The dependence of cast structure on geometric shape, vibration conditions and thermophysical properties of mold

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MS received 7 April 1995

Abstract. This paper contains results of experiments carried out with the aim of assessing the influence of various casting parameters on the microstructure of an aluminium alloy. Castings have been made with and without vibration, in molds with different thermophysical properties.

Keywords. Structure; vibration; type of cast.

1. Introduction

It is well known that the primary aim during the crystallization process of aluminium alloy containing 4.5% copper is to achieve a fine grain structure. To this end, the influence of vibration parameters (amplitude and frequency) as well as of the geometry of the mold on the grain size have earlier been considered (Gončarević 1986). The objective of the present study is to estimate the influence of thermophysical features, vibration parameters and mold shape on the resultant grain size in Al-4.5 Cu alloy.

2. Experimental

The structure of Al-4.5 Cu alloy consists of α -solid solution and grain boundary inter-metallic compound CuAl_2 (ε -phase) which enables easy counting of the grains. Casting was done in sand, graphite or metal (Al-4.5 Cu) mold. Stationary as well as vibration conditions were employed during solidification. The cooling modulus of different geometric shaped molds (roller, cube, slab or ball) was maintained constant with a view to obtain the same heat-technical conditions for the solidification process of the metal bath. The three-factor experiment plan (Krasovskij 1982) presented in figure 1 is followed. Fixing the value of the modulus of cooling ($M_{\text{cool}} = 1$) for cubic (side of length 60 mm) mold, the dimensions of other mold shapes were estimated (Ivanić and Kočovski 1993). Maintaining a constant value for M_{cool} , i.e. equality of ratio between the volume and area of cooling of castings, is desirable in order to avoid the influence of mass and heat variations and ensure approximately equal heat-technical conditions (Krivandina 1986).

The three-factor plan of experiments includes the variations of the following parameters:

A. Vibration parameters

- Amplitude (factor A); 0.2, 0.8 and 1.2 mm
- Frequency (factor B); 8, 16 and 24 Hz

B. Thermophysical mold properties (factor C)

- Casting in sand-clay molds for which the value of accumulation heat coefficient $b_2 = 100 \text{ J/m}^2 \text{ s}^{1/2} \text{ K}$.

Figure 1. Schematic presentation of three-factor experimental plan.

Table 1. The dependence of number of grains (mm^{-2}) on geometric shape of casting, vibration parameters and type of mold.

Geometric shape of casting Factor C Type of mold	Factor A—amplitude A, mm								
	0.2 Factor B Frequency, Hz			0.8 Factor B Frequency, Hz			1.4 Factor B Frequency, Hz		
	8	16	24	8	16	24	8	16	24
Cube:	294	325	316	308	332	347	333	350	359
Metallic	297	326	321	314	335	347	340	350	366
Graphite	165	180	190	178	198	210	209	220	252
	160	175	188	181	201	221	206	223	246
Sand	33	52	66	46	61	85	55	83	130
	27	45	62	46	59	80	52	78	125
Roller:	243	224	265	248	353	268	253	267	291
Metallic	236	239	262	248	256	272	260	274	294
Graphite	124	140	150	130	148	160	159	176	190
	129	142	148	132	150	163	164	169	196
Sand	16	25	40	24	34	45	33	43	67
	18	24	38	27	36	47	34	46	65
Slab:	325	333	350	338	344	376	340	352	383
Metallic	323	342	366	338	356	379	344	362	393
Graphite	213	218	235	226	293	280	252	280	328
	210	222	230	230	240	276	248	265	322
Sand	30	58	94	39	70	134	60	82	142
	33	54	90	43	71	103	57	82	139
Ball:	436	496	447	462	519	573	475	556	615
Metallic	444	497	454	467	513	576	479	556	619
Graphite	249	296	328	296	338	356	346	360	403
	245	284	320	290	342	360	339	353	410
Sand	42	82	102	49	84	130	61	105	154
	41	82	105	50	80	127	63	109	149

Figure 2. Variation of grain size with geometric shape of casting, vibration parameters and type of mold.

- Casting in different shapes of graphite molds,
 $b_2 = 185 \text{ J/m}^2 \text{ s}^{1/2} \text{ K}$.
- Casting in different shapes of metallic molds,
 $b_2 = 364 \text{ J/m}^2 \text{ s}^{1/2} \text{ K}$.

C. Geometric shapes of the casts—cube, slab, roller and ball. Each experiment was repeated three times. The cast structure in each case was examined under optical microscope in order to estimate the number of grains per unit area.

3. Results and discussion

The experimental results gathered have been subjected to a regression analysis by a computer. These data on the effect of various parameters on the cast structure are presented in table 1 in terms of the number of grains per unit area. The values reveal that there exists a strong dependence of the grain size on the mold shape, vibration parameters and thermophysical properties of the mold. Figure 2 brings out more clearly this influence. Conditions favourable for minimizing the grain size should therefore be selected in practice. In general, metallic molds and slab or ball shape for the castings in conjunction with high frequency vibration are conducive for the production of fine grained castings.

The influence of vibration on the structure of castings has been explained in terms of the spreading of waves and reflection from the cast surfaces which increase the number of crystallization centres. Similarly the mold shape and material affect the heat transfer characteristics, which in turn determine the density of crystallization nuclei.

References

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