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VIBRATING METAL MELTS SOLUTION COMPACTION WALL CASTINGS

I. MĂRGINEAN , B. FLOREA, B.Al. VERDEŞ
UNIVERSITY POLITEHNICA BUCHAREST

ABSTRACT: *Compacting casted parts and reducing the blister on the solidification of alloys are equally interests in improving the quality, characteristics and reducing manufacturing costs by increasing the removal result index from blister compaction.*
Theoretical and experimental research conducted by the authors has lead to obtain beneficial results in this respect.
This paper presents the results and conclusions drawn from this research.

1. INTRODUCTION

The structure and physical-mechanical characteristics of a casted metal material are influenced by its density and compactness.
At the alloys solidification it can occur discontinuities, due to the shrinkage phenomenon, characteristic of most alloys and to the pronounced decrease in solubility of gases in the melt, at crystallization temperature.

2. THE STUDY

Obtaining a compact metal material is provided if the v speed of the alloy penetration into capillary channels of the biphasic zone is equal to the contraction speed v_{contr}.
$v_{contr} = \alpha \cdot m \cdot R$ [m/s]
(1)
where: α - contraction coefficient of the alloy at solidification;
m - ratio between the liquid mass volume from the biphasic zone and this zone's volume;
R - rate of occurrence of solid phase [m/s].

In ordinary conditions, the v speed is expressed as such:

$$v = \frac{r^2}{8\eta} \cdot \frac{P_e + P_m - P_g + \frac{2\sigma}{r}\cos\theta}{l}, \text{ [m/s]} \quad (2)$$

where: r - radius of the capillary channel [m];
P_e – external pressure [Pa];
P_m – metalostatic pressure [Pa];
P_g – channel gases pressure [Pa];
σ - superficial tension of the alloy [N/m];
θ - wetting angle [rad];
η - dynamic viscosity of the alloy [$Pa \cdot s$];
l - length of penetration of the alloy in capillary channels [m].

From the equality of the two speeds $v=v_{contr}$ results:

$$\frac{r^2}{8\eta} \cdot \frac{P_e + P_m - P_g + \frac{2\sigma}{r} \cdot cos\theta}{l} = \alpha \cdot m \cdot R \quad (3)$$

from where:

$$l = \frac{r^2\left(P_e + P_m - P_g + \frac{2\sigma}{r} \cdot \cos\theta\right)}{8\eta \cdot \alpha \cdot m \cdot R} \quad (4)$$

Mechanical oscillations decreases the superficial tension σ at the liquid-solid interface wetting angle θ and imprints the alloy a maximum initial speed $v_i = A\omega$.
Mechanical vibrations action produces in the biphasic zone a dendrite fragmentation,

reducing the length of capillary channels to be covered by the liquid alloy to fill the gaps caused by shrinkage and increase the speed of the liquid alloy flow in these areas, improving supply conditions in micro-cavities.

Also, vibrations determine a macro-blister concentration and a reduction of the porosity in the hot spots, an effect explained by increasing the melt flow.

Mechanical vibrations applied in liquid metal alloys introduce new forces that determine changes in the macrostructure and macro-blister of the casted parts.

The size, shape and position of micro-blister can be determined theoretically by plotting isotherms of solidification in the walls of the casted parts.

Macro-blister is located in those areas of the wall where the liquid alloy solidifies last and alone. Macro-blister consists of one or more concentrated cavities in clearly defined areas, they result from the solidification of large volumes of liquid alloy. Macro-blisters are called as well concentrated blisters. The alloy layers that isolate the blisters between them and cover them in the top part are called decks. The main macro-blister is found in the upper part to the casted part compared with the casting position, while the secondary macro-blister is found in the lower part or in hot spots in the thermal axis zone.

Macro-blister is determined using technological evidence, while micro-blister by applying methods of flaw (X or gamma rays) or by determining the density of samples cut from the casted part wall.

The volume, shape and position of the macro-blister and micro-blister in the walls of the casted parts are influenced by several factors which at their turn depend on the technological nature of the alloy, the nature of the mold, the casting conditions and the casted part geometry.

The total volume of the blister is:

$$V_r = V_{MR} + V_{mr} \quad (5)$$

in which: V_{MR} - the macro-blister volume;
V_{mr} - micro-blister volume.

The factors which influence the blister are the following:

- alloy's nature;
- form's nature;
- casted part geometry;
- casting conditions.

Avoiding the process of developing a micro-blister is impossible, but the routing of the contraction process in order to obtain a macro-blister with as smaller as possible volume and with an optimum distribution in the part's wall is possible.

3. ANALISES, DISCUSIONS, APPROACHES and INTERPRETATIONS

The development of the alloy was made in a crucible furnace, heated by burning a natural gas flame. After melting, the temperature was increased and maintained at 800^0C.

For casting and solidification of the samples were used metal forms.

Fig 1. Alloy's solidification

Fig. 2 Extraction of vibrated samples from the mold

Among physical properties, density is directly related to the development process and represent the unit volume's mass.

From the performed measurements performed we can remember the following:

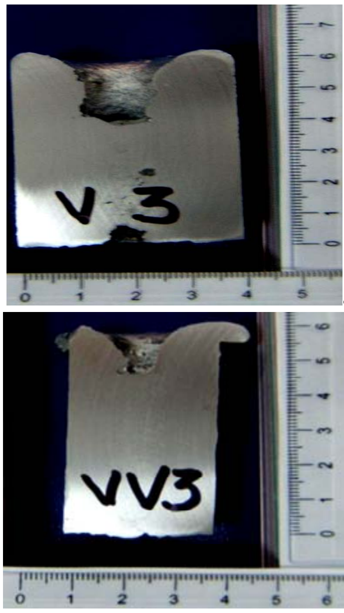
- sample casted from non-vibrated alloy, solidified in outdoor air; (O)

- sample casted in non-vibrated alloy, solidified under the influence of vibration after casting until solidification; (V)
- sample casted from alloy vibrated in pot, solidified without vibration (O')
- sample casted from alloy vibrated in pot, solidified under the influence of vibration after casting until solidification. (VV)

a

b

Fig. 3 Blister aspect for different situations
a- non-vibrated; b- the vibration of melted alloy (only in pot, before casting)



a

b

Fig. 4 Examples of section blisters
a- solidified under the influence of vibration after casting until solidification; b- vibrating the alloy in the pot and during casting until solidification.

Vibrations determine macro-blister concentration, a decrease of porosity from the liquid alloy, to manage the formation processes and structure compacting with small crystals which present the best physical and mechanical characteristics, including increased density of casted alloys with those advantages. Measurement results are presented in Table 2 for an aluminum alloy type ATSi12.5 Mg0.25.

Table 2. The measurements results on non-vibrated, vibrated samples

No.	Sample	Sample mass [g]	Volume [cm^3]	Density [g/cm^3]	Density increase thought vibrating [%]
1	O	30,9044	11,6	2,66	-
2	V	31,9044	11,4	2,79	4,88
3	VV	30,8544	10,9	2,83	6,39

Mechanical properties are also determined by the macrostructure because of the existence of chemical heterogeneity, crystalline or mechanical or discontinuities that play the role of power and micro-concentrators, by size, crystal form, nature and morphology of structural constituents.

Table 3 shows the values obtained by carrying out systematic evidence of resistance to fracture, yield, and elongation at break for the four types of casting:

- casting in gravitational field (O);
- casting after the liquid alloy vibrating in the mold (O'$^{'}$);
- vibrating after casting in the mold until solidification (V);
- sample from the liquid alloy vibrated in the pot casted in the mold and vibrated until solidification (VV).

Table 3. Values for tensile strength, yield, elongation, weakening the fracture toughness for the cast alloy AlSi12.5Mg0.25 of samples realized during research.

No.	Sample type	R_m [MPa]	$R_{p0,2}$ [MPa]	A_u [%]	Z [%]	HB [MPa]	Observations
R1	O1	170	102	3,5	2	87.5	Un-worked sample
R2	O2	176	101	3	2,04	88,6	The split inclusions 0.5 mm
R3	O3	175	103	3,2	2,2	87,3	
R4	O/1	185	111	4,2	5,8	89,3	Un-worked sample inclusions in the area from feeder
R5	O/2	93,8	-	-	-	-	Defect in structure, blister with a diameter of 1.5 mm
R6	O/3	186	112	5	-	90,6	
R7	V1	295	162	4,4	3	105	
R8	V2	296	162	4	2,7	104,3	
R9	V3	295	160	3,9	2,7	106,3	
R10	V4	294	170	3,9	-	103,1	
R11	V5	294	165			103,2	
R12	VV1	150	-	-	-	-	Defect in structure
R13	VV2	295	147	5,6	3	99,3	
R14	VV3	294	145	4,2	1,5	98,6	
R15	VV4	290	150	2,1	2,1	97,2	
R16	VV5	285	151	4	2,8	97,3	Turning diameter of 50 mm, sample in the thermal axis

Following research which refers to treating metal melts with mechanical vibrations, highlighting the fact that they have positively influenced the structure obtained after solidification and on mechanical properties, in the sense that it improves them. The values obtained are much higher than those obtained in the classical variant.

The mechanisms by which these vibrations act on the liquid phase during solidification and melting are complex. Explanation and understanding of these mechanisms is of great theoretical and especially practical importance, allowing us to define appropriate technology for treatment of melt with vibrations.

Figure 5 shows the variation of the degassed alloy hardness under the influence of vibration (50Hz) in the casting pot. It is noted that thought gas elimination was achieved a material compaction, evidenced by increasing the hardness by about 5 percent compared with the gross alloy.

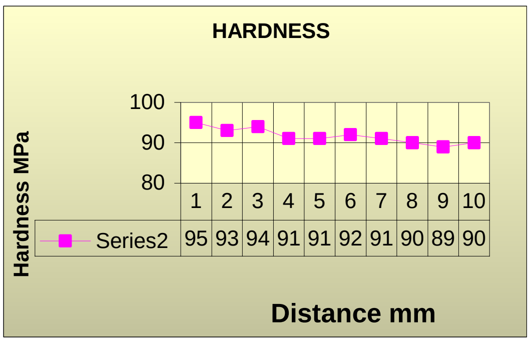


Fig. 5 HB-hardness variation on the radius for alloy AlSiMg vibrating pot, gravitational casting for the ϕ20mm disc, sample O'2

4. CONCLUSIONS

The contour analysis of the contraction gap leads to the conclusion that under the natural action of vibration is reduced the blister depth and its lower part is rounded.

For the alloys with high contraction, prone to cracking, it was observed that due to mechanical vibrations the micro-blisters decrease reducing axial porosity.

Under the influence of mechanical vibration decreases the total volume of macro-blister and focuses on the superior side, reducing the volume of liquid alloy for feeders.

The main favorable technological effects obtained by applying physical-mechanical treatments, consisting of increasing compactness and improving the structure of castes parts.

It also finds a sharp increase in hardness values by 25 percent compared to a gravity cast alloy (static), a slight decrease in the hardness towards the thermal axe, at the same diameters or different diameters of the samples a longer vibrating time leads to chopped microstructures and higher hardness values.

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