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

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$_3$BO$_3$, 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$_2$, $\text{SH}35\%, 4,5 \%$ North Bohemia bentonite activated with soda and 5 % of inhibitor based on sulphur of moisture corresponding to compactibility of $46 \pm 2 \%$ was chosen for experiments [10]. Magnesium alloys were molten in a steel crucible in an electric resistance furnace. The
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 a gently moistened salt matrix.
The cores are strengthened as a result of mechanical de-
formation of grains (conglomeration) and recrystalliza-
tion 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 verti-
cal (amplitude) roughness – mean arithmetic rough-
ness $R_a$ [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 rough-
ness $R_a$ (according to the ISO 1997 standard). With re-
gard to microstructure the prepared samples were ex-
amined on a scanning electron microscope (SEM) with
X-ray energy-dispersion superficial and spot microa-
nalysis (EDAX).

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 arith-
metic roughness $R_a$ as a mean value from ten measure-
ments 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; Fig-
ure 2 -26,31 µm). Positive effect of additives was evi-
dent; 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).

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

<table>
<thead>
<tr>
<th>Sample</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>21</th>
<th>22</th>
<th>23</th>
<th>31</th>
<th>32</th>
<th>33</th>
<th>41</th>
<th>42</th>
<th>43</th>
</tr>
</thead>
<tbody>
<tr>
<td>$R_a$/µm</td>
<td>8.43</td>
<td>14.46</td>
<td>8.57</td>
<td>17.54</td>
<td>26.31</td>
<td>12.40</td>
<td>25.63</td>
<td>18.94</td>
<td>16.51</td>
<td>5.91</td>
<td>21.5</td>
<td>14.88</td>
</tr>
</tbody>
</table>

It is generally valid that with growing pressing pow-
er the core porosity is decreasing what decreases a pos-
sibility 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 high-
est surface quality (sample 41, $R_a = 5.91$ µm) was chosen
for metallographic analysis and it was compared with the
sample 2I prepared by the same way. For preparation of
these samples the cores with the additive A were pre-
pared, squeezed with higher pressing power (200 kN)
and the samples were cast under casting temperature of
700 °C (sample 4I) and 800 °C (sample 2I). Microstruc-
tecture 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 Cl₂.

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
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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REFERENCES


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