution without of defects according to the criteria functions. It consists of series of computer simulations of filling and crystallization of the casting, which is accompanied with targeted changes in technology based on the analysis and evaluation of the results.

Keywords: mathematical modelling, optimization, casting formation, computer simulation.

1. INTRODUCTION

Mathematical modelling of the complicated processes of casting formation and its algorithmization in the form of computer simulation mark more than

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thirty years of development and improvement [1, 2, 3, 4]. In addition to the basic processes of filling the cavity of the mould with molten metal [5, 6] and the phase transition from liquid to solid state [7, 8], computer modelling recently has been increasingly used to develop and obtain new materials and alloys [9, 10].

In the present paper, based on an author's approach [11], a study of the possibilities of reducing the casting defects in a heuristically created technology for an auto wheel formation by Counter Pressure Casting (CPC) method is presented. For this purpose the latest version of the world famous software package MAGMAsoft – MAGMA5.3.1, is used.

2. NATURAL SIMULATION

Under “natural” simulation below we shall understand simulation of casting formation in the mould with simple geometry. It can be assumed as cube, parallelepiped or straight cylinder. In MAGMA5.3.1 such kind of moulds are generated with the tool “Automatic mould”. The results obtained from such kind of simulation give an idea about the nature of the filling of the mould cavity with liquid metal and the type of crystallisation, mainly arising from

Fig. 1. Heuristically constructed mould parts

Fig. 2. Criterion “Porosity”. Natural simulation. Variant 1

the geometry of the casting. They point out the possible defects due to the geometrical characteristics and the masses distribution in the casting. Based on the analysis of these results, the first changes in technology are realized to reduce the defects.

In the present case we already have a heuristically constructed mould parts shown in *Fig. 1*. That is the reason why the natural simulation is realized with them without using the additional tools like cooling or heater for example.

The foundry equipment pointed out in *Fig. 1* includes the casting machine plate, four side cores, lower and upper steel cores from X40CrMoV5_1 alloy. The process of filling and crystallization of the casting is simulated with MAGMA5.3.1 in a single cycle at initial temperatures of 715 °C for the casting alloy (AlSi7Mg) and 350 °C for mould parts. The initial temperature of the plate is assumed as 100 °C. The obtained result for the “Porosity” criterion in this case (Variant 1) is presented in *Fig. 2*.

It seems clear that the main problems are concentrated in hot spots where the wheel arms meet the part of the wheel witch is in contact with automobile tyre. This is due to the mass concentration in these zones. On the other side there is a significant distributed porosity in the same part of the casting. It can be explained by the absence of a monotonous growing section in the area indicated in *Fig. 3*. It shows a cross-section of the casting on the axis of

Fig. 3. Cross-section of the casting

Fig. 4. Heuristically designed cooling

rotational symmetry.

Heuristically designed cooling is shown in *Fig. 4*. It has zones of action completely different from the problems outlined in *Figs 2* and *3*. They can be switched on only after formation of the hotspots and the distributed porosity of *Fig. 2* and therefore cannot be influenced by them. Therefore, in the next variant of the casting equipment, additional cooling is built, attacking the thermal node zones depicted in *Figs 2* and *3*. The geometry and displacements of this cooling are pointed out in *Fig. 5* in the next section.

3. VARIANT WITH NEW COOLING

The simulations MAGMA5.3.1 of this variant are performed with different regimes and intensities of the cooling presented in *Fig. 5*. The best obtained result is presented in *Fig. 6*.

It is realized using water cooling with maximum intensity. It seems that the hotspots have become smaller in volume and moved in the right direction (towards the axis of rotation) but unfortunately they are not eliminated.

Since the used cooling is of maximum intensity and its impact potential is exhausted, the search for an efficient solution continues with other means.

Fig. 5. Additional designed cooling

Fig. 6. Criterion “Porosity”. Variant 2

4. VARIANT WITH DIFFERENTIAL DISTRIBUTED COATING

In this variant, the additional cooling of the previous version is retained, but another efficient tool is used to influence on the crystallization. It consists in the application of coatings with different conductivity and thicknesses on different mould parts. In *Figure 7* the casting is cut into two parts. They are presented in light grey (Part 1) and dark grey (Part 2). All mould parts contacted with Part 1 are supposed covered with a thin coating with high

Fig. 7. The two parts of the casting

Fig. 8. Criterion “Porosity”. Variant 3

conductivity (graphite, for example). The parts of mould contacted with Part 2 are supposed covered with a thicker coating with small conductivity (insulated coating). With such changes the casting formation is simulated using

MAGMA5.3.1 again. The obtained result is illustrated in *Fig. 8* with criterion “Porosity”.

As it looks good, the hotspots in the spokes are already eliminated.

5. VARIANT WITH CORRECTION OF THE RIM GEOMETRY (VARIANT 4)

In order to solve the problem of distributed porosity in the rim of the casting, a correction of its cross-section is made with the additive shown in *Fig. 9*.

Figure 10 presents the result for the criterion “Porosity” obtained with MAGMA5.3.1 for this case. The porosity in the rim of the wheel is significantly reduced in comparison with the previous variant – Variant 3.

However, it is worth noting that small porosity zones at the top of the rim have no rotational symmetry. This circumstance suggests that there is no rotational symmetry of temperature field in this area of the casting. The only side cores have not rotational symmetry in the cast-mould system (they are presented in *Fig. 1* above). Thus, naturally, an idea arises to check what happened if they have rotational symmetry. Such an option is developed in the next section.

Fig. 9. Correction of the geometry

Fig. 10. Criterion “Porosity”. Variant 4

6. SIDE CORES WITH ROTATIONAL SYMMETRY

The geometry of new side cores with rotational symmetry (Variant 5) is shown in *Figs 11* and *12*.

In the case of the technological solution, they could be realized through two halves or four quarters. As can be seen in *Fig. 11*, the large masses are placed against the areas requiring more intensive cooling and at the height of the rim an increasing mass distribution is realized, which favours directed crystallization from the top down. The result for the “Porosity” criterion in this case is shown in *Fig. 13*.

Obviously, the recent changes have led to complete elimination of defects.

Fig. 11. Rotary side cores. View 1

Fig. 12. Rotary side cores. 3D View 2

Fig. 13. Criterion “Porosity”. Variant 5

7. CONCLUSION

The authors hope that the approach presented above convincingly demonstrates the strength and effectiveness of mathematical modelling and computer simulation in the refinement and optimization of foundry technologies. The optimal solution is found only at the cost of several virtual variants and with no more than 10–15 hours of processing time. Moreover, this optimization is achieved in a much shorter time than traditional development and can save significant financial costs.

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ЕДИН ПОДХОД ЗА ОПТИМИЗАЦИЯ НА ЛЕЯРСКА ТЕХНОЛОГИЯ СЪС СРЕДСТВАТА НА КОМПЮТЪРНОТО СИМУЛИРАНЕ

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Резюме. Представен е общ подход за оптимизация на леярските технологии. Подходът е илюстриран чрез пример на технология за формиране на автомобилна джанта по метода на

леене с газово противоналягане, но той би могъл да се приложи с успех при леене под ниско налягане или кокилно леене. За тази цел е използвана последната версия на световно известния софтуерен пакет MAGMAsoft – MAGMA5.3.1 на фирмата MAGMA GmbH, базирана в гр. Ахен, Германия. Методът се състои от целенасочени последователни изменения на геометрията на отливката и формообразуващите, както и на охлажданията, които да доведат до намаляване на дефектите в отливката, регистрирани от инструментариума на софтуера. Процесът стартира с евристично разработена технология и след серия от итерации води до технологично решение без дефекти, съгласно критериалните функции. Тази серия се състои от последователни симулации на процесите на загълване на формата и кристализацията на отливката, които са съпроводени от технологични изменения, съобразени с анализа и еволюцията на получените резултати.

Ключови думи: математическо моделиране, оптимизация, леене, компютърна симулация.

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