D. NOVOSELOVIĆ, I. BUDIĆ, I. SAMARDŽIĆ

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RESIDUAL STRESSES IN CASTINGS PRODUCED BY PRESS DIE CASTING TECHNOLOGY

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The influence of technological parameters on residual stresses in pressure die castings is analysed in this paper. In order for the residual stresses to be as low as possible the optimization of technological parameters is necessary. The centrally composed plan of experiment 2^{4cs} is used in the investigation. Technologically influencing parameters are changed according to the mentioned plan of experiment and they are: temperature of pouring, rate of die cavity filling with the melt, post pressure in already filled die and the casting cooling time along with the pouring system.

Key words: casting technology, pressure die casting, residual stresses, the influential technological parameters

INTRODUCTION

A common cause of defects in castings is residual stresses that can cause cracks and deformations of castings. In order to reduce the amount of residual stresses, it is necessary to know the reason of their occurrence, to determine the technological parameters that influence the occurrence of residual stresses, to determine the relative importance of each of the technological parameters, and to conduct testing of the influence of technological parameters in which the amount of residual stresses will be minimal in order to avoid the occurrence of casting defects.

Residual stresses in castings being affected by various parameters, they cannot be avoided but can be reduced to the least possible value.

Residual stresses can be reduced if the corresponding technological parameters in the casting fabrication are used. They can also be reduced by heat treatment (annealing for stress reduction) as well as by natural ageing.

Residual stresses occur frequently in pressure die casting and can cause defects on castings (cracks and deformations).

They have not been investigated in detail and are therefore a frequent subject of current investigations.

Residual stresses depend on a number of technological parameters, some of them acting simultaneously.

With the increased need for alluminium alloy castings (particularly in automobile industry) a need has also been shown for investigating the influence of technological parameters in reducing casting defects and increasing production quality and productivity.

A review of literature [1 - 7] has shown that until now the on mechanical and structural characteristics has been most often investigated while the parameters affecting residual stresses in pressure die casting have not been systematically studied. The reason for that is the fact that under operating conditions they are very difficult to determine.

To calculate residual stresses computer programs are often used (e.g. MAGMAsoft and ProCast) which simulate the casting process and approximately determine the residual stresses. The programs are based on theoretical assumptions that are within certain limits different from real operating conditions.

EXPERIMENTAL PROCEDURE

At pressure die casting various technological parameters affect the occurence of residual stresses in castings, some of the parameters acting simultaneously. Pressure die casting technological parameters are:

- melt pouring temperature
- rate of filling the pouring system with the melt
- cross-section and form of the pouring system
- rate of filling die cavity with the melt
- post pressure in a filled up die
- start of the casting second phase
- dimensions of pressure cylinder
- pressure cylinder rate of filling
- type and quantity of lubricant
- dimensions of the venting system
- dimensions of the cooling system
- composition of the melt.

In order for the residual stresses to be as low as possible the optimization of technological parameters is necessary. Only some of the technological parameters of influence will be investigated in the paper while the other parameters will be constant.

The centrally composed plan of experiment 2^{4cs} is used in the investigation.

D. Novoselović, I. Budić, I. Samardžić, Mechanical Engineering Faculty in Slavonski Brod, University of Osijek, Croatia

Technologically influencing parameters are changed according to the mentioned plan of experiment (Table 1) and they are given as follows:

- ϑ_u - temperature of pouring,
- $v_{II\ faze}$ - rate of die cavity filling with the melt,
- $p_{III\ faze}$ - post pressure in already filled die,
- t_{ods} - the casting cooling time along with the pouring system, upon withdrawal from the die, min.

Table 1 **Centrally composed plan of experiment 2^4cs**

Parameter	Levels				
	-2	-1	0	1	2
ϑ_u / °C	660	670	680	690	700
$v_{II\ faze}$ / m/s	0,83	1,67	2,5	3,33	4,16
$p_{III\ faze}$ / bar	150,5	188	225,5	263	300,5
t_{ods} / min	0	20	40	60	80

The test casting (Figure 1) was cast according to the centrally composed plan of experiment 2^{4cs} in the Lipovica Foundry d.o.o. on compression machine with cold chamber type ItalPresse 250 t.

The alloy (EN 46100) was used for casting. It was molten in a gas furnace from the firm Botta – Italy. Previous to pouring into the mould the melt temperature was measured by a digital thermometer DT 02 (thermosteam Fe - Cu Ni).

Upon the casting removal from the mould its cooling time along with the pouring system was measured by a measuring watch (stop-watch).

Figure 2 shows the cast castings and their measured cooling time according to the plan of experiment 2^{4cs}.

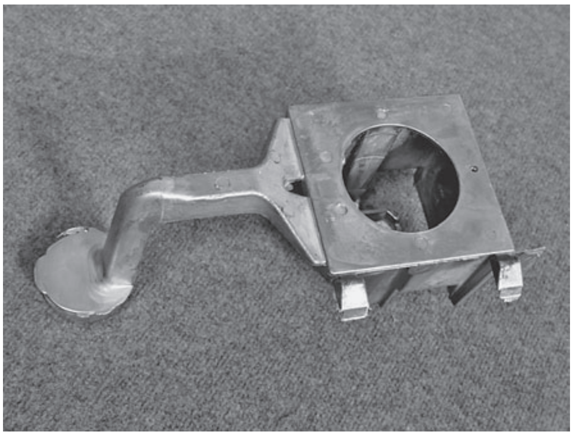

Figure 1 Test casting with pouring system

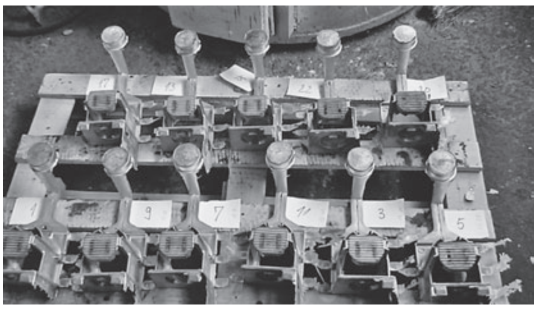

Figure 2 The cast castings measured according to the plan of experiment

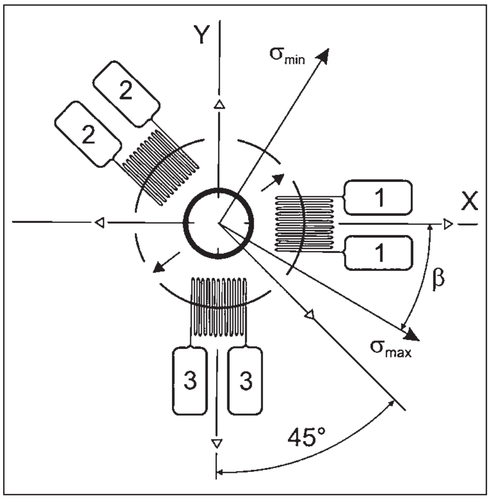

Figure 3 Schematic presentation of a general purpose strain gauge rosette

The method of measuring used to determine the residual stresses is a method of drilling, belonging to the partly destructive methods.

To calculate residual stresses in linear elastic materials in which the stress does not change with the depth of drilling a method is used that is described in terms of the standard ASTM E837-08.

For some general purpose strain gauge rosette according to Figure 3 [8] normal stresses σ_x, σ_y, τ_{xy} are measured from the measured deformations. Based on normal stresses the main stresses $\sigma_1 = \sigma_{max}$, $\sigma_2 = \sigma_{min}$ and their direction *b* are measured.

Calculation of residual stresses in terms of ASTM E837-08 for uniformly distributed stress is carried out based on measured deformations ε_1, ε_2, ε_3 on strain gauges. Based on measured deformations the main i.e. equivalent stresses are calculated according to:

$$\sigma_{ekv} = \sqrt{\sigma_1^2 + \sigma_2^2 - \sigma_1 \cdot \sigma_2} \leq \sigma_{dop} \qquad (1)$$

σ_{ekv}- equivalent stress,
$\sigma_{1,2}$- main stresses,
σ_{dop}- design stress of material.

The firm HBM (Figure 4a) measuring equipment was used for deformation measuring. Drilling control and data collection are performed by computer (main selector of the RESTAN software (Figure 4b), I/O card and electric device). Upon deformation measurement, for separate strain gauges, obtained data are entered into the program „SINT_RSM.EXE“, where the residual stresses are calculated based on the measured results [8].

The results of measuring obtained according to the centrally composed plan of experiment 2^{4cs} are shown in Table 2.

Graphical presentation of the function dependance of the calculated residual stresses depending on two technological parameters is shown in Figure 5. One technological parameter is t_{ous} – cooling time of the casting along with the pouring system upon removal

a) b)

Figure 4 Measuring equipment for determination of residual stresses a) device for drilling, b) measuring software RESTAN

Table 2 **Results of measuring obtained according to the centrally composed plan of experiment 2[4cs]**

ϑ_u / °C	$\upsilon_{II\ faze}$ / m/s	$p_{III\ faze}$ / bar	t_{ods} / min	σ_{ekv}, / MPa
670	1,67	188	20	22,08
690	1,67	188	20	18,30
670	3,33	188	20	21,43
690	3,33	188	20	23,19
670	1,67	263	20	24,14
690	1,67	263	20	19,97
670	3,33	263	20	28,46
690	3,33	263	20	24,20
670	1,67	188	60	37,60
690	1,67	188	60	32,88
670	3,33	188	60	13,57
690	3,33	188	60	50,53
670	1,67	263	60	13,54
690	1,67	263	60	28,18
670	3,33	263	60	29,14
690	3,33	263	60	13,38
660	2,5	225,5	40	33,30
700	2,5	225,5	40	12,04
680	0,83	225,5	40	17,38
680	4,16	225,5	40	24,10
680	2,5	150,5	40	16,18
680	2,5	300,5	40	11,38
680	2,5	225,5	0	14,98
680	2,5	225,5	80	37,14
680	2,5	225,5	40	9,16
680	2,5	225,5	40	11,97

from the mould, the second technological parameter is the melt pouring temperature (Figure 5).

It can be concluded from the diagram that the equivalent residual stresses increase with the cooling time prolongation of the casting along with the pouring system (upon removal from the mould). This means that the shape and dimensions of pouring system cause residual stresses in castings.

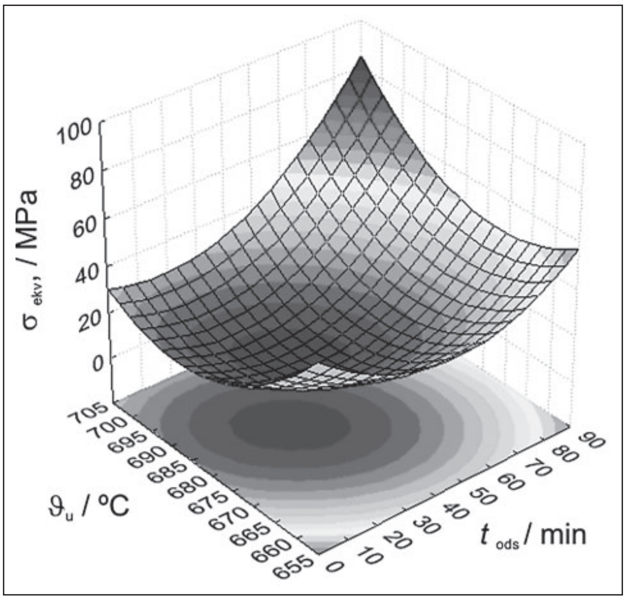

Figure 5 Calculated equivalent residual stresses $\sigma_{ekv} = f(t_{ods,}\ \vartheta_u)$ at $\upsilon_{II\ phase}$ = const. i $p_{III\ phase}$ = const.

CONCLUSION

The investigation has demonstrated that equivalent residual stresses increase with prolonged cooling of the casting together with the pouring system outside the mould. This can be explained by the fact that at cooling the casting cools off earlier than the pouring system (due to a thinner wall).

Based on the investigations it can be concluded that they should be continued in the following direction:

- perform computer simulations and compare them with the residual stresses computed based on the measured deformations
- carry out pressure die casting on a machine provided with the possibility of computer adjusting the influencing technological parameters for a more precise analysis
- study also the influence of other technological parameters on residual stresses at pressure die casting.

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Note: The responsible translator for English language is S. Setina, Slavonski Brod, Croatia