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CONDITIONS FOR BALANCING EVAPORATIVE PATTERN – REFRACTORY COATING - LIQUID METAL – SAND SYSTEM

USLOVI POSTIZANJA RAVNOTEŽE SISTEMA: ISPARLJIV MODEL-VATROSTALNA OBLOGA-TEČAN METAL-PESAK

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ABSTRACT

Technological possibilities for evaporative pattern casting are examined and basic laws of the influence of a great number of parameters on the process flow and castings quality are determined by monitoring and analysis. The process includes a large number of insufficiently examined phenomena in connection with physiochemical and thermodynamic changes in the evaporative pattern - refractory coating - liquid metal - sand system. Solid, expanded polystyrene pattern – chemical formula $(C_6H_6)n$ – of the mollar mass of 300.000, in contact with liquid metal is subject to decomposition and forming of liquid and gas products. At the same time, formation and solidification of castings process is in progress. Decomposition process is extremely endothermic so that solidification of castings develops in under-cooling conditions. The conditions of solidification are not uniform by the cross-section of castings which results in unhomogenous structure and specific surface appearance and volume fraction defects. Besides, complex physiochemical reactions in metal and mould, as well as in the contact zones metal - pattern and metal – mould, are developing. All this prevents precise monitoring of casting process with evaporative patterns owing to which development and application are going very slow.

Key words: evaporative pattern casting process, quality of casting, polystyrene pattern

IZVOD

Proces livenja sa isparljivim modelima (EPC metod) obuhvata znatan broj nedovoljno ispitanih fenomena vezanih za fizičko-hemijske i termodinamičke promene u sistemu iparljiv model – vatrostalna obloga – tečan metal – pesak. Razlaganje modela u dodiru sa tečnim metalom je izrazito endoterman proces, tako da se očvršćavanje odlivaka odvija u uslovima podhlađenja. Uslovi očvršćavanja nisu istovetni po preseku odlivaka, što rezultuje u nehomogenoj strukturi i pojavi specifičnih površinskih i zapreminskih defekata. Pored toga odvijaju se i složene fizičko-hemijske reakcije kako u samom metalu i kalupu, tako i u kontaktnoj zoni metal-model i metal-kalup.

Odlivci dobijeni EPC metodom odlikuju se visokim kvalitetom i niskom cenom izrade. Međutim, osvajanje i primena metode u proizvodnji nosi niz teškoća obzirom da je priprema - određivanje parametara procesa, izbor materijala i konstrukcija alata za izradu isparljivih modela, izbor materijala – polimera za modele, definisanje sastava vatrostalne obloge i drugo, skupa i dugotrajna. U radu su prikazani rezultati dugogodišnjih istraživanja uticaja relevantnih tehnoloških parametara na kvalitet odlivaka silumina i tok EPC-procesa.

Ključne reči: livenje sa isparljivim modelima, kvalitet odlivaka, polistirenski modeli

INTRODUCTION

Based on the analysis of the evaporative pattern casting process, (Figure 1.), the following technologic parameters are found as being essential for balancing the evaporative pattern – refractory coating – liquid metal-sand system and for obtaining high quality castings:

- pattern density;
- granulometric contents of moulding sand (mould permeability);
- thermophisical features of pattern coating material;
- pouring temperature, and
- gating system structure (Figure 1, 2).

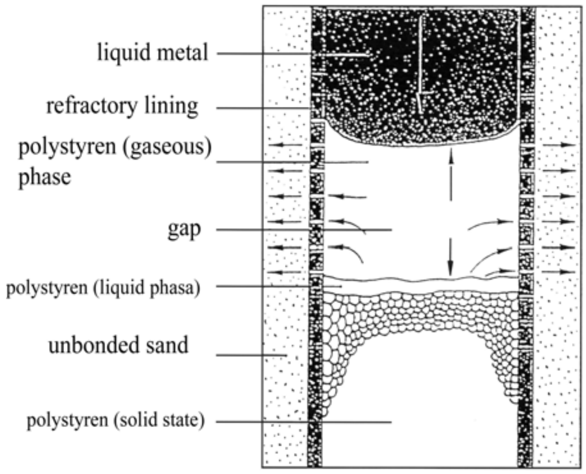

Figure 1. Scheme of EPC process

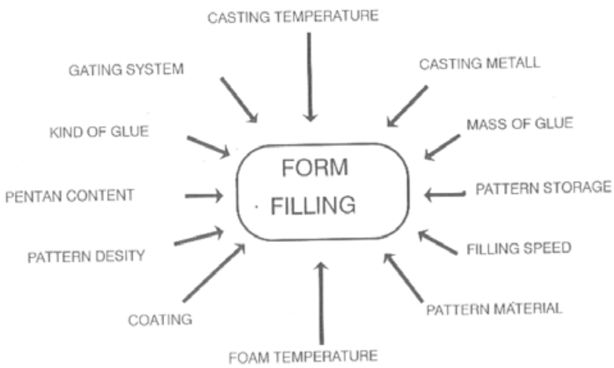

Fig.2. Technological parameters of the EPC process

To produce high quality castings, the pattern density must be uniform (Figure 3). Higher density gives harder pattern, resistant to cracking and folding at moulding, but they produce more gas and liquid when metal is poured which must be prevented if high quality castings are to be obtained [1-5].

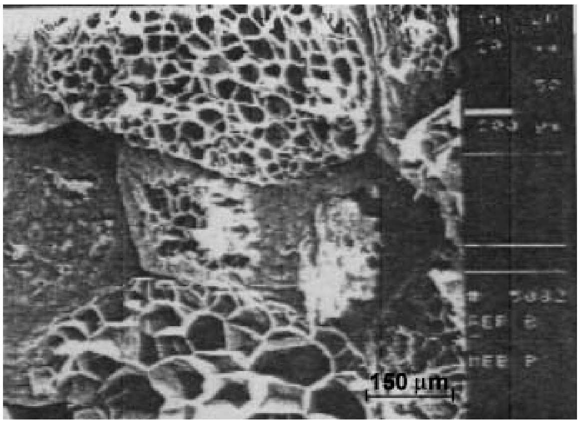

Figure 3. Fracture surface of foam pattern

Selection of moulding sand and the method of sand compaction are very important for obtaining proper permeability of the mould and for preventing pattern deformation. Grain size of sand should be chosen in dependence on quality and thickness of refractory coating dry layer. AFS 30 – 45 grain size guarantees good permeability of the pattern to gas and liquids. Finner grain size is characterized by the lower permeability for such gases and liquids which makes their release more difficult. This has a negative effect on castings quality [6].

The refractory coating of the pattern is of particular importance from many points. It ensures hardness and stiffness of the pattern, controls releasing of gas and liquids during decomposition process and evaporation of the pattern, and ensures high quality surface of castings. To some respect it possesses also the insulating properties, slows down liquid metal to sand heat transfer, which reduces sensitivity to cold welds and other discrepancies. This is particulary useful for aluminium castings [7].

Thickness of pattern refractory coating depends on castings conditions, i.e. pouring temperature, metal to be cast, sand quality. The examinations have shown that uniform thickness of the refractory coating is utmost importance for high quality castings and this can achieved by steady slow stirring of pattern coating mixture, temperature and density during the application process (Figure 4, 5).

To obtain high quality castings, properly shaped and solidified, the metallostatic pressure should be mantained at the proper level which will be enough to neutralize gases and liquid counter pressure during decomposition of the pattern, and also the positive external pressure (or thrust) on the patternwall should be maintained to prevent premature destruction of the mould. Metallostatic pressure is the only “driving force” of liquid metal flow, which is able to overcome the internal pressure of gas products being developed by evaporation of the pattern and concentrated in front of the metal flow. To reduce porosity of castings and gas holes formation, it is important to have the adequate gating system to prevent clogging zones and concentration of liquid phase in mould. Namely, it is necessary to provide proper conditions for a continuous liquid metal front, directed filing of the mould and releasing of pattern decomposing products. Pouring metal temperature affects pattern decomposition rate. Higher liquid metal temperatures contribute to faster pattern decomposition and evaporation, owing to which gases pressure in liquid metal increases and as the results thicker refractory coating will be required to prevent metal penetration into the mould and rough surface of castings.

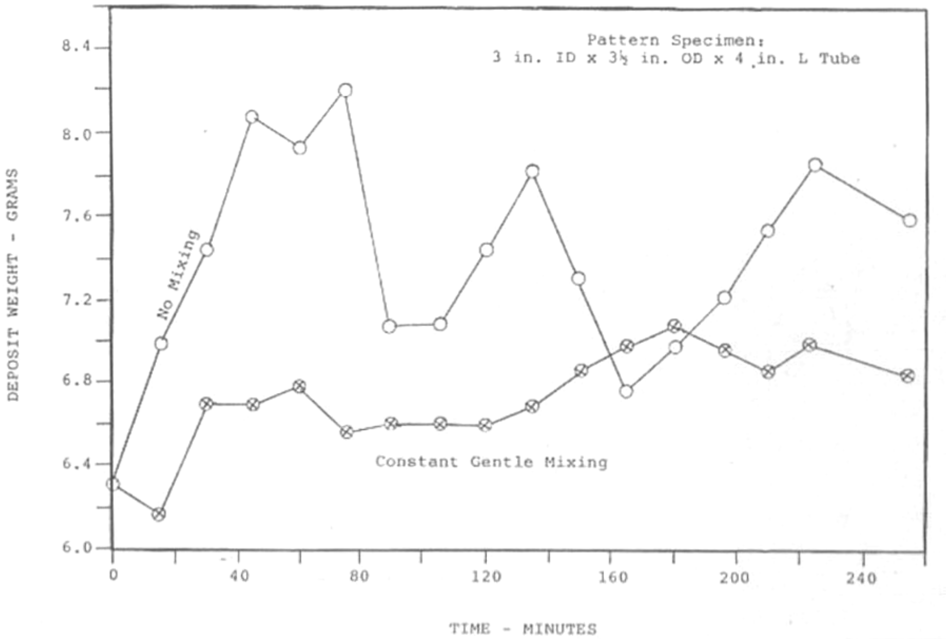

Figure 4. The influence of the mixing on the deposit weight of coating

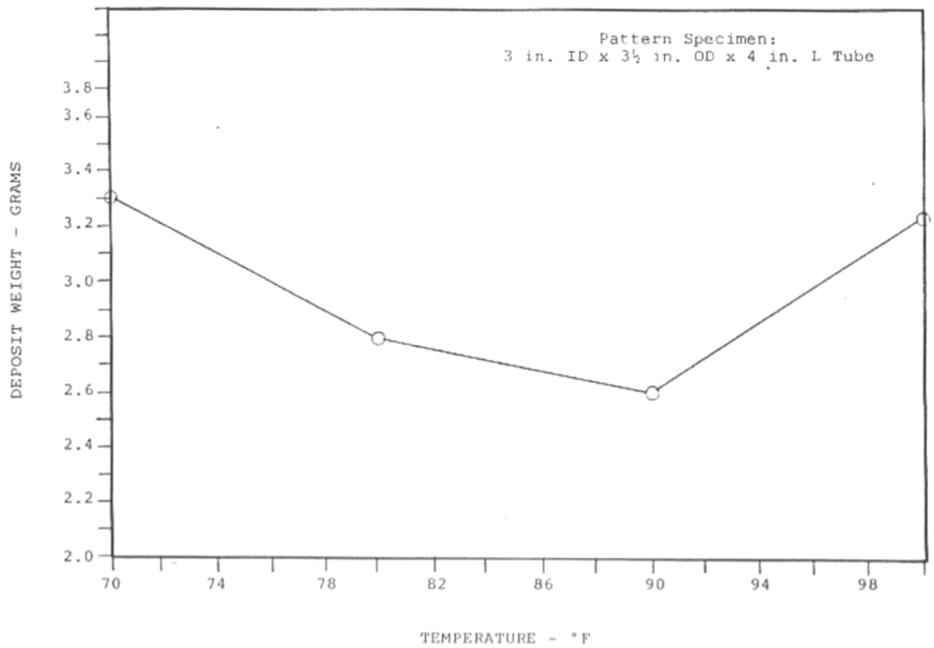

Figure 5. The influence of the temperature on the deposit weight of coating

Main problems which may appear when process parameters are not balanced could be: metal penetration into mould sand, bubbling, incomplete pattern decompsition, cold crackes, blocked gas and liquid decomposition products, uneven and wrinkled casting surface, porosity and carbon defects at pouring out iron and steel (light carbon).

EXPERIMENT

Alloy AlSi10Mg was chosen for the experiment and the following parameters were monitored: poring temperature, type and thickness of refractory coatingt and their effects on the quality and dimensional accurancy of castings, surface quality, compactness, mechanical properties and the structure.

Taking the endotermic process of pattern decomposition into account as well as the influence of various materials and thickness of pattern coating, the examinations werecarried out at the following temperatures: 993 K (A), 1013 K (B) and 1033 (C). The influence of pouring temperature on castings quality was examined in dependence on the type and thickness of the coating. Chemical composition is shows in Table 1. The coatingwall thickness was as follows: 0,5 mm (1), 1 mm (2) and 1,5 mm (3).

Table 1. Chemical composition of refractory coating (%)

Material	SiO_2	Al_2O_3	Fe_2O_3	ZrO_2	TiO_2	CaO	MgO	Na_2O+K_2O
Zirconium Silicate	32,5	0,03	0,05	66	0,05	-	-	-
Molten quartz powder	99,5	0,02	0,05	-	-	0,02	-	0,02
Mulite sand	49,3	47,8	0,98	-	1,78	0,03	0,04	0,07

The grain size of certain refractory elements was 270-325 mesh. The excessive coating after removal from the suspension was always disposed in the same way and at the same time. The coating is draied in its vertical position for 5-10 sec then it is positioned for few seconds at 45^o angle to let the suspensions to be propertly levellend on pattern surface (Figure 6).

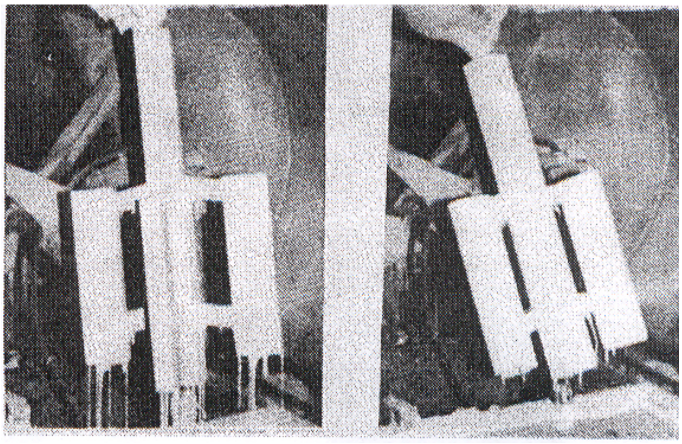

Figure 6. Removing extra suspension from the “cluster”

Monitoring of castings quality was done by means of X-rays, by visual insepction of casting surface, examination of structure and mechanical properties and by quantitative measuring of castings porosity. To be realistic in assessing quality of castings, the comparative examinations were also made with castings produced by classic technologies (designation on the samples: P). All examinations and tests were carried on under industrial conditions.

RESULTS AND DISCUSSION

Castings series with the coating thickness of 0,5 mm to 1 mm are the exact copy of the pattern, which proves the fact that pattern decomposition and evaporation were proper, i.e. that the conditions of system balancing (evaporative pattern – refractory coating – liquid metal – sand) were fully met. Castings series with coating thickness over 1 mm, showed that system balance was disturbed which is proved by unevenness and wrinkles on the upper surface of the castings due to gaseous products of pattern decomposition presence.

Results of radiographic analysis show that porosity mainly exist under the upper surface of castings. Castings with coating thickness of 0,5 mm are of almost smooth surface, those having coating 1 mm thick show some porosity and small undersurface cracks up to 0,5 mm in depth, while castings with coating thickness of over 1 mm show porosity of the surface up to 3 to 4 mm in depth.

By comparing the quality of castings from different series it was concluded that casting temperature of 1013 K is the optimal with respect to the casting conditions. However, castings of B series were of rather good quality, without regard to coating thickness. Comparative qualitative and quantitative analysis of the microstructure was also made with castings produced by classic technologies (Table 2).

Table 2. Comparation of microstructure analysis results and mechanical properties of A, B, C, and P samples series

Series	Porosity					Mechanical properties		
	No. pores (mm^{-2})	Area (μm)	Volume (%)	DAS (μm)	l_e (μm)	Rm (MPa)	A (%)	HB
A_1	-	-	-	69,4	67,2	119	3,5	51
A_2	-	-	-	73,4	72,4	117	3,4	51
A_3	-	-	-	77,8	75,3	113	3,6	47,5
B_1	0,63	107438	4,8	67,8	63,6	127	3,7	52
B_2	0,42	94908	4,0	72,8	69,0	122	3,3	50
B_3	0,52	108849	5,7	78,0	84,3	125	4,2	48
C_1	-		-	64,0	65,0	122	3,2	51,4
C_2	-		-	68,2	67,6	122	3,7	51
C_3	-		-	70,2	79,1	118	3,6	51
P	2.0	11636	2,35	65,5	61,8	110	1,46	59

Based on the results obtained, it can be concluded that with respect to the solidification conditions there were some similarities as well as dissimilarities. Namely, the structure of all samples is of dendritic – cellular type. In the interdendritic area of α-solid solution, the eutectic is released with the IM-phases: Mg_2Si, Al_5FeSi,

$(Mg,Fe)_3Si_2Al_{15}$ whose fineness and dispersion are lowering if compared with that of sand mould castings, which id also the case with thicker coatings (Figure 7).

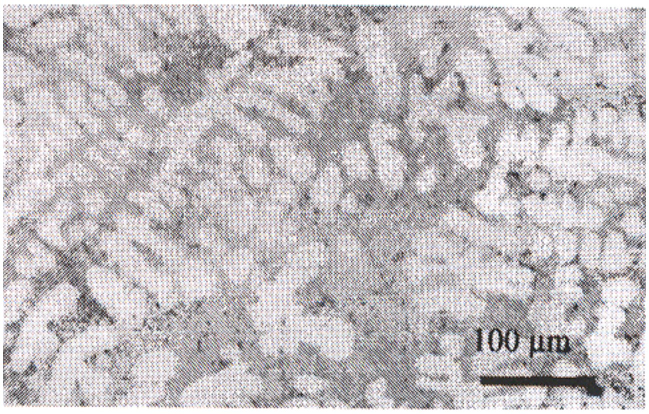

Figure 7. Microstructure of the samples B_1

It can be seen from Table 2. that DAS slowly rises with the increase of coating thickness as an indicator of cooling velocity during solidification. However, the differences in DAS value and IMP dispersity seems to compesate the negative effects of porosity since samples produced with evaporative pattern casting technique have better mechanical properties i.e. tensile strength and elongation. Greater porosity of B samples produced by evaporative pattern technique can be explained by the presence of gas products which develop with polystyrene pattern decomposition and evaporation. Higher porosity of samples with thicker coating confirms this assumtion. Acording to the results obtained one can hardly conclude that castings temperature has some specific influence on DAS values. The discussed defects on castings surface i.e. the porosity and wrinkles, may also be caused by lower permeability of the refractory coating, besides the higher density of the pattern alone.

CONCLUSION

Results of examination of the quality of AlSi10Mg castings produced by evaporative pattern casting method show that the following technological parameters have significant influence on castings quality: pattern density, thermophisical characteristics of pattern coating, shape and dimension the gating system and particulary on the process flow and balance of evaporative pattern – refractory coating – liquid metal – sand system.

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