the collective centre of the Belgian technological industry
Evaluation of surface treatments for high pressure die casting dies

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Outline

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  • Wear phenomena

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  • Sessile drop test
  • Cross sections: barrier properties
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• Industrial tests
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Introduction

- High Pressure Die Casting
  - Aluminium 700 C
  - Zinc (Zamac) 420 C
Introduction

Die Wear (Aluminium)

- Different phenomena
- Also release problems
- High tooling costs
  → Wear can represent high costs

Die steel: hot working steel (DIN1.2343)
Introduction

• Start of a project “SURCAST”
  • Sirris
  • Industrial partners
    • Pedeo
    • MGG Antwerpen
    • Umicore/Nyrstar
    • Hayes Lemmerz

• Objectives
  • Acquiring knowledge on wear and adhesion phenomena
  • How can surface treatments contribute in preventing wear
  • Improvement of the lifetime of dies and core pins to reduce production costs
Experimental

- Selected surface treatments
  - Thermochemical treatments
  - Physical Vapour Deposited coatings
  - Chemical Vapour Deposition coatings
- Examples in literature indicate that these coatings can prevent wear

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Technology</th>
<th>Roughness ($R_a, \mu m$)</th>
<th>Thickness ($\mu m$)</th>
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<tr>
<td>QPQ</td>
<td>Salt bath nitriding + oxidizing</td>
<td>0.39</td>
<td>25</td>
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<tr>
<td>TiN</td>
<td>PVD ion plating</td>
<td>0.22</td>
<td>3</td>
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<tr>
<td>CrN</td>
<td>PVD ion plating</td>
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<td>5</td>
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<tr>
<td>CrAlN</td>
<td>PVD arc evaporation</td>
<td>0.19</td>
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<tr>
<td>TiAlN</td>
<td>PVD arc evaporation</td>
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<td>2</td>
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<tr>
<td>CVD-TiN</td>
<td>Thermal CVD + polishing</td>
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<td>Thermal CVD</td>
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<td>Reference</td>
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Experimental

Sessile drop experiment: measuring wettability by contact angle

Controlled atmosphere
Al at 700 °C, Zn at 425 °C
Equilibration time of 30 minutes
Experimental

Sessile drop results (highest contact angle: smallest wettability)

- Aluminium
  - QPQ
  - CrAlN
  - TiAlN
  (oxide surface layer)

- Zinc
  - CVD-W
  - TiAlN
  - CrAlN
Experimental

Cross sections of samples with Aluminium drop

Excellent barrier
- CVD-TiN
- CVD-W

Good barrier
- QPQ
- CrN

Poor barrier
- CrAlN
- TiAlN
- TiN (horizontal crack)
Experimental

- **Pulling test: ease of release**
  - Conical pins with different substrate treatments
  - Pins are casted (aluminium)
  - Maximum pulling force (just before release) is noted
  - Three pins per surface treatment
Experimental

- Results for the pulling force on release
  - Also indicated is roughness
Experimental

- Clear correlation between pulling force and surface roughness
- No correlation between pulling force and contact angle
- Visual ranking based on amount of adhered aluminium correlates with contact angle (and hence wettability)
Industrial tests

• Core pins
  
  • Without coating: maximum 16,000 shots
  
  • With CrAlN coating: between 36,000 and 43,000 shots (to date)
  
  • Hence significant lifetime increase due to coating
Industrial tests

Wear analysis CrAlN coated core pins

- Coating shows cracks
- The steel substrate under the cracks is corroded
- Corroded steel is porous Fe-oxide
- Corrosion proceeds under the coating
Industrial tests

Powercoupler

- Frequent rupture of the casting
- Treatment with CVD-TiN and CVD-W (both polished)
- No rupture to date

Left: CVD-W
Right: CVD-TiN
Industrial tests

- Die slide
  - Upper face is functional
  - Problem is adhesion of Aluminium
- Testing
  - First test with PVD CrN: no improvement
  - Second test based on results of sessile drop: QPQ treatment: significant less adhering
Conclusions

• In this work the performance of different surface treatments in dedicated laboratory tests and in high pressure die casting field tests was evaluated.

• It was found that the wettability behaviour as measured by the sessile drop test can indeed be used to select a suitable surface treatment to reduce adhesion of aluminium (soldering) on industrial dies.

• The lifetime of core pins is considerably increased by applying a coating, but when treating core pins surface roughness is important and decisive when high release forces are the problem.

• The examination of a cross section of the drop-substrate interface after the sessile drop test, is relevant for evaluating the corrosion protective properties of a coating or surface treatment.
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