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THE SIMULATION AS PREDICTION TOOL TO DETERMINE THE METHOD OF RISER CALCULATION MORE EFFICIENT

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Abstract: *The riser must be adequate to satisfy the liquid and solidification shrinkage requirements of the casting. In addition, the riser itself will be solidifying, so the total shrinkage requirement to be met will be for the riser/casting combination. The total feeding requirement will depend on the specific alloy, the amount of superheat, the casting geometry, and the molding medium. The shape of a casting will affect the size of the riser needed to meet its feed requirements for the obvious reason that the longer the casting takes to solidify, the longer the riser must maintain a reservoir of liquid metal. A variety of methods have been devised to calculate the riser size (shape factor method, geometric method, the modulus method) needed to ensure that liquid feed metal will be available for as long as the solidifying casting requires. In this research has been calculated the riser geometry by different methods for a piece type wheel and the simulation has been used to determine which of the methods it is more efficient.*
Keywords: *Simulation casting, quality, risers design*

INTRODUCTION

The consequences of a low casting yield are well known in the foundry industry: lower profits due to increased production costs and decreased capacity. Additional melted metal and heats, as well as the increased labor and materials costs required for production, are the primary reasons for the increased costs. Furthermore, it is recognized that a higher casting yield has the side benefit of lowering casting cleaning costs. Essentially, when a foundry achieves the highest possible yield, it can operate at maximum capacity, maximizing its revenues [1]. Casting is a very simple process; apparently, melting, pouring and made the mold is only, but each one has other processes more complex [2]. Green sand casting process involves many process parameters which affect the quality of the casting produced [3]. The rigorous control of the scrap, the use of molding sands appropriate, the correct production of the molds, the good design of the gates and risers systems, among other, they are some of the processes that it is necessary to keep in mind to achieve a maximum quality of the cast pieces. If to that said previously it is added that the optimization of anyone of them, choosing in those cases where it exists more than a way for their determination the best and more economic, it guarantees that the process is efficient and it can guarantee himself the time that delays a product in arriving again at the market is smaller. The main objective of this paper is improvement the efficiency of the sand casting process; to guarantee that it has been divided in three steps: first, to determine the main factors that influence in the final quality of the product, second, to carry out an analysis using the simulation for determines the action of the main factor and to optimize the results obtained in the simulation.

A survey applied experts in foundry and that reflects the main parameters that affect the final quality of the cast piece (see figure 1), provides an evaluation and a vision of those that more affect the productive process, one of them is the pouring process and the design the gate and riser system, the results can see in the figure 2. In these graphics two ways of analysis of the results are presented, the average of points confers by the experts in each variable and the frequency with which a certain valuation appears for the certain ones as more influential.

	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5
Design of Foundry technology					
Personal qualification	9	5	9	8	4
Method applied to obtain the solution	9	1	9	6	4
Preparación de la mezcla de moldeo y machos					
The use of the right sand	9	10	8	9	8
The use of the right clay	9	10	9	9	8
Additives	9	1	9	9	8
Right control in laboratory	10	5	9	8	6
Personal qualification	8	6	7	7	9
Preparación de modelos y cajas de macho					
Quality of the flask	8	1	8	4	8
Quality of the tools for molding	8	5	7	6	7
Molding method	8	5	7	7	7
Personal qualification	9	5	6	8	8

Figure 1. Part of the survey applied to experts

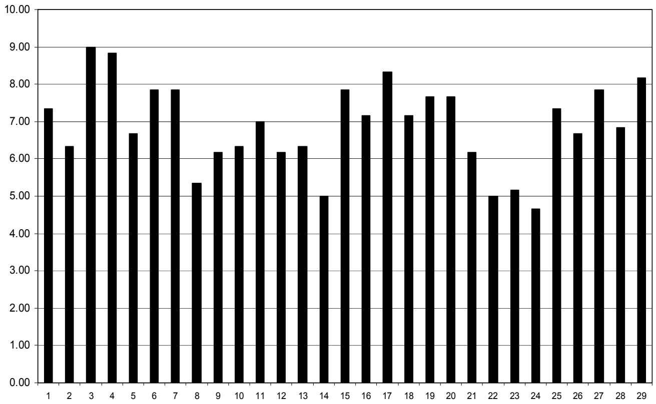

Figure 2. Average of points confer by the experts in each variable

The gating and risering systems as one of the main factors for their effect in the quality of the casting is identified, a brief study is pointed out on the same ones and it is determined for wheel of AISI 1045 which is the effective feeding distance depending on the geometric characteristics of the cast.

Table 1. Data of the risering dimension calculate for different ways

Method	D_R (mm)	H_R (mm)	Neck (mm)	Volume (dm^3)	Weight Riser (kg) 1 Riser	Weight Casting (kg)	Weight Riser-Casting (kg) 4 Riser
Moduli method	100	100	15	3.33	26.16	104.08	208.71
Heuvers method	90.55	142	15	3.50	27.6	104.08	214.48

According to the results, it can say that the difference between methods is significant. Maximizing casting yield, which is defined as the weight of a casting divided by the weight of the metal poured to produce the casting (i.e., including metal that solidifies in the risers, gating, downsprue, etc.), is an important consideration in the steel casting industry [1]. An increase in casting yield decreases production costs; with increased yield, production of the same number of castings requires less melted metal and fewer heats, as well as reduced labor and material costs required for production. Also, higher yield usually has the side benefit of lower casting cleaning costs. One effective way to improve casting yield is through riser optimization, where "optimized" means (1) the riser has the minimum possible volume to provide sufficient feed metal to the casting, without the riser pipe extending into the casting; and (2) the smallest number of risers are used, while still ensuring that the risers are close enough to each other to produce a sufficiently sound casting. Computer simulation of the casting process is becoming an indispensable tool in the effort to increase casting yield. Through the use of simulation, foundries are able to evaluate modifications to casting designs without having to actually produce the casting, thus saving time, material resources, and manpower. However, computer simulation must be applied on a case-by-case basis, and its effective use requires expertise as well as accurate data for many process variables [10].

SIMULATION IN CASTING PROCESS

The replacement of physical experiments with software simulations is increasingly common in many sections of the industry today. Some numerical experiments are carried out in order that optimal tooling and process parameters are selected to get products right first time-avoiding time-consuming and costly physical experimentation. Other studies aim to obtain a deeper understanding of the effect of varying process parameters (sensitivity studies) towards optimizing a process [13]. However, numerical experiments that were based on the DOE method are rare in the open literature. The fact that workers are only just starting to consider such a combination for casting related simulations is apparent from a recent paper [14] where the DOE method is applied to numerical simulations of aluminum permanent mold casting. The aim of their investigation was determinate what is the best method for optimal riser design, in sand casting process. In summary, whilst DOE methods and the use of computer simulations are no longer new to the manufacturing industry, instances of combining the two for achieving significant increases in productivity during a problem solving exercise are relatively scarce and the effectiveness of this strategy therefore remains to be investigated.

Simulation studies, when used in several areas of investigation, are quite useful to study the behavior of some phenomena in which different virtual situations are generated by the researcher using some specialized software. Robustness studies are rather common in statistic research; many of them are used to observe the behavior of an estimator under several hypothetical situations that could happen in practice [15].

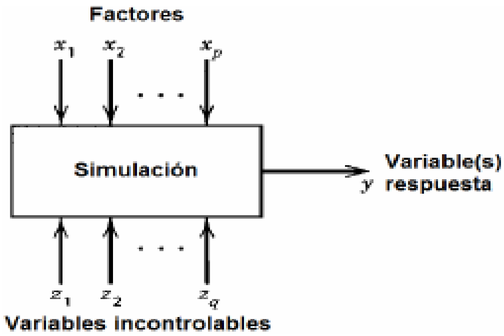

Figure 3. General scheme of a simulation study, adapted from a scheme presented in [15]

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DATA FOR SIMULATION

The filling and cooling simulation was made under the following condition:

Data of the Mold

- ✓ The mold was made with a mixture of silica sand and clay.
- ✓ The mold temperatura was 30^0C

Data of the metal

- ✓ AISI 1045, is important say that the software ProCAST [5] don't have data for this material.
- ✓ Pouring temperature 1540 C
- ✓ Pouring velocity 287 mm/s (0.287 m/s)
- ✓ Pouring time 25 s

The first step is to carry out a simulation of the casting without risers, for to determine, in accordance with the results, the best risers location [6].

In the picture 4 are shown the places of the casting with more modulus, according to Chvorinov equation, this means that, the best location of the riser.

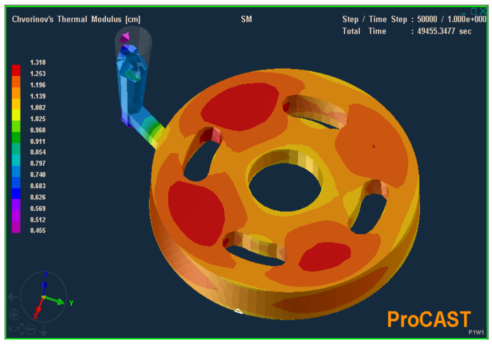

Figure 4. Chvorinov's thermal modulus representation

A sample of that, is the picture 5, where the formation of << hot spots >> is observed and its relationship with the shrinkage porosity [7].

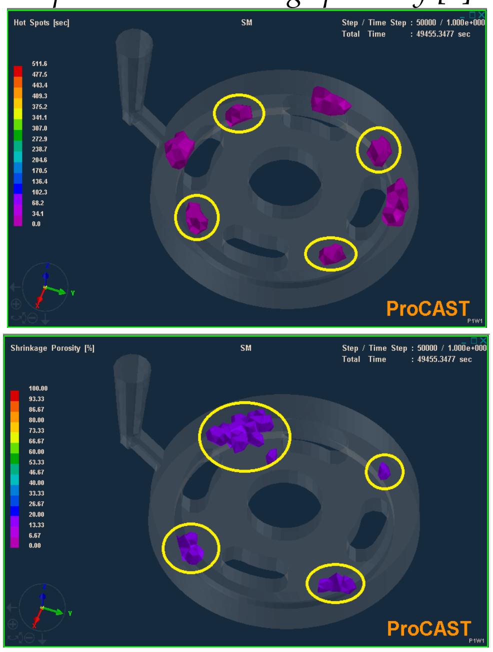

Figure 5. Relation between the hot spots formation and the shrinkage porosity

As second step the calculations to determine the riser geometry are carried out, in an analytic way, through the well-known methods and at the end the simulation of each method.

In the picture 6 the distribution of temperatures is observed, for the 2 methods, after 14 hours, in the *cooling process. If, the parameters of pouring temperature, fill velocity and fill time, stay constant in the three cases, it is observed how the cooling, of both geometries, is different.*

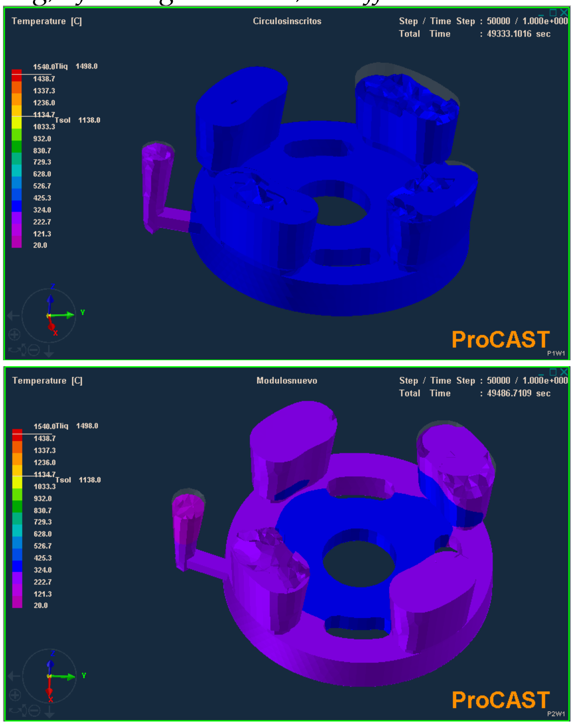

Figure 6. Representation of temperatures distribution for 14 hours by the Heuver's method and Modulus method

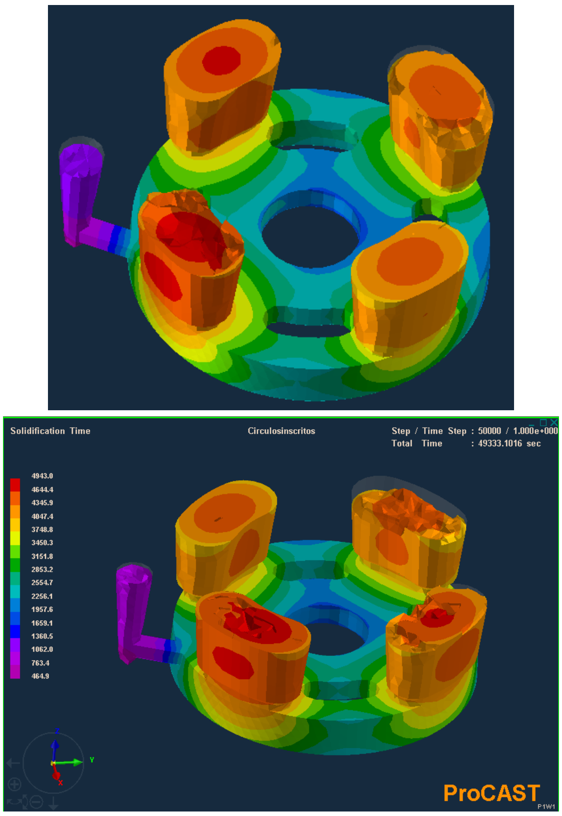

Figure 7. Representation of solidification time by the Heuver's method and Modulus method

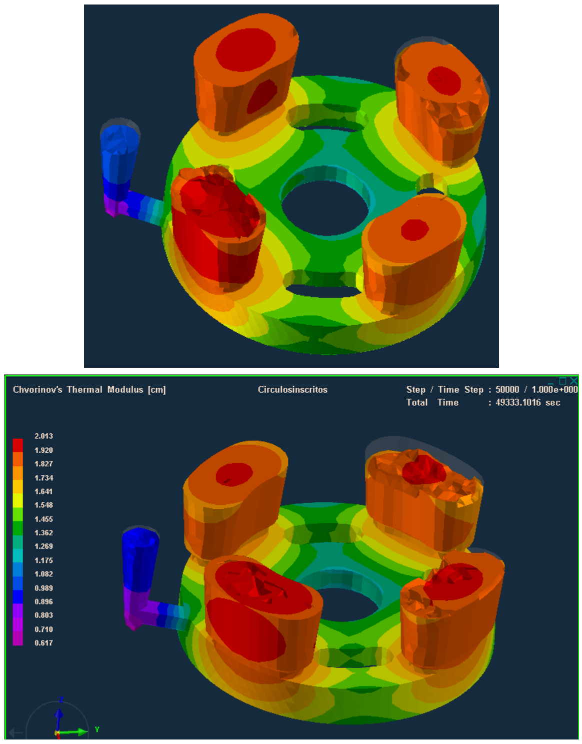

Figure 8. Thermal Modulus determined by the Heuver's method and Modulus method

In the picture 9 the simulation shows some porosities in the surface of the casting, change of coloration, in the Modulus method.

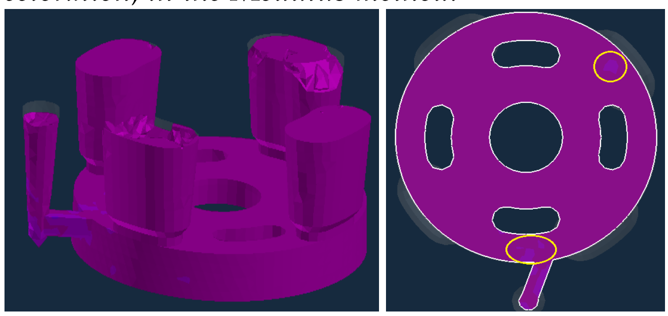

Figure 9. Shrinkage porosities in the surface in the Modulus method

Also, is possible to appreciate, through the simulation, the shrinkage porosities inside of the casting.

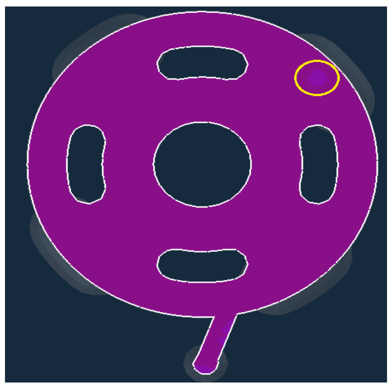

Figure 10. Inside shrinkage porosities in the modulus method

In the case of Heuver's method, the result of shrinkage porosities, are shown in the picture 11.

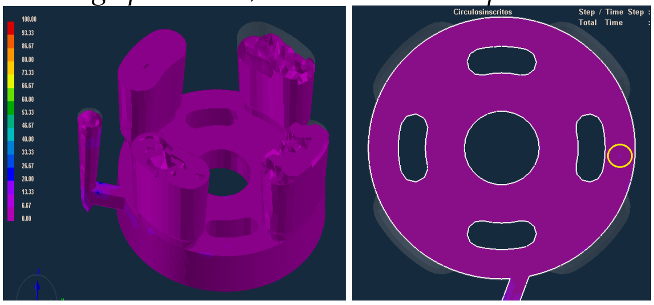

Figure 11. Shrinkage porosities in the surface in the Heuver's method

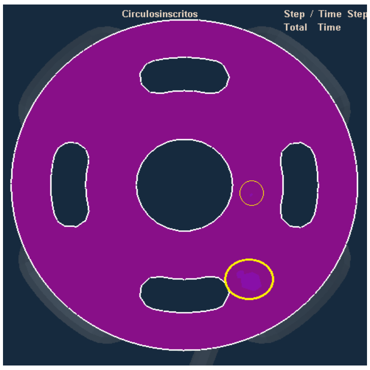

Figure 12. Inside shrinkage porosities in the Heuver's method.

In the pictures 13 and 14 the action of the risers is observed in both methods. In all the cases, the riser carried out their work, assuming the shrinkage porosities in their interior, only one of the riser, of the Modulus method, where the porosity is in the piece, in the rest, the riser works perfectly.

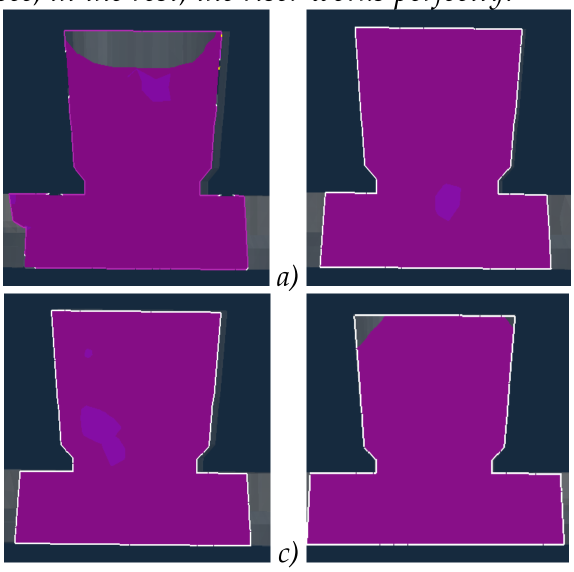

Figure 13. Inside view of risers by the Modulus method. a) riser more near to the metal entrance, b) riser far away for the right, c) riser more fences for the left, d) riser far away for the left

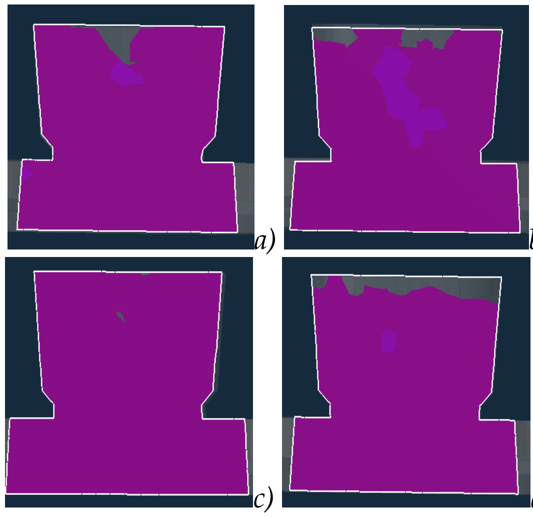

Figure 14. Inside view of risers by the Heuver's method. a) riser more near to the metal entrance, b) riser far away for the right, c) riser more fences for the left, d) riser far away for the left

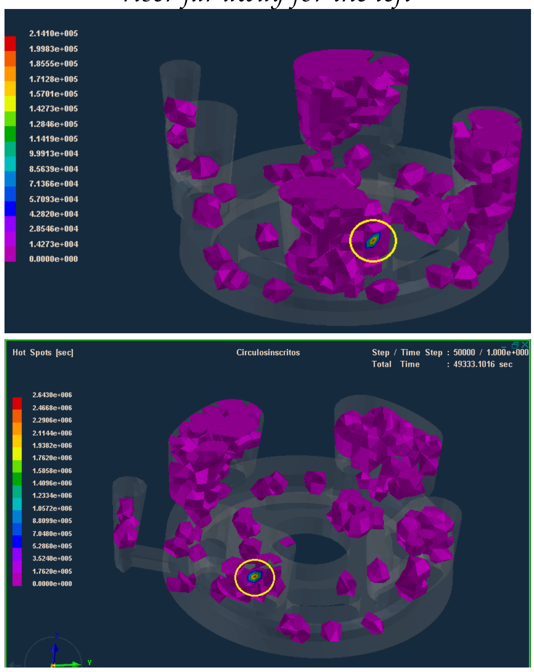

Figure 15. The phenomenon of the Hot Spot can be seen in the simulation by the Modulus method and the Heuver's method.

A foundry was made with the calculated data and the results obtained are shown in the pictures 16 and 17.

Figure 16. Real inside view of risers by the Modulus method

Figure 17. External surface of the real casting without shrinkage porosities

CONCLUSIONS

- ✓ The foundry process has a great complexity due to the great quantity of variables that intervene in the process, subjective many of them.
- ✓ Through the survey carried out experts it can be proven that one of the main parameters that affects the quality of the pieces is the filling of the same ones, influencing the geometry and the calculate method of the risers.
- ✓ The obtained results and shown in the pictures shown that the used methods include a safety coefficient very high, this causes that the riser geometry, be very big.
- ✓ The application of the Modulus method contributes to obtain better quality in the analyze casting, if one keeps fundamentally in mind the appearance of defects of shrinkage porosities, eliminating unnecessary operations and not anticipate expenses.
- ✓ If the Modulus method is applied, a saving is achieved until of 5% in weight of the riser, representing the obtained result, in the total weight until 3%, that is to say 5 kg of metal was saved in a single piece.

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