ARCHIVES
of
FOUNDRY ENGINEERING

ISSN (1897-3310)
Volume 8
Issue 4/2008

213 – 218

40/4

Published quarterly as the organ of the Foundry Commission of the Polish Academy of Sciences

Water mist effect on cooling range and efficiency of casting die

R. Władysiak
Department of Material Technologies and Production Systems, Technical University of Lodz, 1/15 Stefanowski St., 90-924 Lodz, Poland
Corresponding author. E-mail address: ryszard.wladysiak@p.lodz.pl

Received 04.07.2008; accepted in revised form 20.07.2008

Abstract

This project is showing investigation results of cooling process of casting die in the temperature range 570÷100 °C with 0.40 MPa compressed air and water mist streamed under pressure 0.25÷0.45 MPa in air jet 0.25÷0.50 MPa using open cooling system.
The character and the speed of changes of temperature, forming of the temperture's gradient along parallel layer to cooled surface of die is shawing with thermal and derivative curves. The effect of kind of cooling factor on the temperature and time and distance from cooling nozzle is presented in the paper. A designed device for generating the water mist cooling the die and the view of sprying water stream is shown here. It's proved that using of the water mist together with the change of heat transfer interface increases intensity of cooling in the zone and makes less the range cooling zone and reduces the porosity of cast microstructure.

Keywords:: Innovative materials and casting technologies, Cooling, Water mist, Die, Silumin

1. Introduction

Presented results are the continuation of examinations of die castings concerning increasing the quality, shortening of the casting cycle and increasing the effectiveness of the production as a result of the substitution of the way and the speed of cooling the casting die and increasing the mechanical properties of casted silumins in the metal moulds [1-4].
Analysis of the heat transfer process and the assessment of steering possibility with it in the temperature range 570÷100°C were an aim of examinations.
Such a wide range of the temperature results from earlier investigations of casting die while casting of car wheels in process under low pressure.
At present universally used cooling of dies consists in aiding convection giving back the heat with stream of compressed air pointed to appropriately prepared places of the outside surface of die. An application of water mist by evaporation of water droplets on the chilled surface increases many times the efficiency of the heat transfer.
The realization of the work purpose consisted on examining of the process of being getting cold of the research die on the laboratory position and describing the effect of cooling factor and heat interface shape on cooling efficiency and range of cooling zone of die casting. The increase in intensity of heat transfer from chosen die areas will let better steer with course of setting of the cast and will shorten its crystallization influencing reducing porosities of castings, size reduction the microstructure and the improvement in the Rm, A_5 properties.

2. Experimental

In picture 1 a scheme of the position for examinations of cooling intensity was shown. Cooling of the research die (1) heated to temperature 600°C was an essence of examinations. The cuboid-shaped die was made from EN–GJL-200 grey cast iron. The die was being put on the stand (4) in heat-insulating shield (2) with the possibility of the directional heat transfer with the surrounding only by the bare surface of the bottom partition wall.
Two kind shape of heat transfer interface was examined: flat and flat surface with cylindrical hole ϕ16 x 12 mm – socket, in which partly input the cooling nozzle. This surface was being cooled with stream of air or the water mist pointed with the nozzle (3) placed at right angles to the surface.
The temperature of the die was being measured at the same time with 6 K - type thermocouples (5) put in her parallel layer in the distance 15 mm from cooled surface. The thermocouples was placed in distance 0, 20, 40, 60, 80 and 100 mm from the axis of cooling nozzle. The recording of the temperature was being kept with automatic KD7 recorder of the Lumel company with the frequency 2 per second and the accuracy 0.1°C.

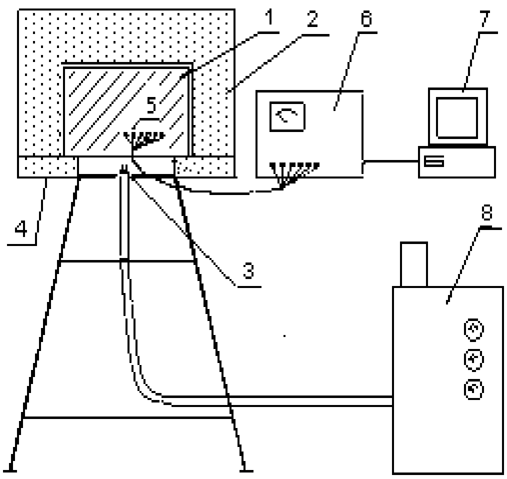

Fig. 1. Position for intensity research of cooling with water mist: 1 - research die, 2 – heat-insulating shield, 3 – nozzle of cooling system, 4 – stand, 5 – thermocouples, 6 – recorder of the temperature, 7 – PC, 8 – automatic cooling servo device

The water mist was being generated in multichannel Automatic Cooling Servo (8), of which the scheme was presented in picture 2. It lets to simultaneous dosing and spraying water in channel of the cooling system. Controlling cooling circumferences consisted in the change of the pressure of compressed air in the 0.20 to 0.45 MPa range and of water from 0.25 to 0.50 MPa. Demonstration streams of sprayed water and the starting cooling mist were shown in picture 3.
The tests of cooling effect on microstructure and Rm, A_5 properties of silumin castings was made in casting station of Rm test pieces. The zonal cooling was used with cylindrical socket on the outside surface of casting die near to centre of gauge length of one of two test pieces casting in the die. The AlSi11 silumin was used to the tests.

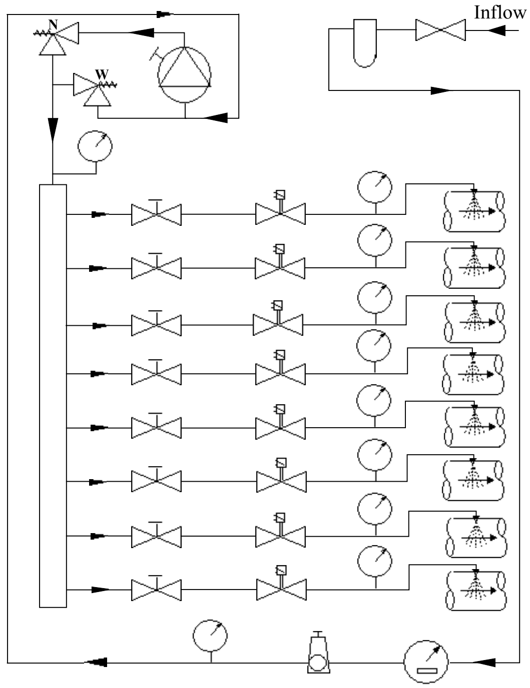

Fig. 2. Scheme of Automatic Cooling Servo

Fig. 3. Streams of sprayed water (a) and the water mist (b) cooling casting die surface with use of designed rotary sprayer, magnification of a) – x 3

3. Results

In this work there was examinated the distribution of temperature in selected points of test mold when cooled by: air at 0.4 MPa pressure, and a water mist as a mixture of air at pressure between 0.20÷0.45 MPa and water at 0.25-0.50 MPa.

In Figure 4 there was presented the results of temperature and cooling rate of casting die (Fig. 1) cooled of air at pressure 0.40 MPa. It results from presented data, that before beginning cooling, the die had the identical temperature in the checked section within the distance of 15 mm from cooling surface.

Beginning cooling caused the appearing of the temperature gradient in direction parallel to the chilled surface what shows on the graph with increasing distances between thermal curves of individual points. As a result the time of being getting cold of the die in the checked denotation from 570 to 100°C achieved a value 1760 s. Maximum speed of the temperature change was registered at the initial stage of cooling for point in axis of cooling nozzle, that was put the nearest from cooled nozzle.

From derivative curve of this point it results that the cooling rate at first is highest and is equal 2.75 °C/s and next it intensively is decreasing and then asymptotic it is approaching the naught.

In picture 5 was presented changes of the temperature and a speed of being getting cold of the research die cooled with water mist under pressure of air 0.30 MPa and with water under pressure 0.35 MPa. The time of being getting cold of the die in the checked range (570 to 100°C) achieved a value 573 s and the highest cooling rate 7.35 °C/s was inscribed at the initial stage of cooling for point in axis of cooling nozzle.

It results from presented data that an application the water mist cooling caused shortening the time from 1760s to 573s (67%) of being getting cold of the die as a result of several times cooling rate increasing.

In picture 6 there was presented the investigation results of time effect and the distance from cooling nozzle on the temperature and cooling rate with water mist at pressure 0,30/0,35MPa of casting die that has the cylindrical socket in the heat transfer surface. The time of being getting cold of the die in the checked temperature range 570 to 100°C achieved a value 2885 s at the maximum of cooling rate 2.64 °C/s.

Besides from presented investigations results the cylindrical socket application in comparing to the flat heat transfer surface cooled with the air (Fig. 4) and cooling with water mist (Fig. 5) caused decreasing of overall cooling efficiency. Decreasing of cooling rate and time's duration are symptoms of the process.

In picture 7 there was presented the effect of distance from cooling nozzle axis and of cooling factor kind on temperature of casting die with flat heat transfer surface. It results from presented data that the temperature in casting die increases slowly and proportionally for cooling with air and it increases much more quickly and progressively in using of water mist cooling. The biggest temperature gradient was recorded for two kinds of water mist at pressure 0.30/0.35 MPa and 0.45/0.5 MPa.

In picture 8 was presented the effect of distance from cooling nozzle axis and of cooling factor kind on temperature of casting die with cylindrical socket in heat transfer surface. As it results from the data the least temperature gradient appeared in casting die cooled with air. An application of the water mist increases the difference of the temperature in tested zone of die. The temperature characteristic is degressive. Big gradient occurs in neighbourhood of nozzle and it decreases together with the distance.

In picture 9 was presented the comparison of distance from nozzle axis effect and the time of being getting cold on temperature of die with flat heat transfer surface (Fig. 9, "Flat") and with surface with cylindrical socket (Fig. 9, "Socket") cooled with water mist at pressure 0.30/0.35 MPa.

Casting die increases slowly and proportionally for cooling with air and it increases much more quickly and progressively in using of water mist cooling.

As follow from described in figure investigations the application of cylindrical socket on the cooling surface of die increases the cooling efficiency in zone at radius 60 mm from axis of cooling nozzle. The maximum of the temperature occurs in distance 40 mm. Moreover from comparison of temperature changes in all area (0÷100 mm) results the mean temperature gradient at the beginning stage of cooling (Fig. 9, upper curves) is similar for both kind of heat transfer surface. Later cooling (Fig. 9, lower curves) causes increasing of the difference for surface with cylindrical socket.

Summarizing, it results from the investigation that the change of surface shape which participates in heat transfer with water mist lets increase taking the heat over from demanding zone of die and of casting and also reduce the range.

In figure 10 there was presented the effect of zonal cooling of casting die with water mist at pressure 0.40/0.45 MPa on porosity and microstructure of silumin casting. The microsection was made in cross-section of measuring length of casted tensile test piece. It results from the observation that cooling with water mist clearly decreases the porosity and homogenizes the microstructure of the casting in comparison to samples casted without the cooling.

It is likely caused by occurrence the maximum temperature gradient in cooling zone of casting which creates the crystallization front at the earliest. It starts the directional solidification process of casting. The front builds microstructure drawing liquid metal from less responsible areas to which at the same time it pushes the gaseous pollutions. It increases the possibility of getting correct microstructure in responsible zone also in difficult conditions of casting process of polluted silumins without right refining.

The tensile tests of carried out silumin pointed out that as a result of improving of casting microstructure quality took place the increase of Rm and A_5 properties from values: Rm = 148 MPa, A_5 = 1.6 % to Rm = 164 MPa and A_5 = 2.8%.

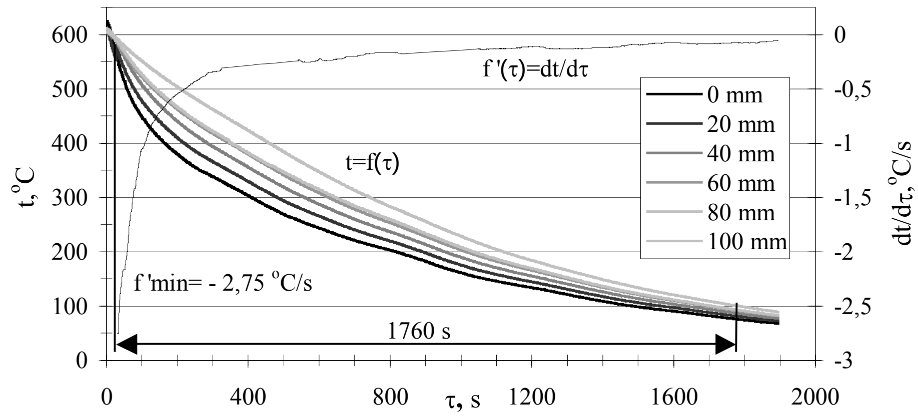

Fig. 4. Effect of time and distance from cooling nozzle axis on temperature and cooling rate with air under pressure 0.40 MPa of casting die with flat heat transfer surface

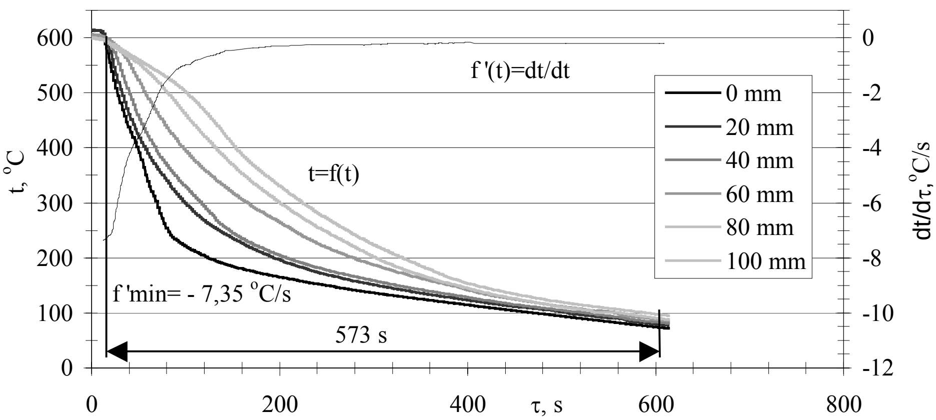

Fig. 5. Effect of time and distance from cooling nozzle axis on temperature and cooling rate with water mist under pressure 0.30/0.35 MPa of casting die with flat heat transfer surface

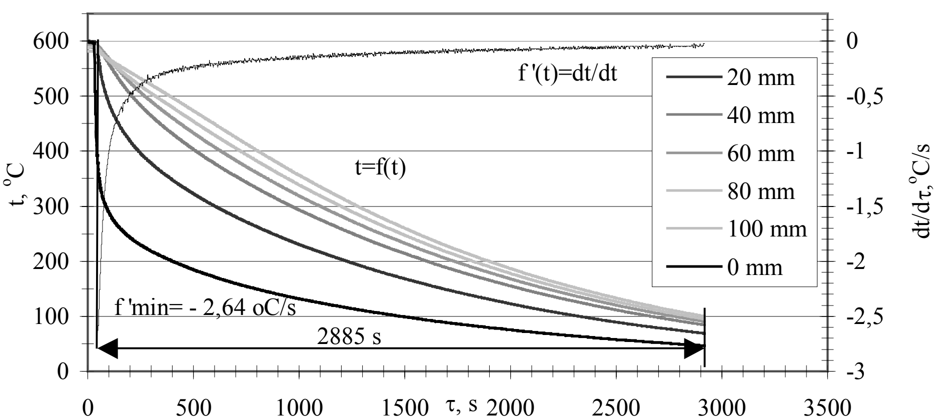

Fig. 6. Effect of time and distance from cooling nozzle axis on temperature and cooling rate with water mist under pressure 0.30/0.35 MPa of casting die with cylindical socket in heat transfer surface

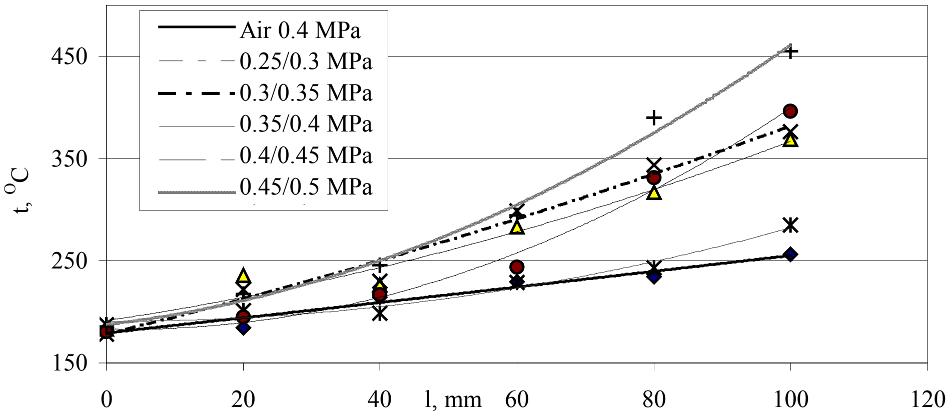

Fig. 7. Effect of distance form cooling nozzle axis and of cooling factor kind on temperature of casting die with flat heat transfer surface

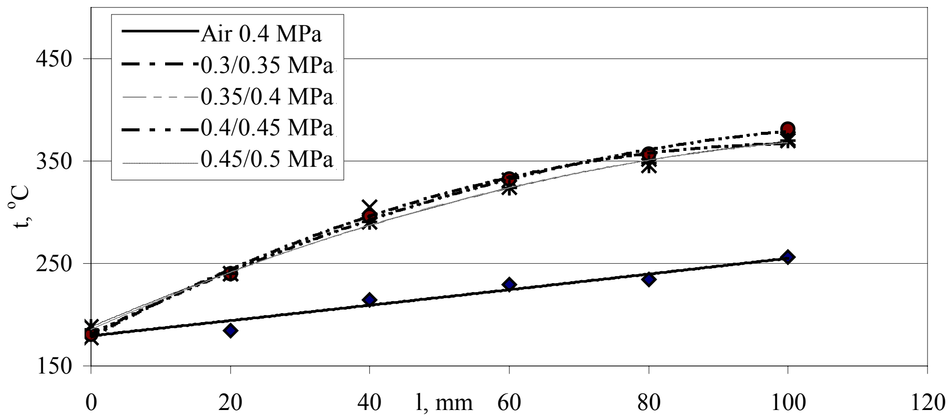

Fig. 8. Effect of distance form cooling nozzle axis and of cooling factor kind on temperature of casting die with cylindical socket in heat transfer surface

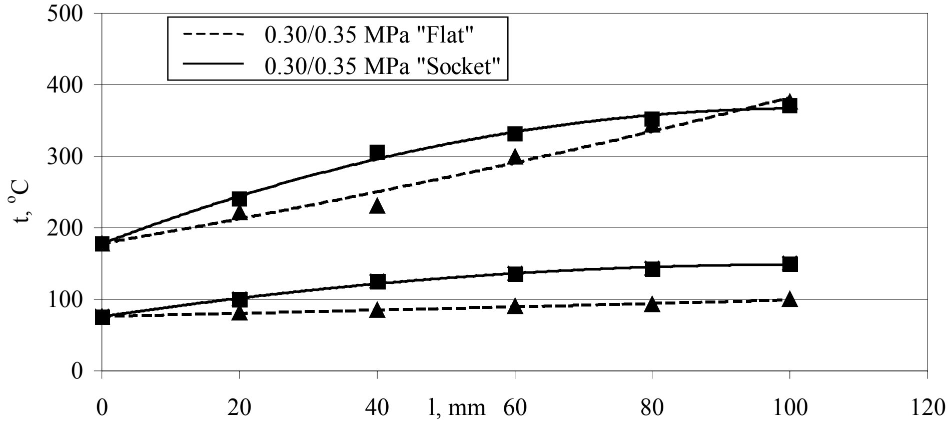

Fig. 9. Effect of distance form cooling nozzle axis and coling time on temperature of csting die with flat heat transfer surface („Flat") and surface with cylindical socket („Socket") cooling with water mist under pressure 0.30/0.35 MPa

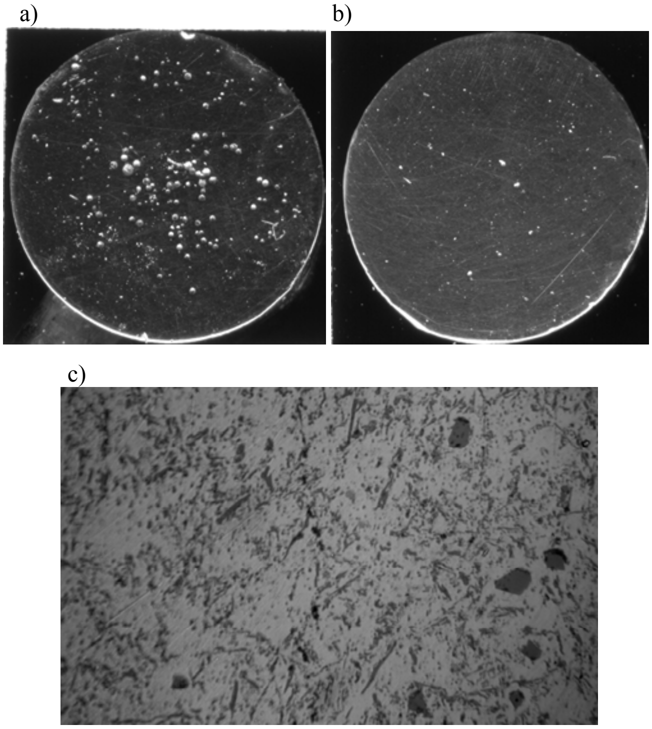

Fig. 10. Porosity of uncooled (a) and of cooled casting (b) and microstructure (c) of cooled with water mist under pressure 0.40/0.45 MPa; magnification: a), b) x 4, c) x 200

4. Conclusions

The following conclusions results from described investigations:

- the change of shape of casting die surface that participates in heat transfer with water mist increases the intensity of taking the heat over from demanding zone,
- an application of the cylindrical socket in cooled surface of the casting die increases the cooling intensity in a range of zone to 60 mm from cooling nozzle,
- the zonal cooling of casting die with water mist under pressure 0.40/0.45 MPa decreases porosity and homogenizes the microstructure of the casting in comparison to samples casted without the cooling,
- cooling with water mist at pressure 0.40/0.45 as a result of the microstructure improovement increases mechanical properties Rm, A_5.

References

[1] R. Władysiak, Zastosowanie mgły wodnej w procesie odlewania kół samochodowych, Archives of Foundry No. 22 (2006) 552-561 (in Polish).

[2] R. Władysiak, Intensyfikacja procesu odlewania kokilowego kół samochodowych - Conference proceedings „Polish Metallurgy in Years 2002-2006", Comitee of Metallurgy, (2006) 359-366.

[3] R. Władysiak, Reengineering of permanent mould casting with lean manufacturing methods, Archives of foundry, vol.7, Issue 3, (2007) 205-212.

[4] R. Władysiak: Water mist effect on heat transfer coefficient in cooling of casting die, Archives of Foundry Engineering, vol.8, Issue 3, (2008) 227-236.