DEPENDENCE OF HARDNESS OF CONTINUES DIE-CASTING PRODUCTS ON FE CONTENT

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Nowadays die-casting is one of the best of metal casting system. Die-casting comparing with the other casting methods is cost preferably, the savings may be 20% of the metal needed for the casting and cost savings of foundry production can be around 30%. In this work we have measure hardness of Al-Si alloy respect to its Fe content. In our experiments we have used digital microhardness tester CV - 400D respect to the Vickers hardness test. Samples were processed in dentacryl. We have made a conclusion that content of the Fe in the alloy have some influence on the product's hardness. Even insignificant difference in chemical composition of the casting products will lead to different hardness characteristics of the products.

KEYWORDS

die-casting, Al-Si alloys, hardness, chemical composition, horizontal die-casting machine

1. INTRODUCTION

Die-casting is a precision casting that is closest to the ideal pursuit of direct conversion of the material to the finished product [Gaspar 2015]. Die-casting comparing with the sand and molds casting is cost preferably, the savings may be from 10 to 20% of the metal needed for the casting and cost savings of foundry production can be around 15-30% [Ragan 2007]. The technology of die-casting is characterized that in the single operation, the liquid metal in a short period of time is converted into a complicated die-cast form with relatively smooth surface and high accuracy of dimensions [Vinarcik 2003, Krenicky 2015]. Another major advantage of this technology is the possibility of thin-walled castings, good mechanical properties, the possibility of casting products with many holes, and the encapsulation of inserts of other metals. An important class of alloys used in die-casting technology is aluminium Al-Si alloy that exist in different variations. They are distinguished by the contain value of various alloying elements, as even small changes in the chemical composition of the alloy can significantly change the mechanical properties of the resulting die-casting products [Gaspar 2003, Panda, 2014, Zaborowski 2015]. Also an important parameter is the chemical composition of the melt as a reason of final product composition. One of the elements occurring in the melt is iron Fe. Ferrite is in Al-Si alloys present as an impurity. The solubility in the solid state is low (about 0.04%) which results intermetallic compound in the aluminium structure in the form of Al_5FeSi. The alloys of intermetallic phase Al - Cu (Al_7FeCu_2) will reduce the copper content in solid α solution which will lead to reduction of the product strength properties. [Bolibruchova 2005, Fedak 2009, Grigerova 1988, Chvojka 1971, Lukac 1987, Sebl 1961]. During the casting process, the Fe concentration can be varied by a range of mechanisms, one of which is the reuse of recycled material. As a recycled material we understand different foundry allowances. For machines with cold chamber it can also be a remnant of the cold chamber. The proportion of recycled material depends on the size of the casting. Drains and other auxiliary foundry additions comprise the following ratios (Table. 1) [Ragan 2007, Valecky 1967]

Table 1. Comparing of drains and castings volumes

Type of the casting by its size	Percentage comparing of drains and castings
Huge castings	10-25%
Middle castings	25-100%
Small castings	100-300%

The proportion of recycled material constitutes around 65% of weight of the liquid metal, twice weight of the castings. In the hot-chamber machines, the proportion of recycled material is around 45-50% of weight of the liquid metal [Ragan 2006, Ragan 2007, Sejbl 1961, Vinarcik 2003].

Change in chemical composition which, even in small limits may effect on the final mechanical properties of the casting [Fedak 2013]. It is clear that an important role in the castings produced by die-casting technology plays hardness, one of the essential characteristics which determining possibilities of casting in technical practice [Malik 2007].

In this work we observed effect of the iron as a naturally occurring element on the melt respect to the casting hardness. Also there were observed the impact of aging on castings described characteristics.

2. SAMPLE PREPARATION FOR HARDNESS TESTS

For the experiment, we made the series casting (casting's shape Fig.1) according to the specified technological regulations (Tab. 4). Castings were made on a horizontal die-casting machine CLH 400.01 with a cold chamber, manual dosage of the metal. Before further processing, all castings undergo to x-ray tests, to verify possible internal defects of castings. The results did not show serious internal shortcomings but in some samples have been observed small errors inside - bubbles. Subsequently electing of samples was made bypassing these areas.

Table 2. Technological prescription of the casting

Casting parameters	
The basic pressure	30±2 MPa
Track length of the third velocity	270 mm
Third velocity	2.5 rpm
Diameter of the chamber	60 mm
Tablets size	25 mm
Temperature of the melt	660±20 °C
Pad under the chamber	40 mm
Weight of a whole metal in the chamber	1300 g
Dosing spoon No.	5
Cycle time	50.42 s
Setting time	4 s
Pressing time	5 s
Time of the decongestion	2 s

For each evaluation we selected eighth cast, so a total number were ten samples, to represent the full spectrum of available capacity of the furnace.

This selection was based on the observation that during the casting process melted metal have a slight changes in the content of some elements [Fedak 2013].

Sampling points are shown schematically in Fig.1, the choice was made according to the functionality of the each part. From each casting were taken two samples (hereinafter marked B, D). Sampling was also chosen by the surface as each sample should be parallel to the axis of the hole, what helped to research samples in the direction of burden changes.

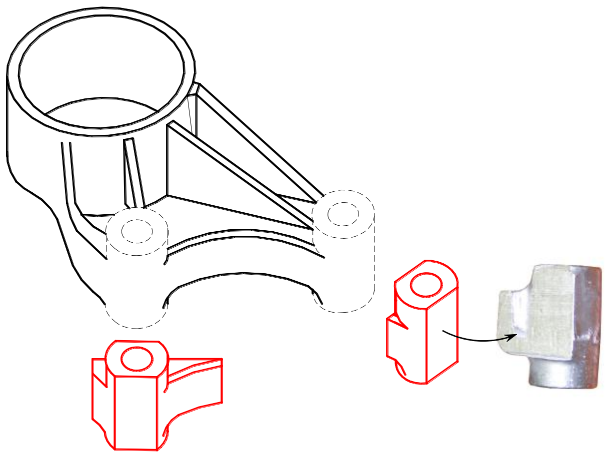

Figure 1. Sampling points of the castings for hardness research

The sample preparation for the measurement of hardness was elected following procedure (Fig. 2).

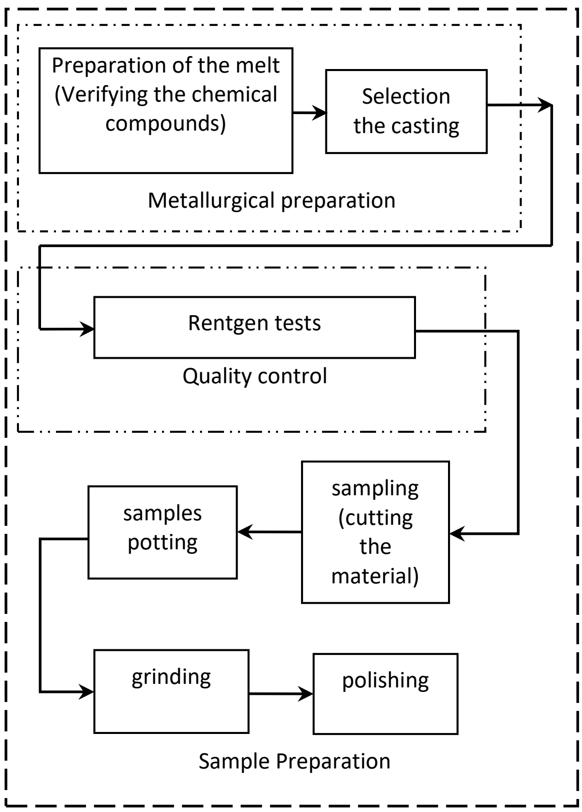

Figure 2. Scheme of samples preparing for the micro hardness measurement

The cold samples were embedded in dentacryl.Grinding was carried out using a rotary sander. It was made as wet grinding using a set of water-resistant sand papers with grain size 120, 400, 800, 1200-2400.

In the last phase of preparation for obtaining samples they were performed using a polishing cloth pads.

Monitoring of iron content in castings was made in SPECTROCSAT spectrometer device. To ensure the highest accuracy of the experiment we have analysed samples element content which were conducted in the two sampling points (Fig. 1) sampling points were as close as possible to eliminate the influence of the change in the composition of Fe.

3. CONDITIONS OF THE EXPERIMENT

Assays were performed at 20 analyzed samples that were taken from castings. Wherein for each sample was carried out 10 measurements. Hardness tests were carried out using a hardness tester CV - 400D according to the Vickers hardness test.

Vickers hardness test (Fig. 3)

$$HV = K\frac{F}{S} = 0.102\frac{2F\sin\frac{\alpha}{2}}{d^2} \quad (1)$$

where:

HV – Vickers's hardness,

K is constant

$$K = \frac{1}{g_n} = \frac{1}{9.80665} = 0{,}102 \quad (2)$$

F – test load[N]

α – top angle of the indenter body α = 136°

d – arithmetic average of the diagonals of the indentation d_1, d_2 [mm]

$$d = \frac{d_1 + d_2}{2} \quad (3)$$

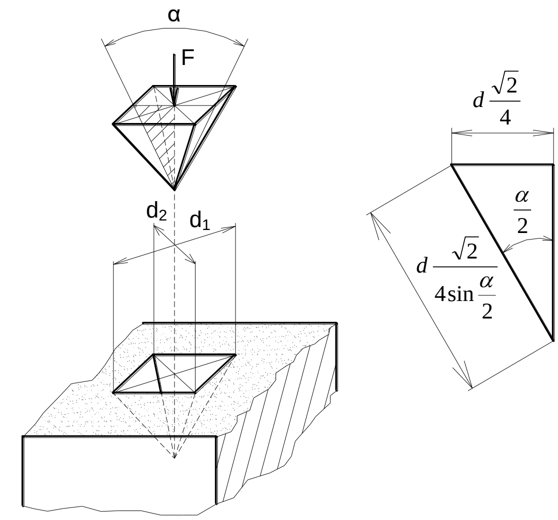

Figure 3. Scheme of Vickers hardness measurement

The test is usually carried out at room temperature 10 to 35 ° C, in laboratory conditions was performed at 23 ± 5 °C. The used test load was 1000 g. Invading indenter is pushed into the body of an investigational test load direction perpendicular to its surface. The time from the beginning of loading to the maximum value shall not exceed 10 seconds. The speed of the indenter ball body with injections shall not exceed 200 µm.s [-1]. Time of a maximum test load was set at 10 seconds.

During the test the testing device must be protected against various shocks and vibrations that can affect the test results [Krenicky 2008]. Hardness tests were carried out on the digital microhardness tester CV - 400D (Fig. 4) designed to measure microhardness and hardness at low loads.

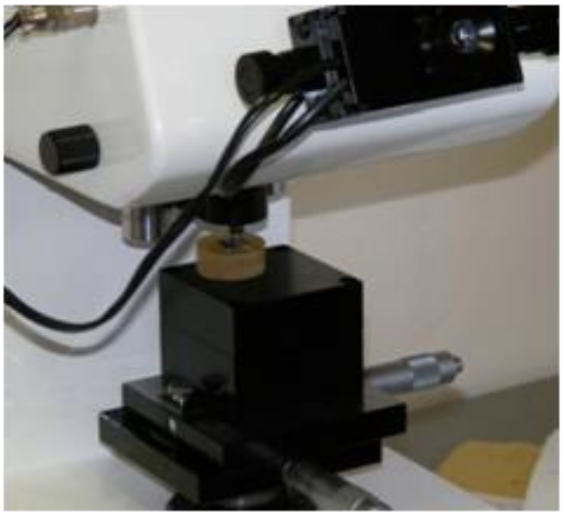

Figure 4. Digital microhardness tester CV - 400D

4. RESULTS AND ANALYSIS HARDNESS MEASUREMENT

The results of chemical composition analysis with respect to the determination of the Fe content in the taken samples are shown in Tab. 3. Also there you can see statistically evaluated values for each of hardness measurement.

Table 3. The Fe content (wt%), arithmetic average values and standard deviations for samples B, D

Castings		Fe [%]	Hardness	
No	Sampling point		$\overline{x}$	s
1	**B**	0.91	97.33	1,0833
	D	0.88	94.05	0,8236
2	**B**	0.86	95.73	0,7196
	D	0.87	92.75	0,7517
3	**B**	0.87	92.72	0.9750
	D	0.88	91.82	0.8574
4	**B**	0.87	102.32	0.9987
	D	0.89	98,23	1,0335
5	**B**	0.87	91.83	0.8407
	D	0.87	92.49	0.4701
6	**B**	0.86	92.80	0.8192
	D	0.87	91.42	0.9852
7	**B**	0.84	96.89	0.8239
	D	0.86	96.90	0.7832
8	**B**	0.79	90.59	0.798
	D	0.78	92.74	1.000
9	**B**	0.77	96.28	0.6512
	D	0.78	95.90	0.5617
10	**B**	0.86	92.11	0.7593
	D	0.86	93.52	0.6215

We have made replicate hardness measurements on sample B with an interval of 30 days. The results are shown in Table (Tab 4).

Table 4. The arithmetic mean and standard deviation, sample B720

	B1	B2	B3	B4	B5
$\overline{x}$	98.82	96.16	94.74	104.26	96.8
s	0.7014	0.4879	1.2641	1.0334	0.8456
	B6	B7	B8	B9	B10
$\overline{x}$	98.24	97.02	95.96	98.82	94.62
s	1.0644	0.3421	1.2700	0.8927	0.9066

Due to next processing of the measured values you can see in the graphs (Fig. 5 to Fig. 7) which displaying the hardness with the respect to the Fe content.

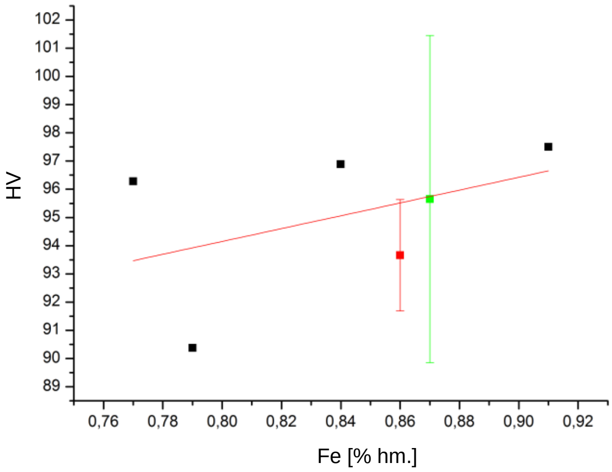

Figure 5. Hardness of the sample B with the respect to the Fe content

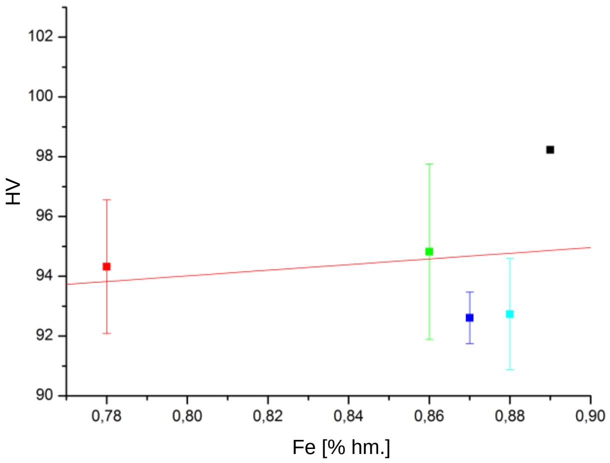

Figure 6. Hardness of the sample D with the respect to the Fe content

The monitored measurement value dispersion was in the range from 0.76 to 0.91 wt% of the iron content of the samples. The variance is 16.5%. Measured hardness values are in a positive equation with shown weight percent of iron content. As it shown in the graph (Fig. 4-6) we can say that increasing of the iron content causes a slight increase in the measured values of hardness.

The results point to the fact that the hardness of the sampling point B shows higher values than at the point of sampling. The of repeated intervals of the measurements are 720 hours, the results shown in the figure (Fig. 7) where you can see an increase of hardness.

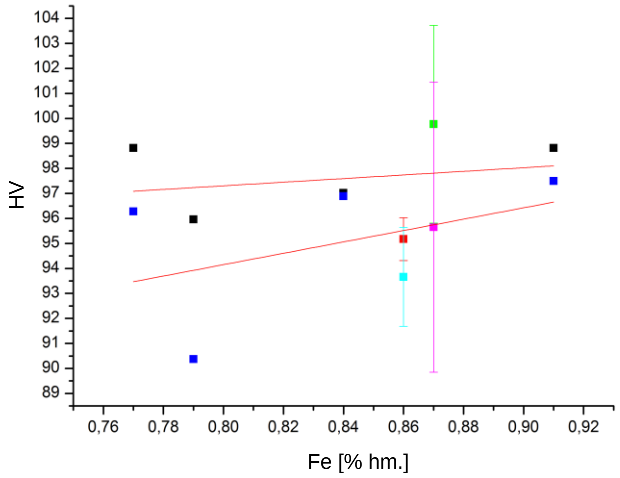

Figure 7. Hardness of the sample B(B720) with the respect to the Fe content

Theoretical information appears that the place nearest to the inlet have the higher hardness values than points of some distant from the inlet.

5. CONCLUSIONS

Quality assurance of the die-casting depends on different aspects. Practical experiments have proven theoretical knowledge of die-casting, and before analysis and measurement we have made samples radiographic tests carried out to identify possible internal defects. Evaluating the results of this test was found a low rate of internal faults, and has not been proven that errors are affecting hardness. Faults occurred on the castings in the points markedB, D samples does not have internal faults. These defects of B samples are attributed to the location of the sampling point near to the inlet where metal stream divided on some smallest streams. Turbulent flow of the liquid metal in these areas causes the appearance of vortex.

According to the results, with increasing Fe content hardness of castings will increase only slightly. The result is the necessity of the positive correlation. Also, the aging effect of the castings was observed at 30 days and confirmed the increase of hardness of the samples.

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