FAILURE ANALYSIS OF DIES FOR DIE-CASTING OF ALUMINIUM ALLOYS

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Abstract
Die design, material selection and thermal stress fatigue due to the cyclic working process (heat checking), as well as inhomogeneous and to low initial die temperature, contribute to the failures and cracks formation on/in dies for die-casting of aluminium alloys.

In the frame of the presented investigation work the homogeneity and intensity of the temperature field on the working surface of the dies were checked through thermographic measurements. Failures and cracks on the working surfaces of the dies were analysed by the non-destructive metallographic examination methods: such as penetrants and metallographic examination of polymeric replicas, and by numerical stress-strain analysis.

1. INTRODUCTION
Die-casting is the most economical and technical easy process of casting very sophisticated and precise aluminium products of big-scale series [1,2].

Aluminium die-castings are made for final installation, and need very little machining. They are used in automotive industry, household appliances, electrical industry and instalations, fittings, etc. [3].

Aluminium die-casting dies fail because of a number of different and simultaneously operating stresses. The stresses are of two basic kinds: the first which are created during the manufacturing of the die, and the second which are produced during exploitation process [4].

For economical production of aluminium alloys die castings it is important that the dies have a long working life. The replacement of a die is expensive in both money and production time [5].

The most frequent failures of aluminium die casting dies are [3]:

?? heat checking,
?? gross cracking or cleavage cracking,
?? cracking in corners, sharp radii, or sharp edges, and
?? wear or erosion.

It is generally agreed that one of the principal causes of termination of die life is heat checking, which occurs through a process of crack initiation and propagation from the thermal stress fatigue induced on a die surface [4].

Some of the factors that affect die failures may be controlled to some extent by the die-casting experts (designers, manufacturers and operators). These factors include [7]:

?? design,
?? materials selection,
?? heat treatment,
?? finishing operations, and
?? handling and use.
The hot work die steel must have excellent materials properties in respect of [6]:

- thermal shock resistance,
- high temperature strength,
- high temperature toughness,
- retention of hardness,
- thermal conductivity,
- high temperature wear resistance,
- workability / machinability,
- dimensional stability, and
- tendency to microwelding.

2. IMPORTANCE OF PREHEATING PROCESS

When hot aluminium or its alloy strikes the active working surface of the die, the die expands and then contracts during cooling, as the heat in the casting is conducted into the steel bellow the surface of the die. The greater difference between the temperature of the die and that of the hot aluminium shot into the die, the greater will be the expansion and contraction of the die surface, and sooner the die surface will be heat check.

Since the stresses produced on the die surface are inversely proportional to the die temperature, it is good practice to run the dies as hot as is practical and/or economical. Aluminium die-casting dies should be preheated to approximately 240 to 300 °C. Experiences have shown that by increasing the die operating temperature from 205 to 315 °C, die production may be doubled [1,8].

2. EXPERIMENTAL WORK

In Figure 1 are shown the whole machine for die-casting (left), and the fixed half of the testing die-casting die (right)

![Figure 1. Machine for die-casting (left). Fixed half of the testing die-casting die (right).](image)

The discussed die has been manufactured from well known Boehler W300 ISODISC hot work tool steel which has frequently been used for similar dies [9-11].

3.1. Thermographic Analysis

By thermographic [12,13] measurements the required intensity and homogeneity of the initial temperature field on the working surface of the fixed die half have been examined (Figure 2). Testing thermographic measurements on the chosen die have been carried out due to the relatively simple geometry of the discussed die, so the simple thermographs (heat images) analysis have been performed.
Figure 2. Position of the thermographic camera.

On the working surface of the fixed die half thermographic measurements have been carried out in the preheating period of the die heating to its initial operating temperature (240 °C and homogeneous through the whole working surface of the die) [14]. In the presented case the required initial operating temperature was a minimal in comparison to the before mentioned reference values [15].

Figure 3. Working surface of the fixed part of die-casting die (Figure 1). Thermographs. Preheating process. At the beginning (1), after approx. 2 hours (2) and at the end (3 – initial temperature field) of the die preheating process [15].
Thermographs (temperature images) in Figure 4 are represented in the temperature range between 90 and 161 °C, and in Figure 5 in the range between 90 and 195 °C; in both cases black (uncoloured) regions are below 90 °C.

Figure 4. Working process. Thermographs. The fixed part of die-casting die: working surface and casting (above), working surface without casting (below).

3.2. Metallographic Analysis
The cracks which appeared on the fixed die half after less than thousand shots were revealed and identified by the use of penetrants \(^{16}\). Some of them were also clearly seen by the use of magnifying glass or even by naked eye. In the frame of our experimental work also non-destructive metallographic examination by optical microscope (OM) and by scanning electron microscopy (SEM) of polymeric replicas was applied (Figure 5) \(^{17}\).

Figure 5. Working surface of the die. Surface crack and pits; SEM; magn. 500x.

4. CONCLUSIONS
Cracking on/in die-casting dies of aluminium alloys is caused by a number of different and simultaneously operating factors. Some of them that affect die failures may be controlled to some extent by the die casting experts.
In the experimental part of our work the failures on the working surface of the fixed half of the testing die for die-casting of aluminium alloy were observed with the use of non-destructive testing methods: such as thermographic analysis, penetrants, and metallographic examination of polymeric replicas. The failures observed on the working surface of the discussed fixed die half for die casting of aluminium alloy belong to heat checking initiated at identification marks, and cracking in corners, sharp edges and transitions.

5. BIBLIOGRAPHY