POLISH ACADEMY OF SCIENCES - MATERIALS SCIENCE COMMITTEE
SILESIAN UNIVERSITY OF TECHNOLOGY OF GLIWICE
INSTITUTE OF ENGINEERING MATERIALS AND BIOMATERIALS
ASSOCIATION OF ALUMNI OF SILESIAN UNIVERSITY OF TECHNOLOGY

Conference Proceedings

11th INTERNATIONAL SCIENTIFIC CONFERENCE
ACHIEVEMENTS IN MECHANICAL & MATERIALS ENGINEERING

Improvement of dies casting tools with duplex treatment

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A comparative performance test of duplex treated tools was made in die casting of driving wheels for automobiles with 2 cores in one casting plate. One set of cores was improved with Tenifer®, while the other was improved with duplex treatment (plasma nitriding + deposition of 4,5µm thick PVD CrN coating). After 2700 injections surface damages on both types of tools were analysed using optical and scaning electron microscopes.

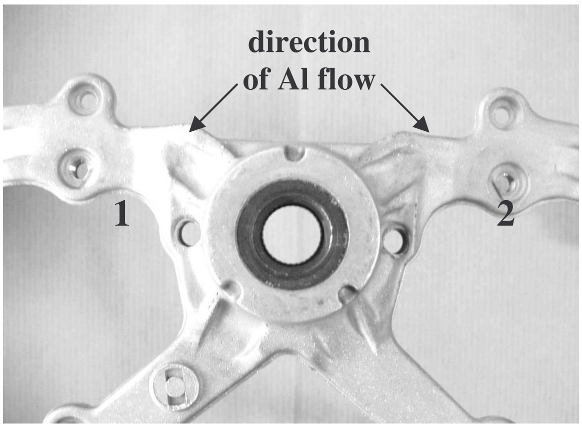
1. INTRODUCTION

Aluminium injection molding permits high-volume production of uniform castings with closer dimensional tolerances, superior surface finish and improved mechanical properties at relatively low cost. In aluminium die casting, tools are exposed to erosion, corrosion and soldering due to the frequent contact of the tool surface to the casting alloy, to heat checking and gross cracking due to thermal fatigue, and to oxidation due to high pouring temperatures. The gradual destruction of die surfaces during service decreases the casting piece quality and limits the die lifetime. In aluminium die casting Tenifer® nitriding is used as a reference for any other surface technology. Plasma nitriding in the manufacturing of components resulted in "better" tooling behaviour (easier separation of the product, less frequent cleaning of the die-core system and only a 20-50 % increase of service life). Hard coatings based on nitrides and carbides of transition metals also protect the steel surface from erosion and soldering of aluminium and improve the resistance against thermal cracking [1-5]. The following advantages were observed: tool life increase, less damages during removal from the die, less frequent cleaning needed, lubricant is more effective and a smaller quantity is needed, lowering the costs per injection. It should be added that PVD coatings represent a more environmentally friendly process, as compared with the traditional technology.

* Author participates in the CEEPUS No PL-013/02-03 project headed by Prof. L.A. Dobrzański.

The first positive results on aluminium die coating moulds were obtained with PVD TiN, CrN, TiAlN and recently also with CrC coatings. The duplex treatment (plasma nitriding + PVD hard coating) has also been used to improve dies and cores [6,7].

Within this study a comparative performance test was made in die casting of driving wheels for automobiles with 2 cores in one casting plate (Fig. 1). Results obtained on plasma nitrided cores protected with PVD CrN coating are compared with those protected by Tenifer procedure.



a)

b)

Fig. 1. Casting driving wheel (a) and the pair of PVD-coated test cores for positions 1 and 2 on the left side (b).

2. EXPERIMENTAL DETAILS

Hot working tool steel AISI H11 (quenched at 1150 °C and tempered at 560 °C to a hardness of 46 HRC) was used as the material for aluminium die casting tool. All the cores were formed by the high speed machining (HSC). Functional surfaces of the cores were ground and polished to a surface roughness $R_a = 0.013$ µm. One set of cores was improved with Tenifer® process. The thickness of diffusion layer was app. 120 µm. Onother one set of cores were improved with duplex treatment (plasma nitriding + deposition of 4,5 µm thick PVD CrN coating). Plasma nitriding was carried out at the Institute for Materials and Technologies in Ljubljana, using Metaplas Ionon equipment (Germany). The following plasma nitriding parameters were selected: gas composition N_2/H_2 = 10/90 %; pressure 300 Pa; surface temperature 480 °C and treatment time 8 hours. After plasma nitriding the dies were mechanically polished to obtain a nitrided surface without a compound layer. The diffusion layer, induced by the pulsed plasma nitriding, was app. 55 µm thick. A 4,5 µm thick CrN coating with microhardness 1900 $HV_{0,025}$ was deposited by ion plating in a BAI 730M (Balzers) deposition system equipped with low voltage plasma beam.

The performance tests were made under real manufacturing conditions in the TCG Unitech Lth-ol factory in Ljubljana, Slovenia. Automatic die casting machines (Buchler H400) was used in these experiments.

The process parameters were as follows:

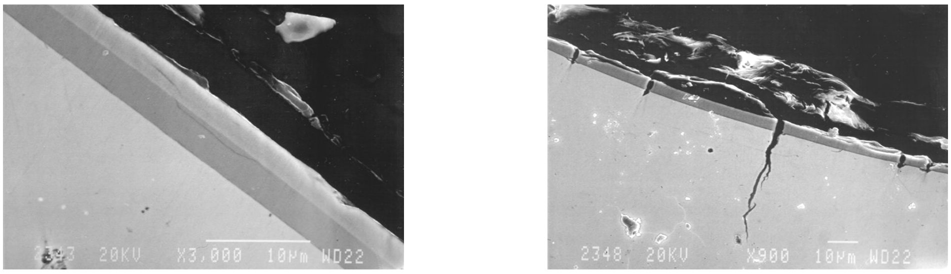
a. gate velocity 23,1 m/s,
b. final pressure 34×10^5 Pa,
c. alloy temperature: 740 ± 25 °C,
d. tool temperature: 190 ± 20 °C.

After 2700 injections the cores were taken out of the die casting machine and the functional part of the cores were cut off by the wire EDM technique in order to study the coating damages of the core bearing surface using SEM. Microhardness depth profiles were also measured on the metallographic cross-section of both types of cores. The thickness of diffusion layer was determined from microhardness depth profile as well as from optical micrographs of metallograhic cross-sections of nitrided cores after chemical etching.

3. RESULTS AND DISCUSSION

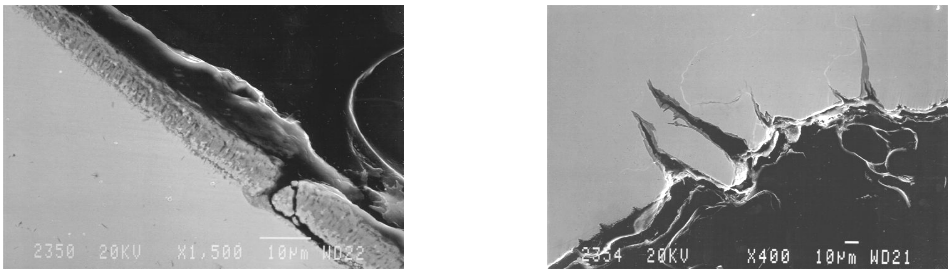
During the performance tests we identified many problems, when die casting tools were produced by EDM procedure. The reason was the white layer induced by the EDM process, which is not an appropriate surface layer for PVD coatings. Therefore the white layer must be removed by grinding, polishing or also micro-sand blasting (with 25-30 µm Al_2O_3 particles). However it is very difficult to remove the white layer from some parts of tools like holes, channels and depressions. Today we could avoid these problems by preparing the die casting tools by high-speed machining (HSC).

The bearing surfaces of both types of cores were checked after approx. 2700 injections. The wear was studied by optical and SEM microscopy at various points of the metallographic cross-section. We found that the CrN coating remained practically unaffected on the almost complete bearing surface of cores (Fig. 2a). After 2700 injections a 2,7 µm thick chromium oxide layer was observed on top of the tool surface. The thickness of the remaining CrN coating was still 3,4 µm. The oxide layer is brittle and therefore it was partially removed. The part of core surface on the side of the gate, was strongly damaged (Fig. 2b). The CrN coating was completely removed as well as large part of basic material. In this region a large micro-cracks and craters were formed. The reason for these defects could be the relatively thin diffusion layer (50-60 µm) as well as soft basic tool material H11 (46 HRC). In the case of cores protected by Tenifer process (Fig. 3) the damages on the side of the gate was a little bit smaller, while the thickness of the diffusion layer was 2-times larger (about 120 µm). However the damages on the rest of the core surface which was in contact with aluminium melt was much more expressive. An app. 10 µm thick oxide layer was observed as well as a lot of micro cracks. We found that such cores exhibited a higher tendency to adherence of aluminium alloy than those protected with CrN coating. This effect together with larger damages of the surface reflected also in higher surface roughness of such tool in comparison with that coated with CrN.



a) b)

Fig. 2. Cross-sectional SEM micrographs of PVD CrN coated core after 2700 injections: a) on the opposite side of the gate; thick oxide layer (bright layer on the top), and b) on the side of the gate.



a) b)

Fig. 3. Cross-sectional SEM micrographs showing of cores nitrided by Tenifer process after 2700 injections: a) on the opposite side of the gate; thick oxide layer is visible, and b) on the side of the gate.

4. CONCLUSIONS

We found that cores protected with CrN coatings exhibited a lower tendency to adherence of aluminium than those protected with Tenifer process. The wear of coated tools was also smaller except the core surface on the side of the gate, where it was removed together with the basic tool material. Obviously the diffusion layer must be thicker to provide better mechanical support for hard coating than original hot working tool steel, which was in our case probably also too soft.

Acknowledgements

This work was supported by the Ministry of Science and Technology of the Republic of Slovenia. The authors would like to thank Dr. Vojteh Leskovsek (Institute for Materials and Technologies in Ljubljana) for plasma nitriding of die casting cores and Z. Samardzija for SEM analyses.

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