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INFLUENCE OF ECOLOGICALLY FRIENDLY CORES ON SURFACE QUALITY OF CASTINGS BASED ON MAGNESIUM ALLOYS

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Constructional materials as Al - alloys can be replaced by other materials with high strength to low mass density ratio, e.g. Mg-alloys. In order to pre-casting of holes and cavities cores based on pure inorganic salt can be applied due to easy cleaning of even geometrically complex pre-cast holes. This technology is applied mainly for gravity and low-pressure casting technology. This contribution is aimed at studying of mutual interaction of the Mg-alloy and the salt core. Experiments were focused on surface quality; macro- and microstructure of testing casting samples determination. Metallographic analysis and scanning electron microscope (SEM) with X-ray energy-dispersion superficial and spot microanalysis (EDAX) were employed.

Key words: magnesium alloys, microstructure, salt cores, castings

INTRODUCTION

Optimal ratio of high specific strengths and low mass density predetermine the magnesium alloys for their utilization in the field of constructional materials especially in the aircraft, automobile [1] and rocket industry but in manufacture of optical and instrumental technique, in textile and consumer goods industry too. Mg-alloys also show good castability and weldability under controlled atmosphere and better machinability than Al-alloys. Disadvantages of Mg-alloys consist in steep decrease of mechanical properties under increased temperatures (above 120 °C) [2], low creep resistance caused by increasing volume amount of Al, low elastic modulus, high degree of shrinkage during solidification and low corrosion resistance in some applications [3]. These properties are decisive for using of castings from these alloys for thermally stressed parts in car design – e.g. engine blocks and cylinder heads. Thus among these applications [4, 5] all the time predominate the castings from aluminium alloys or Mg-alloys alloyed with rare earth metals higher resistant to increased temperatures.

In spite of attractive properties the casting of Mg-alloys is connected with a number of problems as a result of high affinity of magnesium to oxygen. For that reason it is necessary during casting to use special additives – inhibitors (fluorides, H_3BO_3, additives based on urea or sulphur) that protect the melt flow from oxidation with no negative influence on magnesium alloy quality. Casting in metal moulds – pressure, low-pressure, and partly gravity casting – are predominant manufacturing technologies of magnesium alloys castings. For pre-casting of less complicated holes the metal cores can be used. At present the core mixtures based on organic binders are ousted and replaced with inorganic binders that have the same utility properties (primary strengths of cores, optimal shelf life, surface quality of pre-cast holes etc.) and they are not too environmentally straining. Those criteria are also met by cores based on inorganic salts manufactured either by high-pressure squeezing of crystalline salts, injecting of the salt melt [6], or the use of salt solutions [7-9]. Cores can be manufactured in a closed ecological cycle. In addition to it during casting, cooling, and solidification of castings the salt cores don't emit any VOCs emissions. Properties of salt cores can be further on modified and optimized for individual casting processes by changing the preparation conditions (intensity of squeezing pressures, shooting temperature etc.), by composition of the base matrix (kind of salt, of the additive). This contribution is aimed at study of mutual interaction of salt cores with surface of the casting from chosen Mg-alloys.

MATERIALS AND METHODS

Magnesium alloy *AZ91* was (of chemical composition 9 % Al; and up to 1 % Zn;) casted in the bentonite bonded moulding mixture of composition 91 % SiO_2 *ŠH35Š*, 4,5 % North Bohemia bentonite activated with soda and 5 % of inhibitor based on sulphur of moisture corresponding to compactibility of 46 ± 2 % was chosen for experiments [10]. Magnesium alloys were molten in a steel crucible in an electric resistance furnace. The

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Table 1 **Mean arithmetic roughness of testing cast samples**

Sample	11	12	13	21	22	23	31	32	33	41	42	43
R_A/μm	8,43	14,46	8,57	17,54	26,31	12,40	25,63	18,94	16,51	5,91	21,5	14,88

molten metal protection was provided by a covering and refining preparation EMGESAL.

Salt cores based on chemically pure salt (chloride) and the same salt with two different additives (marked A and B) that on the one hand improve surface quality of the casting from the core side and on the other one they increase mechanical strengths and heat resistance of the cores were used as test cores. The cores were prepared by high-pressure squeezing (100 and 200 kN; marking *1* and *2*) from z gently moistened salt matrix. The cores are strengthened as a result of mechanical deformation of grains (conglomeration) and recrystallization along the grain boundaries.

With the aim of determining the influence of casting temperature on surface quality of Mg-alloys the test castings with salt cores were cast under two casting temperatures (700 and 800 °C) in oxidation atmosphere under constant thermal load of the mould (weight ratio of mould: metal 9,3:1). Surface quality of the casting from the core side was determined with the aid of vertical (amplitude) roughness – mean arithmetic roughness Ra [μm] as a mean value from ten measurements of roughness of the given sample surface.

A digital roughness meter SurfTest SJ-301-Mitutoyo was used for measurements of mean arithmetic roughness R_A (according to the ISO 1997 standard). With regard to microstructure the prepared samples were examined on a scanning electron microscope (SEM) with X-ray energy-dispersion superficial and spot microanalysis (EDAX).

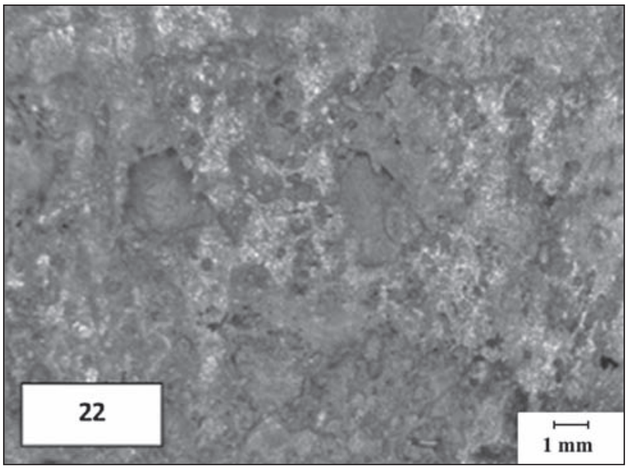


Figure 1 Surface quality of test sample 22

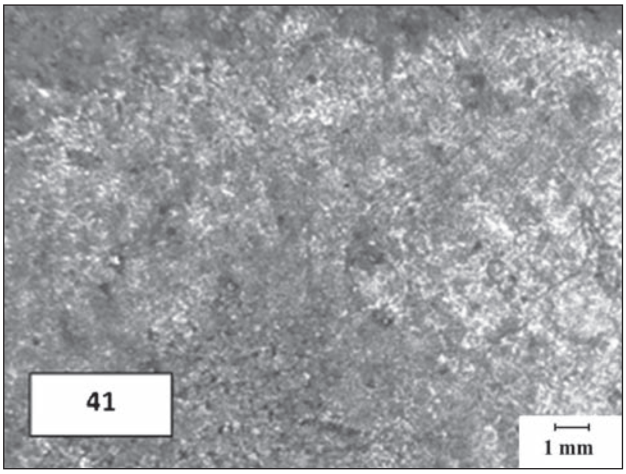


Figure 2 Surface quality of test sample 41

RESULTS AND DISCUSSION

Surface quality of the test castings in the framework of the experiment was evaluated with use of cores of different composition (chemically pure salt; the same salt with 15 % of an additive) with the aid of mean arithmetic roughness R_A as a mean value from ten measurements on the total casting surface from the core side and with the aid of a stereomicroscope (Table 1). The Table gives the numerical marking of samples xy where for x = 1;2 the casting temperature is 800 °C and x = 3;4 the casting temperature is 700 °C. For y = 1 the additive *A* was used; y = 2 with no additive; y = 3 the additive *B*.

From obtained results of surface quality of castings from the core side evaluated in as cast state the high surface quality is evident. Surface roughness ranged within 5,91 and 26,31 μm (Figure 1 – 5,91 μm; Figure 2 -26,31 μm). Positive effect of additives was evident; their presence improved the smoothness of the casting surface. This assumption has been proved by the lowest value of mean arithmetic roughness (5,91 μm) determined for the additive *A* prepared with maximum pressing power (200 kN).

It is generally valid that with growing pressing power the core porosity is decreasing what decreases a possibility of metal penetration with resulting in a smother final surface of the casting. In case of combining the salt cores for magnesium alloys it is highly necessary to care about good degassing of the mould for the reason of huge gas generation mainly during casting resulting in a number of surface and internal casting defects.

Metallographic analysis of the casting surface layer

With regard to results obtained from evaluation of surface quality of test castings a sample giving the highest surface quality (sample *41*, R_A = 5,91 μm) was chosen for metallographic analysis and it was compared with the sample *21* prepared by the same way. For preparation of these samples the cores with the additive A were prepared, squeezed with higher pressing power (200 kN) and the samples were cast under casting temperature of 700 °C (sample *41*) and 800 °C (sample *21*). Microstructure of the surface part of test castings is shown on Figure 3 (sample *21*) and Figure 4 (sample *41*).

From the point of view of microstructure of the *AZ91* alloy it is possible to observe considerable influence of casting temperature. Samples cast under lower casting temperature (700 °C; Figure 4) have considerably more fine-grained structure and higher mechanical properties of the cast material can be expected in this case.

Higher material homogeneity in the total studied sample volume without conspicuous differences between the superficial and internal casting part is perceptible in this sample.

Samples of castings prepared under higher casting temperature (800 °C; Figure 3) show considerably lower homogeneity degree and considerable differences between the peripheral and central part of the test sample can be found. Increased inhomogeneity of studied samples can be further on augmented by the salt matrix decomposition (770 °C) accompanied with considerable generation of gaseous Cl_2.

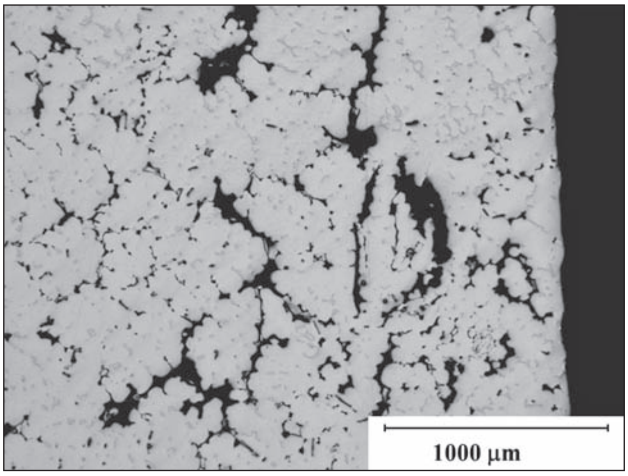


Figure 3 Detail of surface of sample 21

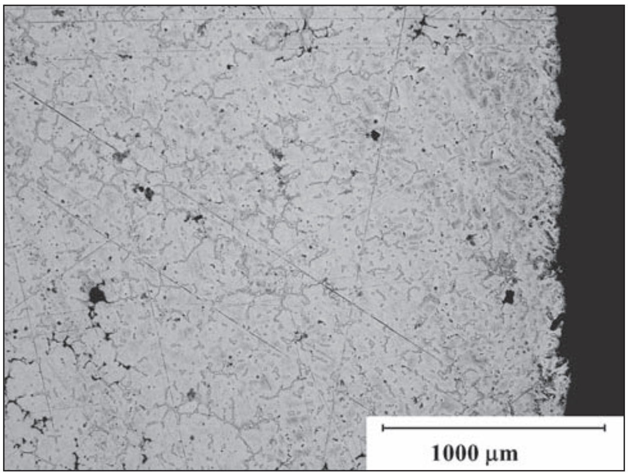


Figure 4 Detail of surface of sample 41

Evaluation of microstructure with the aid of SEM and EDAX analyses

Samples of the material that was in contact with salt cores prepared from pure salt matrix only (without additives) and squeezed with higher pressing power (200 kN), i.e. the sample *42*, were chosen for this part of the experiment only.

The used additives are inorganically based only with decomposition temperature considerably exceeding experimental temperatures achieved during casting, solidification, and cooling of castings and thus it can be expected that they will have no influence on the base metal matrix. Microstructures of studied samples were evaluated from different points of measurement (Figure 5) of both the base metal matrix and other structural constituents, and the present porosity for identification of the kind of formed defects. Analyzed chemical composition of studied samples is given in Table 2.

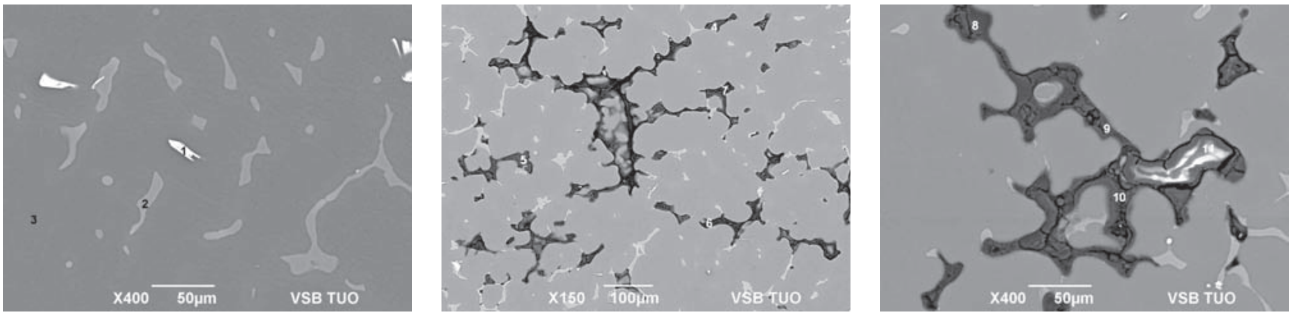
From resulting values of EDAX analysis it is possible to identify internal defects of the cast material. Gaseous products of thermal destruction of both the salt matrix of the core itself, and the inhibitor present in the bentonite bonded moulding mixture participate in defects formation (Table 2). Increased concentration of chlorine and sulphur was primarily determined especially in points corresponding to points of measurements Spectrum 4 ; 7 and 11 of the studied sample.

CONCLUSION

This contribution was aimed at checking the use of cores based on inorganic salts for casting of magnesium

Table 2 **Results of EDAX analysis of sample 42**

Name	Elements/ weight %										
	O	Na	Mg	Al	Si	Mn	Zn	S	Cl	K	Ca
Spectrum1			1,34	42,12	0,65	55,89					
Spectrum2			59,27	37,49			3,24				
Spectrum3			94,51	5,49							
Spectrum4	61,77		32,24	3,68				1,06	1,25		
Spectrum5	54,41		43,86	0,97	0,32			0,43			
Spectrum6	65,12		26,19	7,20				1,00	0,33	0,16	
Spectrum7	22,81	0,24	3,31	2,91	0,89			2,08	0,48	1,77	0,62
Spectrum8	38,81		11,25	9,05	1,69			0,36	0,13		2,38
Spectrum9	56,14		41,98	0,27				0,23	0,28	1,10	
Spectrum10	52,79		45,75	1,03	0,11			0,31			
Spectrum11	62,29		31,75	4,33				1,20	0,42		



5a Magnification 400x | 5b Magnification 150x | 5c Magnification 400x

Figure 5 Details of microstructure of sample 42 with different extension

alloys. The application of salt cores for pre-casting of cavities and holes for gravity and low-pressure cast castings from Mg-alloys is not known in common practice.

From the point of view of chemical basis of used moulds, cores and the inhibitor, chemical processes running during casting and cooling of the casting, it is necessary to ensure a sufficient exhausting of gases from the mould cavity for ensuring high casting quality. In case of cores used in this experiment an increased occurrence of internal defects of cast samples has been confirmed. It was caused by interaction of generating gas with the base metal matrix. One of possibilities of achieving higher quality of cast parts is the application of spirituous preservative coatings or the use of cores with different base salt matrix.

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Note: The responsible translator for English language is František Urbánek, Brno, Czech Republic