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MDPI

IMPACT OF SURFACE TREATMENT AND SURFACE CONDITION ON FATIGUE AND FRACTURE RESISTANCE OF MATERIALS IN HOT FORGING OF ALUMINUM ALLOY PARTS

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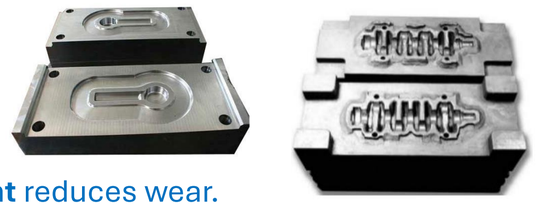
INTRODUCTION

HOT FORGING: Manufacturing process by plastic strain of metallic materials at ~75% of their melting point.

Hot forging tools:

- Abrasive wear.
- Mechanical and thermal fatigue.



- ✓ Selection of adequate **forging lubricant** reduces wear.
- ✓ **Nitriding** enhances surface hardness, induces compressive residual stresses and improves wear and fatigue performance.

Hot forging products:

- Mechanical fatigue.
- Corrosion.

- ✓ **Shot peening** improves fatigue performance through strain hardening and compressive residual stresses.
- ✓ **Anodizing** enhances corrosion resistance generating a protective oxide layer.

Investigation of surface treatments and conditions on the fatigue performance of hot forging tools and products

MATERIALS AND METHODS

Hot forging tool steel: AISI H13

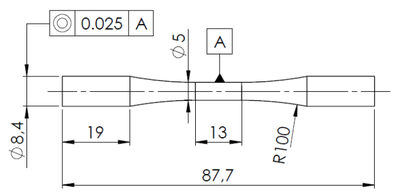
- ✓ **Nitriding.**
  - Salt bath composition: CNO^- (36%), CO_3^{2-} (19%), CN^- (≤1%)
  - Temperature and time: 570°C for 5 h
- ✓ **Forging lubricant.**
  - Water-based graphite lubricant (3.8%)
  - Different exposition times by immersion (flow) and local contact (static).

Hot forging products: AA 6082 T6

- ✓ **Shot peening.**
  - Use of silica microspheres of 100-200 µm in pneumatic system.
  - Peening intensity of 0.24 mm A during 4 min.
- ✓ **Anodizing.**
  - Electrolyte: 2 M citric acid + 1% vol. H_2SO_4.
  - Current density of 1.5 A/dm² for 1 h.

Fatigue testing:

- Axial fatigue (ISO 1099)
- Stress ratio: $R = 0$
- Frequency: $f = 10$ Hz

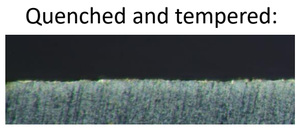


RESULTS

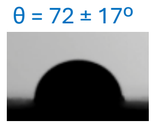
Hot forging tools: AISI H13 steel

Surface nitriding

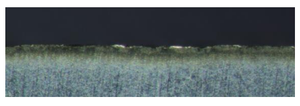
Quenched and tempered:



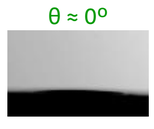
θ = 72 ± 17º

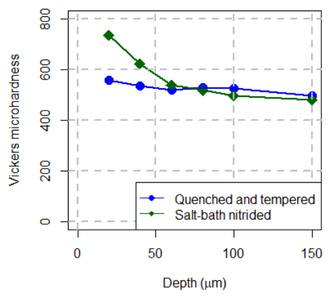


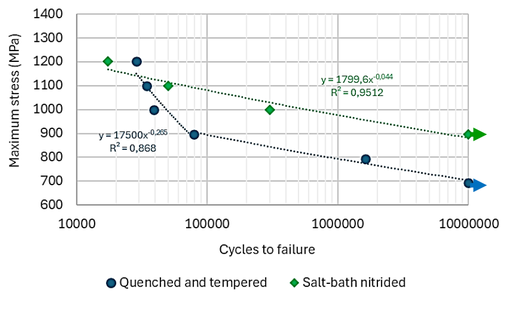
Salt-bath nitrided:



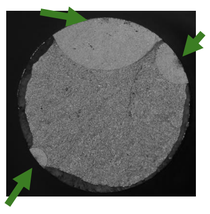
θ ≈ 0º



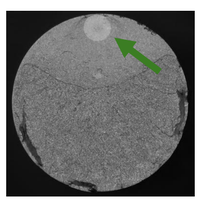




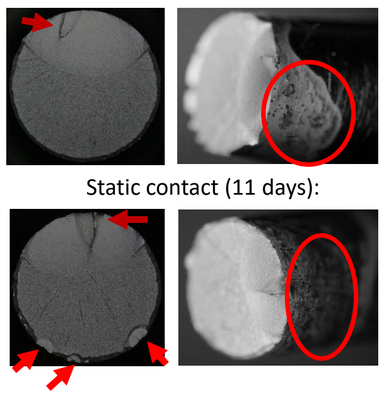
Quenched and tempered:



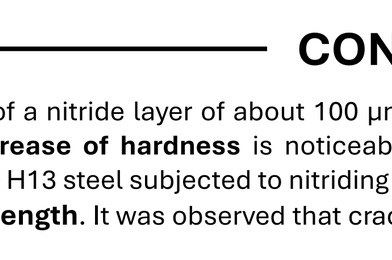
Salt-bath nitrided:



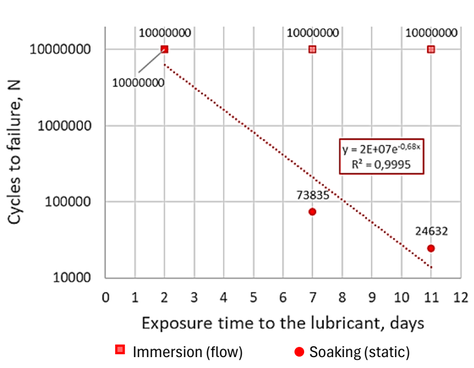
Static contact (7 days):



Static contact (11 days):

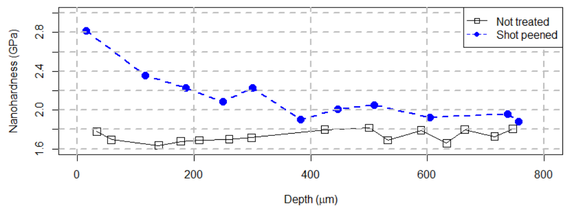


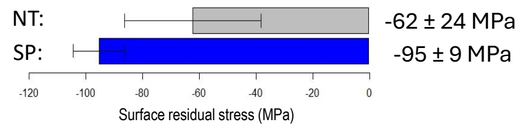
Lubricant exposition

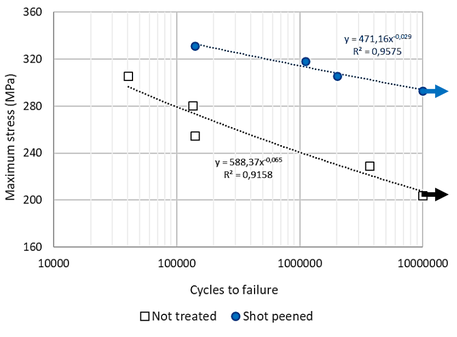


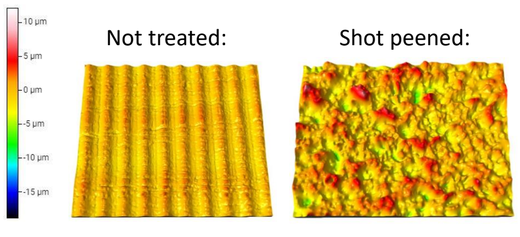
Hot forging products: Aluminium 6082 T6

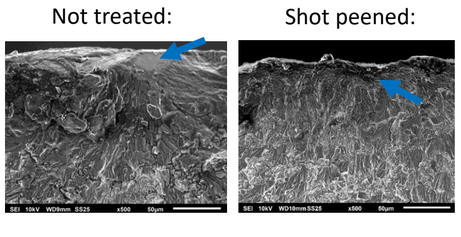
Shot peening



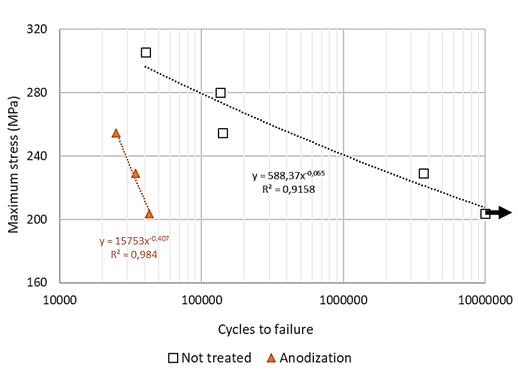


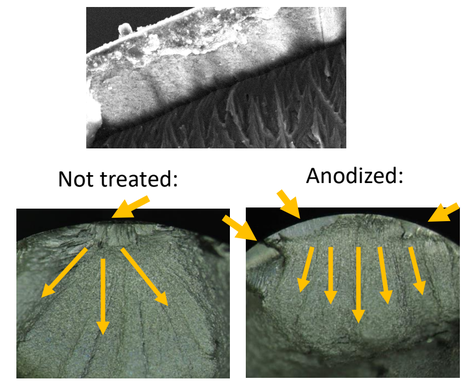






Anodizing





CONCLUSIONS

- ✓ The **salt-bath nitriding process** leads to the formation of a nitride layer of about 100 µm. This layer turns the surface **superhydrophilic**. The **increase of hardness** is noticeable within that depth. As a result, the fatigue behaviour of the H13 steel subjected to nitriding is remarkably improved, with a **28% increase of fatigue strength**. It was observed that crack initiation was shifted to the interior of the specimens.
- ✓ When the H13 steel specimens were immersed in the **forging lubricant**, fatigue lives were not altered, as the fluid did not present a corrosive behaviour. However, **fatigue lives decreased when the lubricant remained stagnant for several days**, and signs of **crevice corrosion** were observed.
- ✓ The **shot peening treatment** with silica microspheres caused significant plastic deformation in the surface of the AA 6082 T6, leading to an **increase of roughness**, surface **hardness** and **compressive residual stress**. Consequently, fatigue lives of these specimens were significantly enhanced, and **the fatigue strength of the alloy increased by 45%.**
- ✓ The **anodizing** process with citric and sulfuric acids created a protective oxide layer of about 20 µm. However, **the fatigue behaviour of the alloy worsened** due to the brittleness of such layer. Signs of **high stress concentrations** were observed in the fracture surface analysis.