GREAT DESIGNS IN STEEL

DEVELOPMENT OF TABLETOP INCLINED SLIDING TRIBOMETER FOR TOOLING OPTIMIZATION

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INTRODUCTION (BACKGROUND)

Die wear and friction coefficient are affected by

- contact pressure between sheet and die
- sliding speed and distance
- tool and sheet materials
- surface finish and coating

Wear mechanisms over the die/sheet (at microscopic scales)

- adhesive
- abrasive
- surface fatigue

INTRODUCTION (BACKGROUND)

Wear mechanisms over the die radius (primarily at macroscopic scales)

- Ploughing (everywhere, highest at 1 and 2)
- Galling (likely at initial portion)

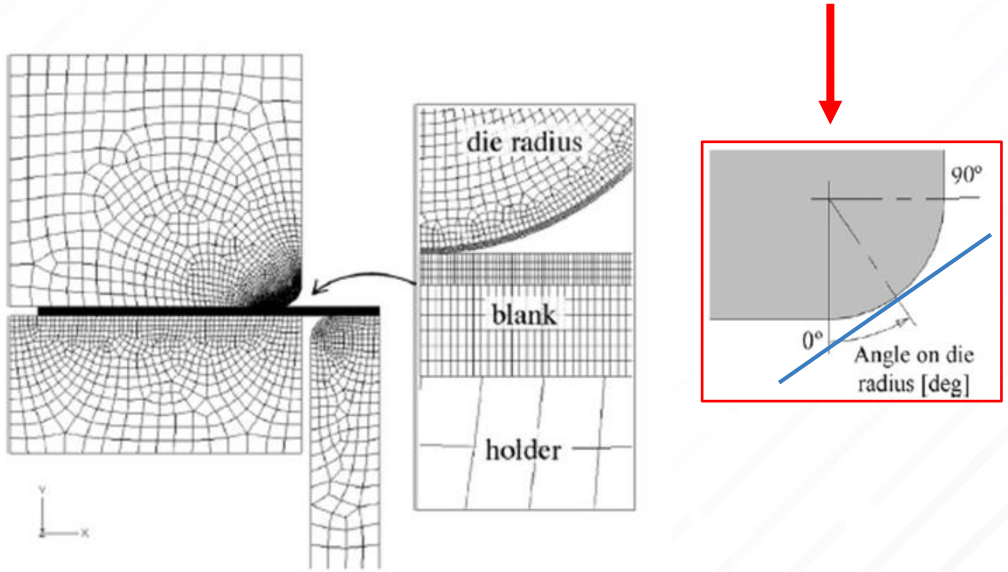


Fig. 1. Schematic of the channel forming wear test, (a) prior to the forming stroke and (b) at the end of the forming stroke. (c) FE model geometry, showing local mesh refinement near the blank–die radius interface.

Pereira, Wear, 2008

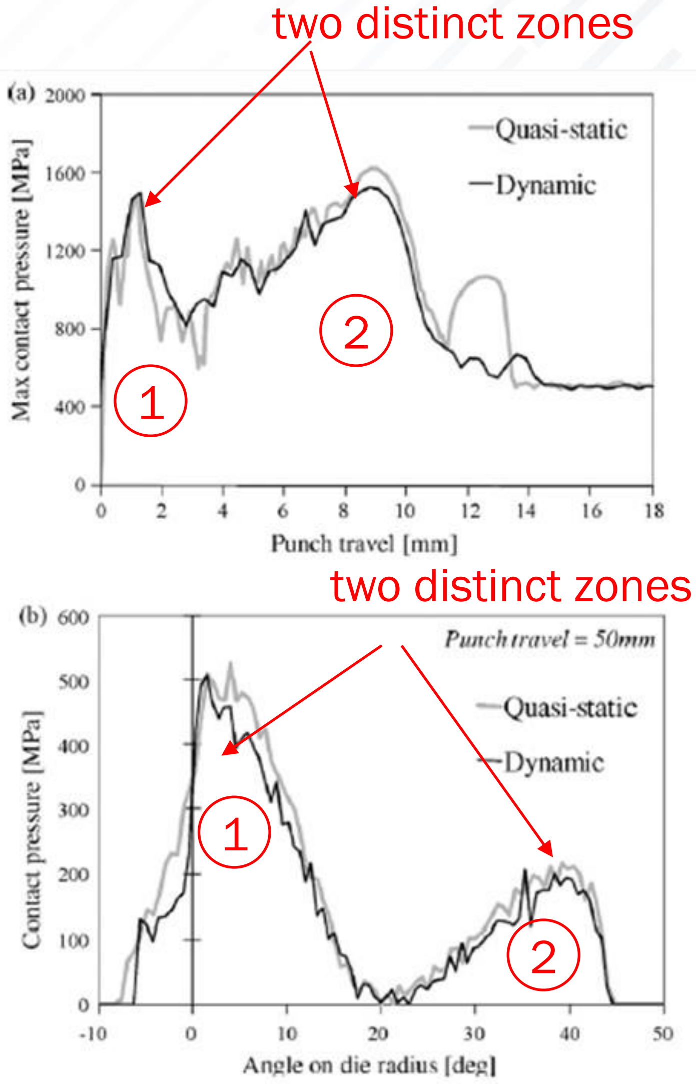


Fig. 8. Comparison between quasi-static and dynamic FE simulation results for (a) maximum contact pressure evolution during transient region of process, and (b) steady-state contact pressure distribution on die radius.

INTRODUCTION (BACKGROUND)

Wear mechanisms over the die radius primarily

- Ploughing (over entire blank contact region, with two distinct zones observed within the overall contact region)
- Galling (at the severe contact pressure & sliding conditions which take place during the stamping process)

Therefore, degrees of ploughing and galling induced failures seem relevant to the die contacting radius (i.e., die/sheet contacting angles) during the stamping operating transient stage.

DIE WEAR ENERGY PREDICTION

The die wear frictional energy can be readily obtainable from an incremental finite element stamping simulation package, such as LS-Dyna3d or Autoform.

$$Friction\_energy = \int_0^T \tau_{friction} v_{slide} dt$$

Where:

τ friction is the frictional stress exerted to the die by sheet metal at one particular area (element).

v slide is the sliding velocity of the sheet metal.

t=0 beginning of the forming cycle;

t=T end of the forming cycle

Both the software LS-Dyn3d and AutoForm are being used at an OEM for the Forming Simulations.

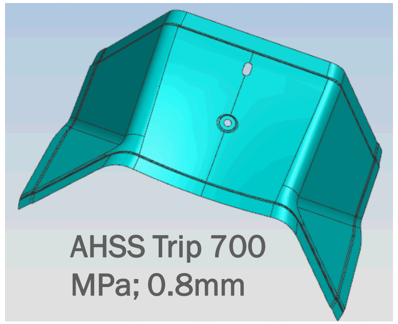
AUTOFORM DIE WEAR PREDICTION

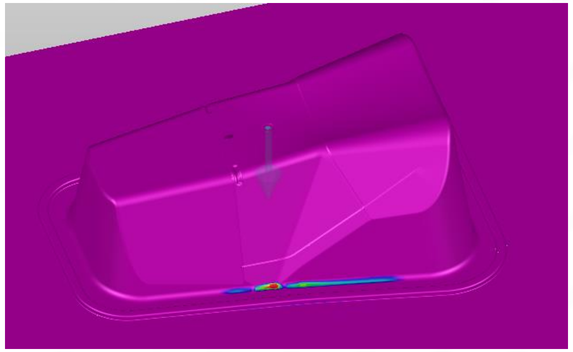
Die Wear Simulation was used on two dies to run high strength steels: Cowl Side Inner RH & LH and Front Tunnel Center

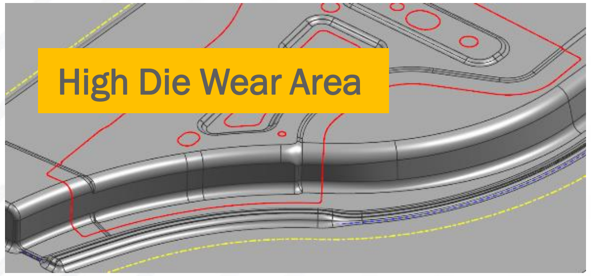
Cowl Side Inner R&L

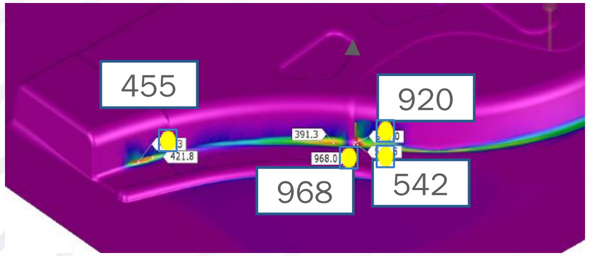
AHSS DP 780 MPa; 1.2mm

Front Tunnel Center

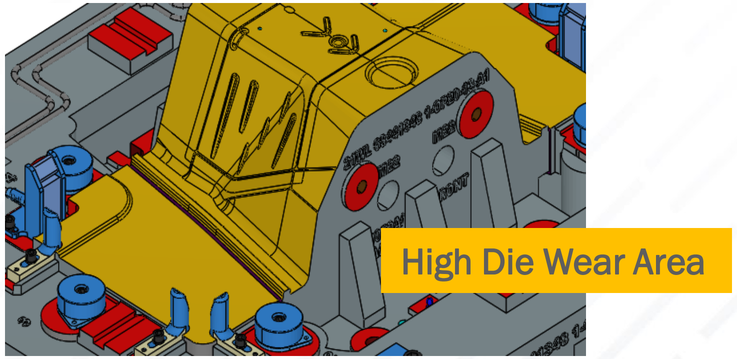








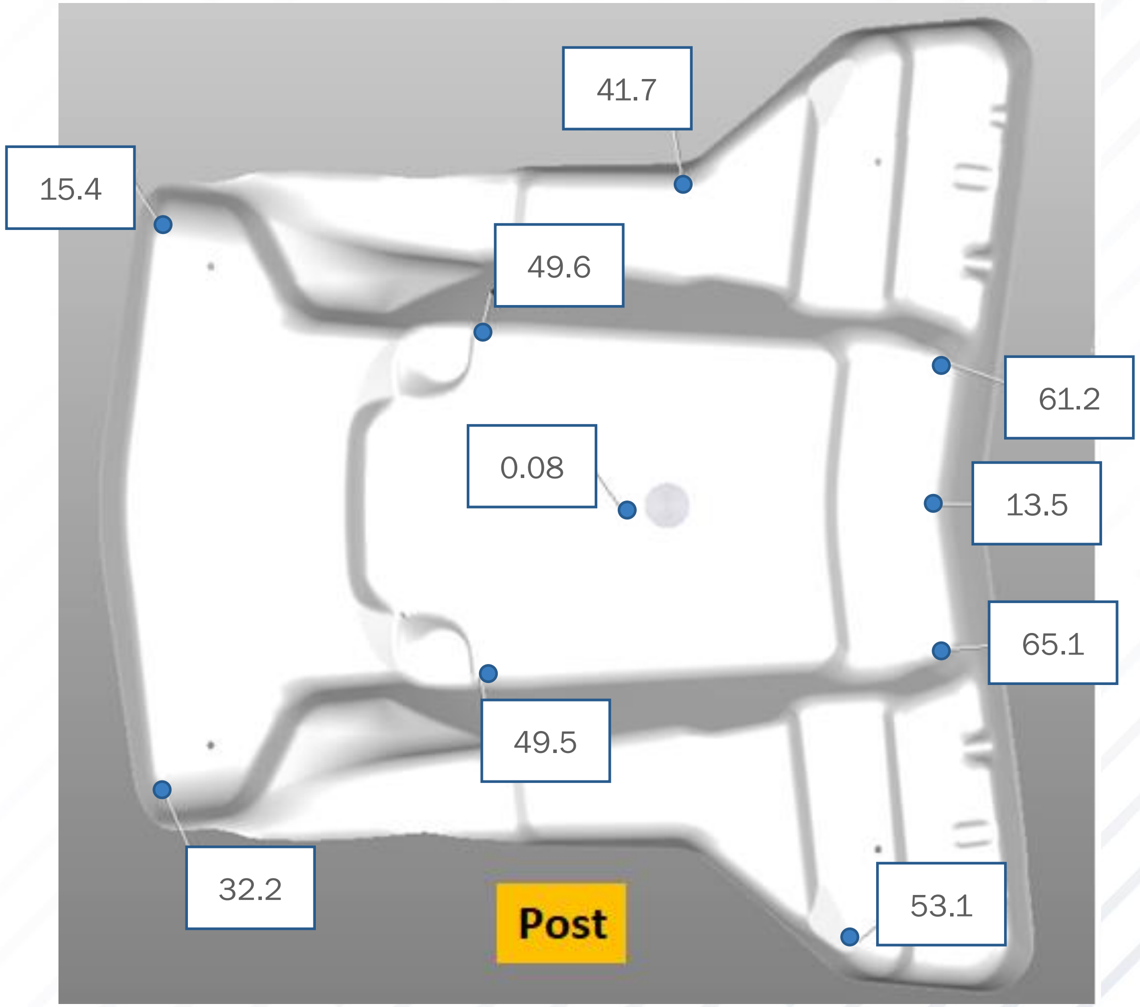
The Die Wear Simulation showed both panels will have high localized die wear on radii. These issues will have to be addressed before construction.



AUTOFORM DIE WEAR PREDICTION OF POST

Friction Work (N-mm/mm^2): >100

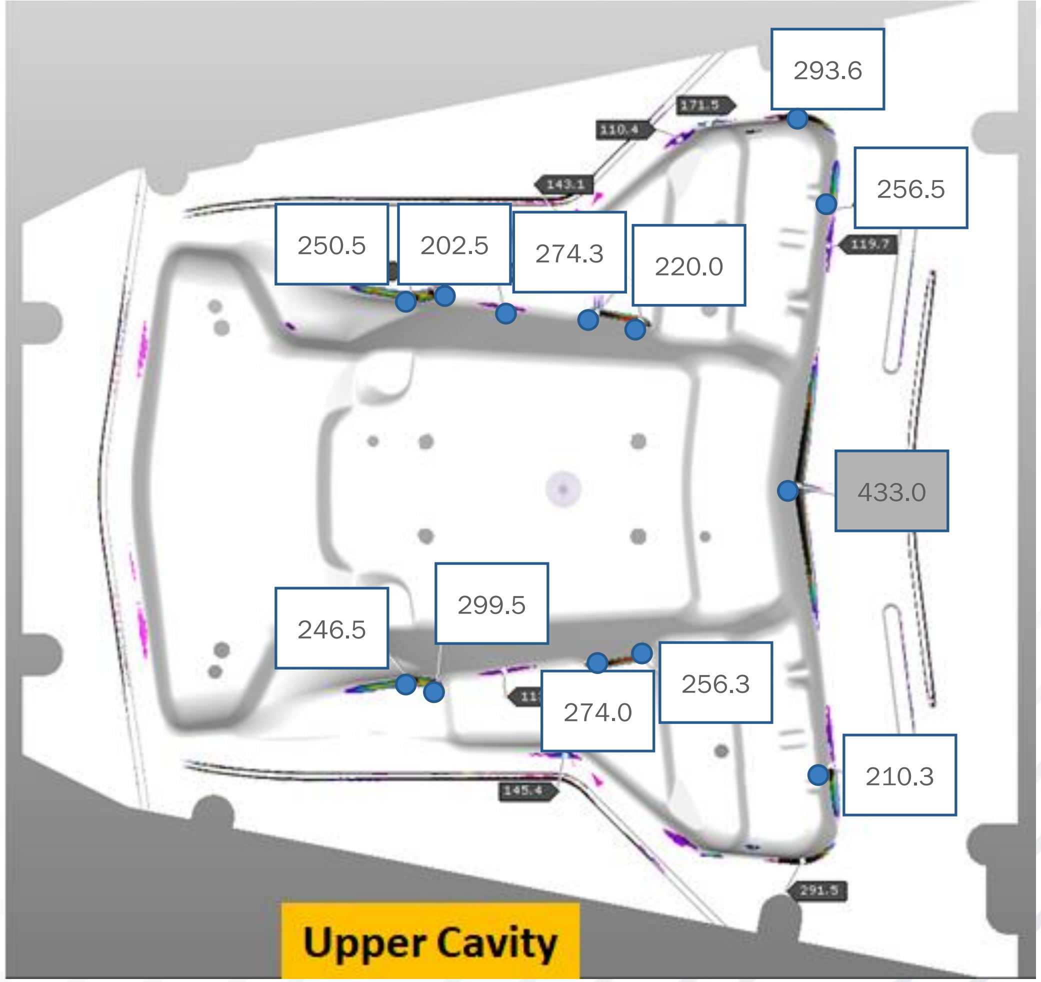
A C-Pillar Reinforcement Lower Post Die Wear Simulation Results



AUTOFORM DIE WEAR PREDICTION OF DIE CAVITY

A C-Pillar Reinforcement Upper Cavity Die Wear Simulation Results

Friction Work (N-mm/mm^2): 100 ~ 433



OBJECTIVE

To develop a table-top inclined sliding tribometer

- change contact angles of die material/metal sheet from 0 to 20 degrees
- contact pressure from 0 to 2 GPa
- sliding stroke distance from 0 to 100 mm
- The instrument can have an index stage movement so that the sliding wear track is generated on a fresh metal sheet surface in each sliding stroke
- A data acquisition system can record contact load, friction force and sliding distance
- Severe wear and galling occur when the COF is significantly increased
- The wear behavior of die materials and metal sheets can be observed afterward
- This information is important for better understanding wear behavior at different contact angles and quite valuable for simulation of metal forming

TABLE-SIZED FRICTION WEAR TESTER DESIGN

1. Loading/Sensor Module
2. Frame Structure Module
3. X/Y/Z Moving Module
4. Motors and Control Module

Parameters of tribometer

X index range: up to 500mm

Y slide distance variable: (100mm or 200mm)

Inclined Angle: 0-20 degree adjustable

Slide Velocity: 0-100mm/s

Slide line spacing: 1-5mm

Z axis normal load: 0-800N

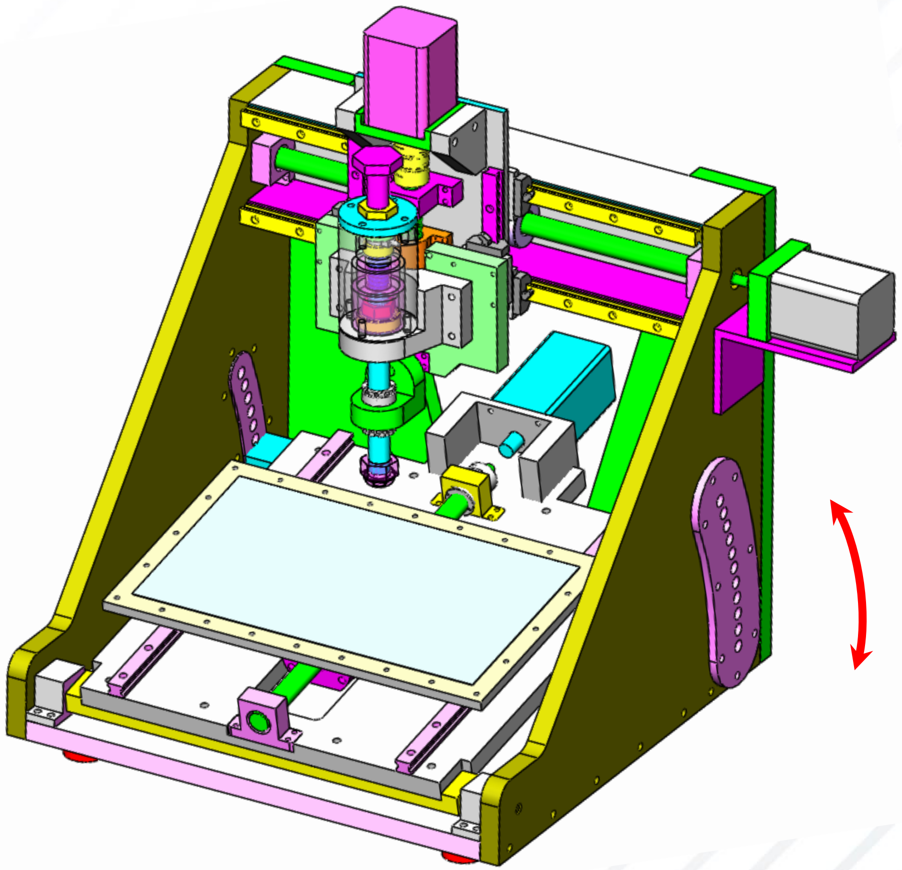
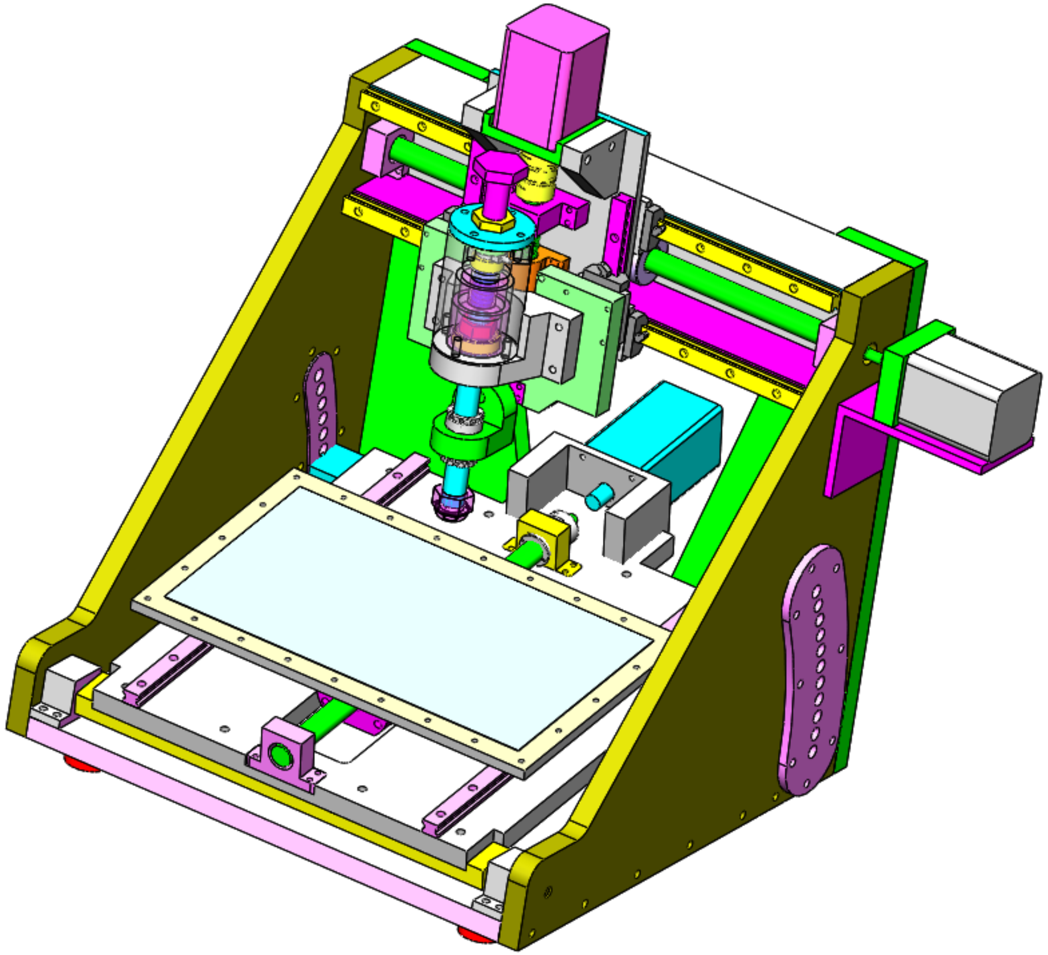
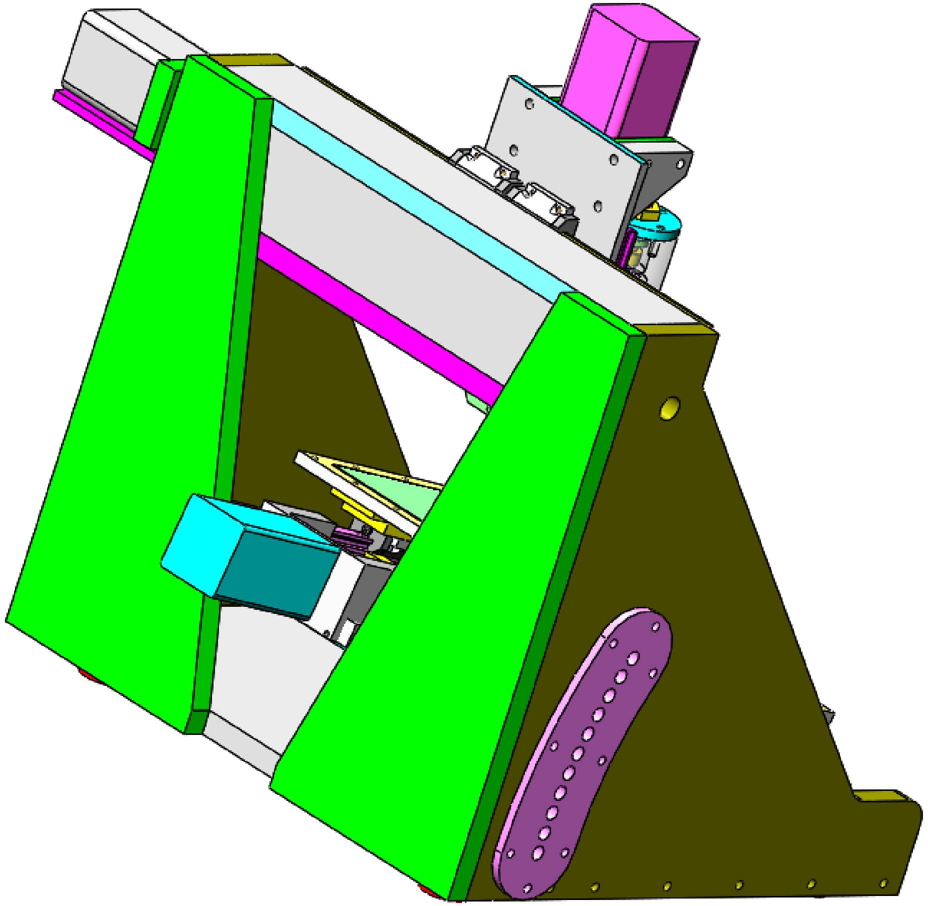


TABLE-SIZED FRICTION WEAR TESTER DESIGN

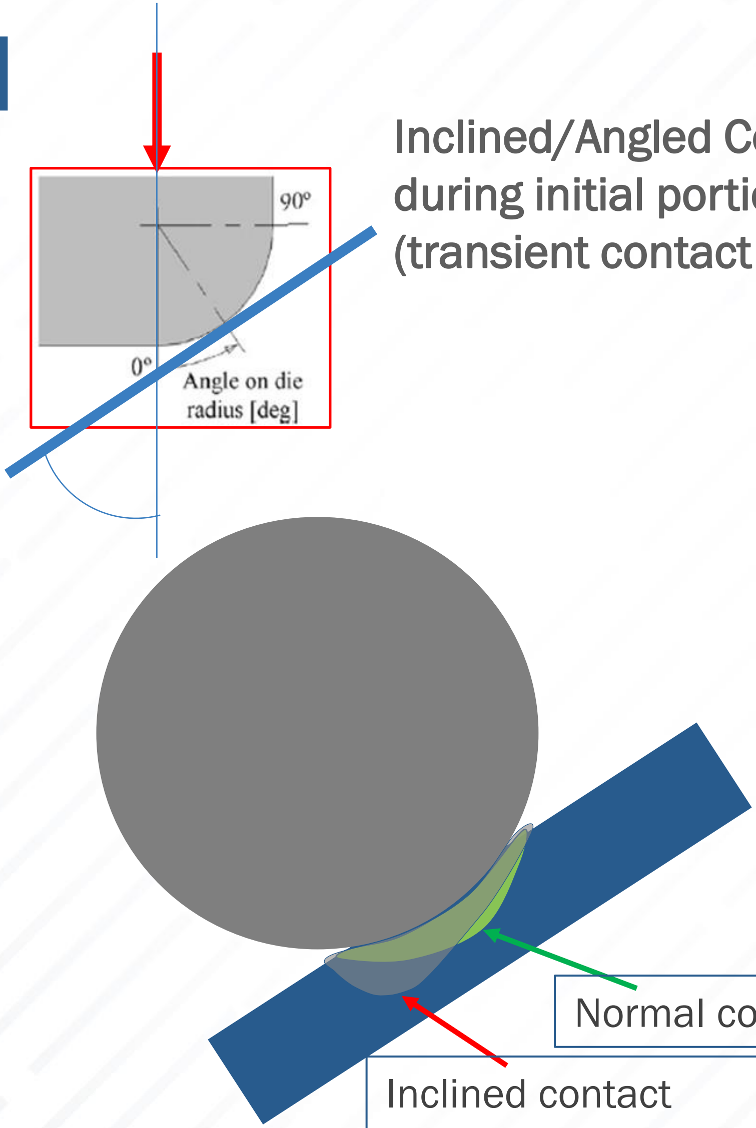


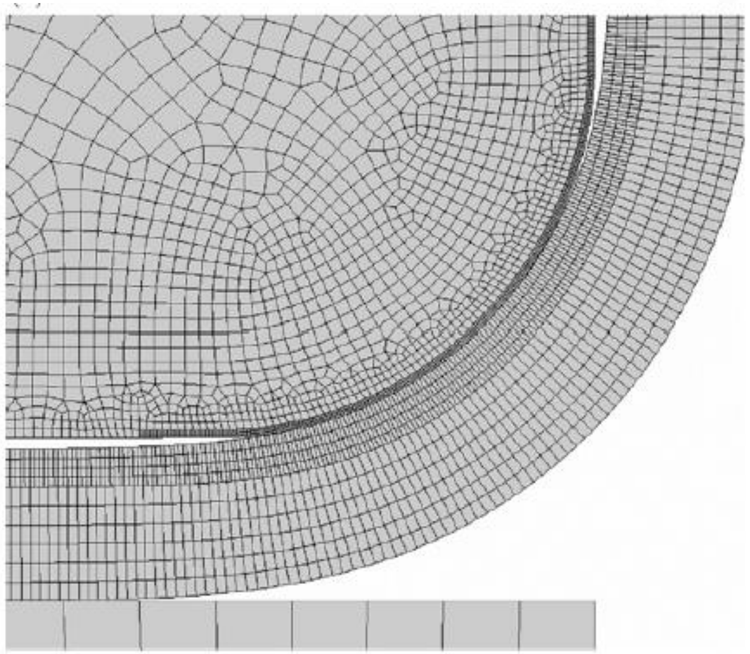


A/SP STO Team decides to use this version of design (stronger to hold the bending forces on corners)
Many modifications have been done from conception design to production manufacturing.

TABLE-SIZED FRICTION WEAR TESTER DESIGN

Inclined/Angled Contact between Die and Sheet Surfaces
during initial portion of stamping process
(transient contact stage – mainly responsible for the galling wear)

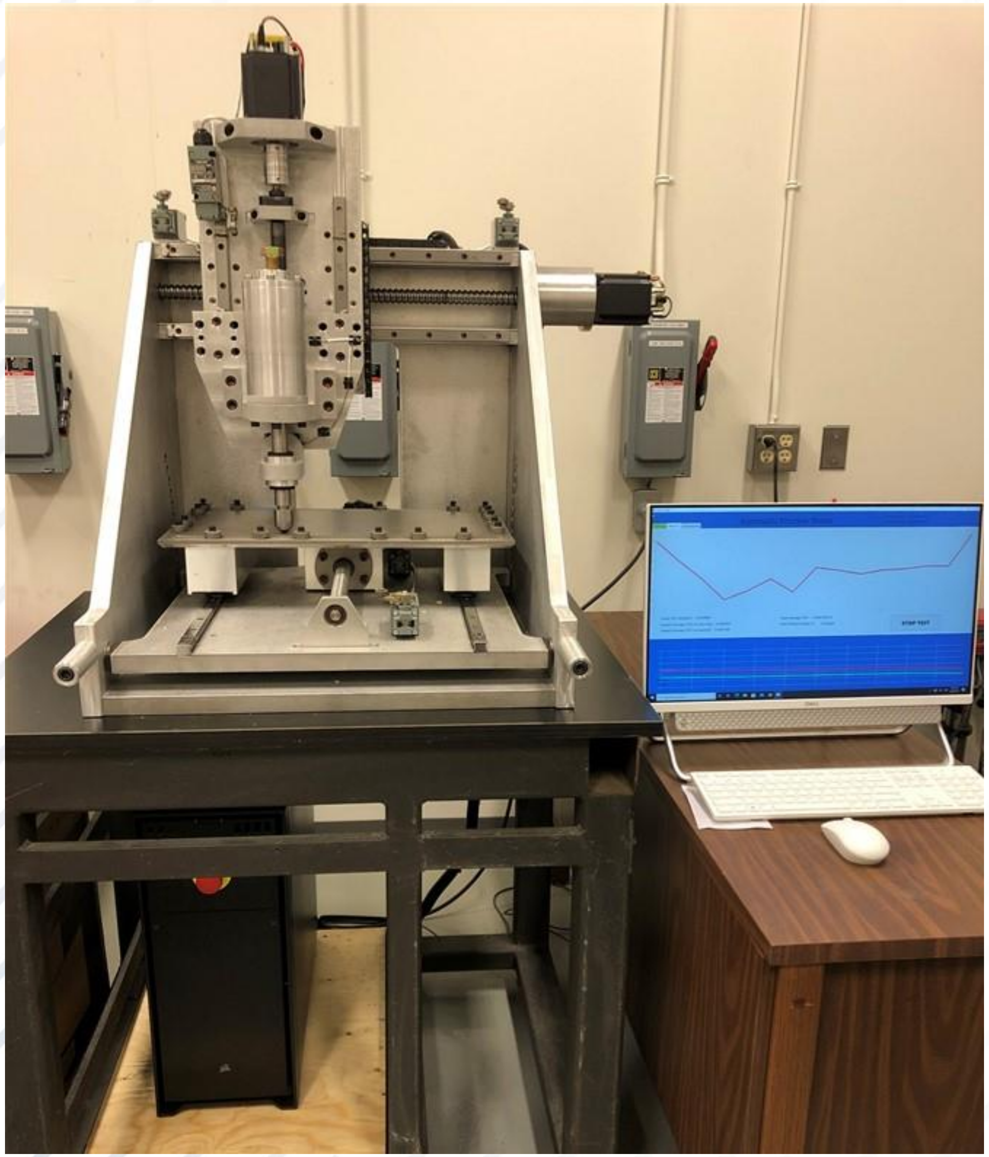


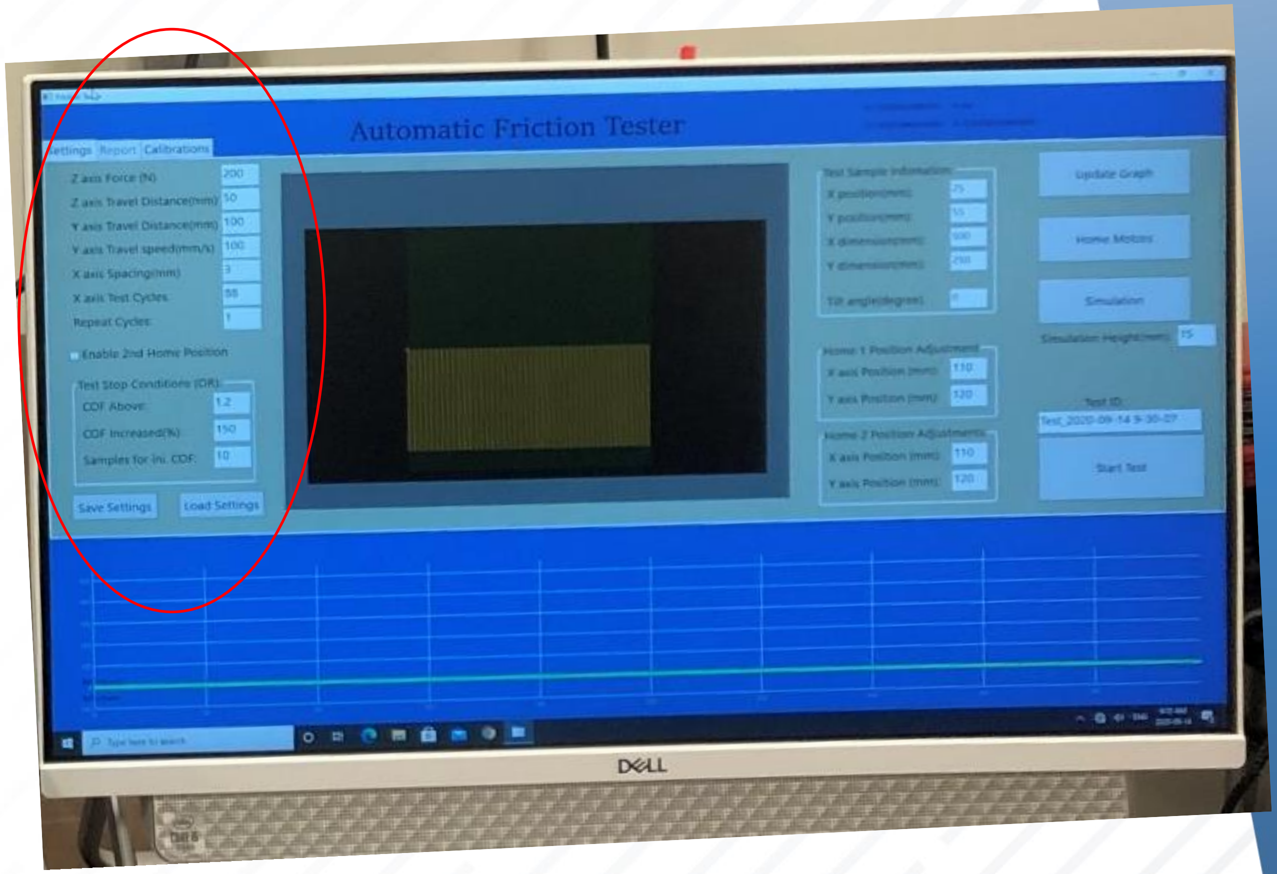


Normal contact

Inclined contact
(larger shear force/ploughing force
or tensile stress behind indenter for hard coating cases)

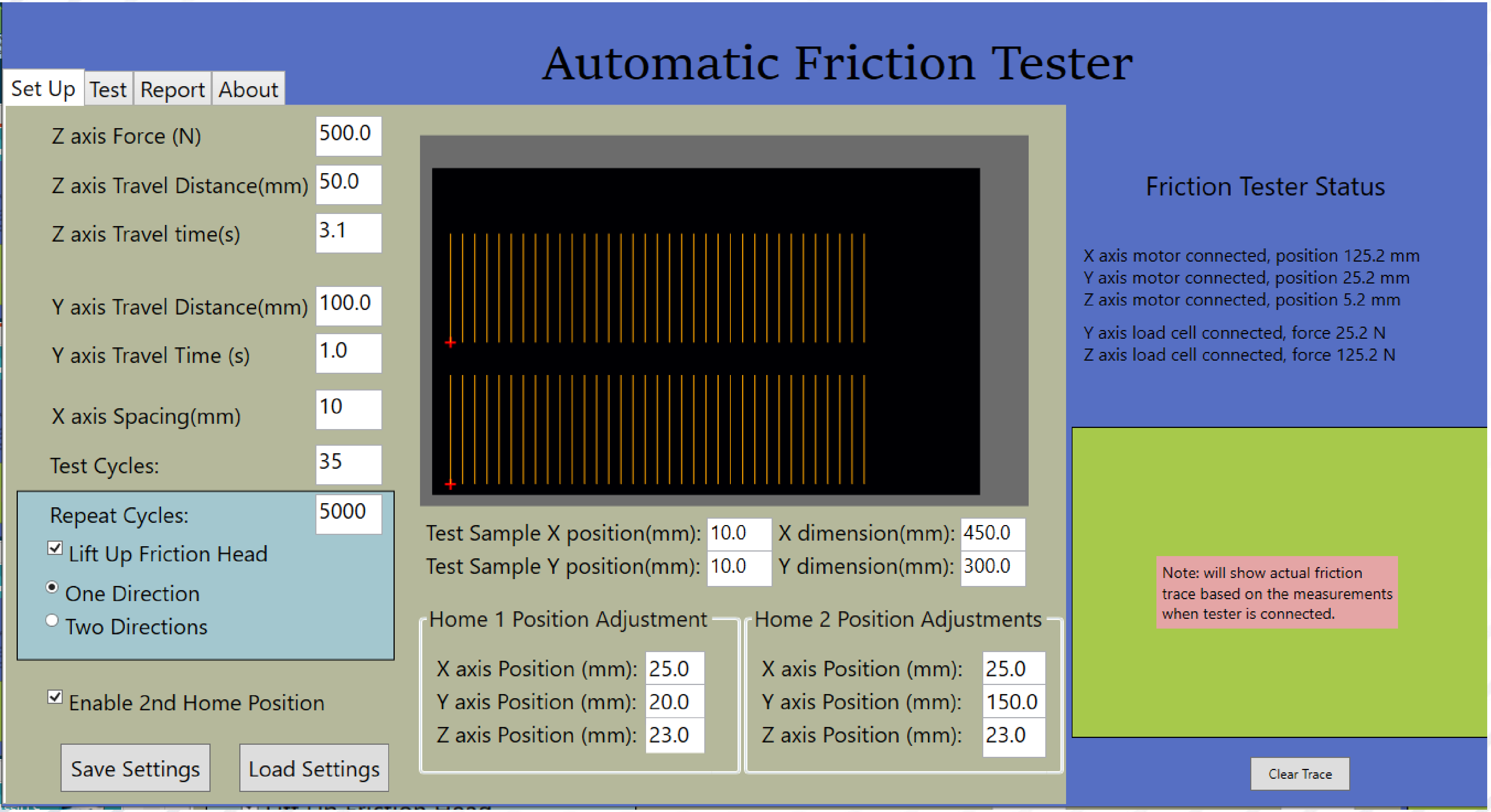
TABLE-SIZED FRICTION WEAR TESTER
(INTEGRATED)





Test Stop Conditions:
COF above: 1.2
COF increase (%): 150
Samples for initial COF: 10

CONTROL SYSTEM BLOCK DIAGRAM –
TOUCH SCREEN PC



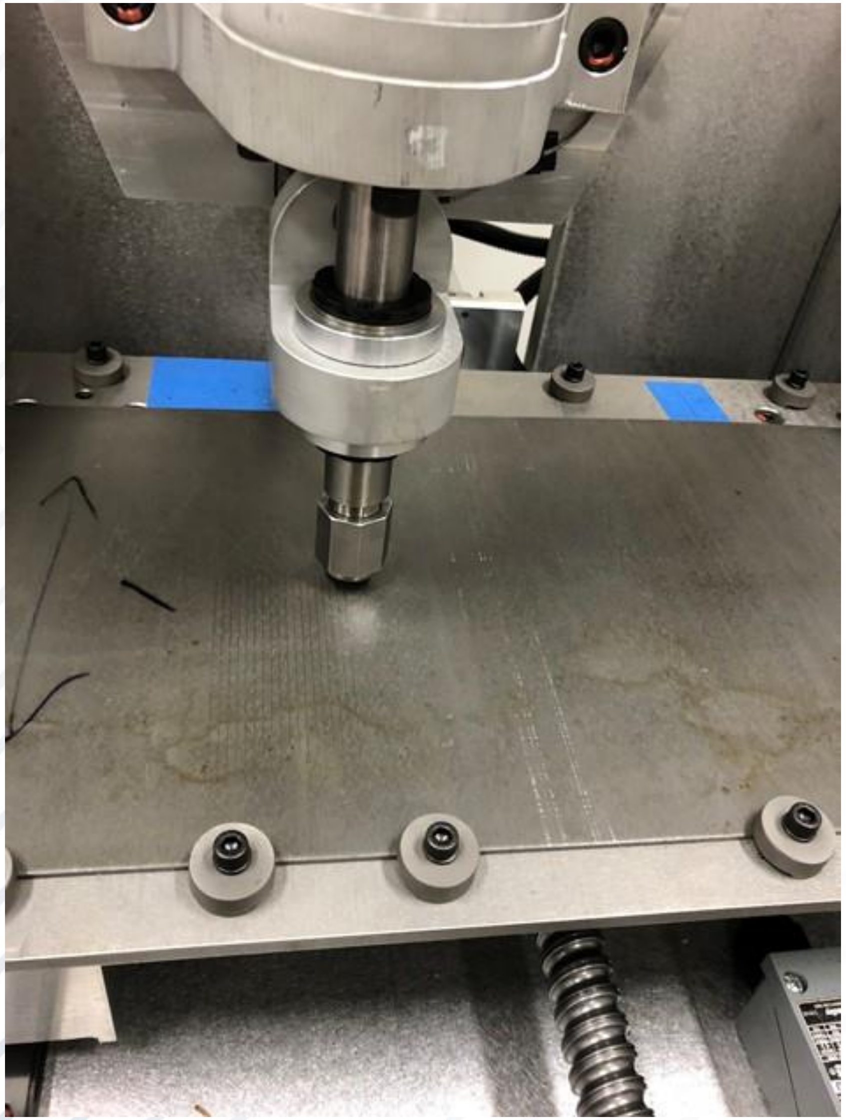
Configuration page updated:

For user to change test parameters. All the settings will be saved and automatically loaded next time. If needed, multiple settings can be saved.

The user can set 1 or 2 home (starting) positions.

SLIDING WEAR TEST RUN

Metal sheet (DP980 bare) provide by A/SP



Counterpart materials: Steel ball (SAE 52100, hardened HRC 60)

Sliding Wear Test Run:

200N normal load,
100mm each wear track length,
3 mm line spacing,
100 mm/s sliding speed

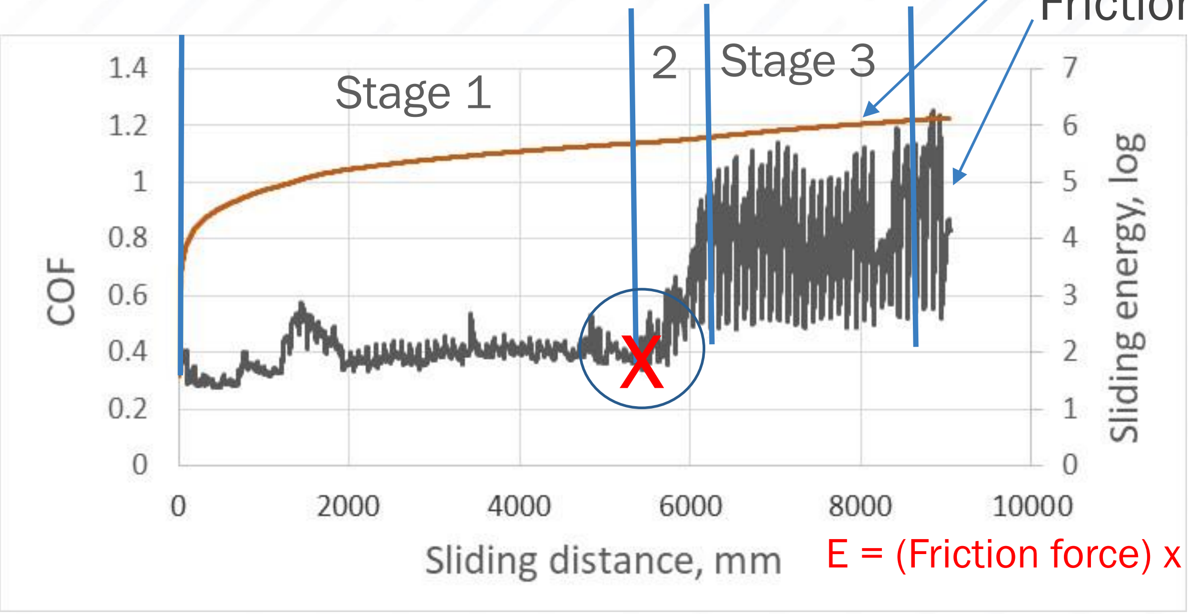
SLIDING WEAR TEST RUN

Stage 1: Stable lower friction
Stage 2: Increasing friction
Stage 3: High friction
Galling starts at point X

Galling point "X" is quite dependent on uniformity of metal sheet surface conditions, particularly related to oil/lube conditions on the sheet surfaces.

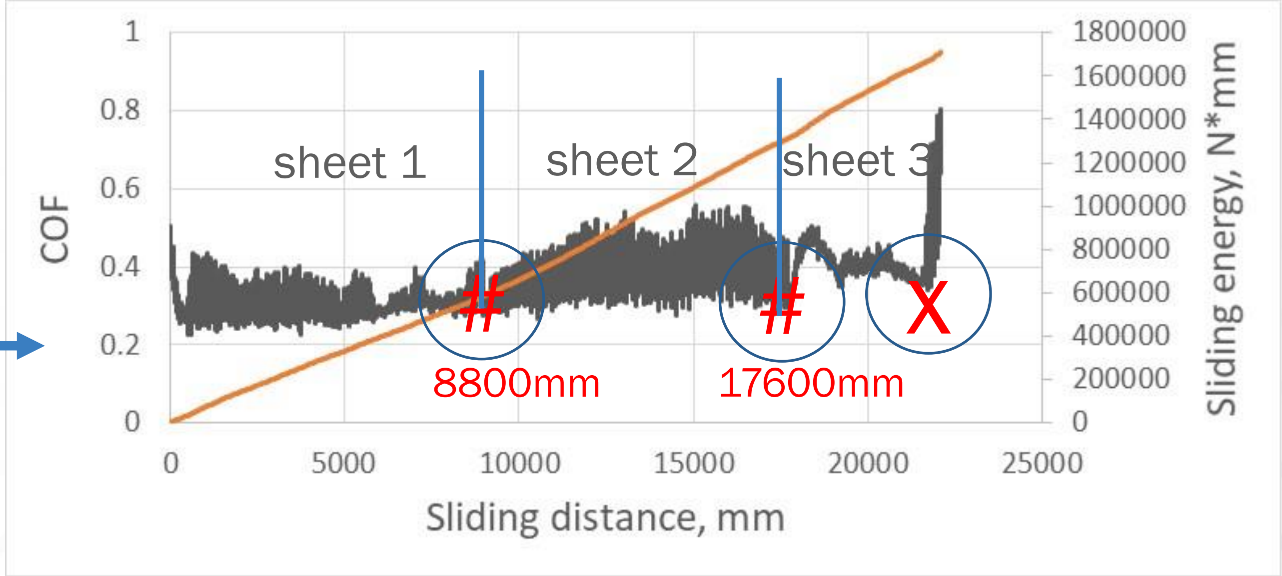
Three tests:
88 wear tracks on sheet 1 continuously (8800mm) +
88 wear tracks on sheet 2 continuously (8800mm) +
54 wear tracks on sheet 3 continuously (5400mm)

Sliding Energy
Friction



Oil-cleaned sheet

E = (Friction force) x (Sliding distance)



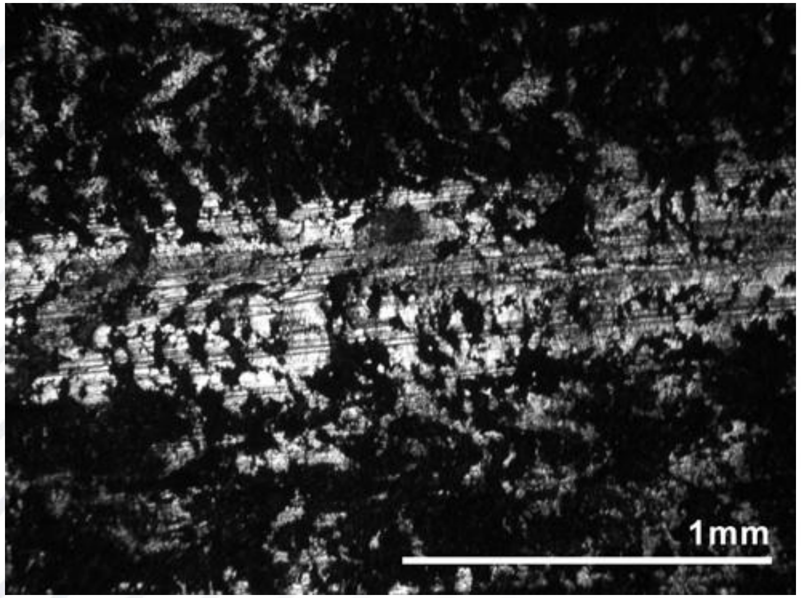
As-received sheet (oil residue)

SLIDING WEAR TEST RUN

Optical microscopy images of wear tracks on steel sheets

Wear track #1

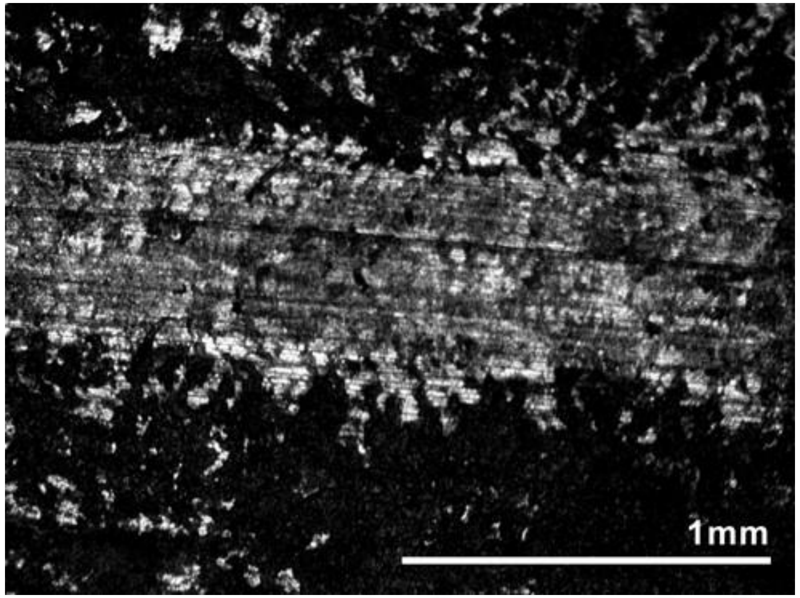
at initial stage



location	1	2	3
width (mm)	0.48	0.55	0.54

Wear track #2

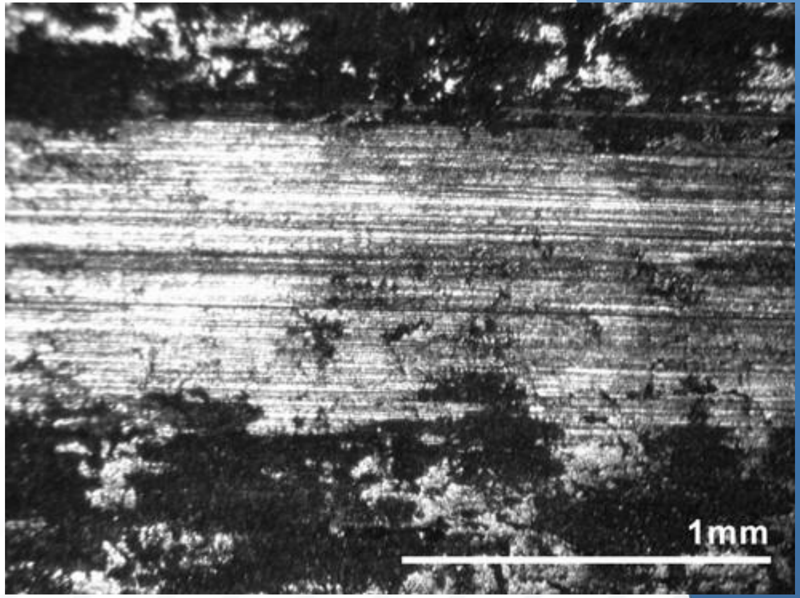
before galling



location	1	2	3
width (mm)	0.58	0.58	0.62

Wear track #3

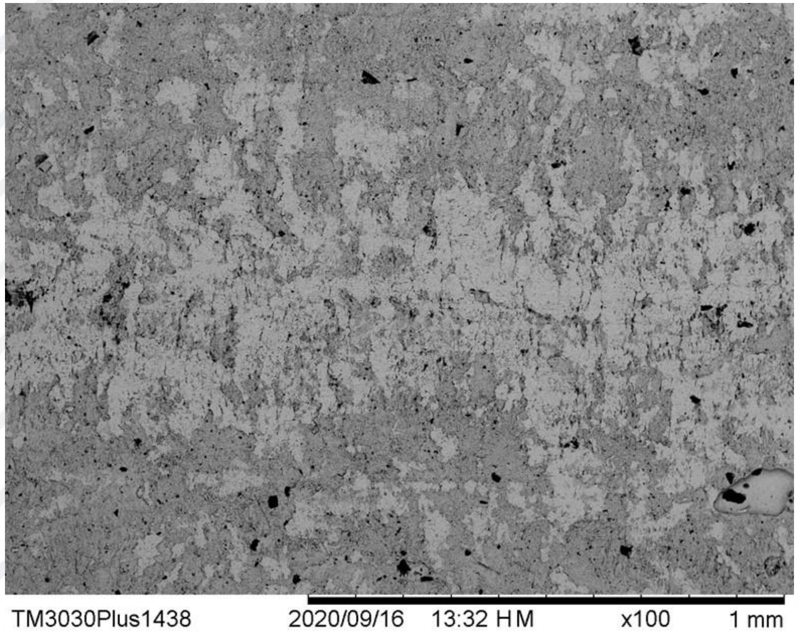
when galling



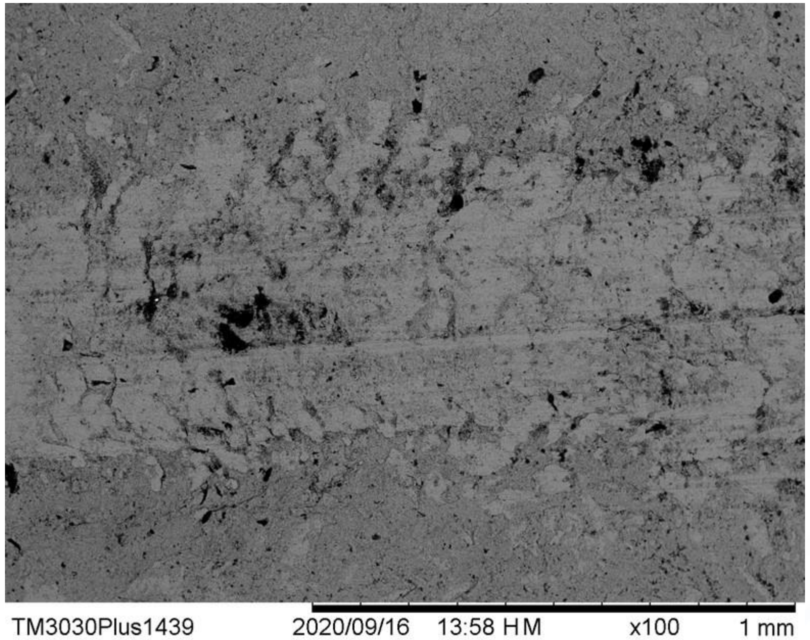
location	1	2	3
width (mm)	0.79	0.85	0.78

SLIDING WEAR TEST RUN

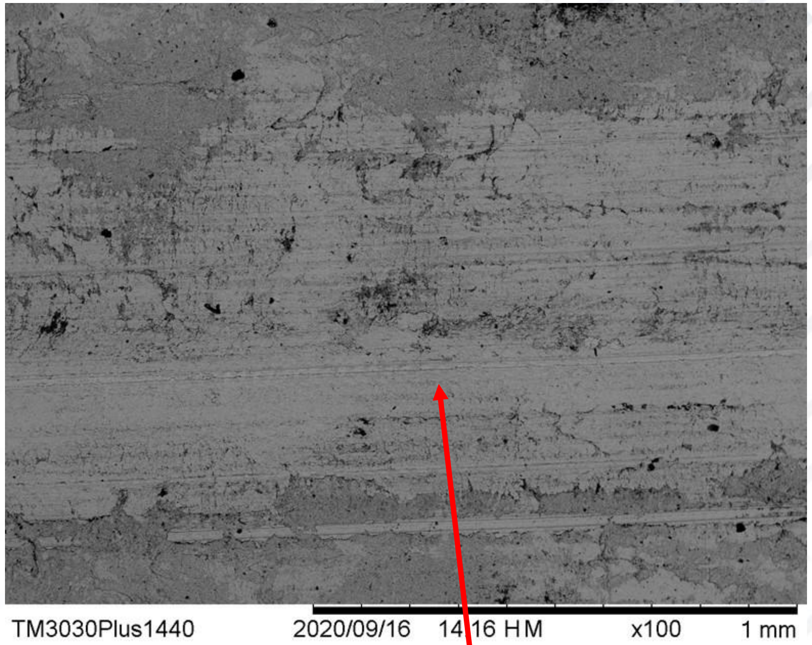
Wear track #1 at initial stage



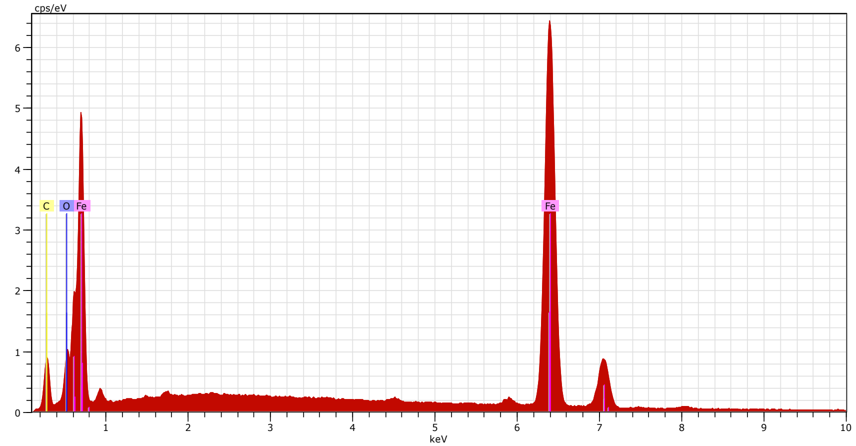
Wear track #2 before galling

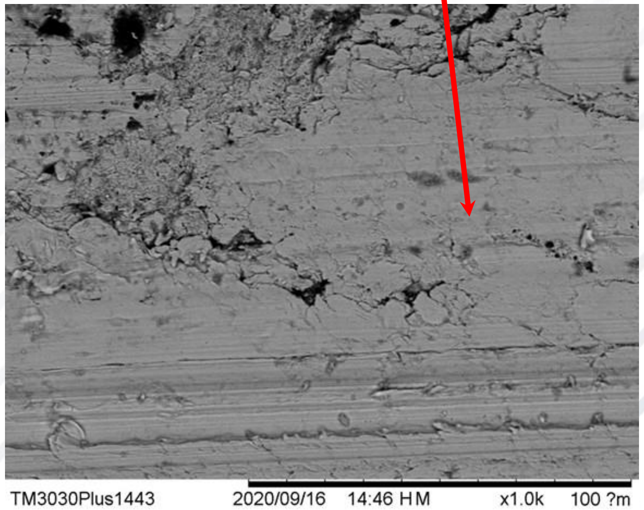


Wear track #3 when galling



SEM images of wear tracks on steel sheets

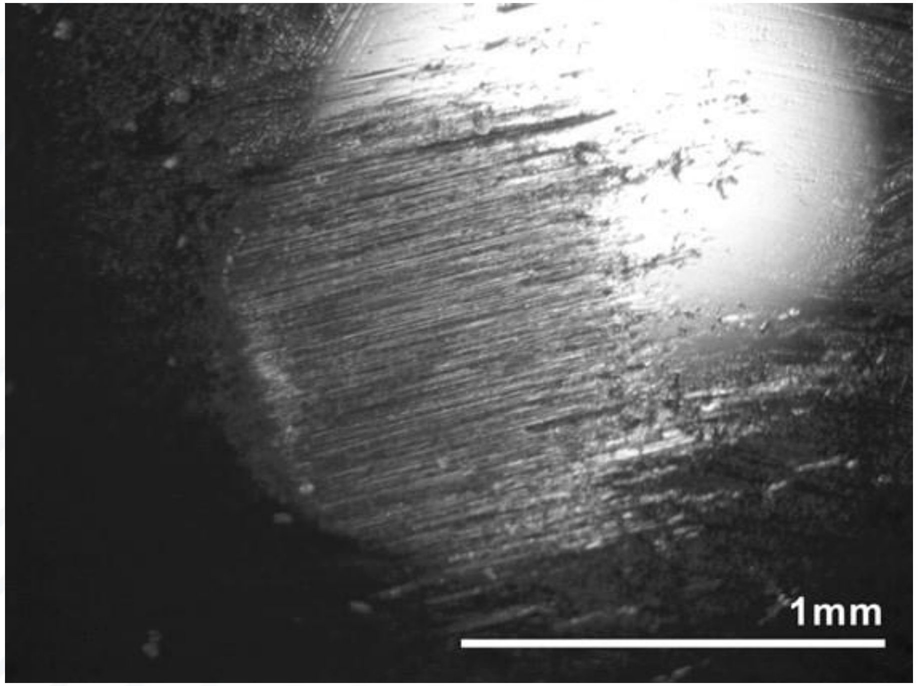




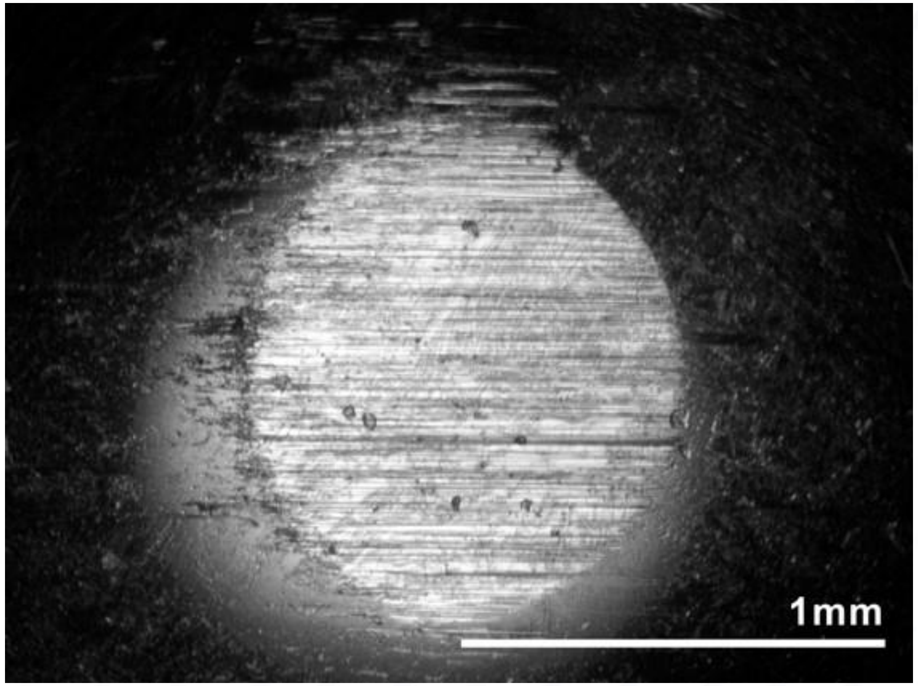
SLIDING WEAR TEST RUN

Counterpart balls

Test 1



Test 2



Test	1	2
Wear scar surface area A (mm^2)	0.81	0.96
Volume loss (mm^3)	7.06E-4	9.93E-4

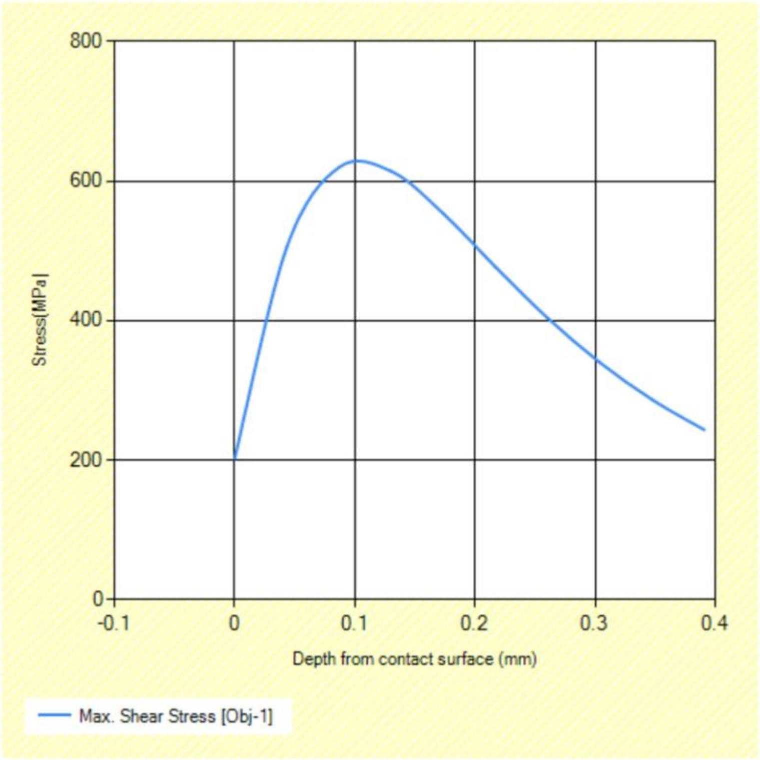
Sliding energy density:
= W/A (Sliding energy / Area)

SLIDING WEAR TEST RUN

Stress and contact analysis at a load - example

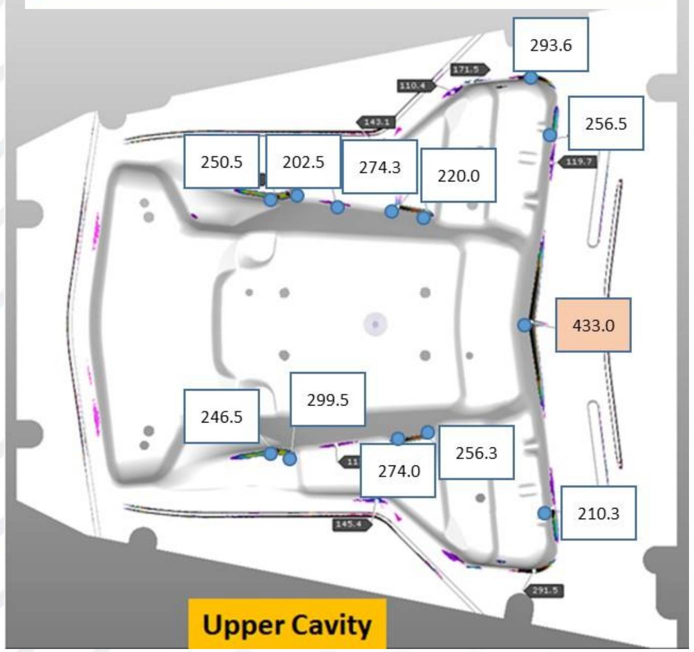
200 N normal load, 15 mm steel ball

	steel/steel	steel/Zn
Maximum Hertzian contact pressure [Pmax]	2025.4 MPa	1473 MPa
Max shear stress [Tmax]	627.9 MPa	456 MPa
Depth of max shear stress [z]	0.104 mm	0.122 mm
Circular contact area diameter [2a]	0.434 mm	0.509 mm

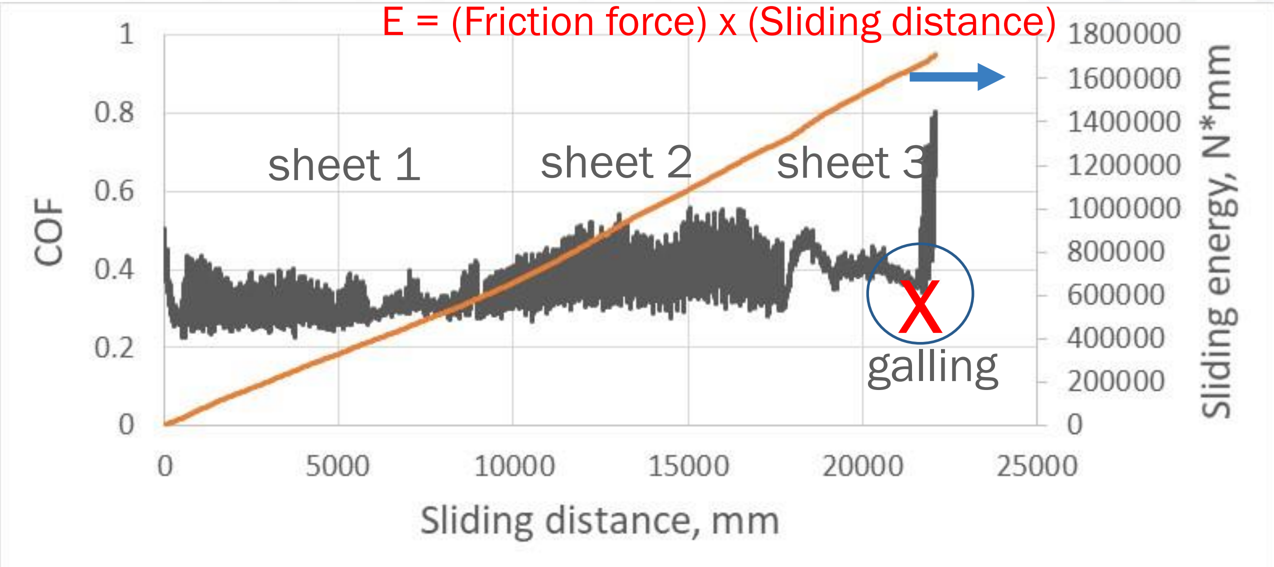


PREDICTION OF NUMBER OF PARTS THAT CAN BE STAMPED BEFORE GALLING

Friction Work (N-mm/mm²): 100 ~ 433



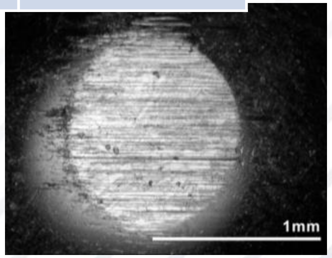
SAE 52100 steel(Die material)/DP980 sheet (as-received, no new lube)



Sliding energy density:
= W/A (Sliding energy / Area)

Wear scar surface area A (mm^2)	0.96
Volume loss (mm^3)	9.93E-4

Number of stamped parts possible before galling at X point:
At stress density 400 N-m/mm^2: (1600000 N-mm/0.96 mm^2)/(400 N-m/mm^2)
= ~ 4000 parts



Better die materials, hard coatings, lube, and lower stresses would increase the number of stamped parts before galling.

SUMMARY ON DESIGN/MANUFACTURING AND OBSERVATIONS OF TEST RUN:

1. Tester has been successfully designed and manufactured
2. Tester can measure coefficient of friction and determine the galling with sliding distances
3. Tester can be used to investigate friction coefficient change with sliding energy
4. Tester can determine the critical sliding energy when the galling occurs
5. The project has studied the typical wear tracks/scars on metal sheets and counterpart balls after galling
6. Each test generates large amount of data which needs post-data treatment

HOW TO USE THE TRIBOMETER (TO BE PROPOSED):

To determine coefficient of friction

To establish sliding energy database for different die materials and coatings

To understand wear behavior of different die material surfaces vs different strength graded steel sheets (such as AHSS. UHSS & 3rd Gen steels).

To understand wear behavior of different heat treated or coated die surfaces vs different galvanized steel sheets.

More importantly, determine sliding energy density (W) of each die material and coating for FEA simulation:

$$W = \text{Stress} \times (\text{Sliding distance})$$

W – corresponding to die materials and treated or coated surfaces
(consider it as a materials property – to be determined the tribometer)
Stress – related to die design and metal strength grades
Sliding distance – related to number of parts to be stamped

FOR MORE INFORMATION

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