Using Direct Energy Deposition to Fabricate Trim Tools for Trimming AHSS

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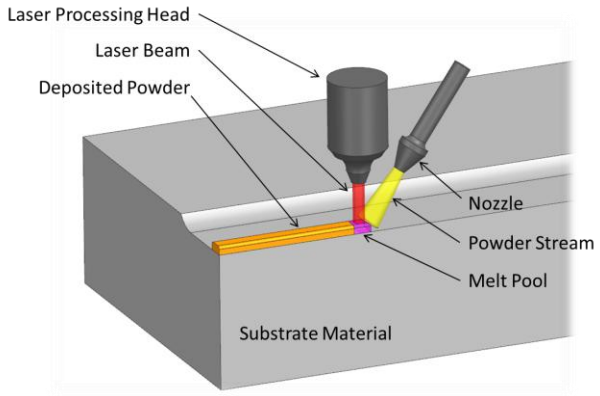
General Motors
Formability and Simultaneous Engineer



Auto/Steel Partnership

GREAT DESIGNS IN STEEL™

Project Details

Goal:

To evaluate the potential of using trim tools created using wire fed direct energy deposition (DED) additive metal process to trim advanced high strength steel (AHSS).

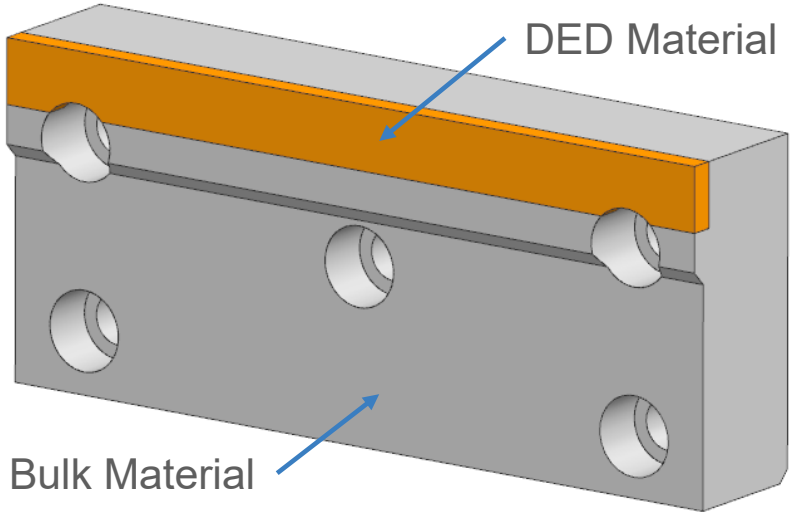
Value Statement:

Trim tools require a combination of high surface hardness to resist abrasive and adhesive wear, and sufficient bulk strength and toughness to withstand the cyclic loads associated with trimming advanced high-strength sheet steels. Achieving this performance typically necessitates the use of high-alloy tool steels and specialized heat treatment processes, which can increase both cost and lead time.

The DED additive metal process can potentially reduce both time and cost by:

1. Allowing the use of less expensive steel substrates for the bulk of the tool
2. Applying higher strength and hardness material for the trim edge portion of the tool without heat treatment

This hybrid approach reduces material waste, energy use, and overall part cost compared to fully additively manufactured or conventionally machined components, while still enabling localized property tailoring, rapid iteration, and in-situ repair.



DED Trim Tool Schematic

Oakland University: 65-ton mechanical press

Approach:

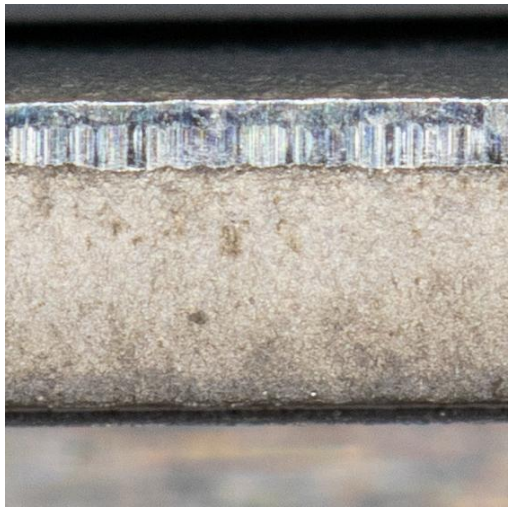
Objectives:

Assess the performance of DED inserts by running a high-volume die trial

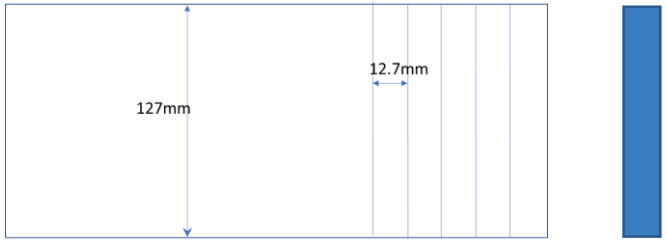
- Using AHSS
- 15% Clearance
- Edge condition of trimmed parts should meet production requirements (e.g., no burr)

Steps:

1. Cast and rough machine D6510 base upper and lower inserts (Northfield Foundry)
2. Remove select area for direct energy deposition
3. Deposit H11 additive material via direct energy deposition (GM In-Kind)
4. Machine inserts to achieve 15% die clearance (GIC Machining)
5. Install inserts into Oakland University trim die / press
6. Run 50,000 hit die trial using 1.4 mm thick DP980 sheet steel
7. Evaluate the condition of the inserts and trimmed sheet metal parts



DP980 Trim Edge



Coil material 1.4 mm DP980

Trimmed Coupon (12.7 mm x 127 mm)

Cast and Machine Inserts

Step 1.1:

- Two (2) castings of the upper and lower inserts were cast from D6510 steel
- Three (3) inserts were cut from each casting and were extracted for three (3) lower inserts and three (3) upper inserts (140 mm +/ 1 mm)

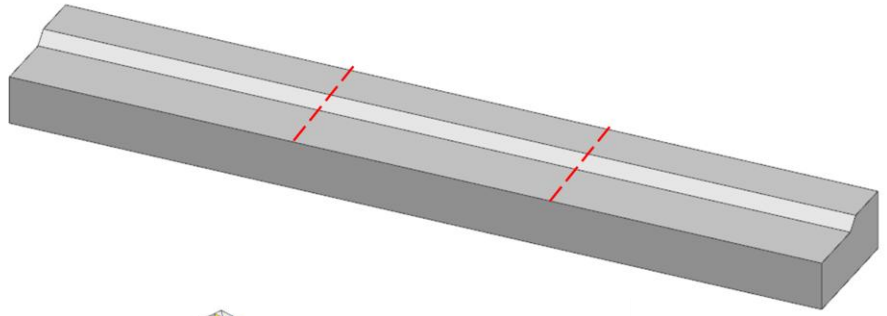
Step 1.2:

- The base and back of all six (6) inserts were machined to be flat and square with a sharp edge break

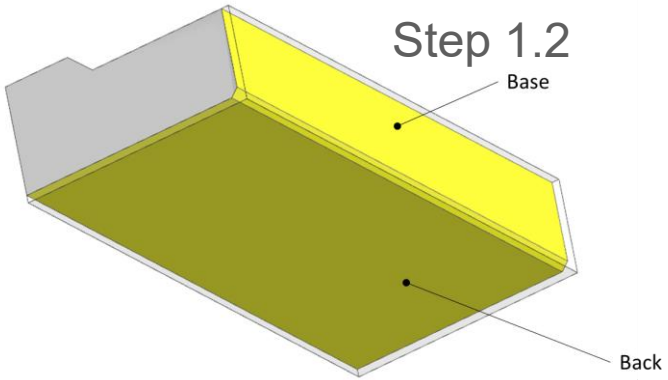
Step 2:

- A groove was machined at the trim edge to prepare for material deposition
- Depth: 23 mm from the back of the cast insert
  - Height: ~15mm
  - This step was done to only two (2) pieces (1 upper, 1 lower)
- The remaining four (4) pieces were saved for future work

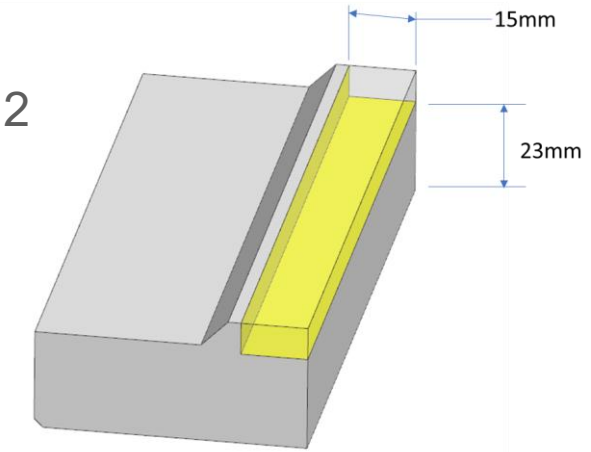
Step 1.1



Step 1.2



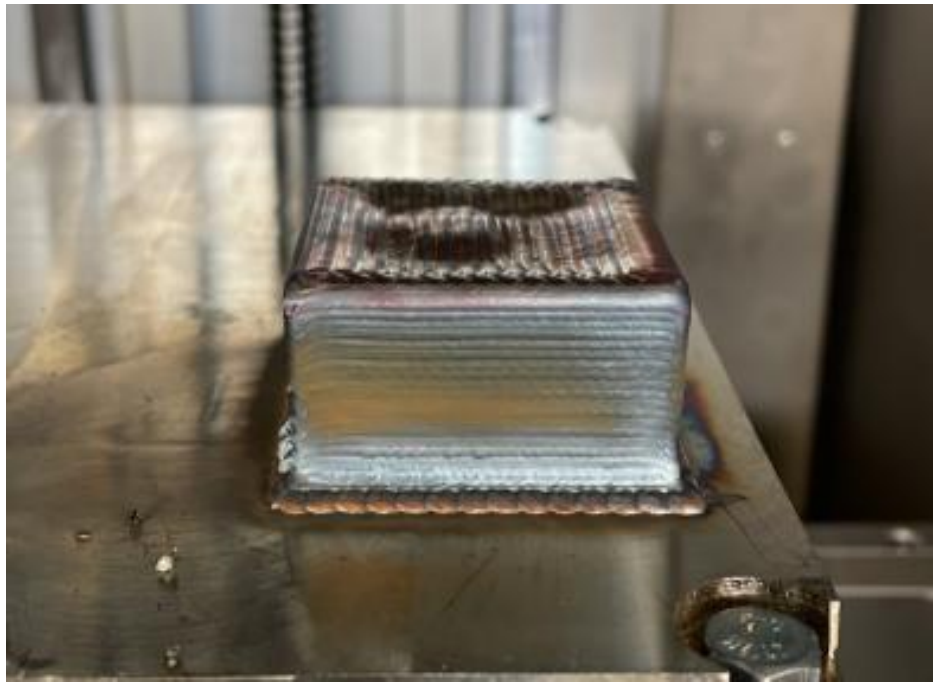
Step 2



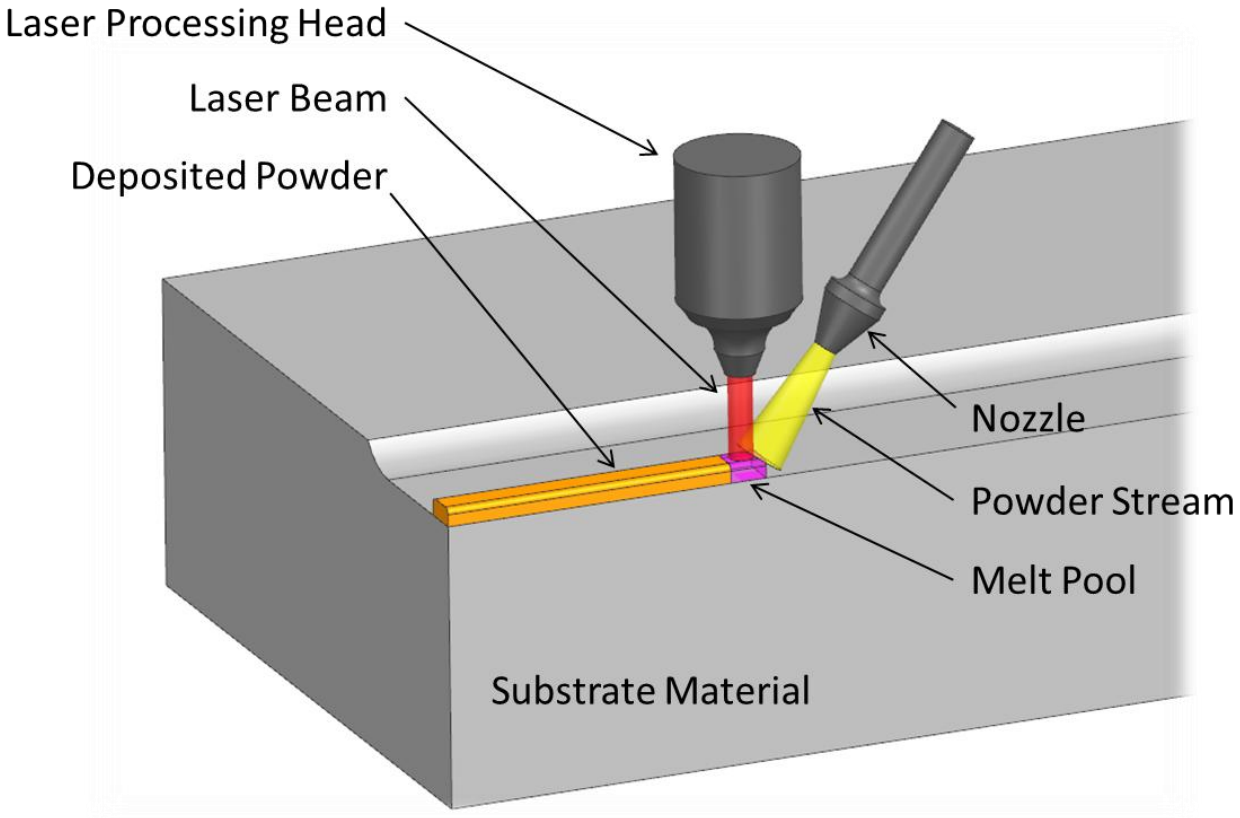
Step 3: Direct Energy Deposition

Inserts delivered to GM for Direct Energy Deposition

H11 Wire used ~ 52 HRC



GM Build Plate



Finish Machining

Step 4.1:

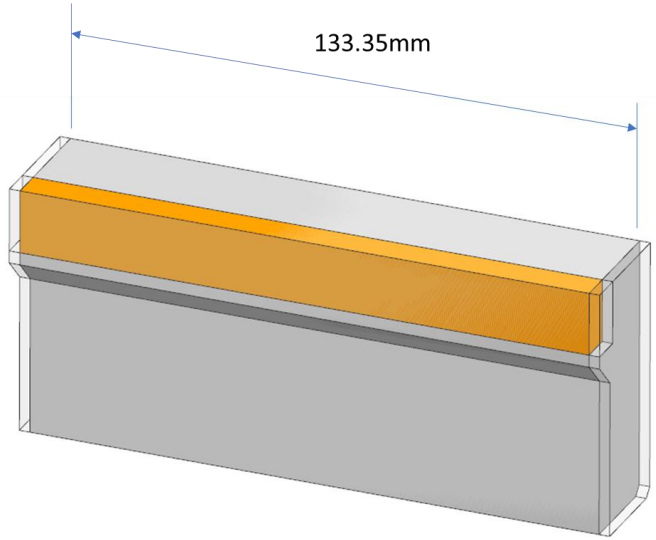
- Machine to finished width of 133.35mm

Step 4.2:

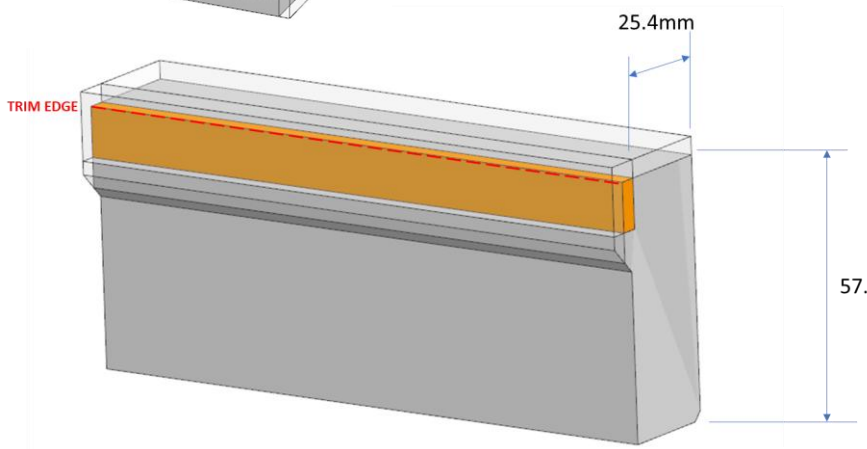
- Machine to finished height and depth
- Ensure a sharp, chip free trim edge

Step 4.3:

- Add mounting holes (4 in the upper, 5 in the lower)

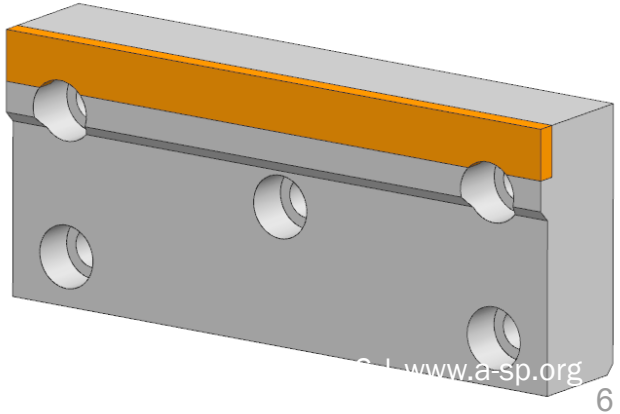


Step 4.1



Step 4.2

Step 4.3



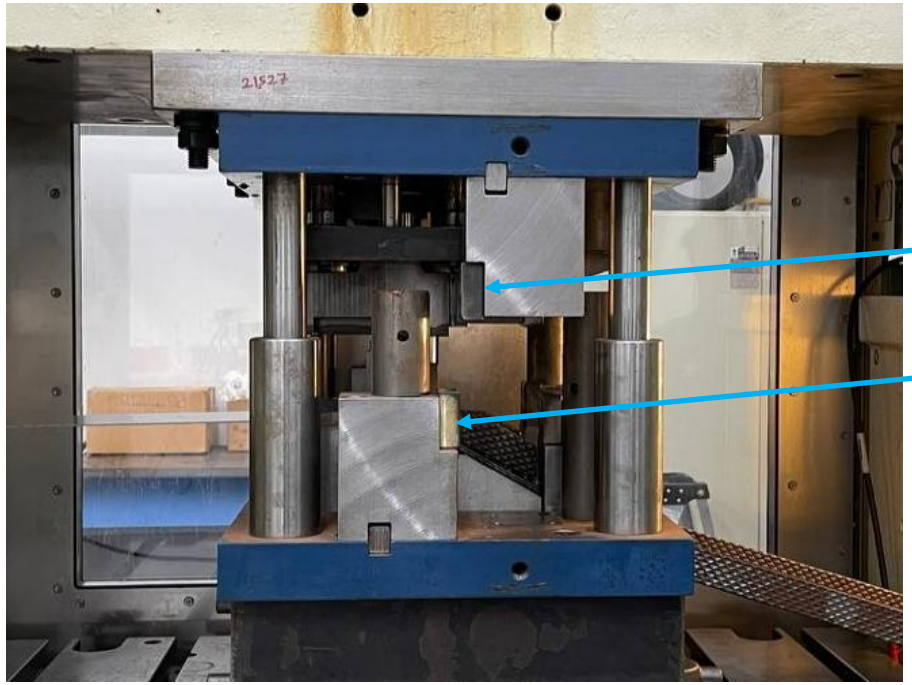
Insert Die Trial

Step 5: Install inserts in OU Trim Die

- Inserts shimmed for 15% Clearance

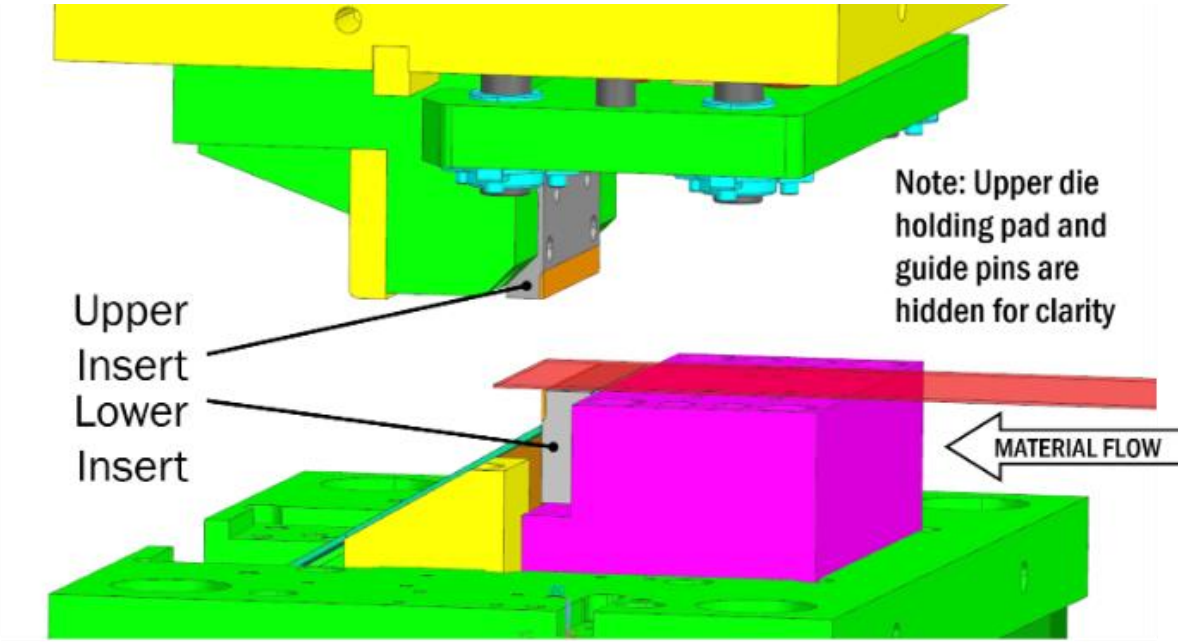
Step 6: Run 50,000 hit die trial

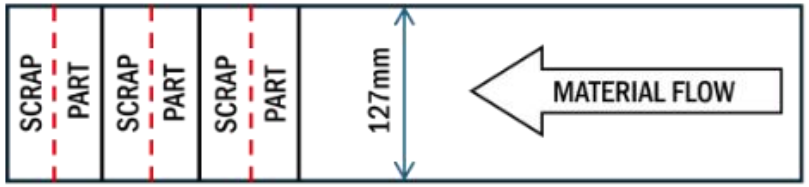
- 1.4 mm DP980 sheet steel



Oakland University Stamping Die (side view)

Oakland University Stamping Die





Evaluate Insert Performance

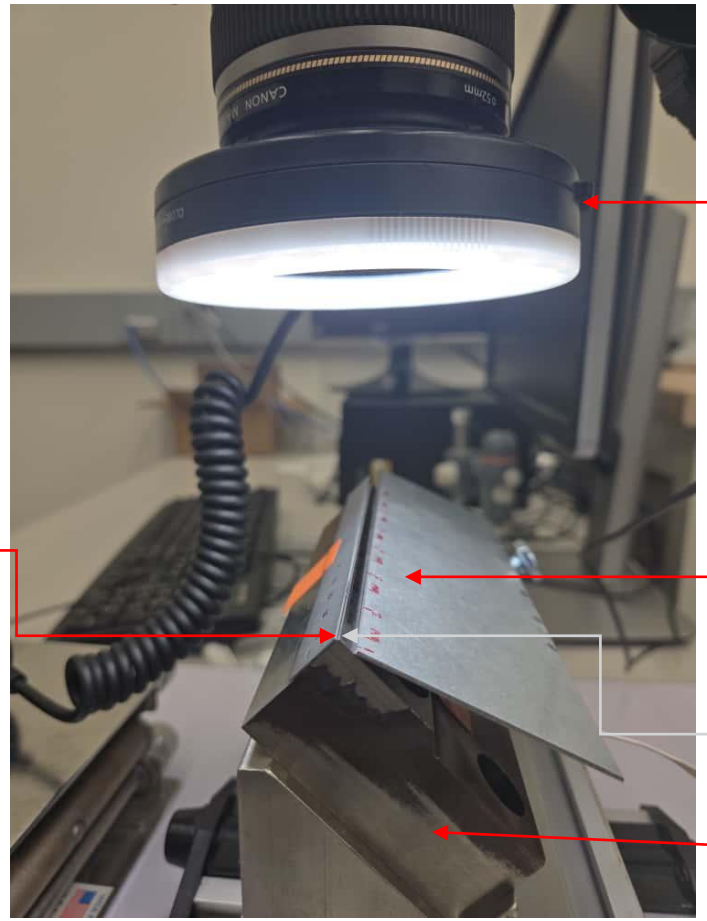
Camera: Canon T6i

Field of view: 25mm

ISO: 100

Focal length / diameter of the aperture : f/5

Shutter Speed: 1/100 sec



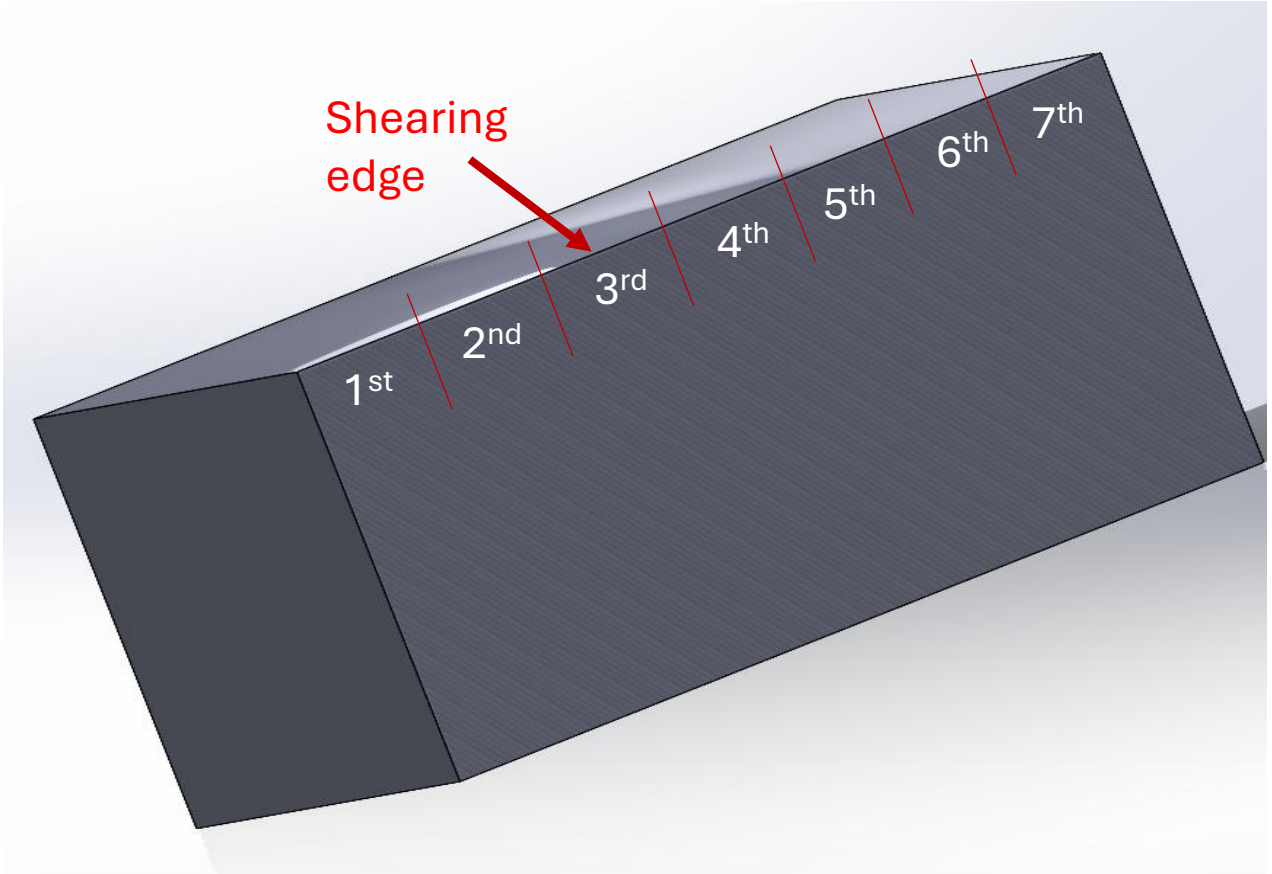
Co-ordinate system
(Starting at 0)

Insert Performance Evaluation

The schematic representation of the upper insert's shearing edge illustrates its zone into seven distinct regions.

Each region is analyzed at:

- as received
- Every 1,000 strokes (1k to 5k strokes)
- Every 5,000 strokes (5k to 50k strokes.)



Insert Inspection Results

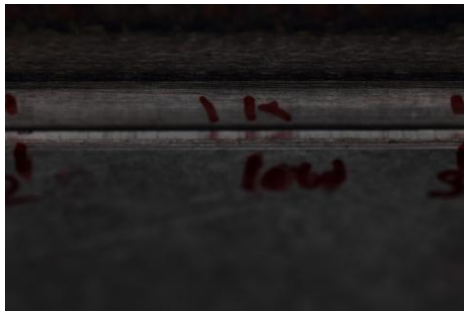
Images of the upper and lower inserts were taken at intervals (hit #) during the die trial:

0	1,000	2,000	3,000	4,000
5,000	10,000	15,000	20,000	25,000
30,000	35,000	40,000	45,000	50,000

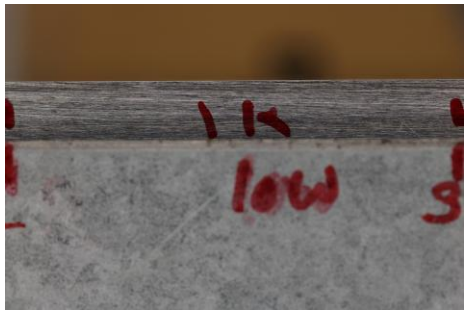
Low magnification photos were taken at each interval for each zone on both lower and upper inserts

- Low magnification photos at 45° degrees to trim edge
- Low magnification photos perpendicular (0°) to the trim edge (vertical face)

Lower Insert, Zone 3, 1,000 Hits

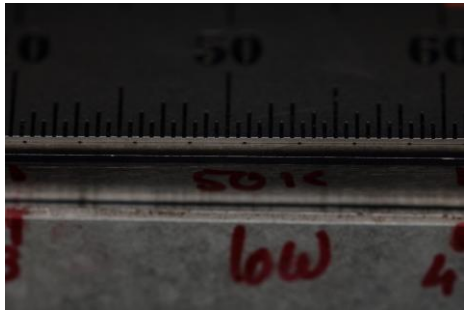


45°

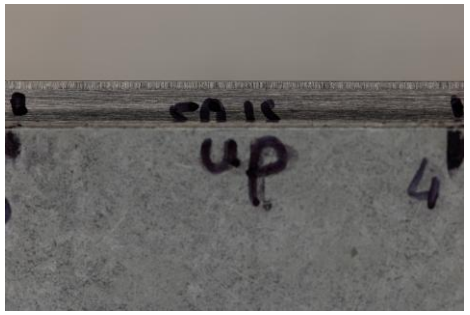


0°

Lower Insert, Zone 3, 50,000 Hits



45°

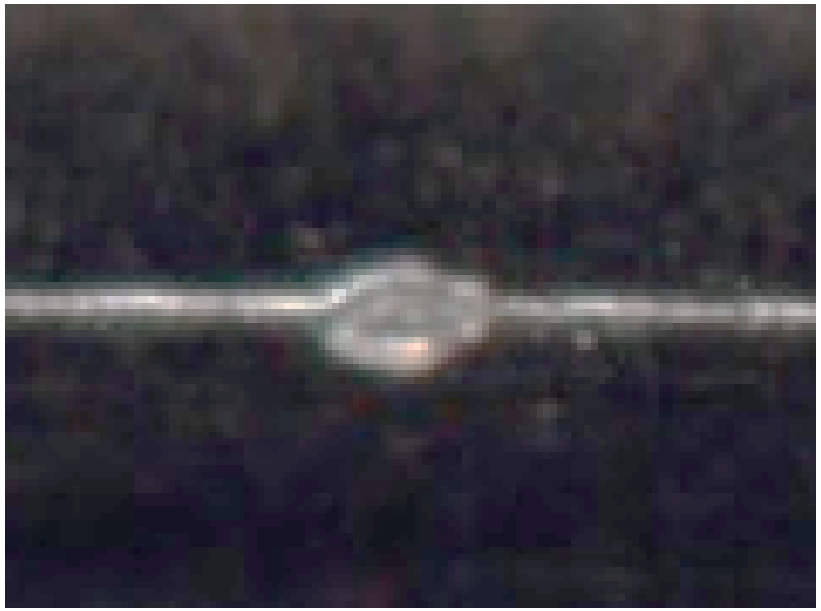


0°

Insert Inspection Results

Any noted damage noted on the trim edge was annotated as follows:
(Insert, Zone# – Increment)

- Insert: (**L**) for Lower and (**U**) for Upper
- Zone #: E.G., "**Z2**"
- Damage Annotation: **A**, **B**, or **C** (indexes with # of defects noted)
- Example: **LZ3-A** (lower insert, zone #3, Damage "A")

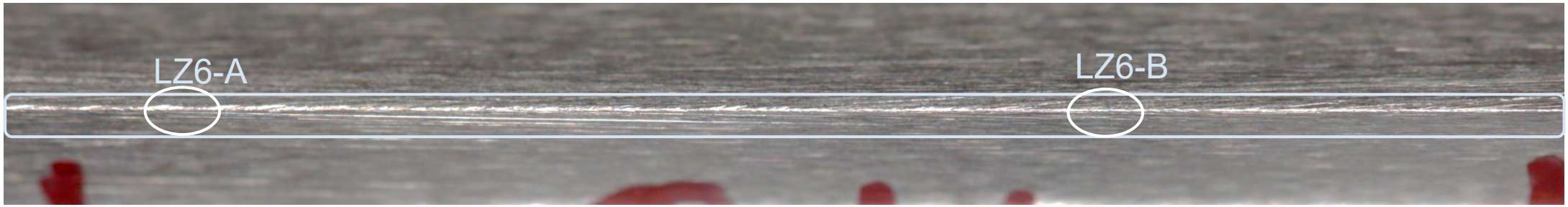


LZ3-A

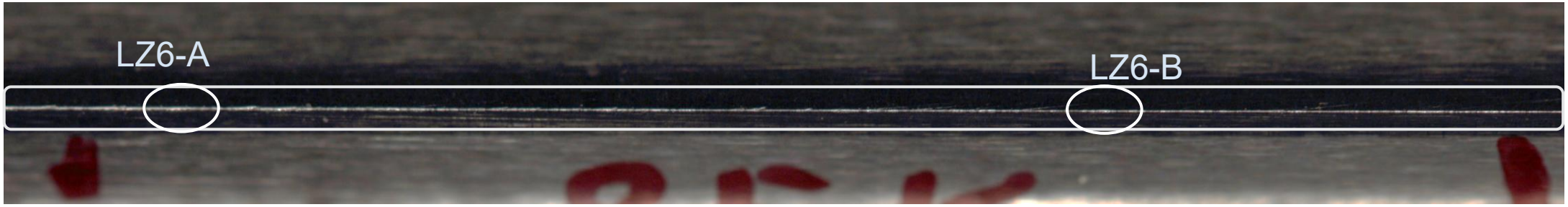
Insert Inspection (Example, LZ6)

Using macro-photos of the insert trim edge, damage noted after 50,000 hits could be traced backwards through the die trial to determine time of origin

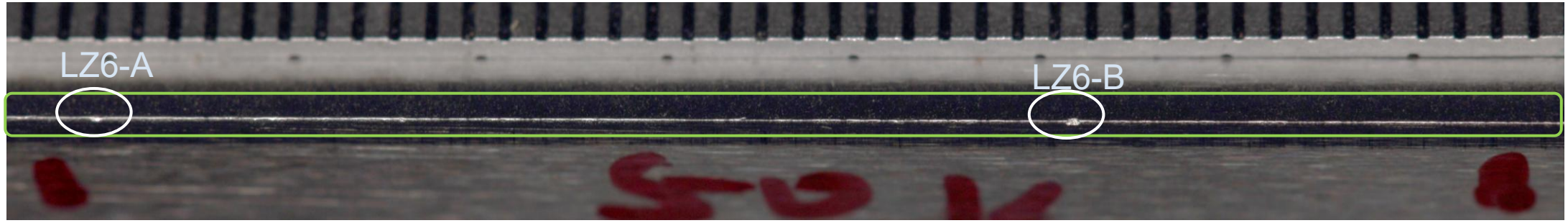
As received



25000 Strokes

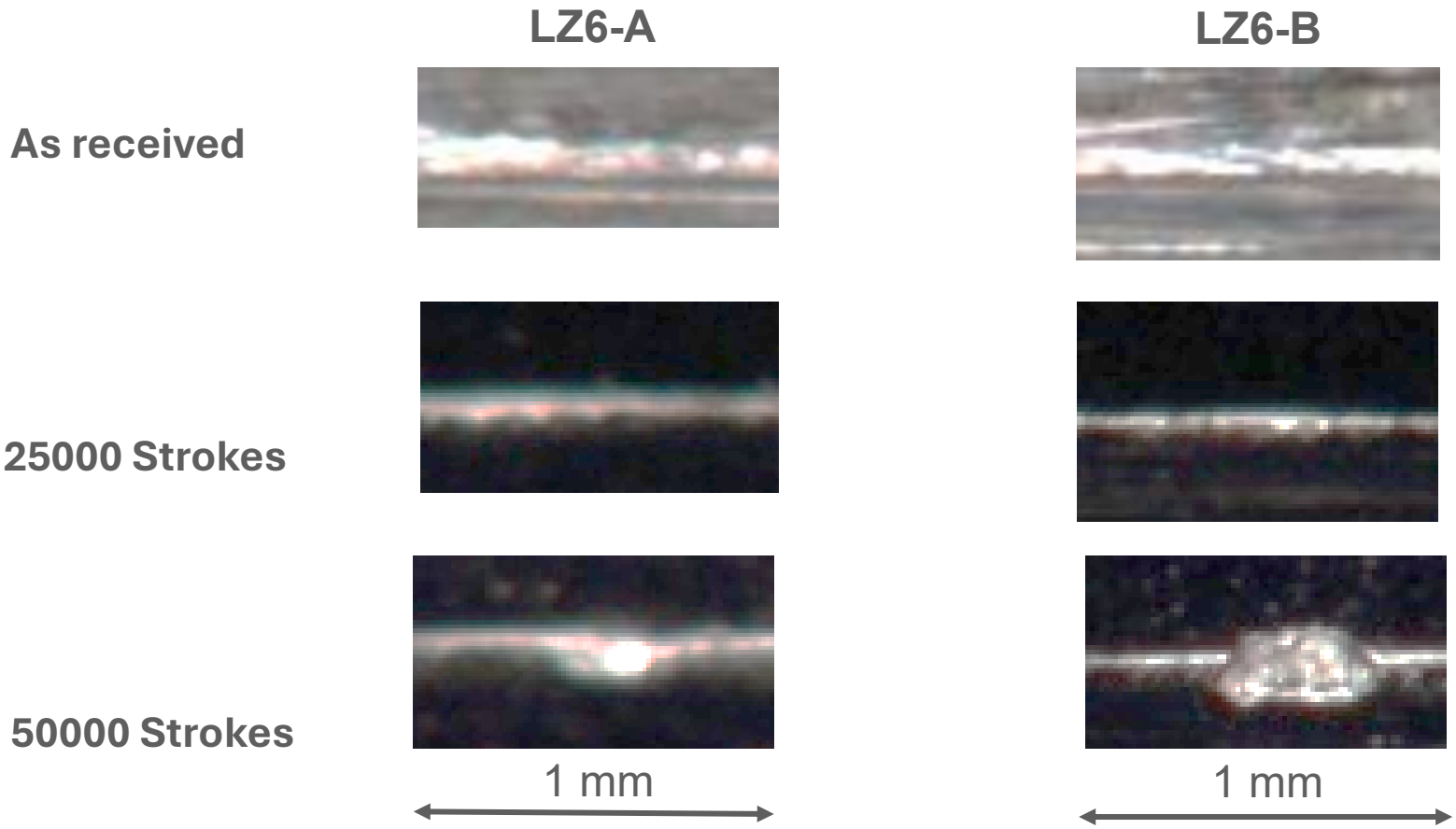


50000 Strokes



Insert Inspection (Example LZ6)

Higher magnification of defects noted showing slight progression in damage.

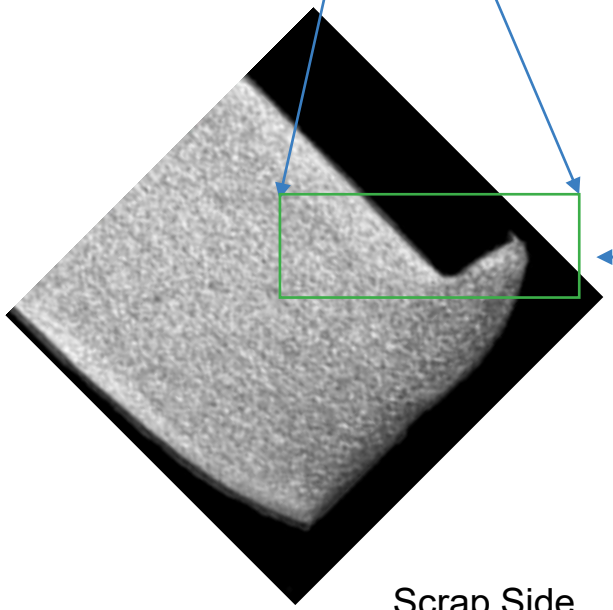


The size of magnified and cropped images of shearing edge is approximate value.

Trim Edge Inspection (Component)

Lense

Camera: Nikon Z7
Field of view: 35mm
ISO: 64
Focal length / diameter of the aperture : f/10
Shutter Speed: 1/100

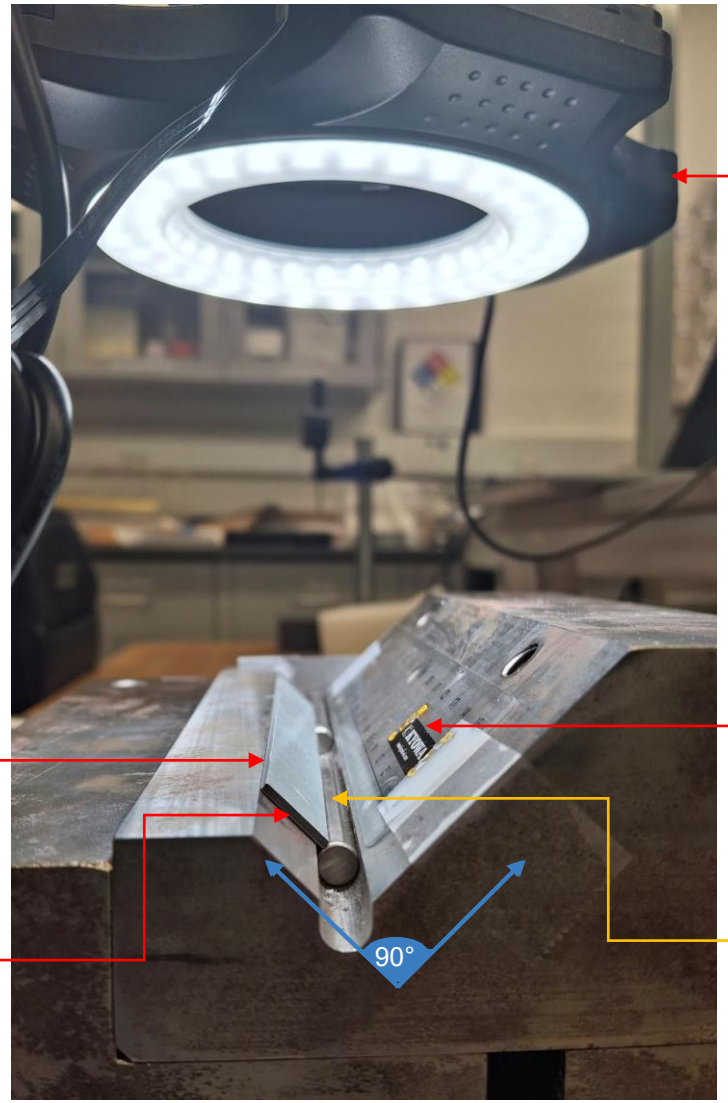


Specimen at 45 °

End with“1” Mark
(on the other side)

Scrap Side

Part Side



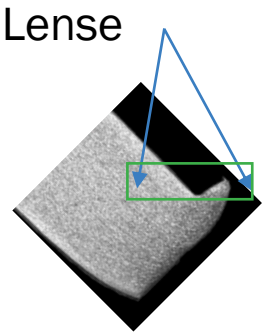
Camera and Light

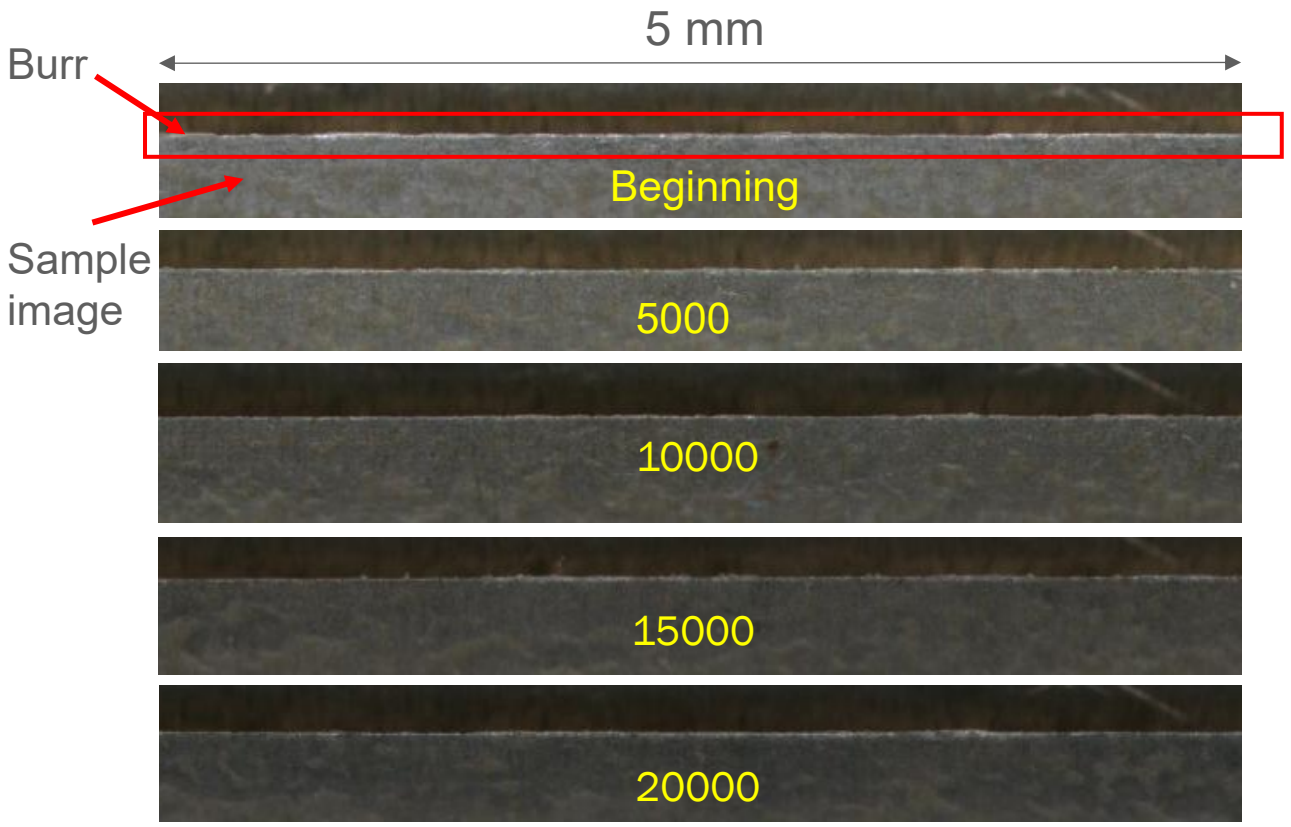
Co-ordinate system
(Starting at 0, from the side marked with “1”)

Burr/Broken Burr

Trim Edge Inspection (Component)

Images shows burr formation from beginning to 45,000 strokes at same location.

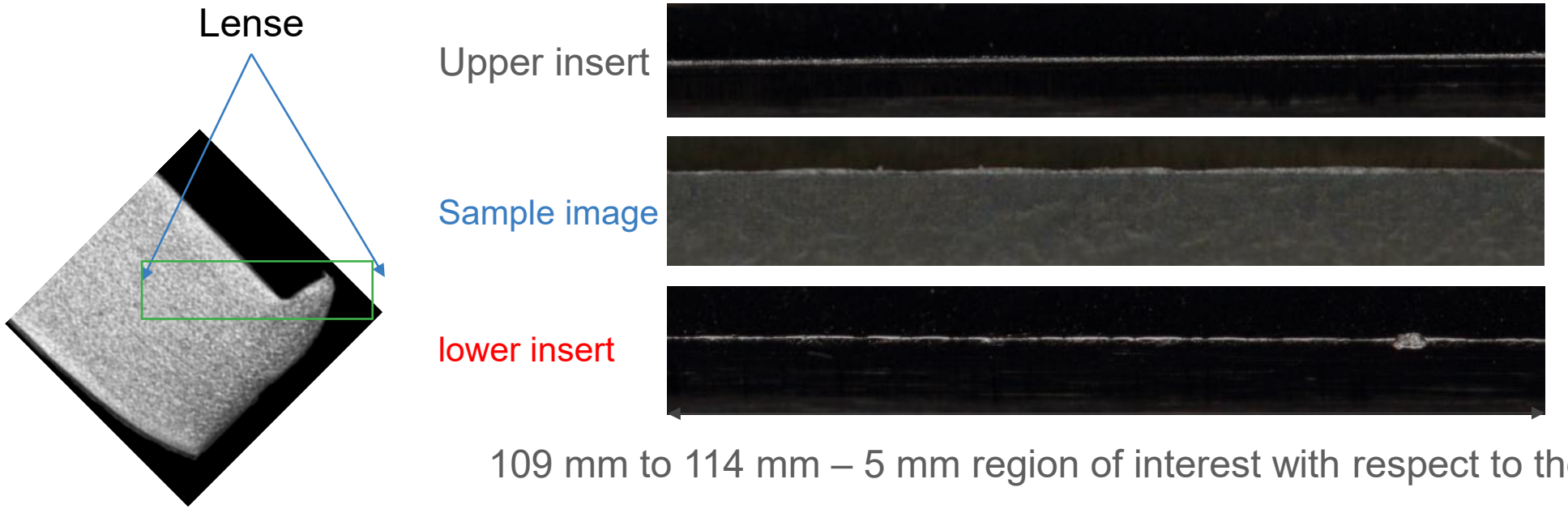




Trim Edge Inspection (Component)

The small defects found on the trim tools did not appear to generate defects on the trimmed component.

- Upper insert (image on top) shows no defects.
- Lower insert (image on bottom) shows a small defect.
- Trimmed component (middle image) shows no damage.

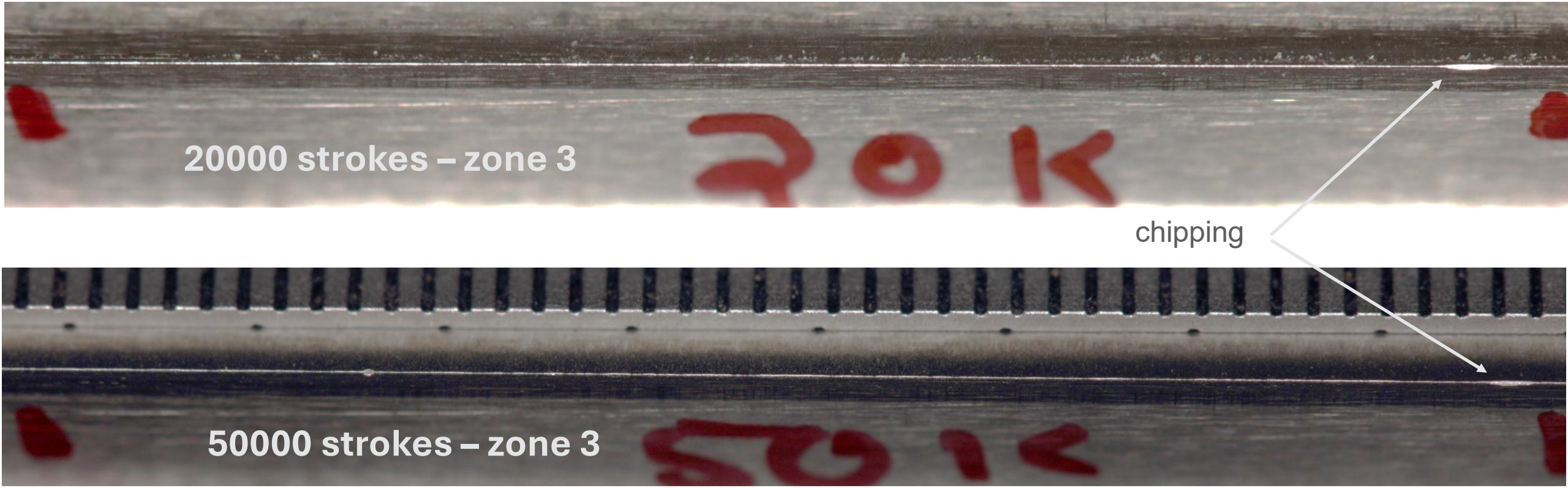


109 mm to 114 mm – 5 mm region of interest with respect to the sample

A minor burr on the part side is visible from the beginning of the program and progressively increases up to 50,000 strokes, along with tool wear.

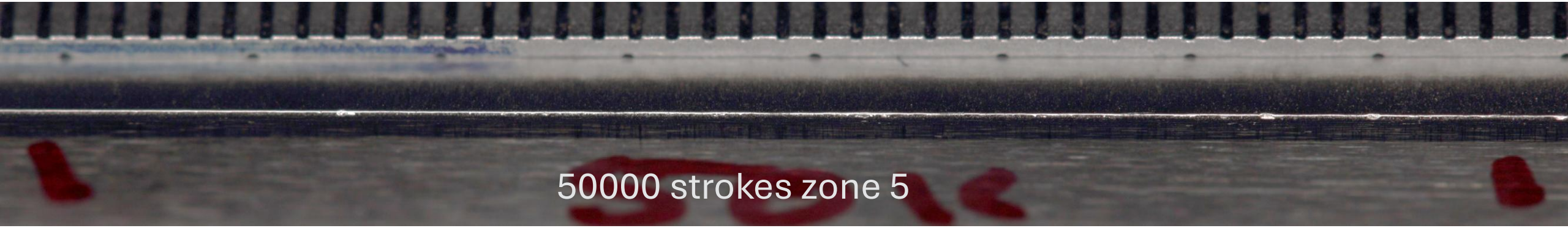
Observations

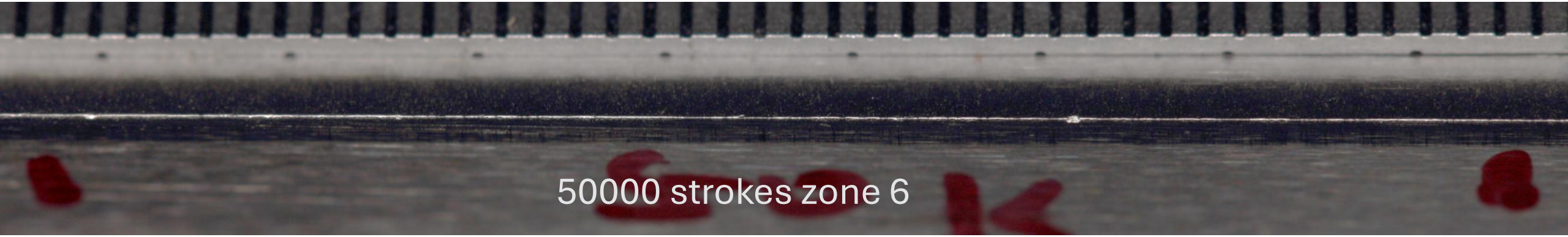
- Lower Insert
  - Significant chipping was observed in zone 3 after 20,000 hits.
  - Chipping did not increase from 20,000 to 50,000 hits.



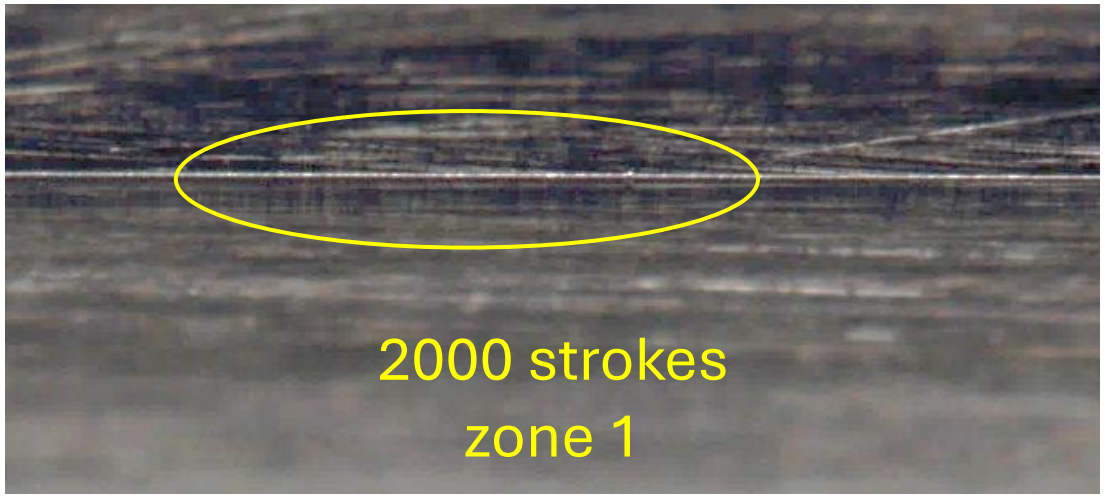
Observations

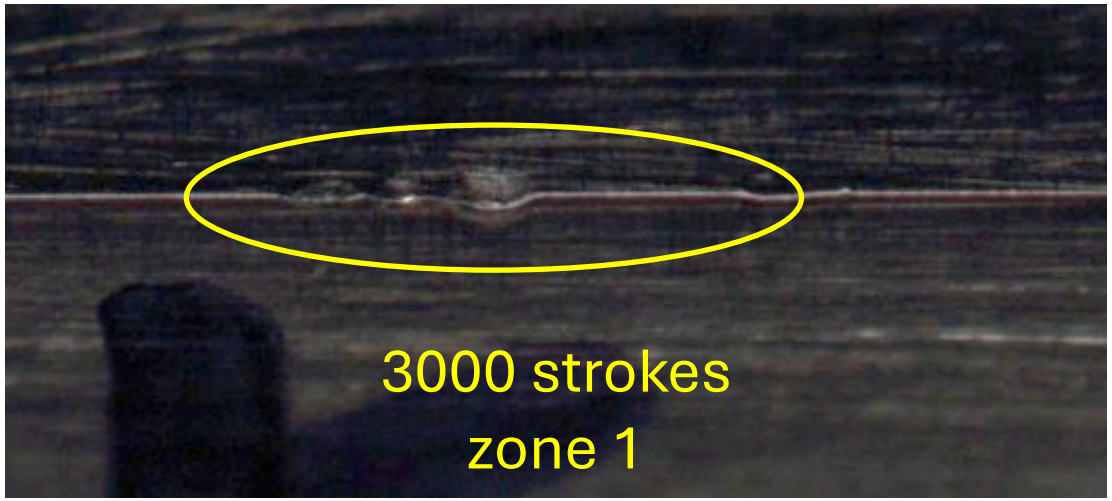
- Lower Insert
  - Minor chipping was observed in zone 5 and zone 6 after 35,000 hits and after 45,000 hits.



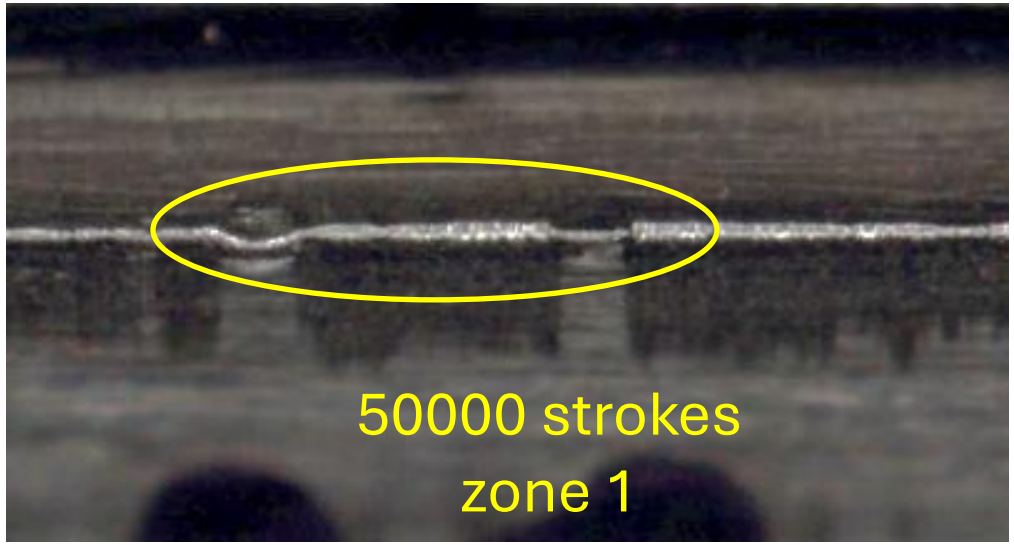


Observations

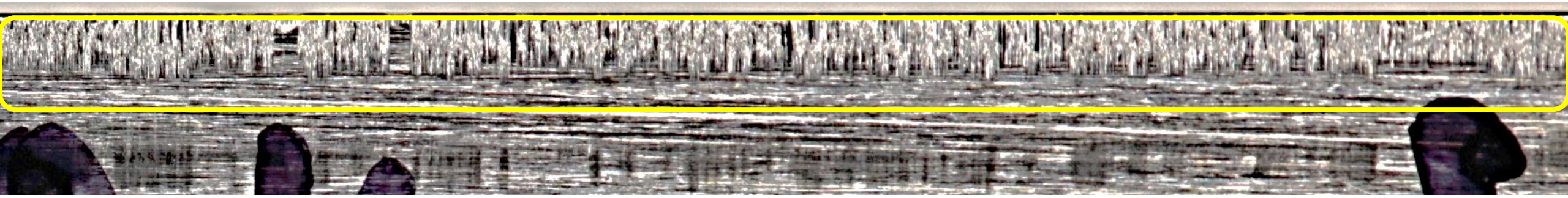




- Upper Insert
  - Slight deformation of the trim edge was noticed at 3,000 hits.
  - Damage remained stable until 50,000 strokes with increased edge wear.

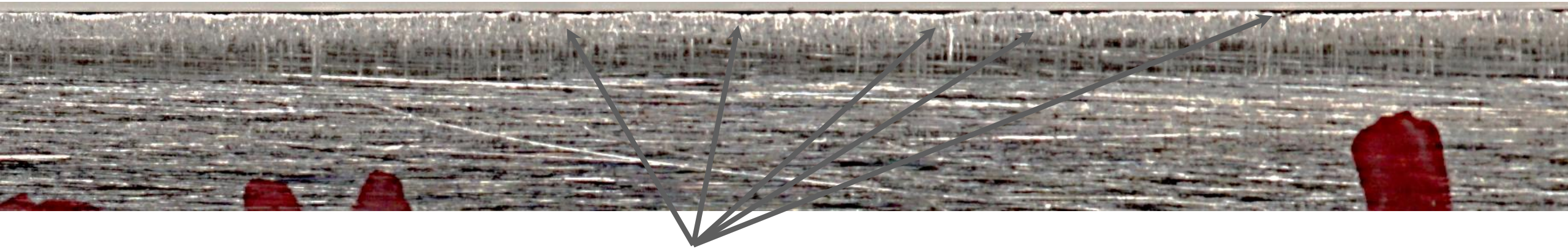


Observations



Upper insert

- Uniform wear is observed on the cutting edge of the upper insert.



Lower Insert

- Non-uniform wear on the cutting edge of the lower insert.

Conclusions

The DED additive metal inserts worked!

- Tools maintained edge sharpness*
- Trimmed components had acceptable edge quality throughout the die trial

*After the 50,000 hit die trial, slight wear of the trim edge was noted suggesting that a prolonged durability trial is warranted to fully validate the potential of DED additive manufactured trim tools.

Small defects, such as dents and chips, occurred at various stages of the die trial.

- Locations varied
- Defects did not progress
- Failure analysis suggested to determine root cause, e.g., inadequate fusion, porosity, etc.

Next Steps

1. A/SP is exploring methods to accelerate trim tool durability testing using the Oakland University's trim die and press to:
   - Facilitate additive manufactured material and process development
   - Decrease the time and cost for tool validation
   - Enable comparison to traditional and emerging tool solutions

2. Should an accelerated test be developed, a durability trial is planned to contrast the performance of additive manufactured trim tools against conventional (e.g., through hardened Caldie) and laser hardened trim tools.

Laser hardened 4140 (machined from prehard bar stock) Trim Tool

FOR MORE INFORMATION

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