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The Effect of Mold and Pouring Temperature on Hardness and Microstructure of a HPDC Hyper-Eutectic Aluminum Alloy

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***Abstract*— The solidification process significantly affects the microstructure and mechanical properties of the HPDC aluminum alloys. This article discusses the effect of some HPDC process parameters on microstructure, density and hardness of a hypereutectic aluminum silicon alloy. The experimental study shows that when pouring and mold temperature are respectively equal to 738 ° C and 130 ° C, the process allows obtaining good quality parts in terms of hardness, density and microstructure, by optimizing primary silicon distribution. Therefore the results will allow obtaining very high quality injected parts.**

***Keywords*— *hypereutectic Al-Si, primary silicon, hardness, high pressure die casting, microstructure, porosity*.**

I. INTRODUCTION

Al–Si alloys are most widely used aluminum alloys due to their castability, high strength to weight ratio, corrosion resistance,…etc [1,2].This fosters use is to reduce cars and aeronautic equipment's weight and other automotive applications [6-10]. Aluminum alloys contain some impurities such as Fe, Mn and Cr which deteriorate the mechanical properties of the casting parts [3–5] The microstructure obtained in the HPDC process is very complex and is affected by many factors associated with liquid and semi-solid melt processing, flow and heat transfer Phenomena. Since microstructure control is a key factor to generate a tribologically excellent cylinder bore, the determination of its structural and thermal characteristics is of primary importance for development of novel HPDC processes [11] ;This work deals with optimizing the production of cylindrical liner with industrial utility. It aims at studying the effect of die and pouring temperature on density, porosity and microstructure of HPDC hypereutectic alloy.

II. EXPERIMENTAL PROCEDURE

The objective of this study is to optimize the manufacturing of a hypereutectic AlSi17Cu4 cylinder liner using HPDC process. The optimization will concern two parameters: the temperature of the alloy casting during pouring and the temperature of the die (mold) at the injection.

The average chemical composition of the hypereutectic aluminum alloy AlSi17Cu4 (wt%) is explained in table 1

TABLE 1: AVERAGE CHEMICAL COMPOSITION OF ALLOY BY (WT%)

Some physical and mechanical characteristics of this alloy are listed in table 2

Element	**Si**	**Cr**	**Fe**	**Ni**	**Cu**	**Zn**	**Mn**	**Al**
Average content wt%	**16,135**	**0,035**	**0,453**	**0,027**	**6,580**	**0,186**	**0,203**	**Bal**

TABLE2: AVERAGE VALUES OF SOME THERMOMECHANICAL PROPERTIES OF ALSI17CU4 ALLOY.

Tensile strength:	**260 MPa**
Young's modulus:	**82 GPa**
Fatigue strength:	**100 MPa**
Hardness :	**120 HB**
Density :	**2,73 g / cm^3**
Liquids temperature:	**650 °C**
Solidus temperature:	**505 °C**
Linear expansion coefficient:	**18 .10^{-6}**

The injection parameters were adjusted on the values that allow obtaining flawless cylinder liner (geometric integrity). These parameters, which were found by previous research, are:
V_1 = 0.4 m.s $^{-1}$ (first shifting speed)
S_1 = 375mm (distance of first movement)
V_2 = 3.5 m.s $^{-1}$(second shifting speed)
S_2 = 410mm (distance second movement)
Molten metal injection speed between 40 and 60 m / s

you

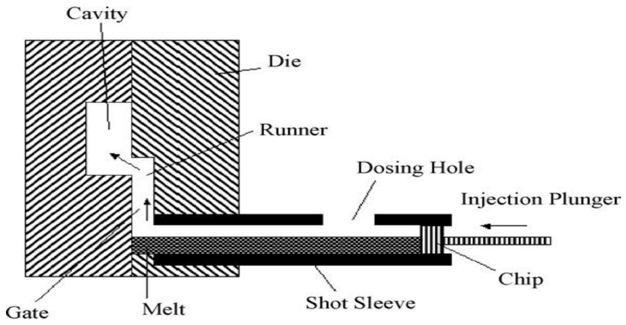


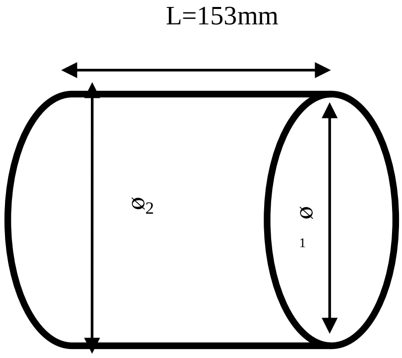
Fig1: Schematic drawing of the HPDC machine with a description of the major components. The plunger injects the melt from the shot sleeve into the die cavity through the gate and runner.

The injection process begins by two blank tests, in order to reach the steady state of the machine. After this step die temperature measurement is performed using a thermal camera and pouring alloy temperature of the alloy is measured using a thermocouple connected to the temperature control of melting furnace.

In a first step, the die (mold) temperature is kept relatively constant and pouring temperature (via melting alloy temperature control) is gradually increased. The table below summarizes the temperatures recorded during this operation:

N° of sample	1	2	3	4	5	6	7	8
Die temperature (°C)	**121.5**	**116.5**	**122.5**	**126.5**	**130.5**	**125**	**124**	**128**
Pouring alloy (°C)	**663**	**680**	**711**	**723**	**738**	**755**	**775**	**810**

TABLE 3: NUMBER OF SAMPLE WITH POURING AND MOLD TEMPERATURE



With:
ø$_1$=83mm : Inside diameter ø$_2$ =88mm: outer diameter

Fig2: drawing geometric shape with dimension manufacture HPDC

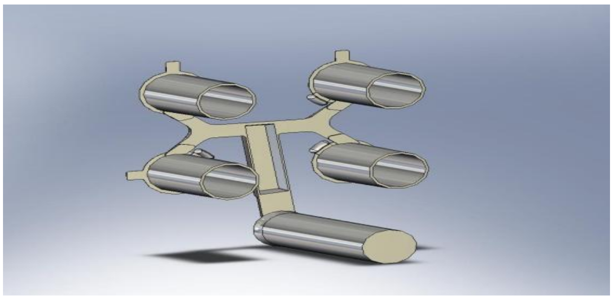


Fig3: drawing Of four cylindrical shapes with the canal filling

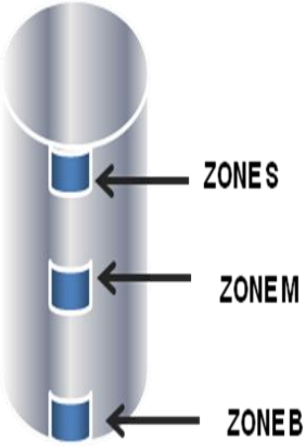


FIG4: the levy for analysis is three Areas mentioned in the drawing

According to the experimental results, it is important to note that physical proprieties such as characteristics and microstructure of the cylinder liners vary between the three zones but remain close to each other within three area (B, M, S) So, in our experimental work, we study the area M.

III. RESULTS AND DISCUSSION

A. *The effect of pouring temperature on hardness*

Hardness of cylinder lining is measured according to Brinel Hardness Test standards; the principle is to measure the diameter of the print that a spherical indenter generates in the material under a determined force. In our case, we are working with a test load of F = 62.5 N and diameter D = 2.5 mm indenter. The table below shows the values obtained:

N° of sample	1	2	3	4	5	6	7	8
mold temperature	121,5	116,5	122,5	126 ,5	130,5	125	124	128
Alloy pouring temperature	663	680	711	723	738	755	775	810
hardness Measurement 1	107	113	107	107	138	115	118	62.4
hardness Measurement 2	107	121	102	121	131	121	121	62.4
hardness Measurement 3	107	112	115	110	128	121	112	95
hardness Measurement 4	107	121	115	121	138	121	107	121
The average hardness HB	107	116.7	109.7	114.7	133.7	119.5	114.5	85.2

TABLE. 4. DIFFERENT HARDNESS VALUES MEASURED ACCORDING TO POURING TEMPERATURE OF THE ALLOYS

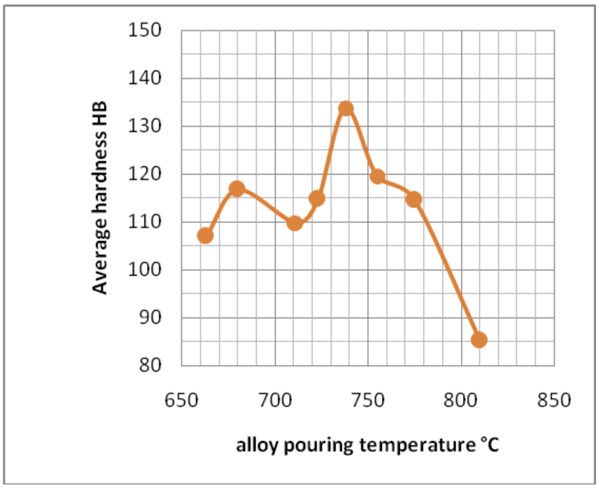


Fig.4.Variation of mean hardness value with pouring temperature

From this study we can infer that: an alloy of hypereutectic aluminum, casting using HPDC process, Mold temperature and alloy having a direct effect on hardness. So we concluded that the temperature which provides a very high hardness value is between 723°C and 775°C. bearing in mind that, the mold temperature must be between 120°C and 130°C.

B. the effect of the casting temperature on densitys

In order to study effect of pouring temperature on the alloy density, we measure the density of cylinder liners prepared, Archimedes' principle of measuring the mass of the sample in air is used (M area) and water (M water).
Therefore the density of the Archimedes' principle was calculated using the following relationship:

$$d = \frac{M_{air}}{M_{air} - M_{water}}$$

N° of sample	1	2	3	4	5	6	7	8
mold temperature	121,5	116,5	122,5	126 ,5	130,5	125	*124*	128
Pouring temperature	**663**	**680**	**711**	**723**	**738**	**755**	***775***	**810**
density	**2,63**	**2,53**	**2,69**	**2,83**	**2,79**	**2,65**	***2,65***	**2,62**

TABLE 5: DENSITY MEASUREMENT IN FUNCTION OF MOLD AND POURING TEMPERATURE

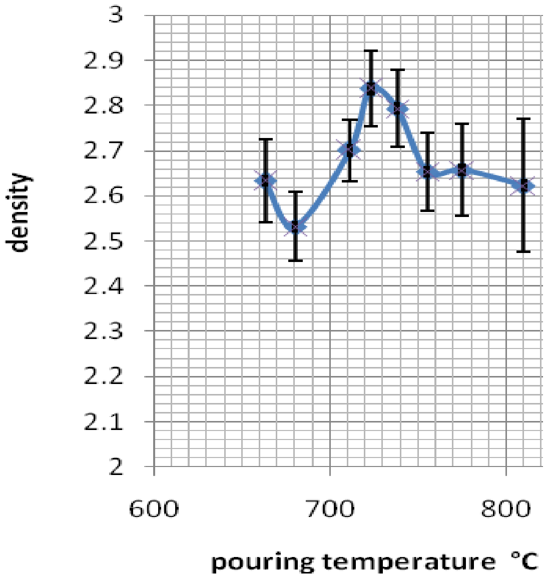


Fig5: Density variation depending on
Pouring temperature

Based on the variation of the curve of density versus the pouring temperature (fig5) we can affirm that the appropriate value of pouring temperature is between 723°C and 775°C. This value gives the highest density and consequently high integrity to the injected part.

According to the two experimental tests finding that: casting temperature of the alloy aluminum hypereutectic has a direct effect on the hardness and density of the molded parts HPDC.

C. The effect of the casting temperature on Microstructure.

Through the study of the effect of the casting temperature on the microstructure, particularly the primary silicon, an optical microscope (AXIOvert40MAT) connected to a camera (Sony XCD-SX910) is used, and images obtained will be processed with software image processing VISILOG V6-Xpert.
A sample preparation which required this experiment is summarized in three steps. The first step of the sample preparation is the machining of the specimen. The second step is polishing a range of carbide paper (P240 P500 P1200 P4000) and the last step is a final polishing with diamond paste 3 microns and lubricants.

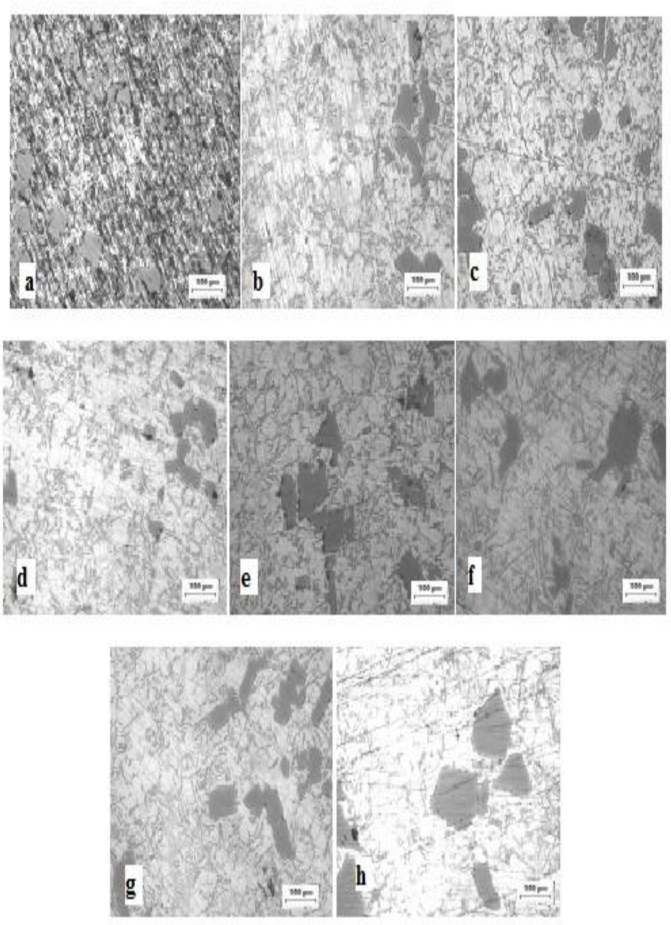


Fig 6: Microstructure of the medium casting part at different temperatures: (a) 663 ° C, (b) 680 ° C, (c) 711 ° C, (d) 723 ° C, (e) 738 ° C, (f) 755 ° C, (g) 775 ° C, (h) 810 ° C.

From the above pictures (fig6) we can see that the size of primary silicon in micrographs (d), (e), (f), (g). is more reduced. In addition, to this other micrographs can be observed that the primary silicon is unevenly distributed.

IV. CONCLUSION

The effect of pouring temperature on the hardness density and microstructure of the hypereutectic AlSi17Cu4 alloy that was investigated using HPDC, for manufacturing a cylinder liner. in this work we can conclude that:

1- When the pouring temperature increases the hardness and density also increases to a maximum value. The maximum hardness that can be achieved is 133,75HB, which represents a significant value for hypereutectic AlSi17Cu4 alloys.

2- Obtaining good quality cylinder liner requires a pouring temperature between 720°C and 750°C, while the mold must be preheated at temperature between 126°C and 130°C.

3- If the pouring temperature is low or heath the primary silicon is not well distributed and most of mechanical propriety is very low like hardness and density.

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