Temperature Effects on Draw Bead Friction for Advanced High-Strength Steels

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Outline

- Background
- Draw bead/die cooling and temperature acquisition system
  - Concept
  - Design and fabrication
  - Cyclic bend test
  - Efficiency validation
- Friction measurements
  - Effects of die temperatures
  - Effects of die materials
  - Effects of climate temperatures (Winter, Summer)
- Field validation-coating adhesion
- Summary
Background

- Observed problems in stamping AHSS
  - Splitting around draw bead
  - High temperature of the panel and die surface
  - Coating adhesion and die surface build-up
  - Die wear

- Potential Cause
  - Higher friction
  - Lubrication and coating breakdown
  - Poor die surface treatment

- Targets
  - Prevent splitting
  - Reduce die surface temperature
  - Reduce coating adhesion
  - Providing a better die material or surface treatment
Water cooled draw bead/die system

- Insert
- Draw bead
- Copper tube (with coolant)
- Coolant in
- Draw die
- Coolant out
Design and Fabrication

- Draw bead/die cooling system
- Temperature acquisition system
Modified BUT test Die

Coolant In

Out

Die (Draw bead)

Thermocouple Insert hole

Pin (Die)
Die temperature measurements

- **Die center**: Insert the thermocouple into the center hole
- **Die surface**: Attach the thermocouple on top of the die (pin)
Temperature acquisition system

Temperature Readout

Thermocouple panel

Coolant tank
Draw bead/die cooling system

Attached Thermocouple

Out

In

Coolant Tank

Inserted Thermocouple

Out
Sample setup

Die surface temp. measurement

Thermocouple for sample surface Temp.
Tryout

- DP 590, HDGA, 1 mm
- Cyclic test: 10 cycles or as needed
- Lubrication condition: As-received vs. 61AUS
- Specimen temperature: Room
Heat generation

Variation of Die Temperature without Coolant

Temperature (degree F)

Sample #

Before forming
Die center
Die surface

Room Temp.

Forming Cycle

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Efficiency of the cooling system

Die surface inc.- no coolant
Die surface inc.- coolant
Die center inc.- coolant
Die center inc.- no coolant

Temp. Difference (Die Surface)
Temp. Difference (Die Center)

Forming cycle
Effects of coolant - Ice water

- Temp. inc. - die surface
- Temp. inc. - sample 1 cycle
- Temp. inc. - die center
- Temp. inc. - sample 10 cycle

Test Specimen

No cooling  Ice water cooling

As-received  61-AUS

As-received  61-AUS

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Effects of coolant
Die surface pick up

Zinc powdering - No coolant

Less powdering - With coolant
Friction Measurements
90 degree bend (BUT) test

- Machine
  - Bending Under Tension test (BUT)
  - 90 degree bend test
- Fixed Din radius: 4.75 (mm)
- Sliding speed: 4.11 (m/min)
- Material
  - DP590, HDGA, 1 mm
- Lubrication condition: 61AUS
- Effects of back tension force
  - 65%, 80%, 100% and 120% of yield strength
- Effects of Die temperature
  - Room, 112, 150, 200 F
- Effects of Die material
  - D2 Flame Hardening
  - Cast Iron + Chrome Plating
  - Cast Iron + Iron Nitriding
Calculations

\[ \bar{\mu} = \frac{2(F_2 - F_1 - F_b)}{\Theta(F_1 + F_2)} \]  
(friction model, Wilson et al. 1991)

\[ F_b = \frac{\sigma_y t^2 w}{2R} \]  
(Swift 1948)
**Effects of die materials**

![Graphs showing the effects of die materials at different temperatures.](image-url)

**Die Temperature - Room**
- **DP-D2-room**
- **DP-CP-room**
- **DP-IN-room**

**Die Temperature - 112 F**
- **DP-D2-112F**
- **DP-CP-112F**
- **DP-IN-112F**

**Die Temperature - 150 F**
- **DP-D2-150F**
- **DP-CP-150F**
- **DP-IN-150F**

**Die Temperature - 200 F**
- **DP-D2-200F**
- **DP-CP-200F**
- **DP-IN-200F**

**Best Forming Condition**

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**Real application**

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Effects of die temperatures

Friction Coefficient vs. Back Tension Force (% of Yield)

- **D2**
  - DP-D2-room
  - DP-D2-112F
  - DP-D2-150F
  - DP-D2-200F

- **Chrome Plating**
  - DP-CP-room
  - DP-CP-112F
  - DP-CP-150F
  - DP-CP-200F

- **Iron Nitriding**
  - DP-IN-room
  - DP-IN-112F
  - DP-IN-150F
  - DP-IN-200F

Graphs show the relationship between friction coefficient and back tension force at different die temperatures and platings.
Climate effect - Summer

Chrome Plating Die - Room

Friction Coefficient vs Back Tension Force (% Yield)

Summer: 100 F

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Climate effect - Winter

Chrome Plating Die - 150 F

Friction Coefficient

Back Tension Force (% Yield)

Winter: 60 F
Field Validation

Coating adhesion
Field validation
Coating adhesion

DP590, HDGA, 1 mm
7 Cycles, As-received lubrication

Duplication of Production Panel around sidewall and draw bead area

D2 Flame Hardening Die
D2 Flame Hardening (Baseline) 7 cycles

Chrome Plating 7 cycles

Chrome Plating + Coolant 7 cycles
D2 Flame Hardening

- 5 cycles: Good
- 6 cycles: Poor
- 7 cycles: Worse

150F D2 Die
150 F Chrome Plating & Iron Nitriding

6 cycles Good

7 cycles Poor

6 cycles Good

7 cycles Worse

Chrome Plating

Iron Nitriding
Friction Index
Cyclic bend test

D2 Flame Hardening Die

Friction Index

Forming Cycles (bend test)

- No coolant
- Water cooled
Water cooled draw bead/die system has been developed and effectively proven to reduce the die temperature.

Implementing this draw bead/die cooling system can reduce coating adhesion/splitting issues during stamping.

The friction coefficient tends to increase with die temperature.

Lower specimen temperatures exhibited better frictional performance than those tested beyond ambient conditions (i.e. 60 versus 100 deg. F).

Die surface treatments, like chrome plating, are highly recommended for stamping AHSS.