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SERVICE LIFE OF A PRESSURE MOULD WITH HEAT-BARRIER AND ANTI-EROSION COATING

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The present paper deals with the issue of determination of the cause of wear of a thermally processed and nitrided pressure mould with (Ti, Al)(C, N) coating. It was found that the service life of the (Ti, Al)(C, N) coating was affected neither by the substrate surface irregularities nor presence of non-metallic inclusions. It can be supposed that the use of a thicker coat can be favourable in view of mitigation of the effect of sudden mould temperature changes in the course of pouring and mould surface cooling down.

Key words: pressure mould, coating of M(C, N) type, metallography, surface roughness

INTRODUCTION

Increased service life of pressure mould translates directly into lower casting production costs. Some recent papers devoted to this issue explore the idea of applying a (Ti, Al)(C, N) coating on the pressure mould surface that constitutes a thermal and anti-erosion barrier. Such coatings increase smoothness of the mould resulting in good casting surface quality. Although foundrymen are keenly interested in this method of extending mould service life, to date they are still offered a very limited selection of comparative data concerning mould durability [1-7]. For this reason, a test described in this paper was focused on establishment of the cause of damage of a pressure mould made of thermally and thermo-chemically processed hot work steel provided with (Ti, Al)(C, N) coating.

EXPERIMENT, DISCUSION OF RESULTS

The pressure mould was fabricated of a hot work tool steel of the following composition: 0,55 % C, 1,68 % Si, 6,35 % Cr, 1,73 % Mo, 1,39 % V, the rest Fe. In the initial state, the steel structure consisted of small equally spaced spheroidal alloy carbides in a fine-grained ferrite matrix. The steel hardness was ~230 HB. Parts of the pressure casting dies were quench hardened in oil from 1 020 °C. The time of austenitising was 30 min. Tempering was performed twice at 620 °C for 50 min. followed by cooling in air. In this state, the steel structure consisted of small equally spaced spheroidal alloy carbides in a high temperature tempered martensite. The hardness of the material after heat treatment was 44 ± 1 HRC. The die parts after such heat treatment were polished with fine grain abrasive paper and then their surface geometry was profiled with a water jet containing 20 % wt Al_2O_3 powder. This treatment was performed for ~3 min, using a jet pressure of ~2,5 bar. The parameters of geometrical structure were measured on the TalyScan 150 of Taylor Hobson brand with software TayMap Expert v.2.0.15. The measured section was 1 mm. Resolution was 5 µm. The values of the surface parameters prepared for nitriding were S_t = 12,10 µm, S_q = 0,90 µm, and S_z = 8,60 µm, respectively, where: S_t - the distance between the total height from the highest to the lowest point, S_q - the mean of the surface deviation from the averaging surface, and S_z - the mean of the highest peaks and the five lows points [8].

The parts of the pressure casting die were subject to diffusion nitriding in ammonia dissociated atmosphere. The nitriding process was performed in two stages. In the first stage, nitriding atmosphere containing 60 % NH_3 at temperature 450 °C was used for 2 hours. In the second stage, ammonia content in the exhaust atmosphere was reduced to 25 % at temperature 520 °C for 10 hours. Then the charge was cooled together with the furnace down to the ambient temperature.

The (Ti, Al)(C, N) coating was applied using the Rübig Technology.

EDS spectrometer combined with SEM (Joel 500) was used for point-wise analysis of areas adjacent to cracks as well as mould material and PVD coating tearouts. Tests were performed on the cross section rather than on its surface.

Tests were conducted with the use of an IDRA OL 320 pressure casting machine and double cavity pressure casting die. The eutectic Al–Si alloy was poured into dies at 690 ± 10 °C. Temperature of the mould in the area most exposed to the liquid metal stream blow, just before pouring was 190 °C, compared to 230 °C

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after taking the casting out of the mould. The temperature measurement was taken by means of Raytek non-contact sensor. The casting with gate assembly weighed 0,65 kg. The average thickness of the casting wall was 4 mm. The casting cycle lasted 8 s. Pressure of the first, second, and third casting phase was 24 bar, 64 bar, and 160 bar, respectively. Liquid metal speed in the pouring slit was 10,5 m/s in the course of the first pouring phase and 112 m/s in the second phase.

To assess the condition of the mould surface, after each 500 pours with liquid AlSi12S the form was being taken out of the pressure machine and subject to visual examination. The visual examination focused mainly on these cavity areas which were exposed to the straight blow of molten metal stream. After the first 500 pours, no wear of the anti-erosion barrier was found. The values of the geometrical structure parameters of the mould surface were: S_t = 16,60 µm, S_q = 2,34 µm, and S_z = 15,8 µm.

The values of the surface geometrical structure parameters increased after 8 000 pours by ΔS_t = 6,70 µm, ΔS_q = 1,18 µm, and ΔS_z = 0,90 µm. This proves that micro damages of the mould surface occurred. Clear symptoms of mould surface wear in the areas exposed to melted stream impact were observed after 13 500 pours. The values of the geometrical structure parameters of the mould surface were: S_t = 56,50 µm, S_q = 6,70 µm, and S_z = 45,50 µm.

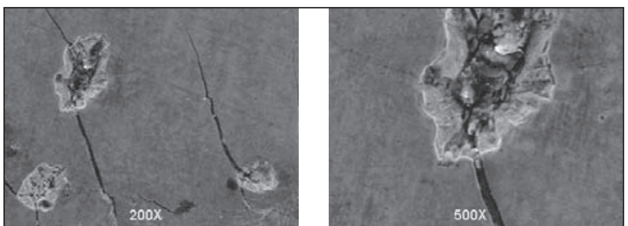
The total service life of mould operation was 17,000 pours. On account of the above, a decision was taken to scrap the mould and perform metallographic tests. Samples for tests were cut out of the areas with visible wear. The results obtained prove that the anti-erosion barrier is damaged by the occurrence of torn-out section and cracks (Figure 1). The barrier damage is an effect of torn-out fragments occurring at the mould material.

Microanalysis of the area where mould material cracks appeared revealed an increased oxygen content (Figure 2).

The microstructure of the PVD coating and the results of point-wise analysis of the PVD coating and non-metallic inclusions in the mould material is presented in Figure 3.

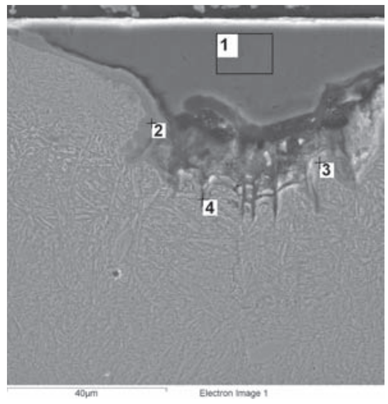
The coating thickness was about 3 µm and its hardness was 3 200 HV (max load: 15 mN).

The microstructure of a hot work tool steel (H13) and microhardness distribution in the surface layer of the material after ammonia nitriding, is shown in Figure 4.



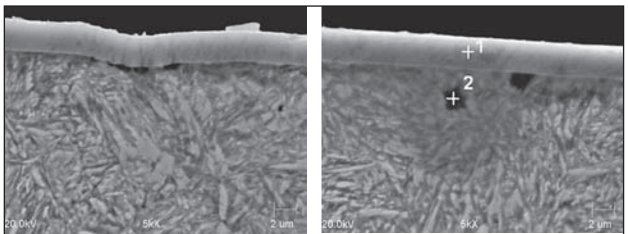
a) b)

Figure 1 View of areas of excessive wear with a damaged barrier (a-b)



Element	Content in Point / wt%			
	1	2	3	4
C	0,00	5,62	8,17	17,63
O	0,00	30,21	31,48	14,64
Al	88,4	0,00	0,00	0,00
Si	11,96	1,92	3,13	7,74
S	0,00	0,00	0,00	14,93
V	0,00	0,58	0,72	0,00
Cr	0,00	7,25	9,44	4,97
Fe	0,00	52,02	41,76	46,09
Mo	0,00	2,39	5,29	0,00
Total	100	100	100	100

Figure 2 Results of microanalysis of the area with mould material cracks revealing an increased oxygen content



Element	Content in Point / %wt	
	1	2
Ti	28,217	31,351
V	0,000	0,324
Cr	0,000	0,074
Mn	0,000	0,086
Fe	0,000	0,143
C	25,113	49,196
N	32,186	0,000
O	0,000	0,000
Al	14,485	0,077
Si	0,000	0,029

Figure 3 Content of elements in PVD coating (Point 1) and in the mould material inclusions (Point 2)

CONCLUSIONS

It was found that excessive wear of the mould occurred in the areas most exposed to the impact of molten metal stream.

It is well known fact that surface nitriding results in an increase of fatigue resistance at occurrence of varia-

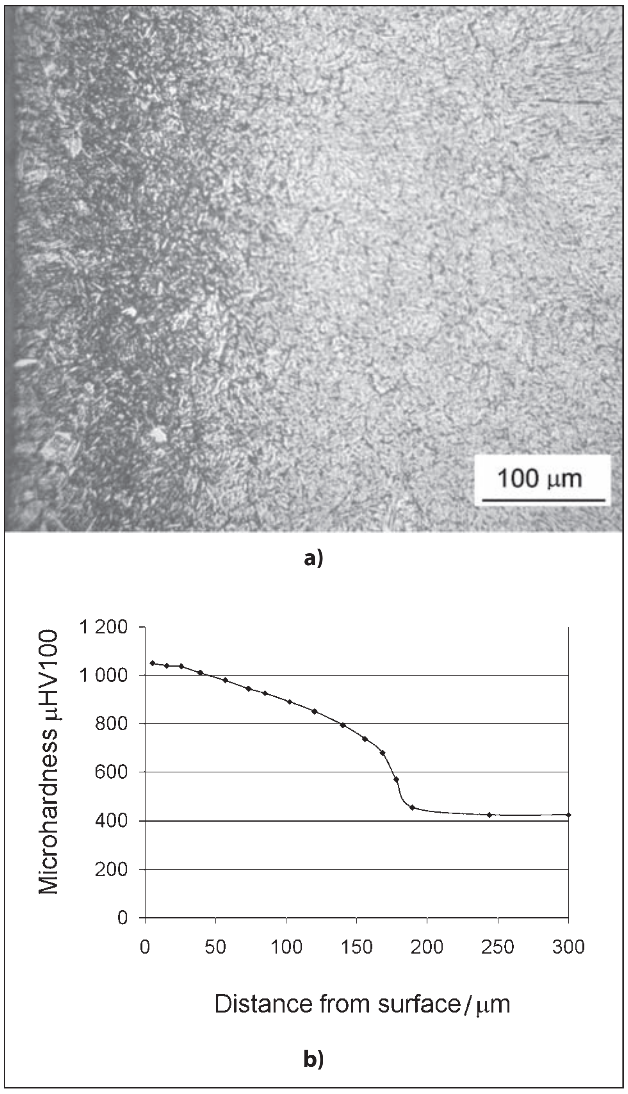


Figure 4 Microstructure of nitride layer on hot work tool steel (H13): (a) nitrides and carbonitrides $\varepsilon + \gamma'$ in the base of high temperature tempered martensite (etched with 3 % natal); (b) microhardness distribution in surface layer sample

ble loads. Therefore, maintaining appropriate thickness of the nitride layer is essential for provision of the pressure moulds long service life.

Absence of microcracks in the substrate is decisive for maintenance of the coating content that in turn protects the substrate against high-temperature corrosion and abrasive wear.

Referring the results presented here to those published in [6] where (Ti, Al)C, N) coating was also applied but with larger thickness (10 μm) and much longer mould service life was obtained, it can be supposed that with increasing thickness of the coating, substrate surface temperature decreases and its resistance to thermal fatigue induced by cyclic temperature changes increases, together with resistance to oxidation.

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Note: Jan Snakowski is responsible for English language, Rzeszów, Poland