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EFFECTIVE INTENSIFICATION METHOD OF DIE CASTING PROCESS OF SILUMINS

EFEKTYWNA METODA INTENSYFIKACJI KOKILOWEGO ODLEWANIA SILUMINÓW

At work were presented the research findings of the water mist's generating process and low pressure casting of car silumin wheels with applying the die's cooling with water mist and compressed air. Research findings were shown the effectiveness of spraying water with use of designed sprayers and effects of generating the water mist in the stream compressed air. Relations enabling the optimisation of parameters of the water mist were worked out to needs of cooling the die. A designed device for generating the water mist cooling the die was shown here. Research findings of speed of the temperature in characteristic points of the cast and cooled die with use of the water mist in comparing to cooling with the air were presented in the paper. They demonstrated, that applying the water mist increases the intensity of cooling the die and the cast, it makes shorter the cycle of die casting, it reduces the defectiveness of casts as well as it increases their properties: $R_{p0,2}$, R_m, A_5 and HB.

Keywords: metallic alloys; casting; die; cooling; mist

W pracy przedstawiono wyniki badań procesu wytwarzania mgły wodnej oraz odlewania pod niskim ciśnieniem siluminowych kół samochodowych z zastosowaniem chłodzenia kokili mgłą wodną i sprężonym powietrzem.

Pokazano wyniki badań efektywności rozpylania wody za pomocą zaprojektowanych rozpylaczy oraz efekty wytwarzania mgły wodnej w strumieniu sprężonego powietrza. Opracowano zależności umożliwiające optymalizację parametrów mgły wodnej do potrzeb chłodzenia kokili. Pokazano zaprojektowane urządzenie do wytwarzania mgły wodnej chłodzącej kokilę. Przedstawiono wyniki badań szybkości zmian temperatury w charakterystycznych punktach odlewu i kokili chłodzonej za pomocą mgły wodnej w porównaniu do chłodzenia powietrzem. Wykazano, że zastosowanie mgły wodnej zwiększając intensywność chłodzenia kokili i odlewu, skraca cykl odlewania, zmniejsza wadliwość odlewów oraz podwyższa ich własności: $R_{p0,2}$, R_m, A_5 i HB.

1. Introduction

While casting car wheels from aluminium alloys under the low pressure process is practising universally cooling the dies with the help compressed air aiding conveying the warmth to surroundings. At the Department of Material Technologies and Production Systems of Technical University of Lodz a research on the intensification of the process of getting the heat back from the die and controlling the crystallisation process and being getting cold of the cast is being conducted. Applying the water mist as the medium in the cooling system is a main element of the examined technology of die. It is an effective way of the casting intensification, it is shortening the cycle of producing casts and it is reducing the size of their microstructure. Implementing this method doesn't require meaning technical-organizational changes on the stands of die casting because it can use the air installation existing on the stands.

Such a selection of parameters of the water mist is the fundamental assumption of leading the process of cooling so that lead to the surface of the hot die in the whole underwent evaporating. It's mean that implementing water into the contact with the die above the holding furnace of metal isn't making additional threat to the safety of the work on the workplaces.

At the work research findings were presented about generating the water mist and the intensification of the die casting of car silumin wheels with using of elaborated method of cooling of dies. Applied device producing and controlling the stream of the water mist they verified in production conditions in the company RH Alurad Wheels Polska Sp. z o.o. in Gorzyce as part of the realisation of the Industrial Grant Project realization [1–6].

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2. Experimental

Cooling the die with mixture of air and water were executed with use the Automatic Cooling Servo device, that was constructed at the Department of Material Technologies and Production Systems of the Technical University in Lodz.

Fig. 1. Automatic Cooling Servo device

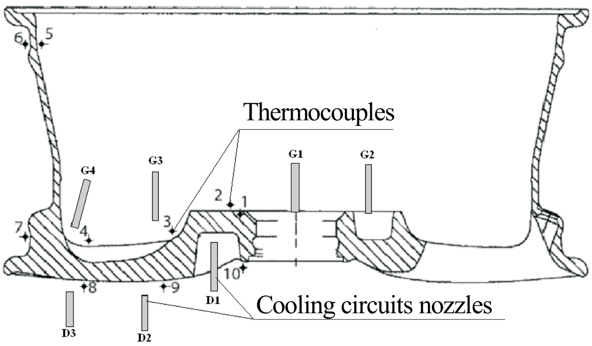

Fig. 2. Layout scheme of thermocouples and cooling nozzles in casting die

Producing the water mist by the device is being carried out at the same time as a result of spraying the water of sprayers with the help specially designed and as a result of mixing sprayed water up with compressed air in wires of the cooling installation.

Examinations were also carried out on the industrial position of casting car wheels under the low pressure. Casts were being produced from silumin AlSi7Mg modified with Ti, B and Sr and refined Ar. The temperature of preliminary heating the chill was included in a 350–460°C range. The die cavity was being filled up under the influence of the pressure in the 0,01–0,09 MPa range exerted on the surface of molten metal in the holding furnace.

Thermocouples were installed in characteristic 10 points of the die of the cast chosen for examinations. Layout points of the measurement of the temperature and cooling nozzles they showed in picture 2.

The recording of the temperature was being kept with JUMO Logoscreen device with automatic recording of the 10 measuring channels. in every second.

The quantitative assessment of the produced stream of the water mist was carried out with optical method with use of computer processing and analysis with systems Adobe Photoshop and Multiscan.

3. Results and discussion

On the pictures 3–5 research findings of generating the water mist for water pressure appropriately were presented 0.04; 0.08 and 0.2 MPa. Shown photographs of the generated stream are representative for the entire examined range from 0.02 to 0.25 MPa of the changeability of the water pressure. It results from these examinations, that applied sprayers with the centrifugal stream rotated nozzle make possible for effective spraying water in surrounding air. In the first stage flowing water forms continuous stream which in the range of the pressure is accepting 0.02–0.06 MPa shape of the spherical bowl (Fig. 3). Together with walking away from the nozzle the ray of the coating is increasing and its thickness is decreasing. In the bottom part, as a result of defeating forces of the surface tension by the centrifugal force of a gyratory movement tearing the thin membrane follows and in consequence dispersion of a drop of water to surrounding airs. The stream being formed has the shape of the compact, elongated stream.

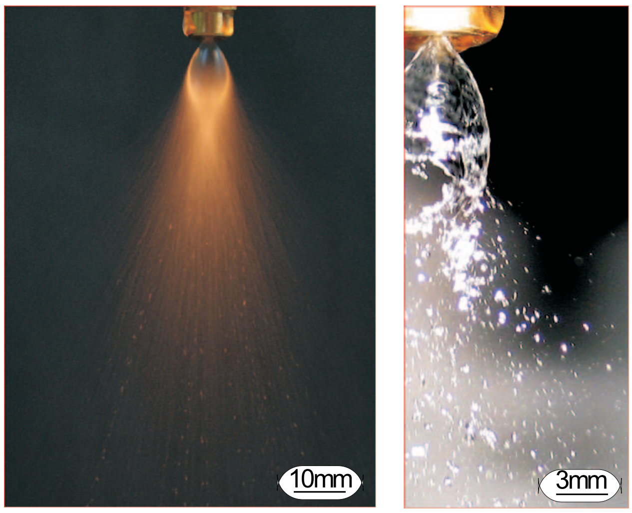

Fig. 3. Stream of sprayed water obtained with pressure 0.04 MPa

Increase of the water pressure to 0.08 MPa (Fig. 4 and 5) causes that in the first stage the stream assumes the shape of conical surface. With increasing the water pressure to 0.2 MPa its apex angles in the place of the outflow of the nozzle grow as well as this coating is undergoing tearing more and more close the nozzle. Droplets dispersed in the second stage seem to be smaller, they have the greater kinetic energy form the wider stream of the water mist.

Fig. 4. Stream of sprayed water obtained with pressure 0.08 MPa

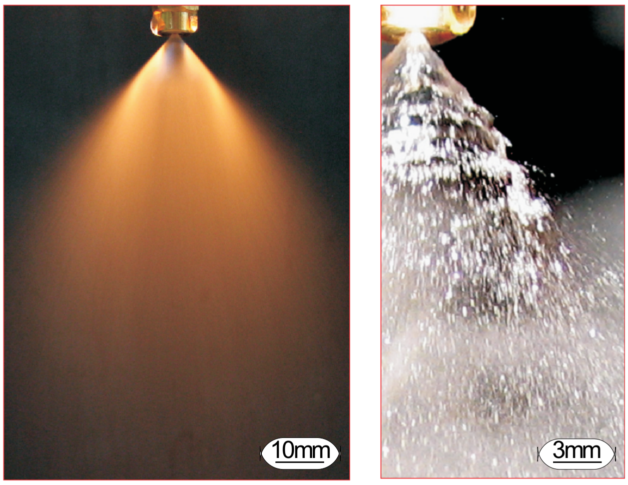

Fig. 5. Stream of sprayed water obtained with pressure 0.20 MPa

In picture 6 a processed monochrome image of the representative fragment of the stream generated at the 0.08 MPa water pressure with distinguished objects, in the state enabling to sum them up and individual manual and automatic measurements were described with the help of computer program. Visible black objects are copying drops of water. They have the diversified shape and the size. The assessment of the size of drops was carried out with use of the automatic measurement of Feret's diameter calculated on the basis of two maximum dimensions of the drop in perpendicular directions.

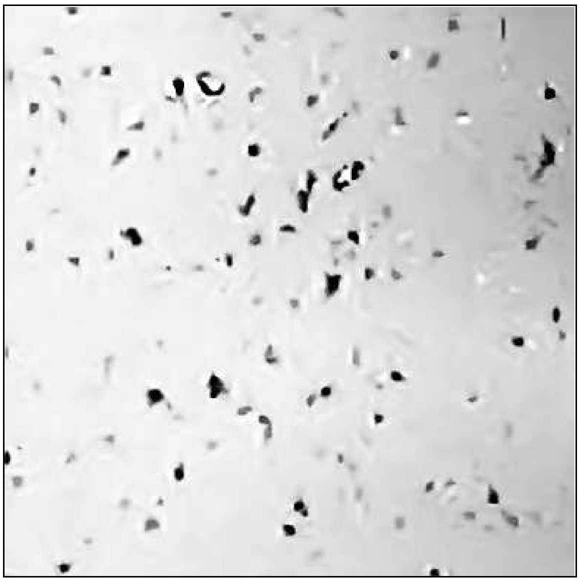

Fig. 6. Result of computer processing and analysis of water mist's stream image obtained for 0.08 MPa pressure

In table for example a descriptive statistics of the analysed image of the water mist stream received for the 0.25 MPa water pressure was presented. It results from these examinations that spraying water is generating drops in a wide range from 28 to 438 μm of the Feret's diameter. Mean value is equal to 142 μm but its 95% confidence interval is +/- 18, 25 μm.

TABLE

Descriptive statistic of Feret's diameter of water mist's drops for 0.25 MPa pressure

Statistic parameter's name	Value, μm
Mean	142
Standard error	9.15
Median	129.72
Standard deviation	77.10
Variance	5944.73
Kurtosis	1.77
Skewness	0.98
Minimum	28
Maximum	438
Size	71
Confidence interval (95.0%)	18.25
Shapiro-Wilk statistic (p-value)	0.0034

It results from the histogram presented in picture 7 of the structure of the water mist that the 0.25 MPa water pressure is generating the most of drop in the range of the 100÷150 μm of diameter. The distribution of density in the all range, how results from the Shapiro-Wilk statistic isn't a normal distribution, but in the 30÷300 μm range in which is located about 90% of the drops, is very similar to it. It results from statistical analyses carried out, that density distribution of the created drops of water mist in the 0.02÷0.25 MPa checked range of water pressure are analogous to described above. So in the process of spraying apart from arithmetic means surface areas of the throw were used to the assessment of the structure of the generated water mist of the drop and the Feret's diameter also median of the Feret's diameter of the drops.

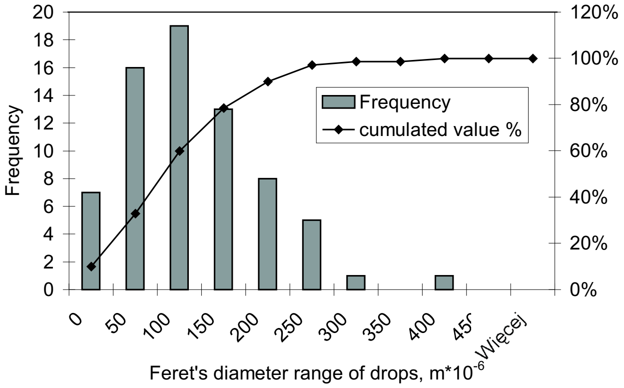

Fig. 7. Histogram of water mist stream image obtained for 0.25 MPa pressure

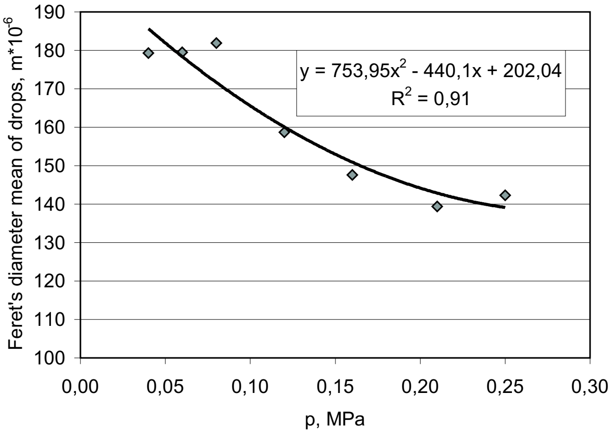

Fig. 8. Pressure effect on Feret's diameter mean of water mist's drops

From presented on picture 8 and 9 data it results that the increase of the water pressure causes reducing generated sizes of drops. It results from picture 10 describing the changeability of the median of the Feret's diameter additionally that for the pressure 0.08 MPa is appearing the maximum of the size of generated drops of the water mist is equal 177 μm. Describing the dependence the mathematical model is characterising with simple form (small number of degrees of freedom) and with big correlation (R^2 = 0.93) for measurements carried out.

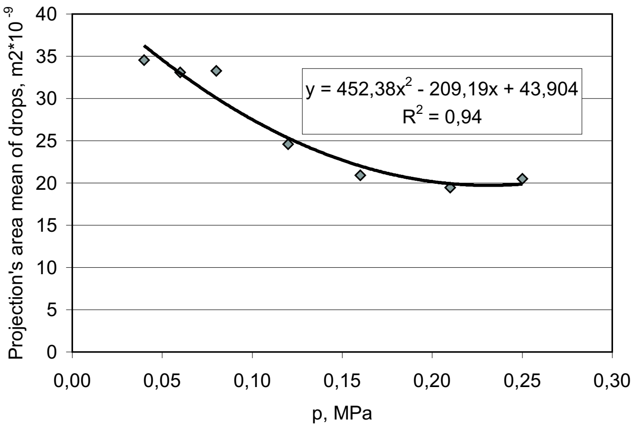

Fig. 9. Pressure effect on projection's area mean of water mist's drops

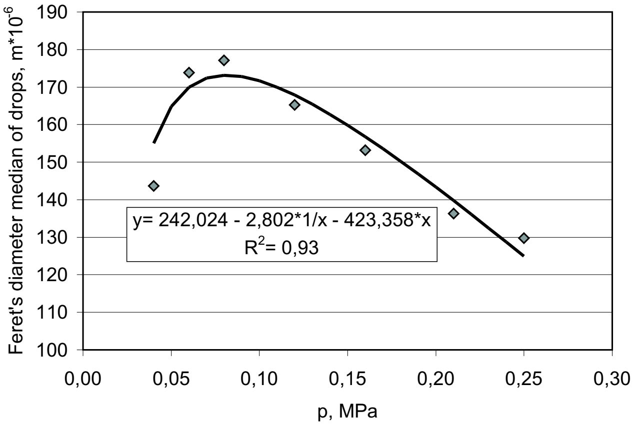

Fig. 10. Pressure effect on Feret's diameter median of water mist's drops

From analysis of literature [7, 8] results, around the heat transfer between the surface of the object and the two-phase stream hitting it is resulting from three mechanisms: of it being struck by a drop against the surface, the convection exchange of the heat of air with drops hung in it and radiation. Greatest intensity of getting the heating back is being get in the case of evaporating of droplets of water on the hot surface. But, drops flowing in are able to enter into the contact with the cooled surface, to spill out on it and to evaporate if overheating it above the Leidenfrost temperature is little or/and when drops of water have the great dynamism. Otherwise it follow reflection from the hot surface and the possible, dependent on the Weber's number of disintegration to smaller drops or losing the kinetic energy off on the steam pillow in the immediate neighbourhood cooled surface and the heat transfer is coming according to the Leidenfrost's phenomenon.

That being so for examinations the effectiveness of chilling chills was being applied water mist obtained for 0.06÷0.1 MPa water pressure, this way in order to get like a large number of big drops of sprayed water. As the transporting and granting right kinetics mist's droplets medium toward the cooled surface of the die were applied air under the 0.2÷0.6 MPa pressure.

In picture 11 a view of the stream of the water mist was presented flowing out from cylindrical nozzle of cooling system. The stream was obtained by spraying the water mist under the 0.38 MPa pressure into the circuit pipe with 0.30 MPa compressed air.

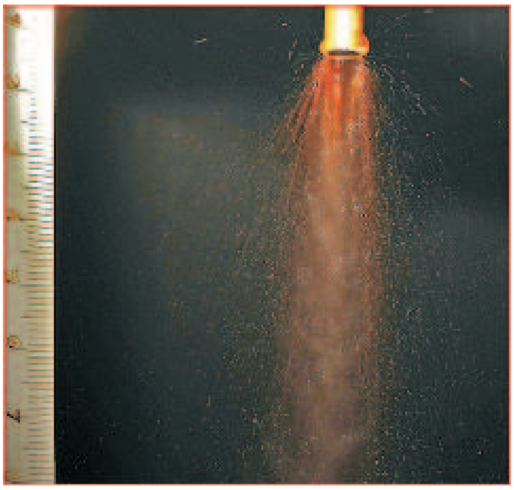

Fig. 11. Sample of water mist stream obtained for 0.30 MPa pressure of water and 0.38 MPa pressure of Air

In picture 12 the comparison of die's temperature was presented in the points "2", "4" and "10" (Fig. 2) of die during the cycle of casting a car wheel from AlSi7Mg silumin on the scientifically – production stand with cooling 0.65 MPa compressed air and the water mist under the pressure: 0.30/0.38 MPa.

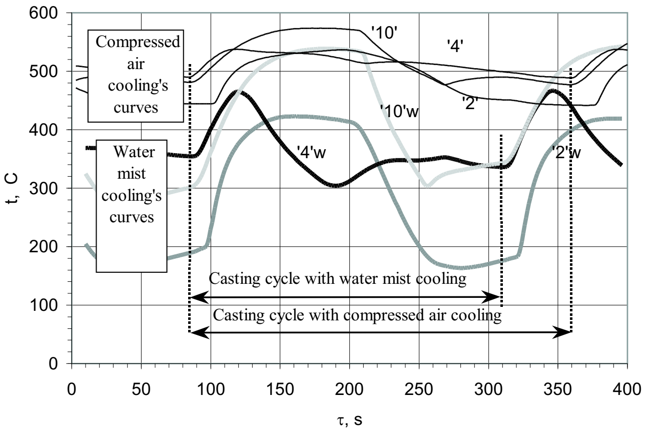

Fig. 12. Comparison of die's temperature during casting cycle of cooling with air compressed to 0.65 Mpa: "2", "4" and "10" curves and water mist cooling for pressure 0.30/0.38 MPa: '2'w, '4'w and '10'w curves obtained with thermocouples shown in Fig. 2

It results from carried out examinations that applying the water mist causes increasing intensity of being getting cold of the die and the cast. It is lowering the maximum temperature from 574 till 538°C, minimal from 437 till 163°C and the temperature range of being getting cold is increasing from 103 to 287°C. The increase enables intensity of being getting cold at the same time to shorten casting the cycle out about 25%.

It results from examinations carried out of the microstructure and mechanical properties, that in the consequence of increase in the cooling rate the die with water mist reducing the porosity and making the microstructure of silumin more homogeneous and increase of the mechanical properties of wheels compared with cooling with air appropriately from: $R_{p0,2}$ = 205 MPa till 280 MPa, R_m = 250 till 310 MPa, A_5 = 4% till 5% and HB = 85 till 97.

4. Conclusions

The following conclusions result from described examinations:

- applied sprayers with the centrifugal nozzle stream rotated allow for effective spraying water in surrounding air,
- the designed Automatic Cooling Servo device is generating droplets about in the 28÷438 μm wide range of the Feret's diameter,
- exists a relation described with mathematical model of the size of the generated droplets of water mist from water pressure of which has the maximum for the pressure 0.08 MPa,
- cooling with use the water mist under the 0.30 MPa pressure of the air and water 0.38 MPa is lowering the maximum temperature of the die from 574 till 538°C, minimal from 437 till 163°C and a temperature range of being getting cold of the die is increasing from 103 till 287°C,
- the increase enables intensity of being getting cold to shorten casting the cycle out about the 25% and the increase in mechanical properties: $R_{p0,2}$, R_m, A_5 and HB.

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