SOLIDIFICATION OF CASTING STEEL PARTS WITH HALF CARBON, TYPE 55Γ

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ABSTRACT

In this work a study of solidification process of the ring and the roller of the rotational transporter (Jacoby) manufactured of steel 55 Γ is made, which after the fusion process defects by contraction cavities are observed, that affect the quality of production. It is also made the analysis of the main parameters of the technology of production for foundry take in to account the factors related the solidification process. It is carry out a simulation of Finite Elements Method using the software ANSYS version 10.0, to visualize the process of solidification of the selected parts obtaining the graphics and curved characteristic of the solidification process. It is also annexed charts, drawings, sketch and other aspects that facilitate a better understanding of the thematic.

Key Words: *Solidification, cavities of contraction, simulation, temperature, maces.*

INTRODUCTION

Due to the growing competition in the world market the Cuban companies are forced to increase the quality and to carry out a wide study in the preparation, execution and sale of the production, with the objective of taking maximum advantage of each process, elaborating products that are able to compete to the more high-level.

As same as in any metallurgist product, it is normal that the fused parts have porosities, inclusions and other imperfections that contribute to a variation in the quality of the product. The defects in casting are given by imperfections in the parts that it doesn't satisfy one or more specifications of design or quality. The defects due to contractions arise as a consequence of flaws to compensate the liquid contraction and of solidification; therefore, its presence is an usual symptom of an inadequate pouring technique of liquid metal. The shape of it depends on design factors, cooling conditions and of the mechanisms of solidification of the alloy [1].

It is imperative to keep in mind the necessity to apply quality and inspection norms in the production of healthy casting parts because it's great economic importance. In consequence therewith, it is essential that the engineer that works in casting workshop should be in capacity of recognizing defects that can take place by means of this process, and in similar way it is indispensable that he knows the causes that originate it; so that he can eliminate or at least to control it.

EXPERIMENTAL METHODS

The use of calculation methodologies and simulation of formation of defects in casting parts constitute important tools to the casting industry for obtaining and verification of important parameters in the solidification process.

In the last decade has been paid attention to the simulation in computers of casting processes in metals, studying aspects such as filling the molts, transfer of heat and solidification defects, being these some of the biggest challenges that it faces the engineering [5].

For the obtaining via casting selected parts, were follows the next steps:

- To analyze the design of the parts and to carry out the recommendations for its obtaining for casting
- To determine the position of the part in the molt
- To determine the plane of division of the molt and its position in the molt
- To determine the male's position
- To determine the dimensions of the shaping box
- To carry out the calculations, to determine its position as well as the drawings of the pouring systems
- To argue the chosen method of shaping and for the preparation of the males. To recommend the mixtures for the molt and the males
- To determine the basic elements for the process of having filled with the molt, the time of cooling and of demolting
- Recommendations for the demolting and cleaning of the casting parts.

The cooling of the part in the molt is an important stage of the technological process in the elaboration of the casting parts, during which is made the formation of the surface, the configuration and the dimensions of the parts and the structure of the casting material that it determines the physical-chemical estates of the material of the part. The process of formation of the main estates depends on the speed and duration of the thermal processes in the system metal-molt [7].

The duration of the cooling of the parts in the molt also exercises a great influence in the organization and duration of the whole technological process of production of the parts.

Stages of cooling of a part in a molt sand-clay:

- Cooling of the metal in movement in the molt
- Extraction of the heat in the immobile liquid metal
- Extraction of the crystallization heat (solidification)
- Cooling of the solidified part.

The extraction of the heat is considered as the first stage of the cooling and it is considered as the principle of the cooling process, it is supposed $\tau = 0$ and the temperature of the liquid metal is similar to the poured temperature $T_1 = T_v$.

The time of extraction of the overheat τ_2 (time of the second cooling stage).

$$\sqrt{\tau_2} = \sqrt{\frac{\pi}{2}} \cdot \frac{V_1 \cdot \gamma_1 \cdot C_1}{b_m \cdot F_1} \cdot \frac{Tv - T_L}{T_v - T_m} \qquad (\text{hour}^{0.5}) \qquad (1)$$

The extraction of the crystallization heat corresponds to the third stage of cooling of the part in the molt. According to Belay (1970) it is determined as:

$$\sqrt{\tau_3} = \sqrt{\frac{\pi}{2}} \cdot \frac{V_1 \cdot \gamma_1 \cdot \rho_1}{(T_c - T_m) \cdot F_1 \cdot b_m} \qquad (\text{hour}^{0.5}) \qquad (2)$$

ρ_1 - Latent Heat (kcal/ Kg)

T_c – Temperature of crystallization of the part, if the material of the part is an alloy, then the first approach will be:

$$T_c = \frac{T_L + T_S}{2} \qquad (3)$$

T_S – Final temperature of crystallization (solidification) of the alloy (°C).

The duration of the time cooling of the part until the solidification temperature is considered the fourth cooling stage (τ_4).

$$\sqrt{\tau_4} = \sqrt{\frac{\pi}{2}} \cdot \frac{V_1 \cdot \gamma_1 \cdot C_1}{b_m \cdot F_1} \cdot \frac{Ts - Tdes}{Ts - Tm} \qquad (\text{hour}^{0.5}) \qquad (4)$$

T_{des} – Demolting temperature

The total time of cooling of the part in the molt from it poured until the solidification, it will be similar to the sum of the duration of the three stages of the cooling process.

$$\sqrt{\tau} = \sqrt{\tau_2} + \sqrt{\tau_3} + \sqrt{\tau_4} \qquad (\text{hour}^{0.5}) \qquad (5)$$

For the simulation the software ANSYS V. 10.0 was used, with a section of the parts and the in charge mace of feeding the contraction, in two dimensions (2-D) [2].

The variables to keep in mind in the simulation of the solidification process were:

- Temperature of then poured, is selected having the type of material of the part to fuse, these are chosen in a range of (1445 - 1550ºC)
- Thermal conductivity of the material to use, this parameter is selected in correspondence with the temperature
- Thermal conductivity of the molt, it is selected taking into account the characteristics of the shaping mixture
- Enthalpy of the steel in correspondence with the temperature
- Density of the molt
- Specific heat of the molt
- Heat transfer coefficient of the molt.

These variables are chosen because it has bigger incidence in the solidification process from the liquid state to the solid in the selected fused parts.

The steps to carry out the simulation for the finite elements modeling (F.E.M) [6] are the following:

- To define the geometric pattern of the roller and the ring
- To establish the border conditions and load
- To define the meshing
- Run the simulation
- The post processing stage.

RESULTS AND DISCUSSION

In the chart 1 the results of the variables corresponding to the material of the selected parts are shown (ring and roller of the rotational conveyor).

Table 1: Properties of the material

Temperature (T)		Thermal conductivity (λ) Btu/(hr-in-°F))	Enthalpy (E) (Btu/in^3)
(°C)	(°F)		
1500	2822	1,22	174,1
1480	2696	1,22	163,8
1450	2624	1,54	128,2

In Table 2 are shown the results of the variables corresponding to the material of the molt:

Table 2: Molt properties

Temperature (T)		Density (lb-in^3)	Specific Heat (C)(lb-°F)	Thermal Conductivity (λ) Btu/(hr-in-°F))	Heat transfer Coefficient (h) (Btu/hr-in^2-°F)
(°F)	(°C)				
90	32	0,054	0,28	0,025	0,022

Figures 1 and 2 show the meshing that is carried out to the section of the part and the molt in the ring and the roller, the type of chosen element is tetrahedral of 8 nodes with intermediate nodes size 3, the points pointed out in the figure represent the location of the thermal knot and like its moves toward the mace (point 3) and there it disappears.

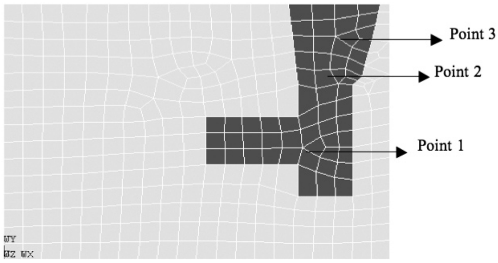

Figure 1: Meshed ring

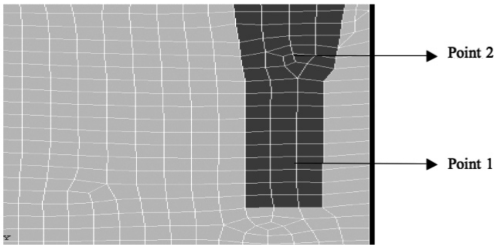

Figure 2: Meshed roller

Figures 3 and 4 represent the solidification curve, it can be observed like in the first tract (1) the cooling of the metal goes accompanied by a soft descent of the temperature that can call it *simple cooling*, the following tract (2) more horizontal, it happens since the extraction of heat is compensated with the latent heat of crystallization that comes off when taking place this. Concluded the crystallization process, finishes the step completely to the solid state (tract 3), the temperature begins again to descend.

The red curves obtained in both represent the solidification in the mace and this had happened last that in the part, for what can feed the contraction cavity and to obtain parts with the smallest quantity in possible defects.

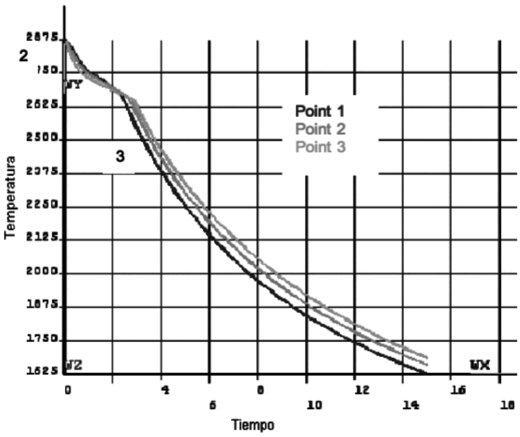

Figure 3: Solidification curves, temperature vs. time in the ring

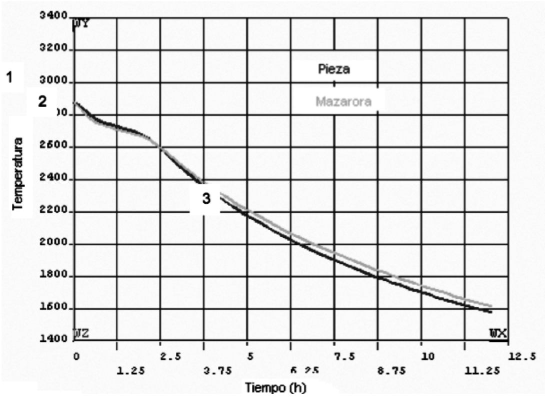

Figure 4: Solidification curves temperature vs. time in the roller

Once realized the procedure for the obtaining of the Figures 1 and 2 and keeping in mind the estates of the material of the parts and of the molt that it refer in the charts 1 and 2, also defining the time of total cooling of the part until the temperature of demolting of 12 hours, the behavior of the solidification of the parts is obtained (ring and roller) with the temperature of having poured selected. Figure 5 shows the beginning of the solidification process in the ring for a time of 0,25 hours and the temperature of 1550ºC, the distribution of temperatures can be appreciated in the part and the molt, identified through the range of colors.

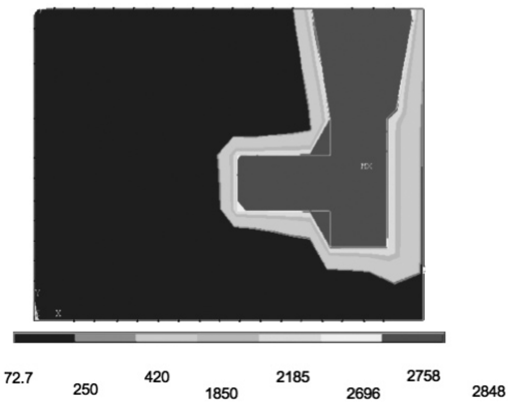

Figure 5: Solidification of the ring at poured temperature (1550°C)

Figure 6 shows the variation of the temperature at the 2 hours of the beginning of the solidification process and as the biggest temperature it goes moving toward the mace as it is shown in Figure 7, red areas are not observed in the part, which indicates the presence of high temperatures and it can give origin to the formation of contraction cavities, this way smaller possibility of obtaining defective molting for the contraction cavities presence.

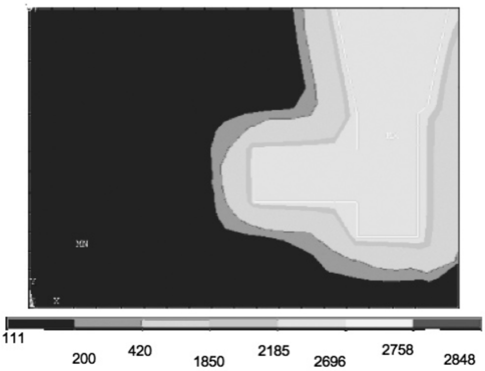

Figure: 6 Solidification of the ring at 2 hours

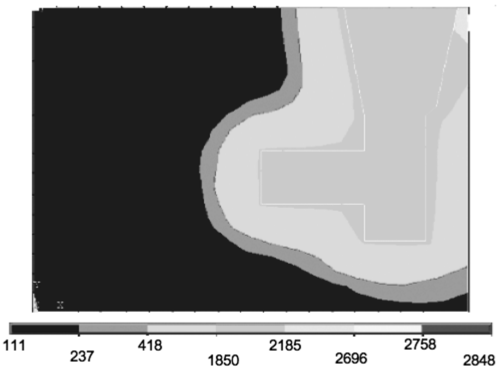

Figure: 7 Solidification of the ring at 6 hours

The solidification process in the roller is shown in Figures 8, 9, 10. Figure 8 shows the beginning of the solidification for a temperature of 1 550ºC and a time of 0,20 hours and like it is the distribution of the temperatures from the part toward the molt.

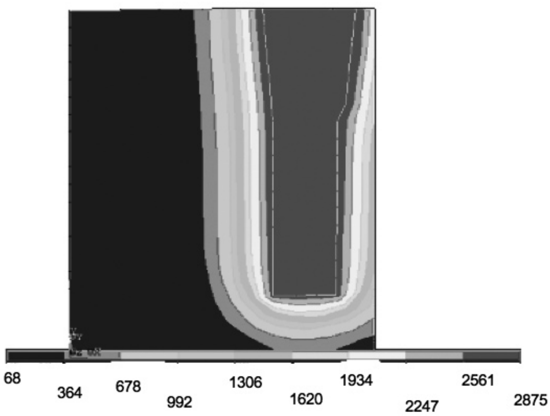

Figure 8: Solidification of the roller at the poured temperature (1550°C) and 0,20 hours

Figure 9 represent the behaviour of the solidification in the roller at the 2 hours and it is observed as the temperature goes diminishing from the part toward the mace, guaranteeing this way the feeding of the contraction cavity.

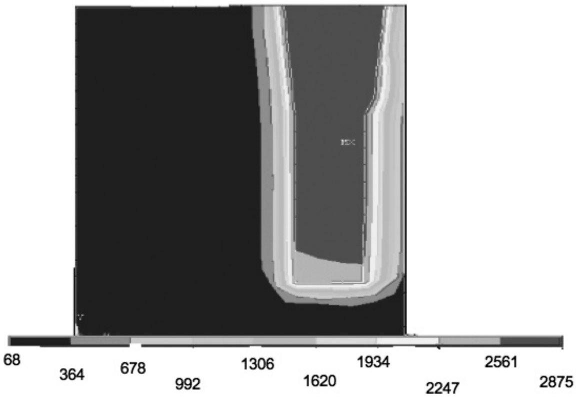

Figure 9: Solidification of the roller at 2 hours

Figure 9 already the lapsed solidification process a time of 6 hours has been completed, where the part will remain in the molt until reaching the temperature of 200ºC. It is observed it doesn't also witness it of areas of high temperatures inside the part ended the solidification process, which indicates the possibility to obtain parts with the smallest quantity in possible defects.

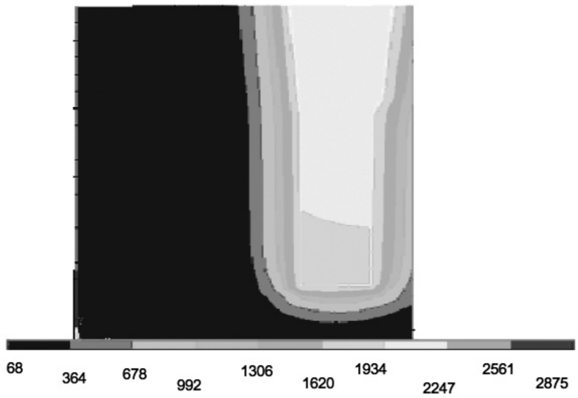

Figure 10: Solidification of the roller at 6 hours

CONCLUSIONS

The analysis of the manufacturing casting process for the ring and the roller of the rotational conveyor shows that the factors that more impact in the contraction cavities appearance are the incorrect selection of the number and mace, dimensions and the poured temperature, influencing this in the manufacturing quality of the fused product. The realized calculation for the maces selection of the manufacturing technology for casting, establishes 8 maces in the ring and 2 in the roller, it will guarantee the feeding of the contraction cavities which will be able to diminish the number of parts rejected by the formation of mentioned contraction cavities. The simulation of the process of solidification of the parts using the M.E.F points out that the maces solidify last that the section of the part, which corroborates that these are correctly designed to feed the cavities with the ranges of poured temperatures, achieving the solidification of the parts with the smallest quantity in possible defects. The obtaining casting parts without the cavities, avoids the process of recovery of parts for welding and it has a significant economical effect.

NOMENCLATURE

T_v = Temperature of the metal during the poured (ºC).
T_L = Temperature at the beginning of the crystallization (liquids) (ºC).
T_m = Temperature of the molt (ºC).
Υ_1 = Specific weight (Kg/m^3).
C = Heating capacity of the liquid metal (kcal/kgºC).
b_M = Coefficient of thermal accumulation (kcal/m^2ºC $h^{0.5}$).
F = Surface of the part or of the molt (m^2).
V = Volume (m^3).

REFERENCES

Altung, L. (1990). *Procesos para ingeniería de manufactura*. Alfa Omega, Mexico D. F. [1]

ANSYS Tutorials (2003). www.mece.ualberta.ca/tutorials/ansys/CL/CAT/Coupled/ Print.html. University of Alberta. Canada. [2]

Barqueño, V., Novo, V. & Sebastián, M. A. (2000). *Gestión y control de calidad*. Colección Cuadernos de la UNED, Madrid. [3]

Barroso, J. & Ibañes, J. (2004). *Introducción al conocimiento de materiales*. Colección cuadernos de la UNED, Madrid. [4]

Borrajo, J. M., Martínez, R. A., Boeri, R. E. & Sikora, J. A. (1999). *Nuevos procesos de diseño y fabricación de piezas coladas*. Anales SAM, Argentina. [5]

Bathe, K. J. (1996). *Finite Element Proceduresin Engineering Analysis*. Prentice Hall, Second Edition Finite Element Analysis: From Concepts to Applications has Appeared. [6]

Callister, W. (1999). *Materials Science and Engineering. An Introduction*. Fifth Edition. Departament of Metallurgical Engineering. University of Utah. John Wiley & Sons, Inc. [7]

Shankar, V., Gill, T. P. & Mannan, S. L. (2003). *Solidification Cracking in Stainless Steel Welds S¯Adhan¯a Journal*. Vol. 28, Parts 3 & 4, pp. 359–382. [8]