Anti-Wear Improvement of Stamping Die Materials Through Duplex Chroming

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Agenda

1. Introduction
2. Sample Matrix
3. Test Method
4. Test Results
5. Failure Mechanisms
6. Summary
7. Conclusions

Introduction

Chrome plating and nitriding have been used to improve the durability and wear resistance of stamping dies.

- Chrome plating….
  - is a thin hard coating
  - is good for low load wear resistance
  - can lower the coefficient of friction
  - is not good for high load wear resistance and subject to peeling, chipping, deformation and wear, spalling, etc.
- Nitriding….
  - produces a hard iron-nitride layer for improved wear resistance.
  - not as good as chrome plating for low load wear resistance
  - Better than chrome plating for high load wear resistance where the thicker nitride layer can better absorb vertical and tangential (sliding) loads

Introduction

Project Hypothesis:

Adding a nitride layer between the chrome plating and the substrate die material can improve sliding-impact wear performance by combining the lower friction of the chrome coating with improved load support of the nitride coating.

The combination of chrome plating over nitriding is called …

Duplex Chroming

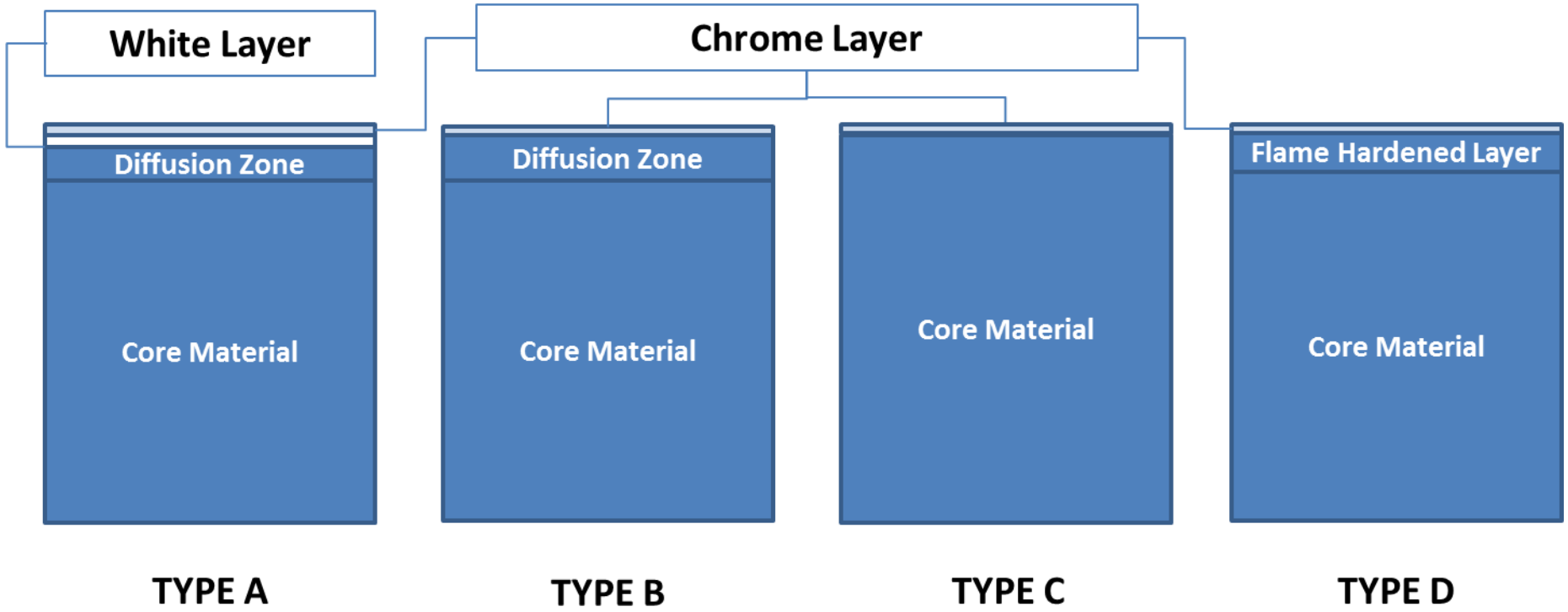
Sample Matrix

Test Set-up

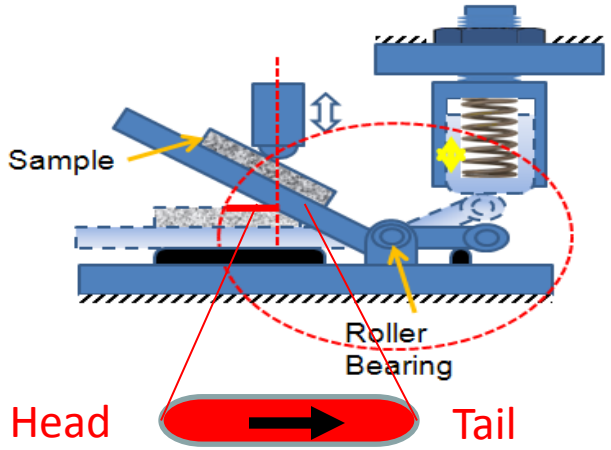
- A = Duplex Chrome: Thick chrome layer over nitrided substrate with a white layer
- B = Duplex Chrome: Thin chrome layer over nitrided substrate without a white layer
- C = Thin chrome plate over a relatively soft substrate
- D = Thin chrome plate over hardened substrate

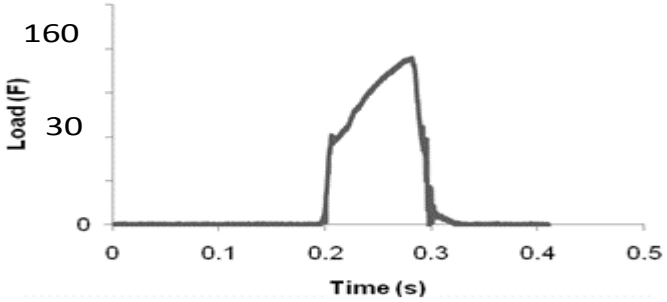
Sample	Cr thickness (um)	Substrate 0050A initial hardness (HRC)	Heat treatment	Post-treatment	Nitrided substrate hardness, before coating (HRC)	Coating hardness (HRC)
A	45	20	Ion nitriding (Sun Steel)	white layer = 0.0002 -0.0004 in.	67	70
B	12	20	Ion nitriding (Teikuro)	No white layer Diffusion Layer = 0.008-0.015 in.	45 - 47	70
C	9	20	NA	NA	NA	70
D	9	60	Flame hardening	NA	NA	70

Sample Matrix



Test Method



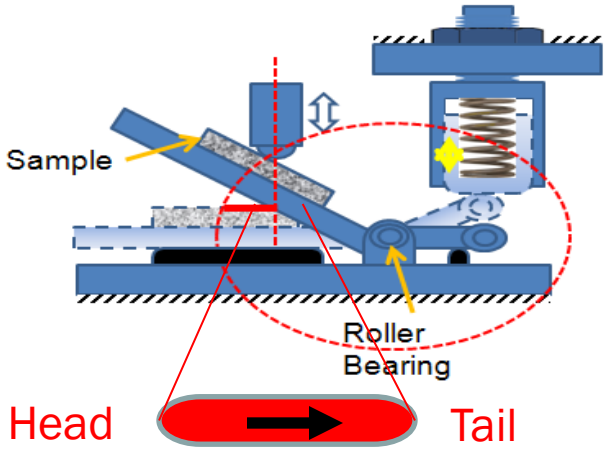


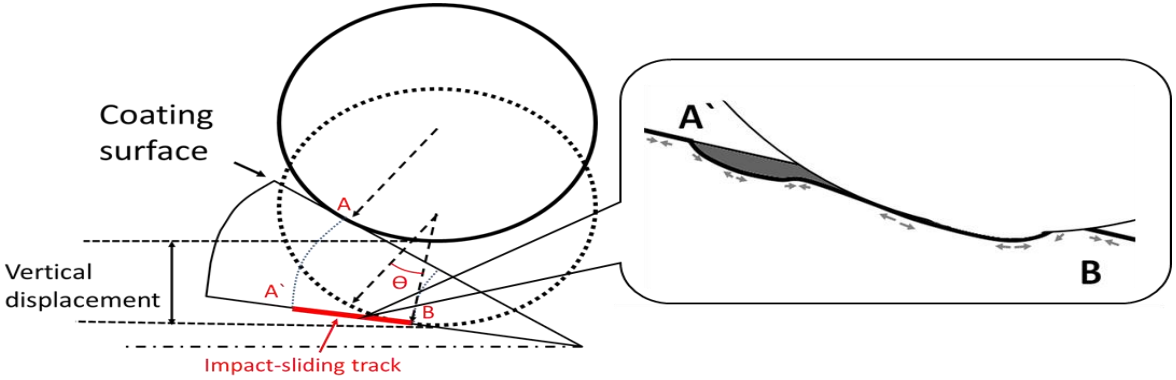
The Inclined Sliding Wear Test Method

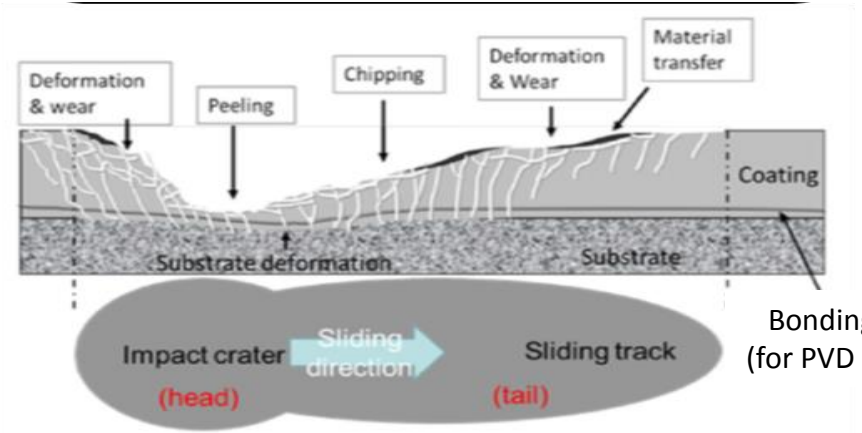
Die wear during the stamping operation is due to stretching motion of the steel sheet over the surface of the die: - sliding with inclined contact

- Dies Steel Substrates: S0050A
- Testing Load Condition: 30 N – 160 N contact mode
- Test Cycles: 150, 300 and 500 cycles
- Counterface Materials: SAE 52100 steel balls
- Steel Ball Size: 10mm in Diameter
- Length of Wear Tracks: 3 - 6mm

Test Method



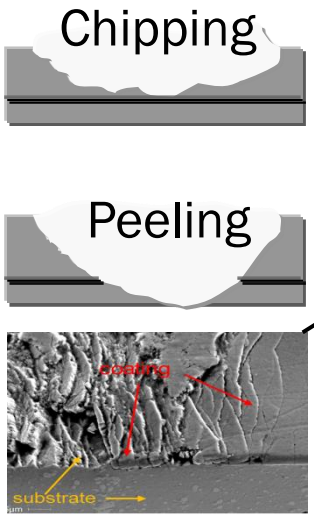


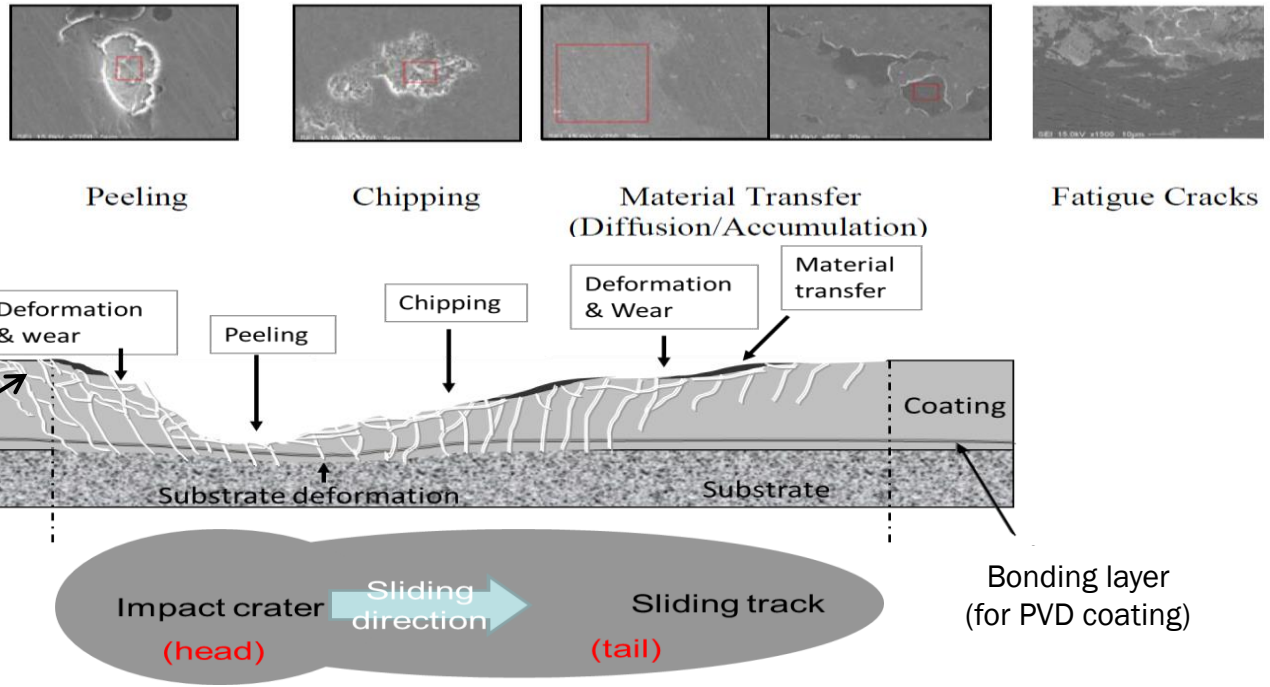


Bonding layer
(for PVD coating)

Test Method

Illustration of failure mechanisms

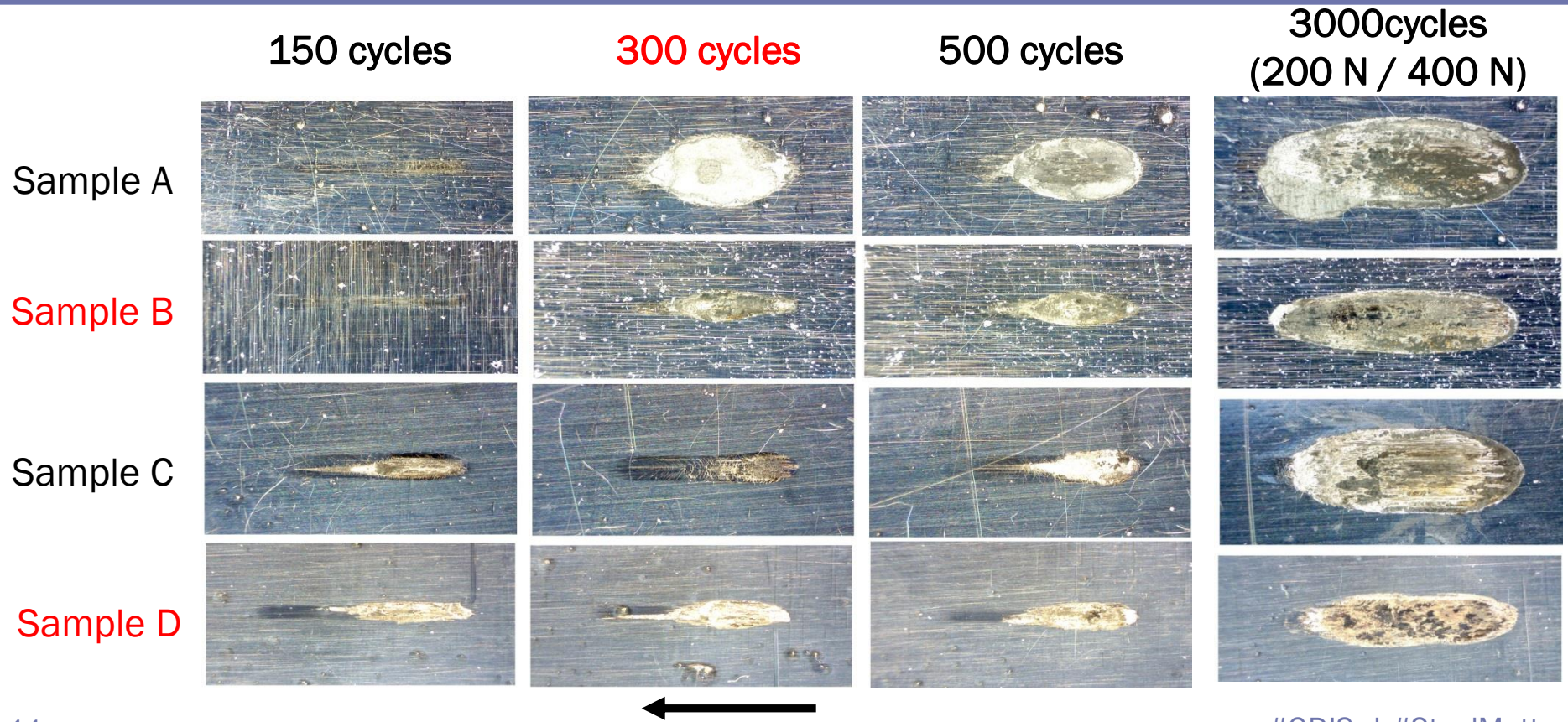




1 - Chipping
2 - Peeling
3 - Material transfer

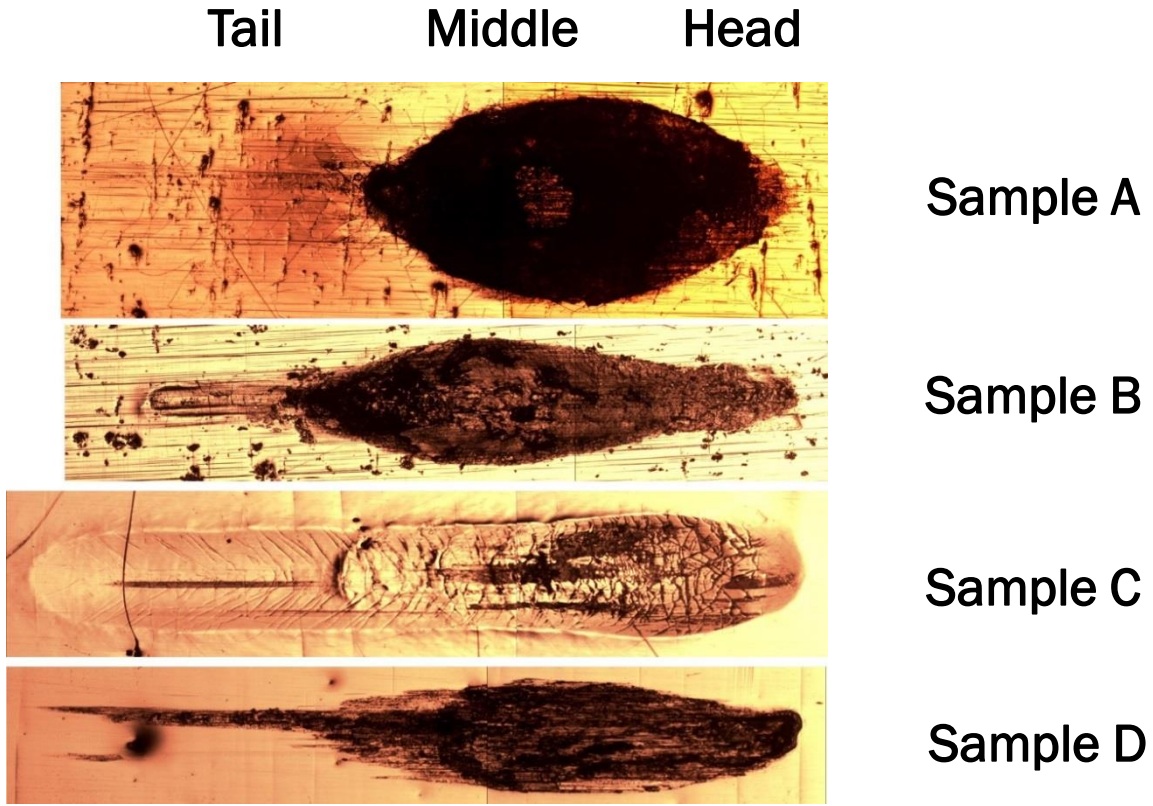
Partially exposure of the bonding layer and substrate

Test Results



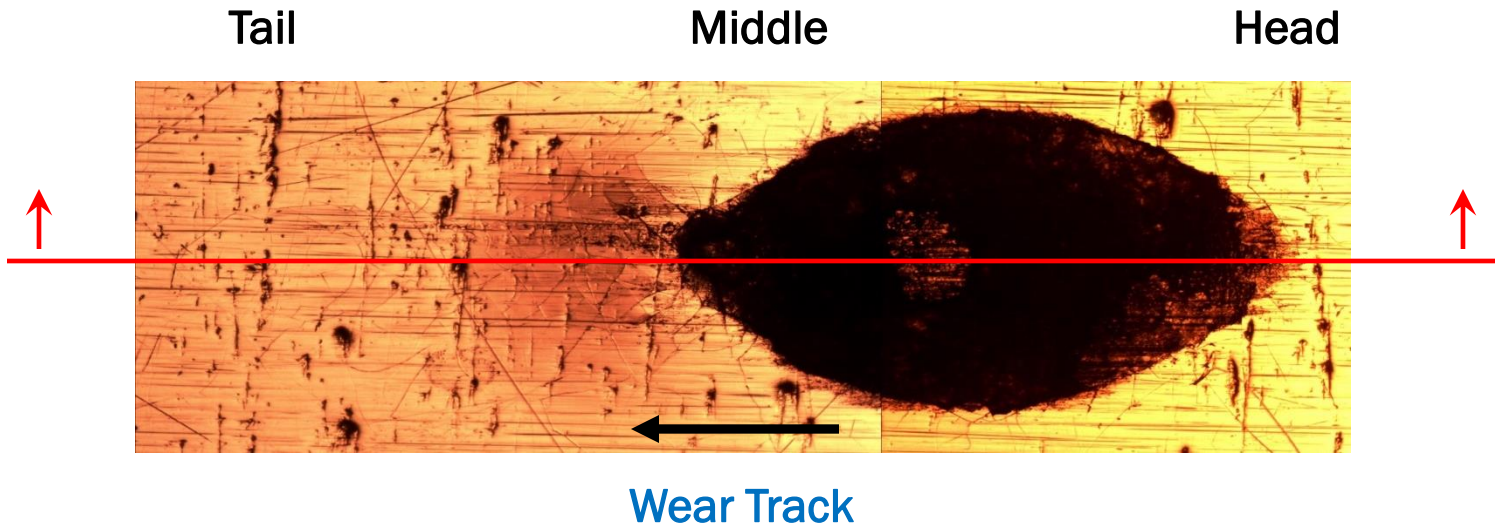
Test Results

300 Cycles
All
Samples



Test Results

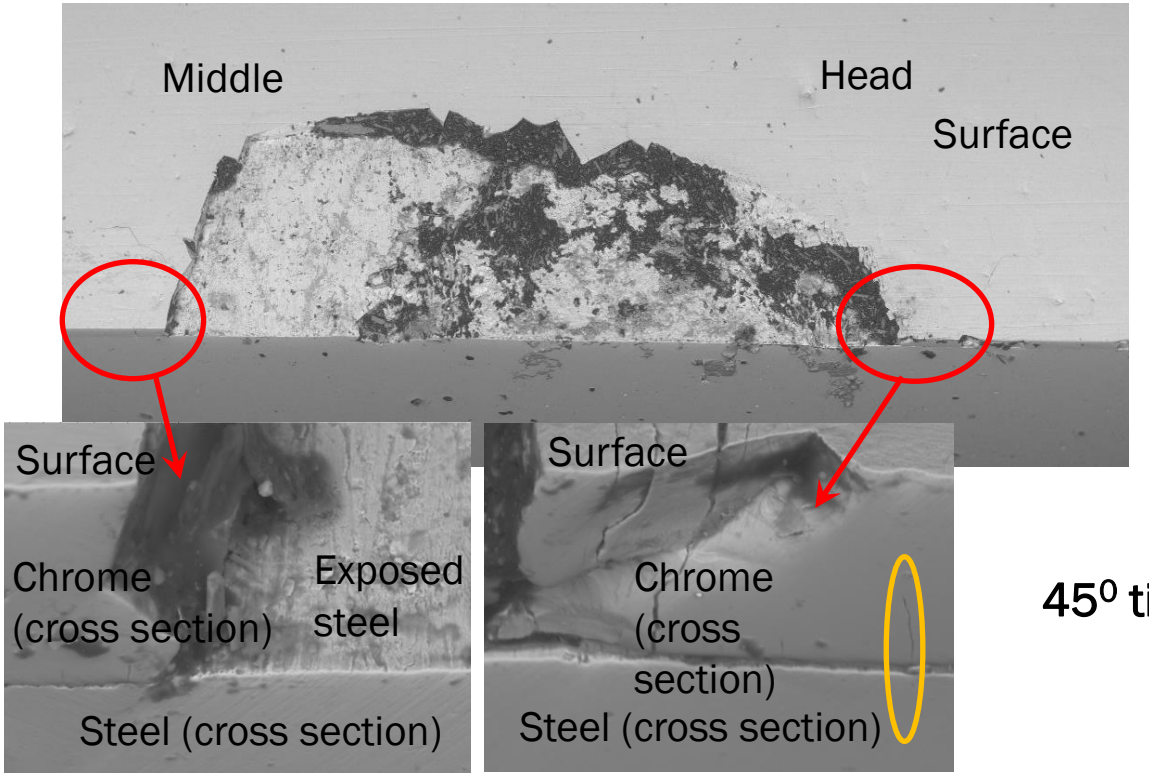
300 Cycles Sample A



A = Duplex Chrome: Thick chrome layer over nitrided substrate with a white layer

Failure Mechanisms

300 Cycles Sample A

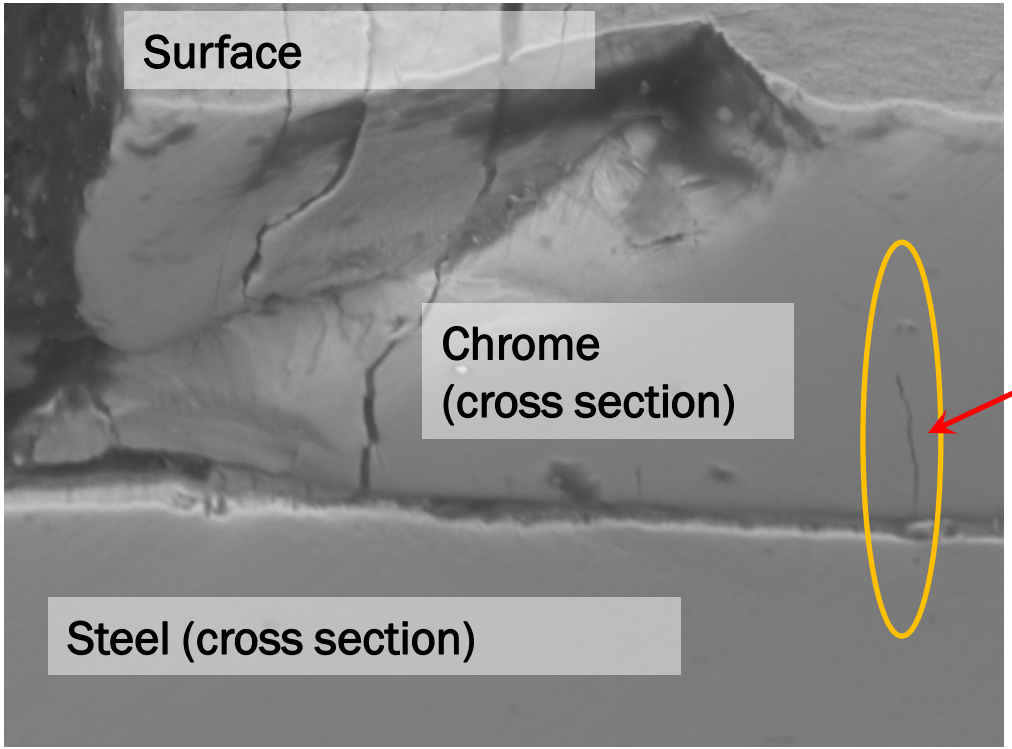


45^0 tilted

A = Duplex Chrome: Thick chrome layer over nitrided substrate with a white layer

Failure Mechanisms

300 Cycles Sample A

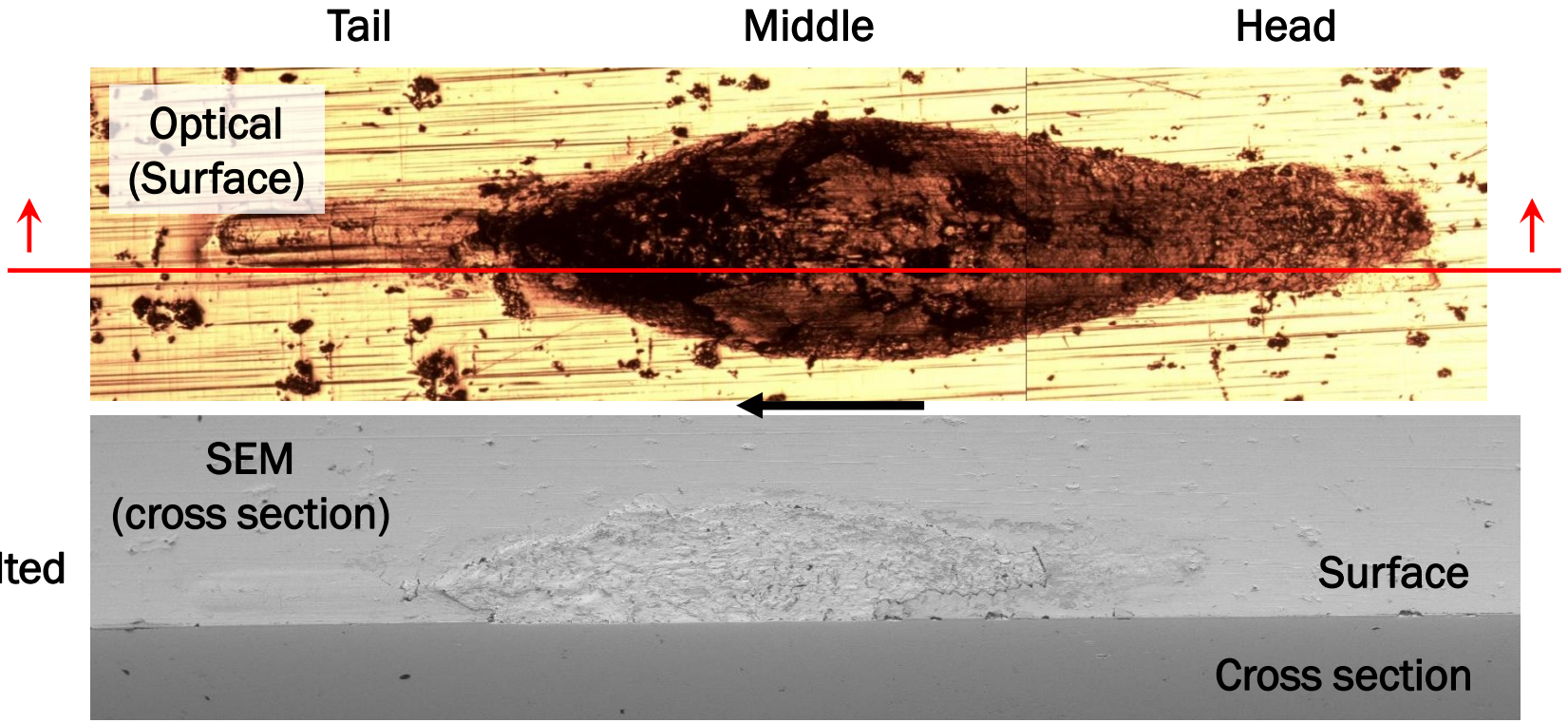


Crack initiating from the coating / substrate interface

A = Duplex Chrome: Thick chrome layer over nitrided substrate with a white layer

Failure Mechanisms

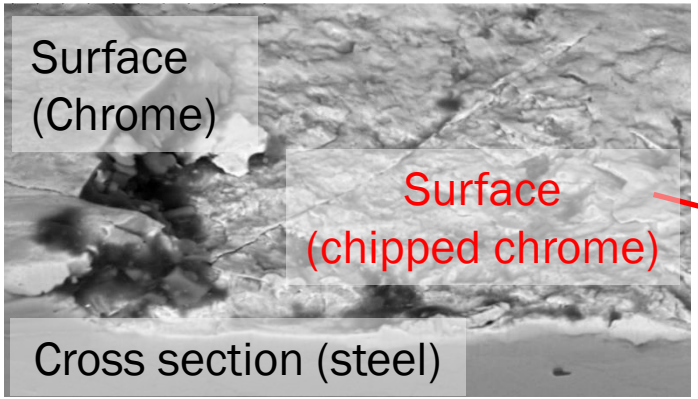
300 Cycles Sample B

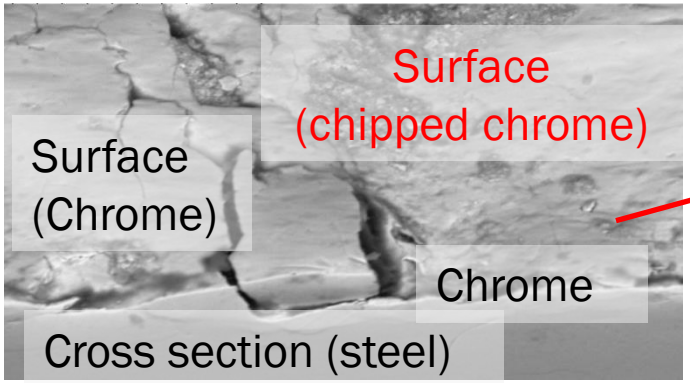


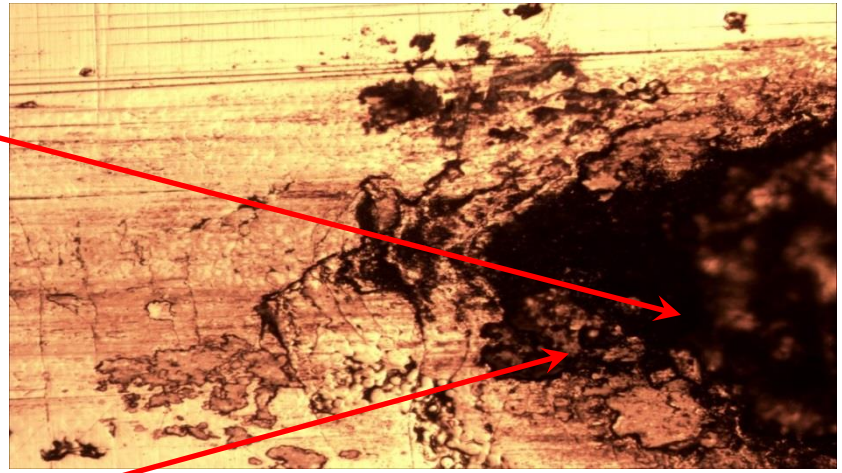
B = Duplex Chrome: Thin chrome layer over nitrided substrate without a white layer

Failure Mechanisms

300 Cycles Sample B







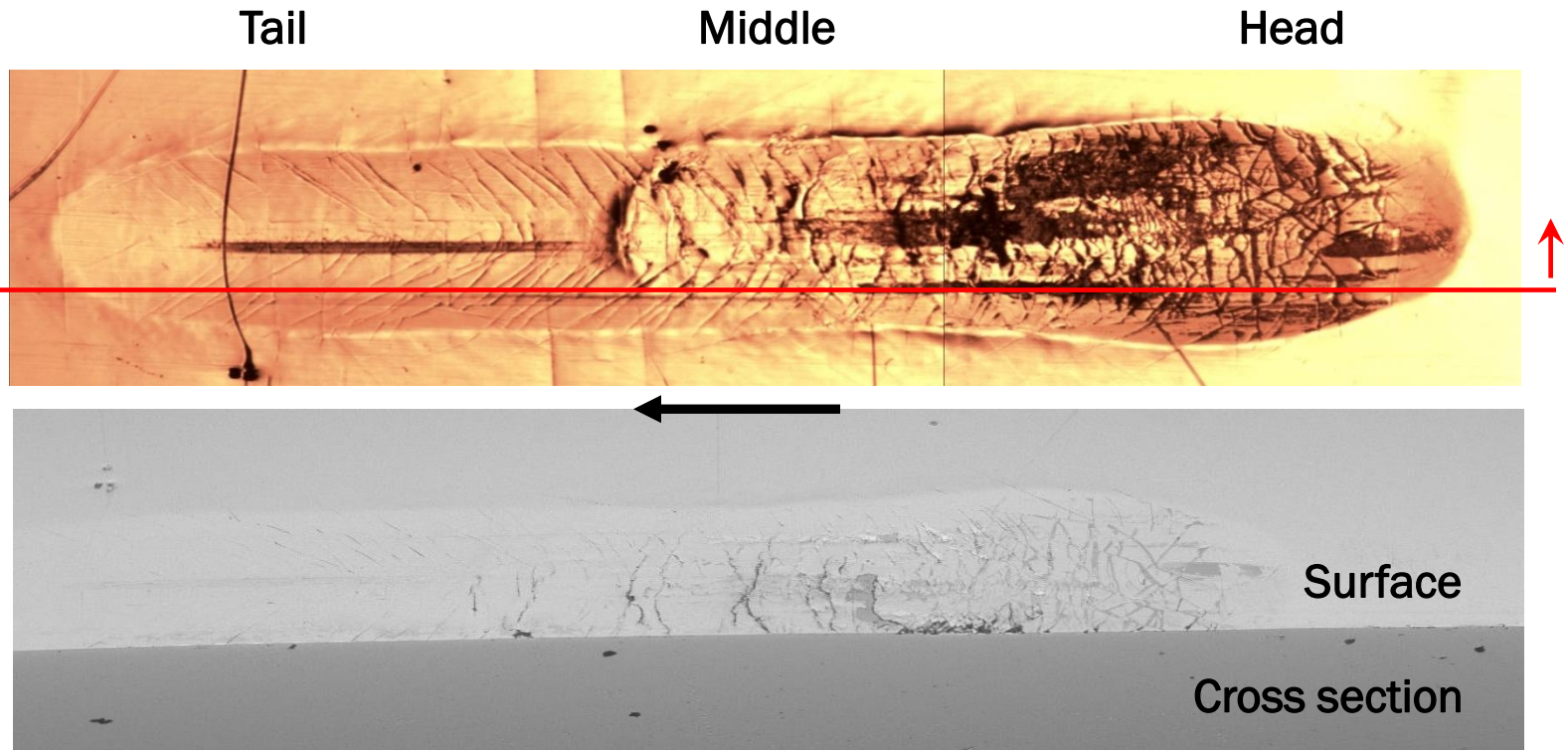
Only cracking, chipping and material transfer

B = Duplex Chrome: Thin chrome layer over nitrided substrate without a white layer

Failure Mechanisms

300 Cycles Sample C

45^0 tilted

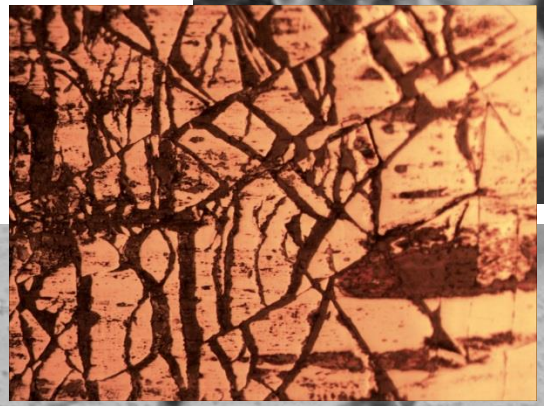


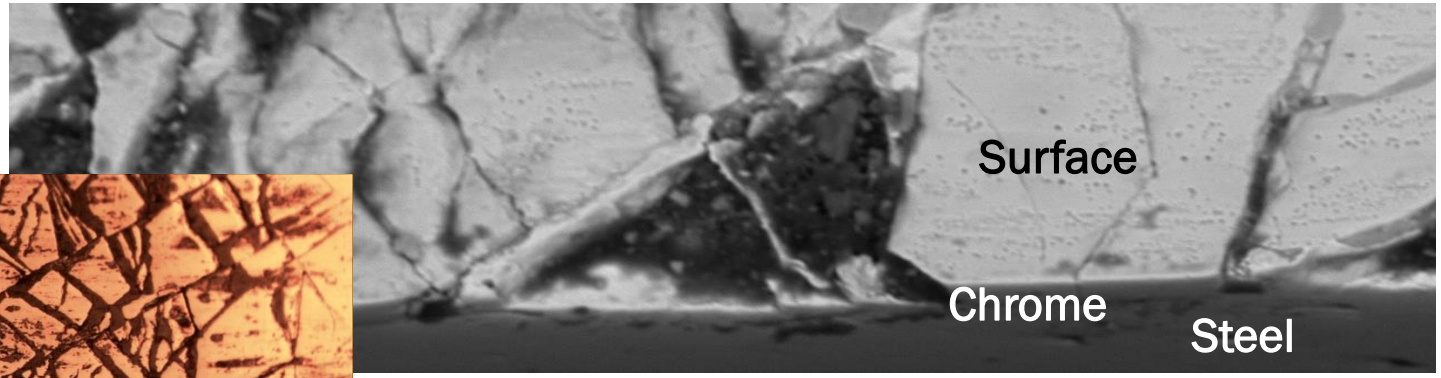
C = Thin chrome plate over a relatively soft substrate

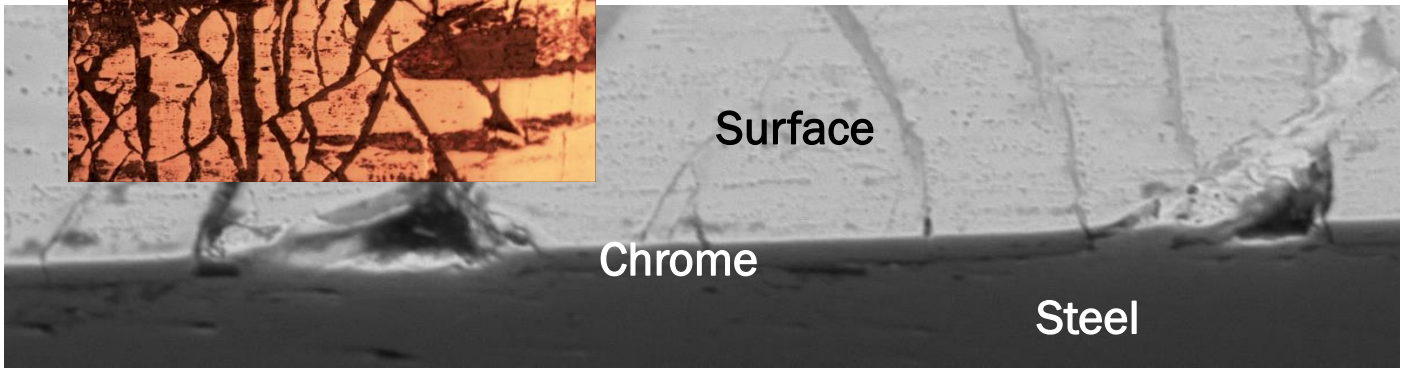
Failure Mechanisms

300 Cycles Sample C

Head Region





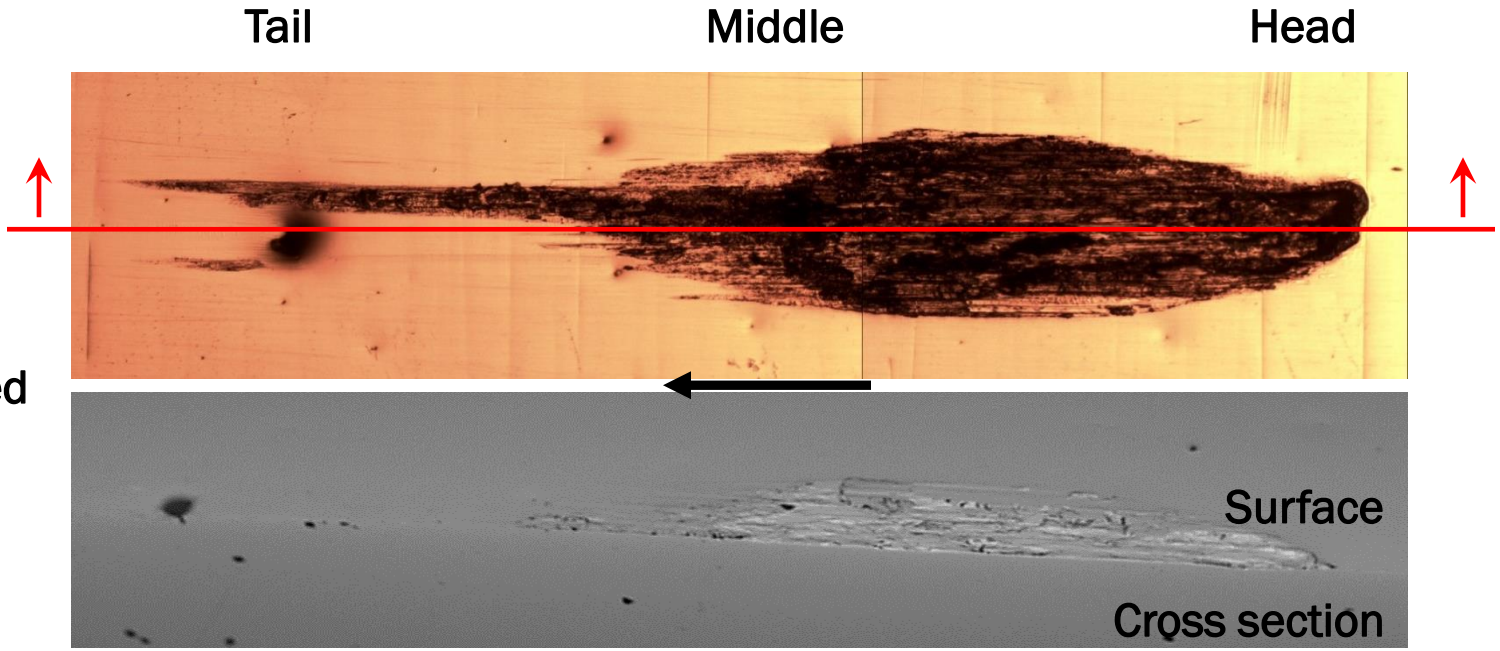


Cracking, chipping, peeling, Sink-in (deformed)

C = Thin chrome plate over a relatively soft substrate

Failure Mechanisms

300 Cycles Sample D

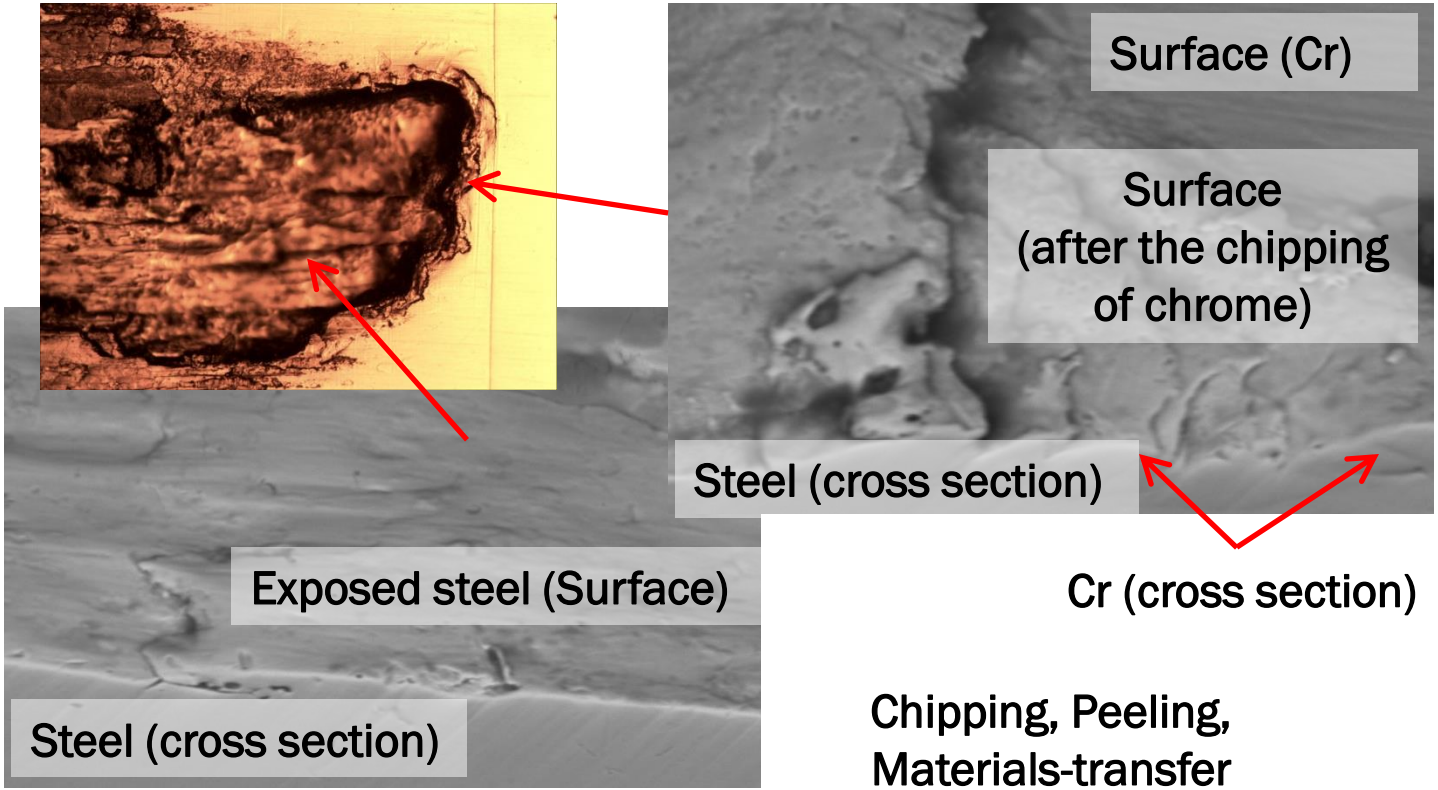


D = Thin chrome plate over hardened substrate

Fracture Mechanisms

300 Cycles Sample D

Head-Middle Region



Chipping, Peeling, Materials-transfer

D = Thin chrome plate over hardened substrate

Summary

- The failure modes of all chrome plated samples included fatigue cracking, chipping, peeling, material transfer.
- Most cracks started from the surface of the chrome coating and extended into the interface between coatings and steel substrates.
- Sample A (Duplex Chrome: Thick chrome layer over nitrided substrate with a white layer)
  - Appeared to also have cracks initiating from the interface between the coating and substrate, which may be due to the brittle white nitride layer.
  - The chrome coating was worn out and the steel substrate was largely exposed at the head and middle regions of wear track.

Summary

- Sample B (Duplex Chrome: Thin chrome layer over nitrided substrate without a white layer)
  - Performed the best
  - Seemed to have only a chipping problem at the middle region of the coating's wear track and the steel substrate was not exposed at any of the test cycles.
- Sample C (Thin chrome plate over a relatively soft substrate)
  - Showed large cracks and the coating peeled everywhere. The chrome coating seemed to have a good adhesion to the substrate but the relatively soft substrate was deformed (sunk in).
  - Long-term durability of this surface treatment appears problematic.

Summary

- Sample D (Thin chrome plate over hardened substrate)
  - Showed a large transfer of material at the middle and head regions of the wear track.
  - The steel substrate was locally exposed where the coating was worn off mainly by chipping and peeling.

Conclusions

- Duplex chrome surface treatments without a nitriding white layer can significantly increase the wear resistance and durability of stamping die steels
- The ranking of all the S0050A samples:
  - at 150 test cycles: $B \geq A > C > D$
  - at 300 test cycles: $B > D > C > A$
  - at 500 test cycles: $B > D > C > A$
  - at 3000 test cycles: $B > D > C > A$

A = Duplex Chrome: Thick chrome layer over nitrided substrate with a white layer
B = Duplex Chrome: Thin chrome layer over nitrided substrate without a white layer
C = Thin chrome plate over a relatively soft substrate
D = Thin chrome plate over hardened substrate

For More Information

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Stamping Tooling Optimization Timeline

Goal: To strategically develop coatings and heat treatment technologies and suppliers through evaluation using Impact-Sliding Fatigue Wear Tester

2007-2008: CVD/PVD coatings on hardened tool steels - D2

- not so good due to lack of enough load support

2009-2011: Duplex PVD coatings plus nitriding on tool steels

- force hard coatings suppliers collaborating with heat treatment suppliers

2012-2014: Duplex PVD coatings (containing C or MoS_2 for friction reduction) plus nitriding on steels

- good for DP 980 MPa AHSS as demonstrated in industrial stamping trial

2015-2016: Nitriding for cast iron and cast steels

- Evaluated plasma nitriding, gas nitriding, and fluidized-bed nitriding

2016-2017: Chrome for cast steels

- duplex chrome – Chrome on nitrided steels, vs. Chrome on hardened/unhardened steels

2016-2018: Duplex PVD coatings (with multilayers for increased fracture toughness) on tool steels

- 2 candidates are good for DP 1180 MPa AHSS shown in industrial stamping trial