QUALITY CONTROL OF ALUMINIUM DIE-CASTING DIES

KONTROLA KVALITETA ALUMINIJUMSKIH ALATA ZA LIVENJE

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ABSTRACT
For economical production of aluminium die-castings it is very important that the dies have a long working life. The replacement of a die is expensive in both: money and production time. 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.

1. INTRODUCTION

Die-casting is the most economical and technical easy process of casting very sophisticated and precise aluminium products of big-scale series. Aluminium die-castings are made for final installation, and need very little machining. They are used in automotive industry, household appliances, electrical industry and installations, fittings, etc.
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 [1]. For economical production of aluminium and its 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.

2. THE MOST FREQUENT FAILURES OF ALUMINIUM DIE-CASTING DIES

The most frequent failures of aluminium die-casting dies are [2,3]:

- 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 [5]:

- design,
- materials selection,
- heat treatment,
- finishing operations, and
- handling and use.

The hot work die material (steel) must have excellent materials properties in respect of [6]:

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

3. 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 conduced 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 approx. 260 to 315 ^{o}C. Experiences have shown that by increasing the die operating temperature from 205 to 315 ^{o}C, die production may be doubled (Fig. 1) [1,3,7].

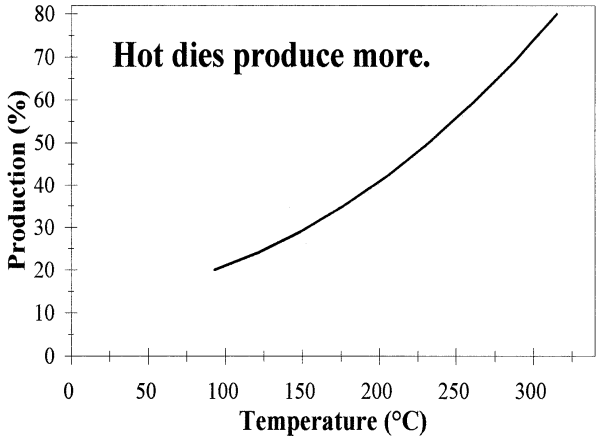

FIGURE 1. PRODUCTION AS A FUNCTION OF THE DIE OPERATING TEMPERATURE.

4. EXPERIMENTAL WORK

4.1. Thermo graphic Analysis

On the active working surface of the fixed die half thermo graphic measurements [8] have been carried out in the preheating period of the die heating to its initial operating temperature (240 ^{o}C and homogeneous through the whole active working surface of the die). In the presented case the required initial operating temperature was a little lower in comparison to the before mentioned reference values.
Thermograph (temperature image) in Fig. 2 is represented in the temperature range between 90 and 161 ^{o}C, where black (uncolored) regions are below 90 ^{o}C.

FIGURE 2. TEMPERATURE FIELD ON THE ACTIVE WORKING SURFACE OF THE FIXED DIES HALF IN THE PREHEATING PERIOD.

4.2. 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 [10]. Some of them were also clearly seen by the use of magnifying glass or even by naked eye [11]. In the frame of our experimental work also non-destructive metallographic examination by optical microscope and by scanning electron microscopy (SEM) of polymeric replicas was applied, Fig. 3 [12].

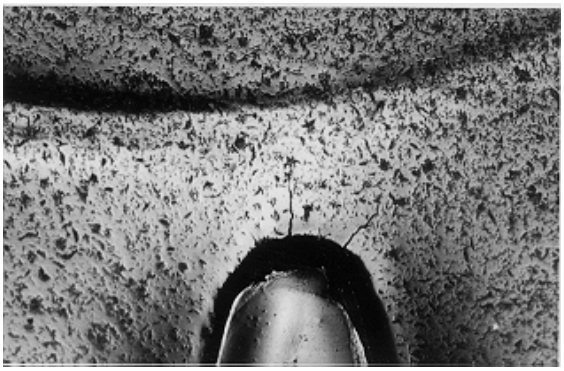

FIGURE 3. ACTIVE WORKING SURFACE OF THE DIE. SURFACE CRACKS AND PITS. MAGN. 50X.

5. CONCLUSIONS

Cracking on/in aluminium die-casting dies is caused by a number of different and simultaneously operating factors. The die-casting experts may control some of the factors that affect die failures to some extent.
In the experimental part of our study the failures on the active working surface of the fixed half for die casting of aluminium alloy were observed with the use of NDT (non-destructive testing) methods such as thermo graphic analysis, penetrants, and metallographic examination of polymeric replicas.

6. REFERENCES

[1] W. Young, 10th SDCE Int. Die Casting Exposition & Congress, Paper No. G-T79-092, pp. 1 - 8, St.Louis, 1979.

[2] B. Kosec and J. Vojvodič-Tuma, Failure Analysis (Postgraduate Course), University of Ljubljana, Ljubljana, 2001.

[3] S. Kalpakjian, Tool and Die Failures - Source Book, ASM Int., Metals Park, Ohio, 1982.

[4] F. Kosel and L. Kosec, Strojniški vestnik, Vol. 29, No. 7-9, pp. 151 - 158, 1983.

[5] Handbook of Case Histories in Failure Analysis, Volume 1, ASM Int., Materials Park, Ohio, 1992.

[6] R. Ebner, H. Leitner, F. Jeglitsch and D. Caliskanoglu, Proceedings of 5th Int. Conf. on Tooling, pp. 3 - 12, Leoben, 1999

[7] B. Kosec, M. Soković, J. Kopač, L. Kosec and B. Težak, Proceedings of 9th Int. Scientific Conf. AMME 2000, pp. 307 - 310, Sopot, 2000.

[8] H. Haferkamp, F.W. Bach, M. Niemeyer and R. Viets, Aluminium, Vol. 75, No. 3, pp. 945 - 953, 1999.

[9] B. Kosec, B. Težak, L. Kosec, J. Kopač and J. Vojvodič Tuma, Materiali in Tehnologije, Vol. 34, No. 6, pp. 415 – 418, 2000.

[10] B. Hertl and B. Kosec, Obzornik Zavarovalnice Triglav d.d., Vol. 21, No. 11, pp. 2 - 5, 1998.

[11] B. Kosec, L. Kosec and J. Kopač, Engineering Failure Analysis, Vol. 8, No. 4, pp. 355 – 359, 2001.

[12] L. Kosec, M. Kmetič and B. Arzenšek, Zbornik 3. Strokovnega posvetovanja: Neporušne metode za kontrolo materiala in izdelkov v sodobni proizvodnji, pp. 251 - 259, Ljubljana, 1990.

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