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Roughness of surface of vacuum castings prepared in plaster moulds

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Summary

The results of researches on surface roughness of CuSn10 and CuSn5Zn5Pb5 bronzes and aluminum AlSi11 alloy vacuum castings prepared in plaster moulds are presented in this paper. Test samples were cut from stripe castings of dimensions 100x15x1 mm. Surfaces were carefully cleaned with use of soft brush than in ultrasonic washer and dried.
Experimental castings were prepared in moulds made of two types of plaster. Cast temperatures were 1120 and 1200°C for bronzes and 700 and 800°C for silumin. Temperatures of the mould were 500 and 600°C for bronzes and 200 and 300°C for aluminum alloy. The roughness measurements were carried out with use of Hommelwerke Tester T1000. The average arithmetic deviation of roughness profile Ra, the ten-point height of irregularities Rz and maximum peak to valley height Rm, were measured.
It can be stated, on the base of obtained results, that technology of casting in plaster moulds allows preparation of castings of very low roughness, average Ra=0,88÷1,74μm for bronzes and Ra=0,59÷0,83μm for aluminum alloys. Roughness of the surface depends in fact on the cast material. Type of plaster and casting parameters have negligible influence on it.

Keywords: Modern casting materials and technologies, Precision castings, Plaster mould, Precision casting surface roughness

1. Introduction

Castings prepared in plaster moulds belong to the group of precision castings [1]. One of the characteristic feature of them is a low roughness, reported to be Ra=0,8÷3,2μm, however authors do not provide information on type of castings and moulds [2,3].

Roughness of the castings is determined with use of Ra and Rz parameters (standard PN-87/M-04251), and the Ra parameter is privileged both to Rz parameter and others listed in the standard.

Parameters given in standard PN-87/M-04251 [8]are defined as follows:

- Ra – average arithmetic deviation of roughness profile:

$$Ra = \frac{1}{L}\int_A^B |y|dx \approx \frac{1}{L}\sum_{n=1}^{i=n} |y_i|$$

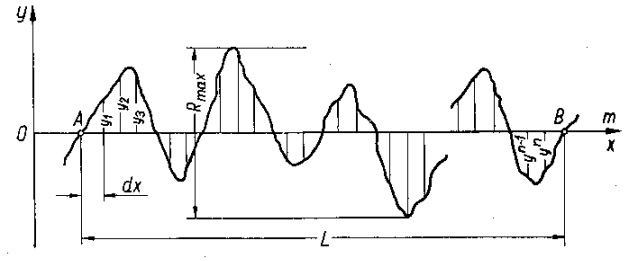

Fig. 1. Scheme of irregularities of surface for define Ra and Rmax parameters

- Rz – ten-point height of irregularities of surface.

$$Rz = \frac{(R_1 + R_3 + \cdots + R_9) - (R_2 + R_4 + \cdots + R_{10})}{5}$$

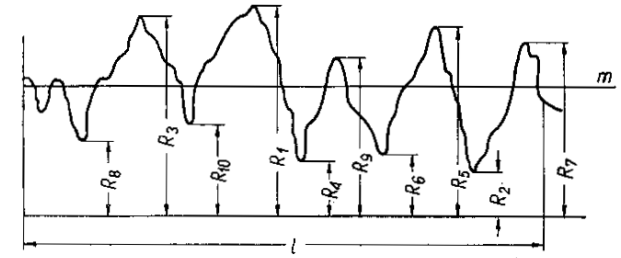

Fig. 2. Scheme of irregularities of surface for define the height of irregularities Rz

Sometimes the Sm(Rmax, Rm) parameter is given determining maximum peak to valley height.

Following parameters influence the quality of the castings surface prepared in typical molding sands [4]:

1. Type of mass and preparation.
2. Type of metal and temperature.
3. Preparation of mould and pouring parameters.
4. Cast cleaning procedure.

This matter looks different in the case of plaster moulds. Casting plaster are very fine-grained, and the characteristic setting mechanism causes the creation of smooth skin inside the cavity [5].It can be inferred from this, that type of plaster slightly influences the casting surface roughness.

Type of cast material thus the cast temperature can influence the state of the cast surface, even if the partial destruction of the shaped cavity surface as a result of thermal and chemical influence of the liquid alloy[6].

In case of vacuum cast plaster moulds the procedures of mould preparation and running castings are determined by devices and applied technology [7].

Casting prepared with use of discussed method are typically cleaned in the same way, so high pressure cleaner and ultrasonic one are used. Final surface treatment is made with use of pneumatic cleaning by grinding material flow.. Dependently on final requirements, Materials strongly influencing surface state can be used (like corundum sands, carbo-corundum or sharp-edge quartz) or ones removing plaster mass remainders and slightly polishing (like glass balls). The last method does not change the surface state, in the matter of fact.

2. Scope and methodology

The goal of the researches was to determine the influence of plaster mould material type and its temperature at the moment of running as well as liquid Alloy temperature on the surface roughness of the experimental casts..

2.1. Range of researches

The range of materials and temperatures in which tests were carried out, was determined on the base of preliminary researches.

Set of parameters is presented in table 1.

Table 1.
Materials and parameters of experimental casts for roughness measurements, preparation

Mold material	Plaster powder Gold Star XL (GS)				Plaster powder Prima Cast (PC)			
Casting material	CuSn10							
Pouring temperature, t_{zal}, °C	1200		1120		1200		1120	
Mould temperature t_f, °C	500	600	500	600	500	600	500	600
Sample mark	1-1	1-2	1-3	1-4	2-1	2-2	2-3	2-4
Casting material	CuSn5Zn5Pb5							
Pouring temperature, t_{zal}, °C	1200		1120		1200		1120	
Mold temperature t_f, °C	500	600	500	600	500	600	500	600
Sample mark	3-1	2-2	3-3	3-4	4-1	4-2	4-3	4-4
Casting material	AlSi11							
Pouring temperature, t_{zal}, °C	800		700		800		700	
Mold temperature t_f, °C	300	250	300	250	300	250	300	250
Sample mark	5-1	5-2	5-3	5-4	6-1	6-2	6-3	6-4

2.2. Materials

a) jewelry plaster bonded investment powder Gold Star XL by Hoben of following properties [9]:
   – water/gypsum ratio for ø 120 mm – W/G=0,40
     setting time: start: t_{wp}=16'20"
finish: t_{wk}=18'00"
   – bendig strength after 2 h Rg^u=1,2MPa,

b) jewelry plaster bonded investment powder Prima Cast by WhipMix of following properties [3]:
   – water/gypsum ratio for ø 120 mm W/G=0,40
   – setting time : start: t_{wp}=17'40''
   finish : t_{wk}=20'00''
   – bending strength after 2h Rg^u=1,1 MPa.

c) model wax (green) by Vigor in form of sheets of thickness g=0,8; 0,6; 0,5 mm,

d) jewelry injection wax (green) by Castaldo for model slips preparation of thickness g=1,0 and 2,0 mm and rods of ø 10 and ø5 mm.

e) distilled water,

f) CuSn10 bronze of chemical composition Sn=10,24%, Pb=0,537%, Zn=0,345%, Ni=1,64%, Sb=0,122%.

g) CuSn5Pb5Zn5 bronze of chemical composition Sn=4,66%, Pb=5,93%, Zn=5,46%, Ni=0,988%, Fe=0,133%.
near eutectic silumin AlSi11 Si=10,89%, Fe=0,648%, Mn=0,311%, Mg=0,142%, Zn=0,0488%, Ti=0,0509%.

2.3. Researches methods

2.3.1. Mixing the slurry

The slurry was prepared in vacuum mixer „St. Louis" 82 according to following procedure:
– pouring weighted dry plaster powder into the mixer chamber,
– degassing during 120 s,
– delivery of measured amount of distilled water,
– mixing under vacuum during 210 s at rates n=150÷350 rpm.pouring the mass into the tube (inside the vacuum chamber).

2.3.2. Experimental model

The experimental cast consisting of four wax straps of dimensions 15x100x1 mm placed vertically around sprue ofdiameter Ø10 mm (Fig.3).

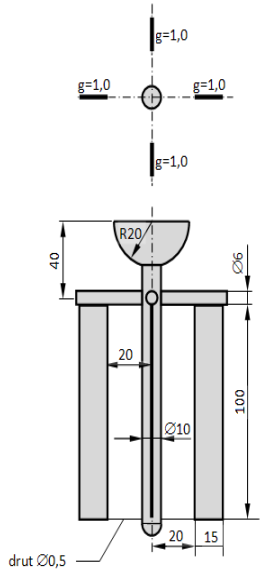

Fig. 3. The wax pattern of experimental casting for researches roughness of surface

2.3.3. Experimental mold

A. Mold preparation

Experimental moulds were prepared in heat-resisting steel perforated cylinders of dimensions ø100x220 according to following procedure:
– mounting the experimental model on the rubber base,
– mounting the cylinder in the base seat,
– placing the cylinder with the pattern in the pouring chamber of the „St. Louis 82" mixer,
– pouring, under vacuum, the liquid plaster slurry into the cylinder,
– removing the mould from the mixer chamber,
– setting and preliminary drying of the mould under ambient conditions during 2h.

B. Heat treatment

Dried moulds were baked in box-type resistance furnace APE 800 according to procedure show in figures 4 and 5.

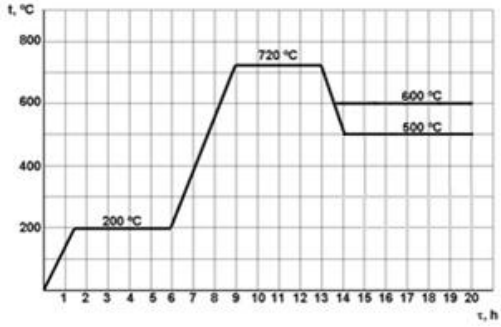

Fig. 4. The scheme of CuSn5Pb5Zn5 and CuSn10 bronzes experimental moulds heat treatment

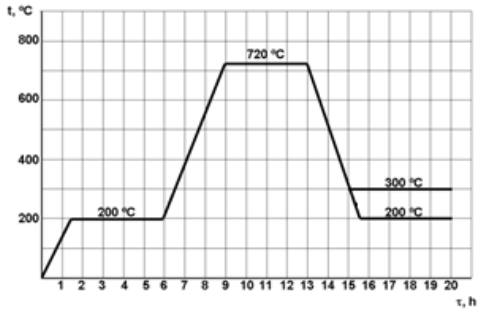

Fig. 5. The scheme of silumin AlSi11 experimental mould heat treatment

2.3.4. Experimental castings preparation

Examined alloys were melted in Vacuum Pressure Casting Machine VC 500D Indutherm in argon atmosphere.

Experimental castings were prepared according to following procedure:

- Castings of CuSn10 and CuSn5Zn5Pb5 bronze:
  melting and overheating to temperatures, respectively, 1120 and 1200ºC.
- Castings of AlSi11 silumin:
  melting and overheating to temperatures, respectively, 700 and 800ºC.
- Next operations were making the same for all alloys:
  - removing of hot mould from the furnace APE 800 and placing it in the caster chamber,
  - checking mould temperature in the canal of sprue,
  - closing the chamber and degassing the mould in vacuum during 90 s,
  - casting the mould (from bottom-pour stopper crucible in argon atmosphere),
  - casting solidification during 120 s
  - removing the cast mould from the chamber,
  - mounting K type thermocouple in the drilled ø2x80 mm hole
  - waiting for 90-300sec for final crystallization (time dependent on the pouring basin volume and lab conditions and was set experimentally)
  - immersing the mould in water to remove the cast,
  - cleaning the cast by high pressure water cleaner,

2.3.5. Samples preparation

Samples for surface roughness measurements were prepared as follows:

- cutting off sample of length 70mm (70x15x1mm),
- careful "wet" cleaning with use of soft brush,
- ultrasonic cleaning,
- drying in the flux of hot air,
- final cleaning (polishing)in the flux of glass balls of diameter ø0,125 mm,
- selection of samples from one casting from the viewpoint of defects elimination resulting from micro cracks of the mould or imperfection of wax pattern.

2.3.6. Surface roughness measurement of experimental casts

Roughness measurement were carried out with use of Hommelwerke Tester T1000.

The accuracy of the surface was determined on the base of measurements of:

- average arithmetic deviation of roughness profile Ra, ,
- the ten-point height of irregularities Rz,
- maximum peak to valley height Rm,

made on the gauge length Lt=4,8 mm. Such gauge length (in accordance with PN-87/M-04251 for Ra=0,4÷3,2 µm l=0,8 mm) was applied to obtain more reliable results.

The final result of measurement is an average from five gauge length runs.

3. Discussion

Results of measurements are presented in table 2 and 3. Examples of profilograms from the surface of bronze CuSn10 casting made in Gold Star XL plaster mould are presented in Figure 6. Analysis of the test results did not revealed a clear dependences between surface roughness of castings and methods of the preparation. Roughness values are random, independent on casting temperature and temperature and material of the molds. The one regularity that could be observed was that lower roughness parameter Ra showed test casts made of aluminum alloy AlSi11, next bronze casts CuSn10 and the higher value was observed for CuSn5Zn5Pb5 bronze.

Generally it can be assumed that roughness of tested casts is very low, comparable to pressure die casts. It can be clearly observed for aluminum alloy AlSi11 for which measured parameters are in the range Ra=0,59÷0,83µm (Rz=4,57÷4,92µm). The most Ra values lay in the range 0,59÷0,72µm and the influence of temperature factor on them is the lowest.

Bronze casts roughness lays in the range Ra=0,88÷1,74µm (Rz=7,07÷12,01µm). The spread of averages of measured parameters is definitely higher than in case of aluminum casts. This is a result of higher mould and cast metal temperature thus more intensive influence of an alloy on the cavity surface.

In bronze castings the values of Ra>2µm are incidental and are the result of insufficient quality of wax pattern surface. Obtaining of ideal wax pattern is very difficult. From the practice point of view it seems that quality of the pattern influences the state of the casting surface more than cavity. This problem requires further researches.

Table 2.
Results of surface roughness of experimental castings made in mould of plaster powder "Gold Star XL"

Casting material: **CuSn10**					
Sample	Pouring temperature, t_{zal}, °C	Mold temperature t_f, °C	Result of roughness measurement		
			Ra, µm	Rz, µm	Rm, µm
1-1	1200	500	0,99	7,73	10,26
1-2		600	0,98	8,52	11,38
1-3	1120	500	1,69	11,82	14,04
1-4		600	1,22	9,28	12,08
Casting material: **CuSn5Zn5Pb5**					
Sample	Pouring temperature, t_{zal}, °C	Mold temperature t_f, °C	Result of roughness measurement		
			Ra, µm	Rz, µm	Rm, µm
3-1	1200	500	1,67	11,71	14,74
3-2		600	2,58	17,02	25,13
3-3	1120	500	1,58	11,05	13,42
3-4		600	1,14	8,20	10,69
Casting material: **AlSi11**					
Sample	Pouring temperature, t_{zal}, °C	Mold temperature t_f, °C	Result of roughness measurement		
			Ra, µm	Rz, µm	Rm, µm
5-1	800	300	0,69	4,34	5,66
5-2		250	0,83	4,92	10,24
5-3	700	300	0,64	4,58	8,98
5-4		250	0,69	4,16	6,29

Table 3.
Results of surface roughness of experimental castings made in mold of plaster powder „Prima Cast"

Casting material**: CuSn10**					
Sample	Pouring temperature, t_{zal}, °C	Mold temperature t_f, °C	Result of roughness measurement		
			Ra, µm	Rz, µm	Rm, µm
2-1	1200	500	0,96	6,41	7,90
2-2		600	0,98	7,07	8,60
2-3	1120	500	0,88	6,77	9,38
2-4		600	1,36	9,97	12,73
Casting material: **CuSn5Zn5Pb5**					
Sample	Pouringtemperature, t_{zal}, °C	Mold temperature t_f, °C	Result of roughness measurement		
			Ra, µm	Rz, µm	Rm, µm
4-1	1200	500	1,28	9,64	13,63
4-2		600	1,74	12,01	14,69
4-3	1120	500	2,60	17,17	21,55
4-4		600	1,50	12,00	19,59
Casting material: **AlSi11**					
Sample	Pouring temperature, t_{zal}, °C	Mold temperature t_f, °C	Result of roughness measurement		
			Ra, µm	Rz, µm	Rm, µm
6-1	800	300	0,72	4,89	6,89
6-2		250	0,62	3,69	4,81
6-3	700	300	0,59	4,57	7,75
6-4		250	0,60	4,00	4,96

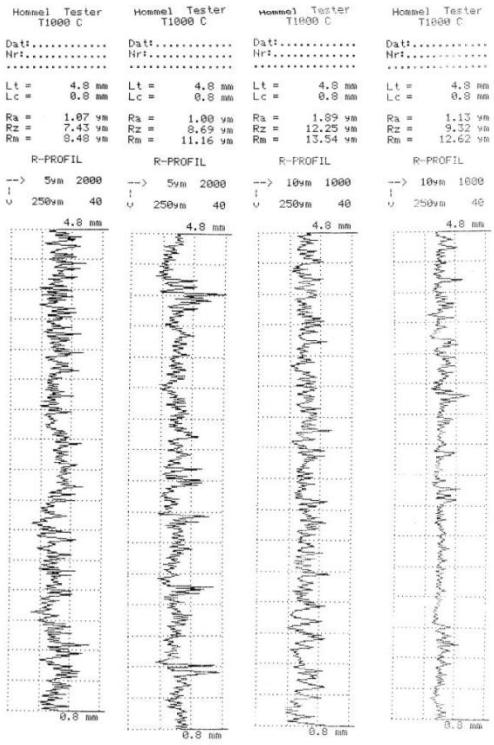

Fig. 6. Examples of profilograms from the surface of bronze CuSn10 castings (samples 1-1 ÷ 1-4). Mold material: Gold Star XL

4. Conclusions

Analysis of measurement results allow to formulate following conclusions:

1. Technology of vacuum casting in plaster moulds allows preparation of casts of very low surface roughness.
2. Roughness of casting surfaces depends on cast material.
3. Roughness of casting surfaces does not depend clearly on the mould material, its temperature and cast material temperature.

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[9] PN-86/B-04360 Spoiwa gipsowe. Metody badań. Oznaczanie cech fizycznych (Bindersbased on calciumsulfate. Method of tests for physical properties).