GREAT DESIGNS IN STEEL

TWENTY YEARS

ADDITIVE MANUFACTURED INSERT PERFORMANCE IN STAMPING OF DP980 STEEL

Paul Wolcott
General Motors Company
On Behalf of Auto/Steel Partnership

OUTLINE

- Team
- Project Outline
- Additive Manufacturing process
- Mechanical / Microstructure results
- Stamping trial results
- Discussion

PROJECT TEAM MEMBERS

<u>Auto/Steel Partnership</u>

Project Mentor: JP Singh, General Motors Company
Team Lead: DJ Zhou, Stellantis
Project Leader: Paul Wolcott, General Motors Company
Project Manager: Michael White, A/SP

Project Team Members:

- Ante Lausic, General Motors Company
- Brendan Larsen, General Motors Company
- Jacek Glowacki, General Motors Company
- Shawn Schaffert, General Motors Company
- Dean Kanelos, Nucor Corporation
- Hokook Lee, POSCO
- Philippa Chiu, Stellantis

Previous Lead:

- Alan Gillard – Ford Motor Company

PROJECT CONTRIBUTORS

- Key participants
  - In-Kind Contributions
    - Ionbond - Coatings
    - Sun Steel – Insert heat treatment
    - General Motors Company – Re-printed inserts
  - Vendors
    - Element Materials Technology
    - Westmoreland Mechanical Testing & Research, Inc
    - Yarema
    - Additive Metal Manufacturing – Original inserts
- Universities
    - Oakland University (Stamping Trials)

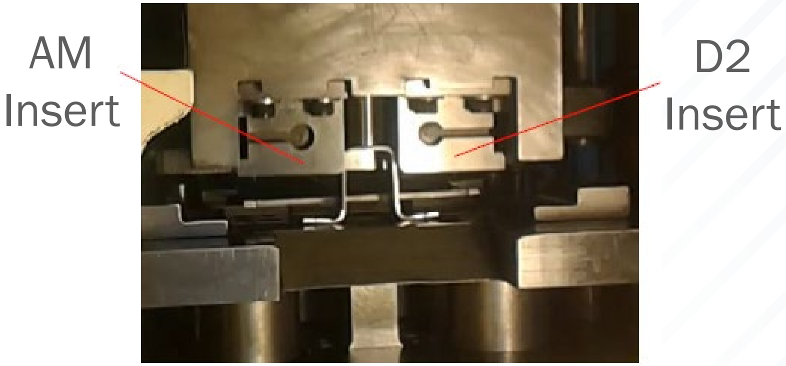
PROJECT DETAILS

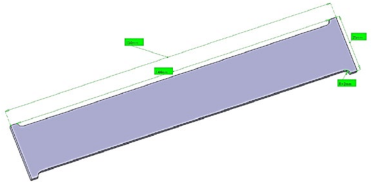
- Die repair can be expensive, especially emergency repairs, and lead to lost production
- Additive manufacturing (AM) offers an opportunity to significantly decrease the time and cost to produce die inserts and die repairs

- Project Objective:
  - Prove that AM printed materials can perform stamping operations with similar or improved performance compared to conventional D2 steel
  - Explore the capabilities of metal AM for fabrication of small die inserts focused on flange steels, trim steels, restrike steels, etc.

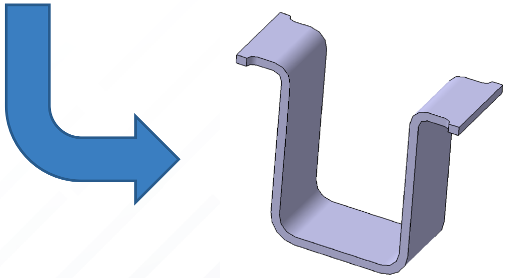
PROJECT APPROACH

- Fabricate AM and conventional wrought inserts
  - AM MS1 maraging steel inserts via laser powder bed fusion
  - Conventional wrought D2 inserts machined from bar stock
  - Both inserts were coated with Ionbond IB90 PVD coating
- Conduct a die trial to compare performance of AM inserts against conventional inserts
  - Both inserts were installed side-by-side
  - DP980 1.0 mm thick
- Testing
  - Compare wear performance of the inserts from the die trial
  - Conduct mechanical testing, durability testing, and microstructural analysis of AM material





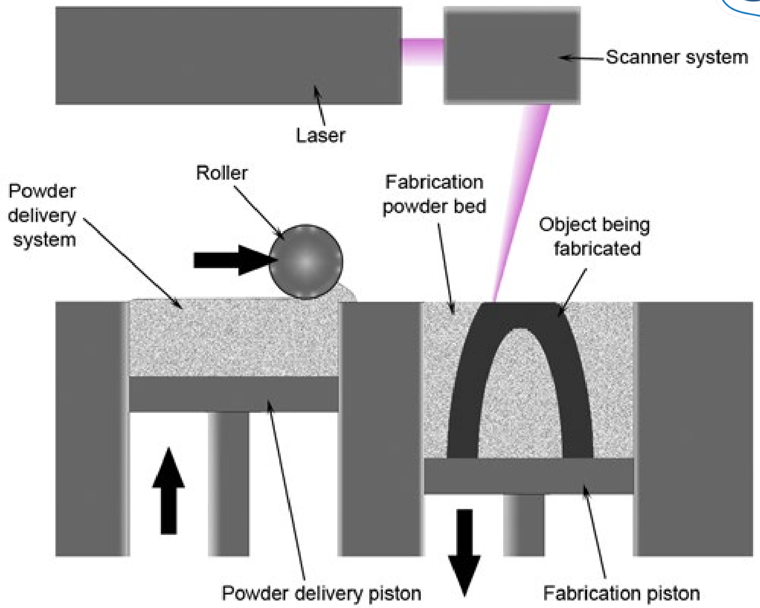
Blanks are: 150 mm x 25 mm



50,000 Stamped U-Channels

ADDITIVE MFG PROCESS

- Laser powder bed fusion process
  - Layer of powdered metal melted via laser
    - Layer thickness 40 µm
  - New layers spread upon previous layers and melted
  - Process continues until part is finished
- Capable of high accuracy, detailed parts
- EOS M400-4 used for printing
  - Material is MS1 Maraging Steel from EOS

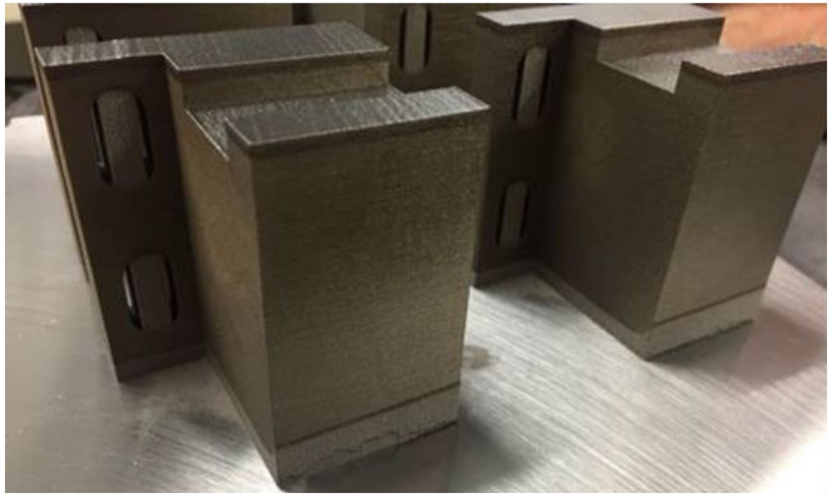


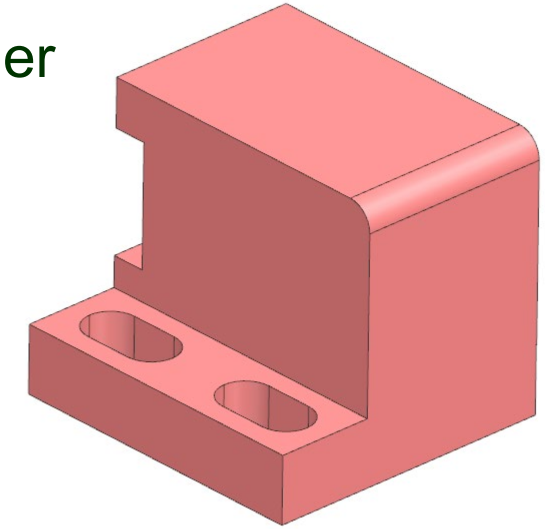
Ni (wt%)	Co (wt%)	Mo (wt%)	Ti (wt%)	Al (wt%)	Cr, Cu (wt%)	C (wt%)	Mn, Si (wt%)	P, S (wt%)	Fe
17-19	8.5-9.5	4.5-5.2	0.6-0.8	0.05-0.15	≤ 0.5	< 0.03	≤ 0.1 ea	≤ 0.01 ea	Balance

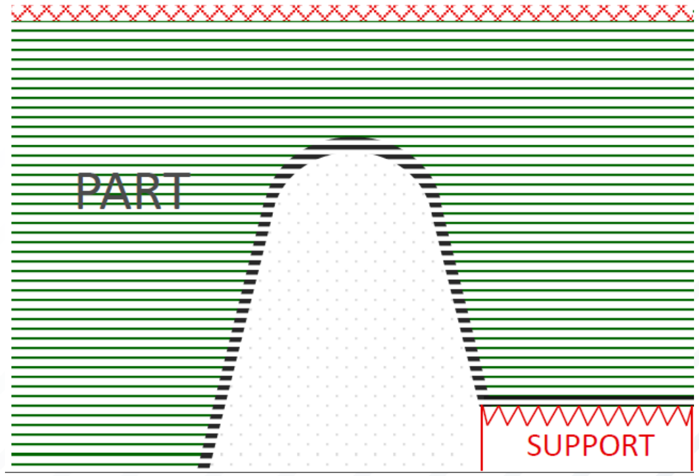
- Heat treatment: 490°C for 6 hours
- IB 90 PVD coating: 460°C for 8 hours

INITIAL BUILD LAYOUT

- AM build layout is important for performance
- Initial set of inserts printed with forming surface on a ‘downskin’ area of the print onto supports
- Beam overpenetration requires decreased energy input in ‘downskin’ areas to maintain desired geometry
- More susceptible to porosity and other issues of mechanical performance

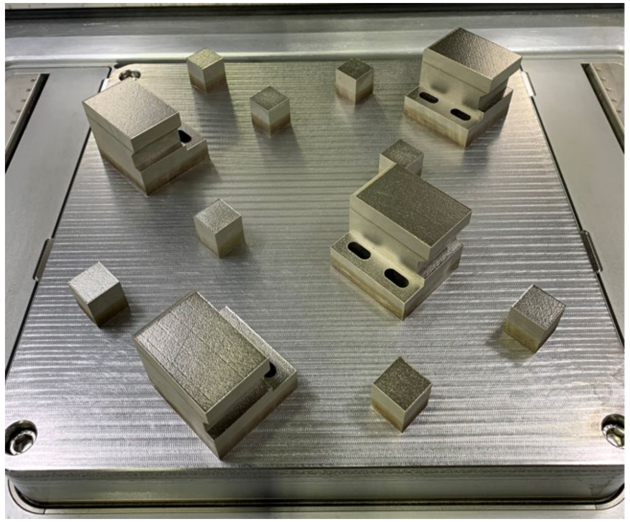


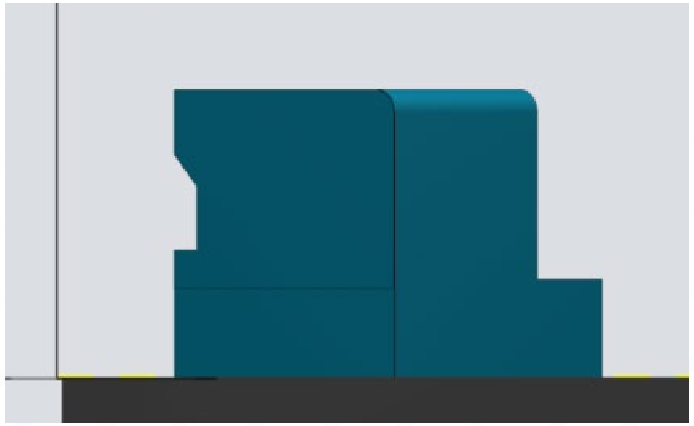




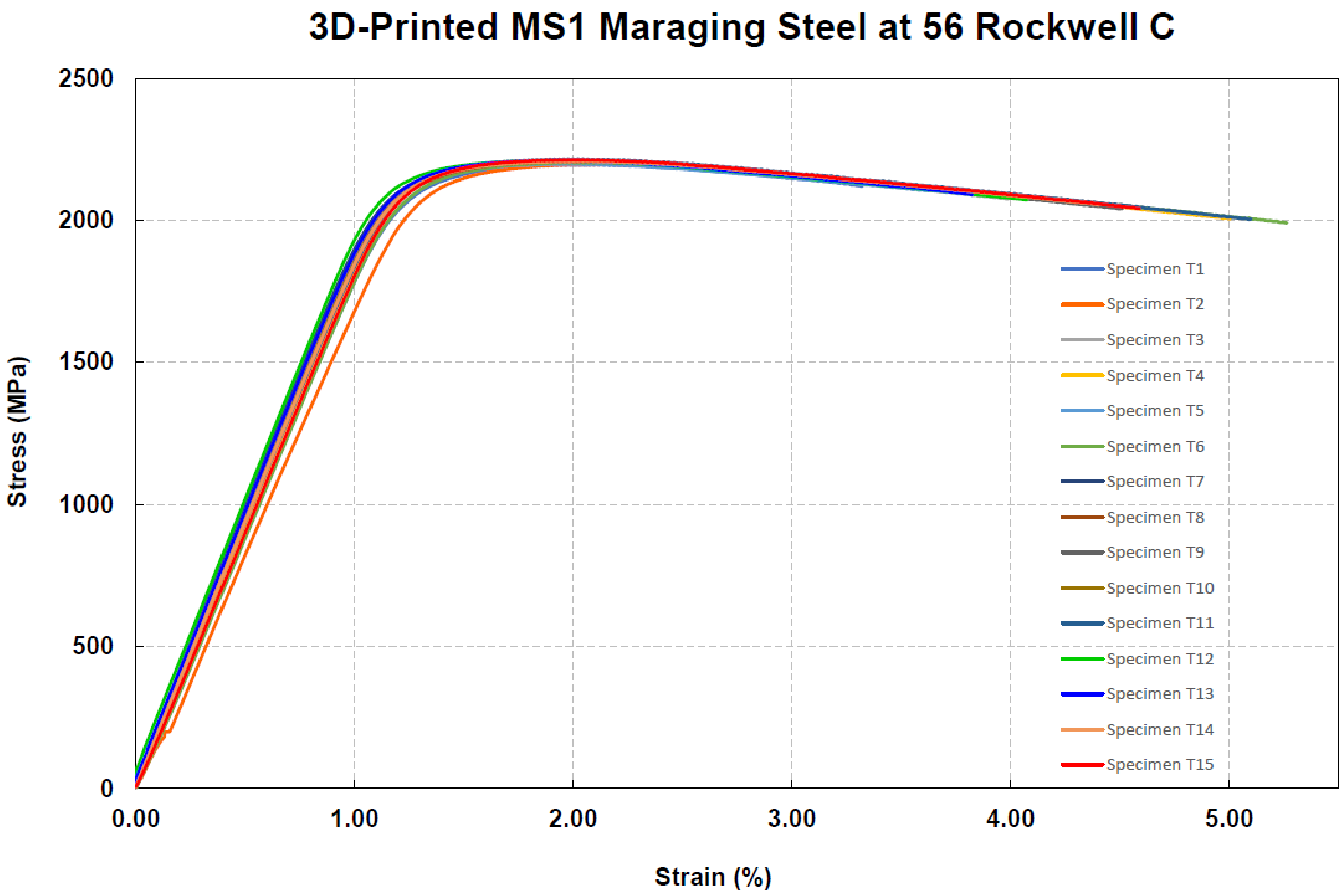
IMPROVED BUILD LAYOUT

- More ideal layout eliminates need for supports, especially considering parts will require machining anyway
- Likewise eliminates 'downskin' exposure on forming surface of the die





TENSILE RESULTS



Tensile Strength

UTS = 2210 MPa

Total Elongation

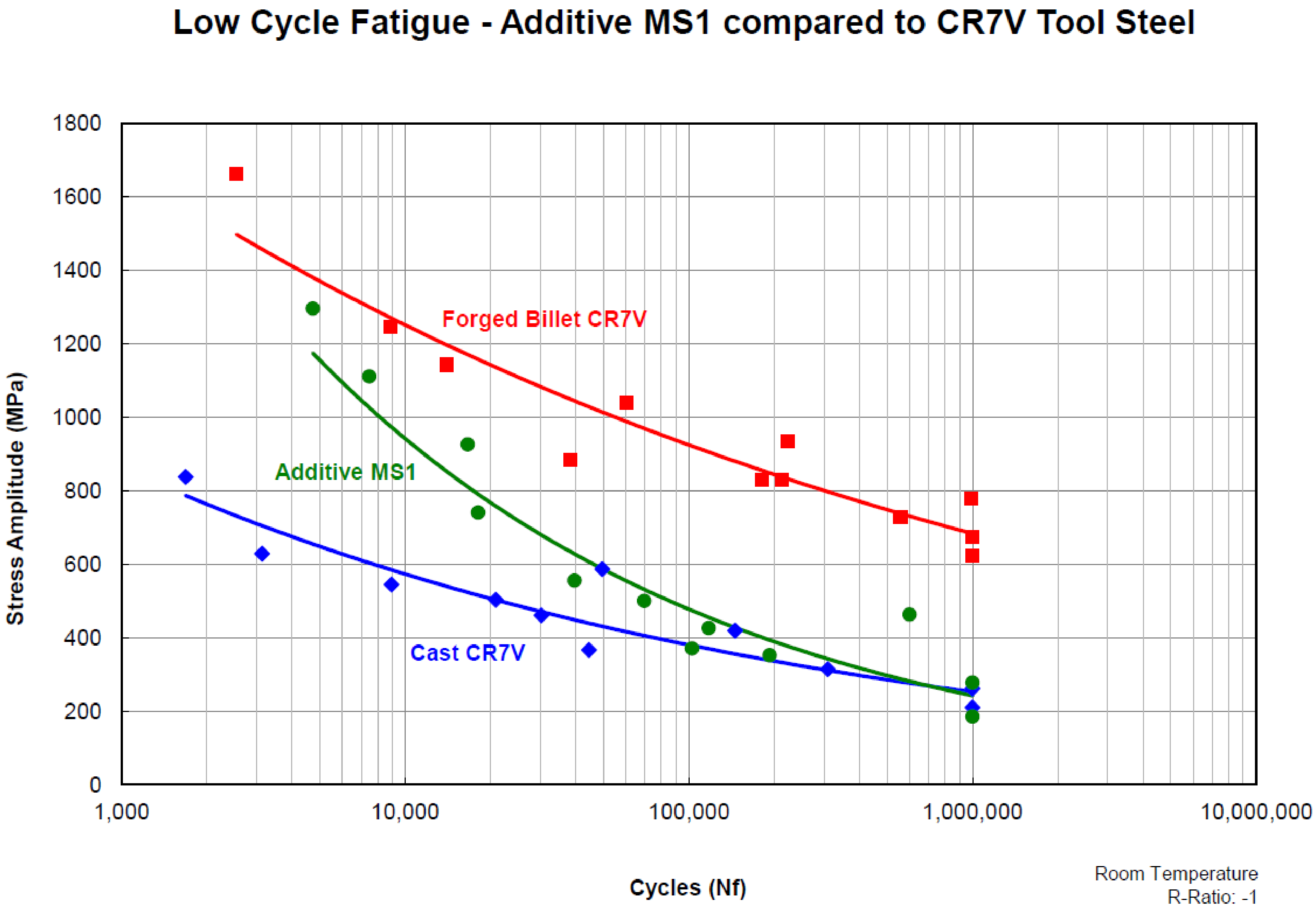
Range: 3.31 % to 5.25 %

Average: 4.25 %

Elastic Modulus:

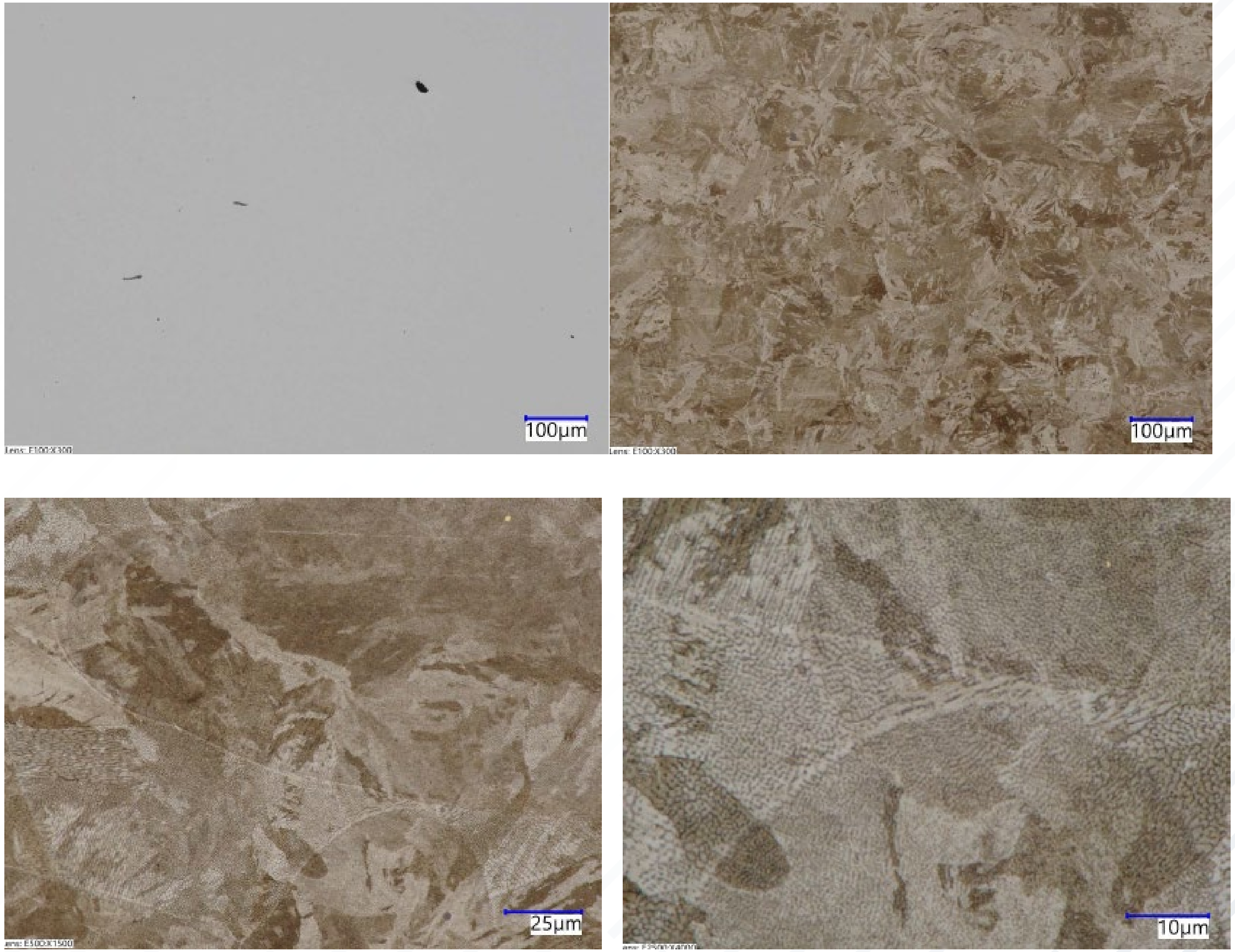
E = 185.2 GPa

FATIGUE RESULTS

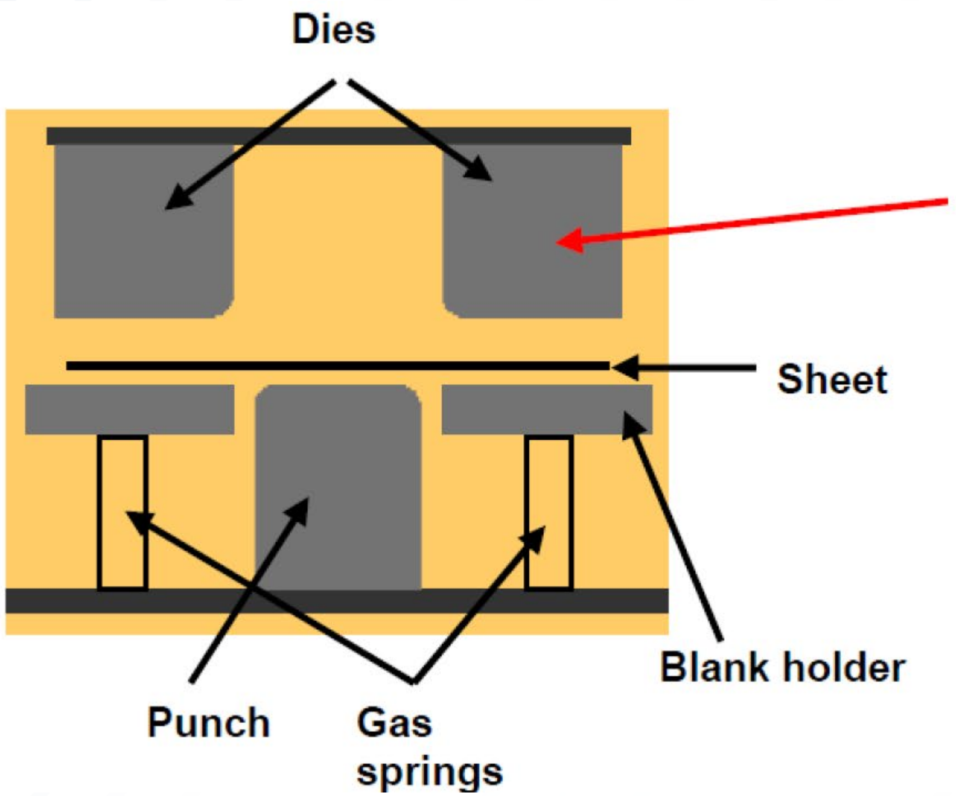


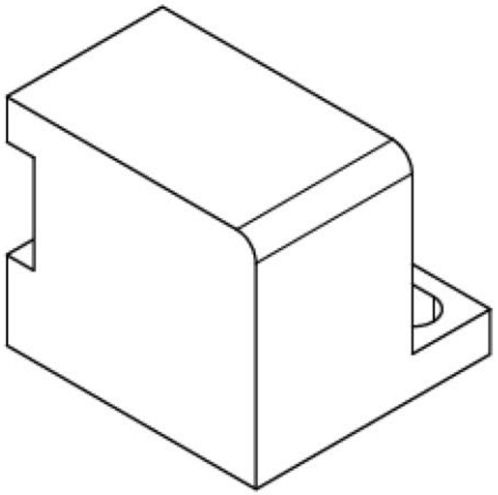
AM MICROSTRUCTURE

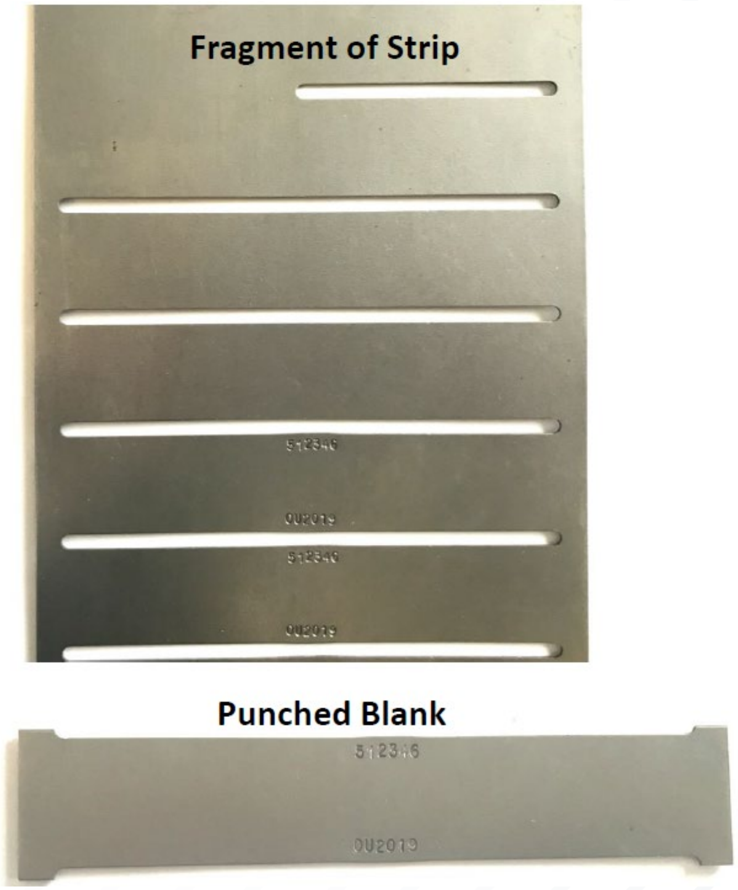
- Maraging steel exhibits tempered martensitic microstructure
- Small amounts of porosity and non-metallic inclusions
- Further details can be provided



STAMPING TRIALS



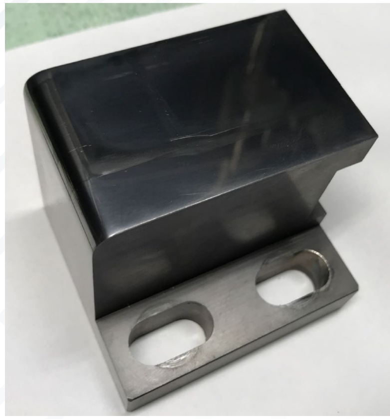




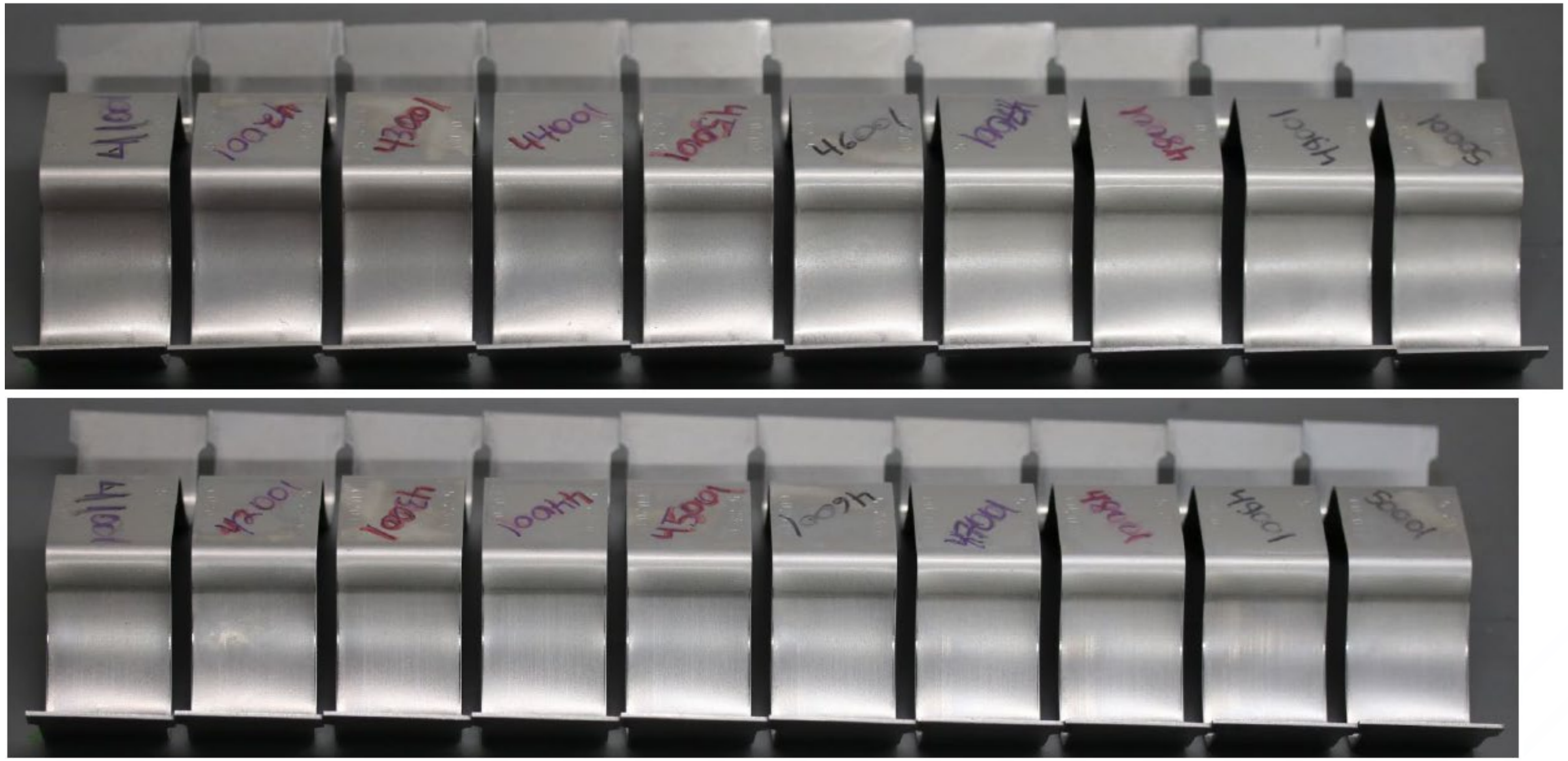
Significant springback:
DP980 1 mm thick

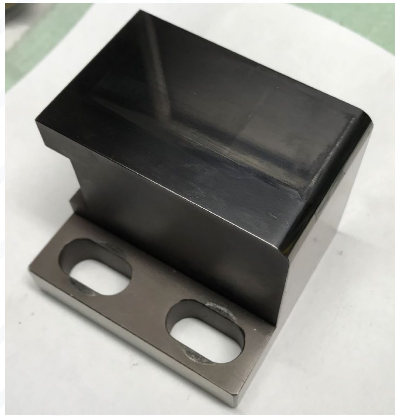
STAMPING TRIAL - RESULTS

Additive



41001-50000 cycles





D2 Tool Steel

- AM quality remained consistent throughout the test, with no indication of flow lines
- D2 exhibited gradual increase in shallow, hair-like flow lines, throughout the test
- Overall, qualitative surface quality on coupons was acceptable from both inserts

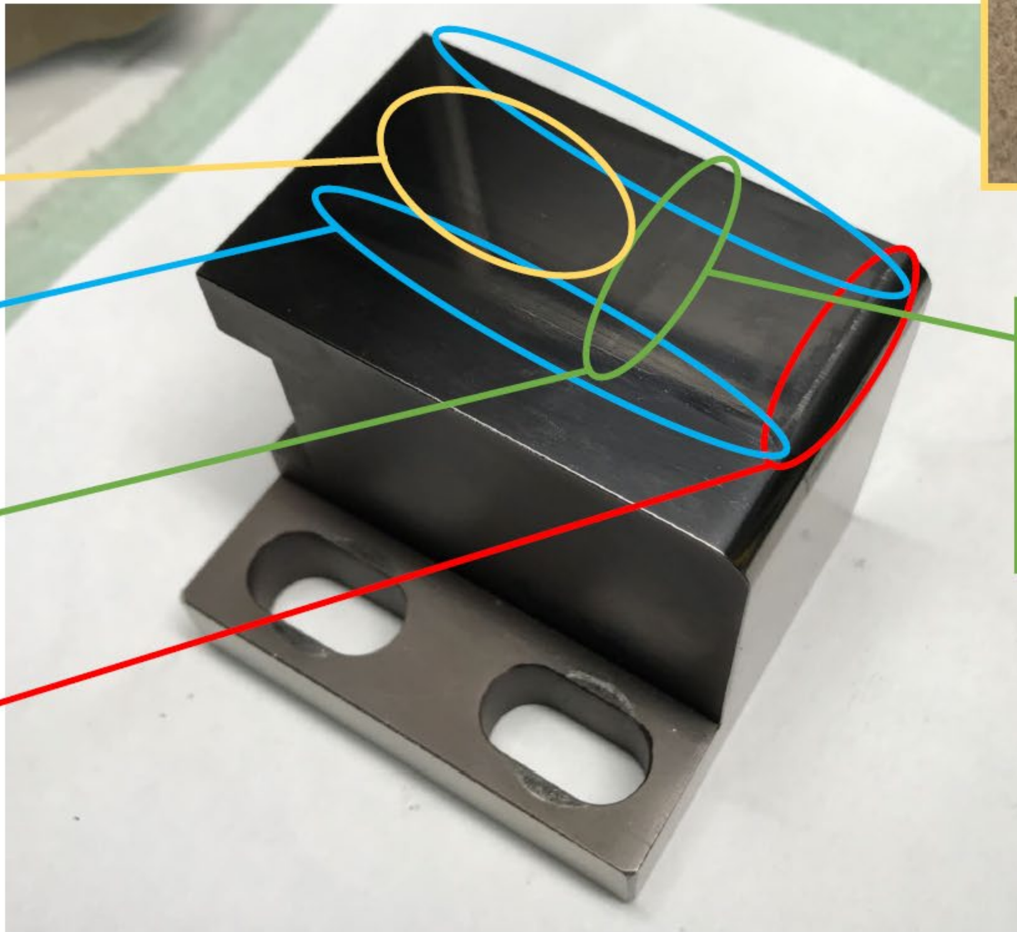
STAMPING TRIAL - RESULTS

Zone A: general wear zone (scratches from particles that are trapped between sheet and insert)

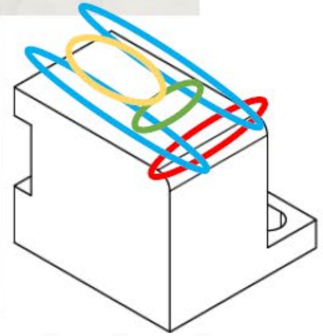
Zone B: wear from contact with the sheet edge on one of the sides

Zone C: wear from contact with the sheet edge on the end

Zone D: wear close to the radius in high contact pressure zone



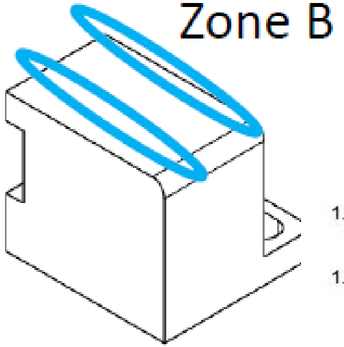
particles wiped from an insert

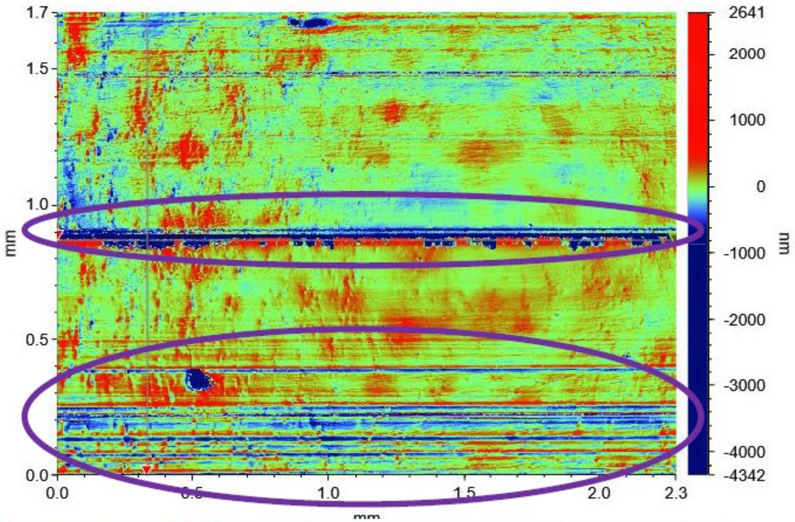


PROFILOMETRY

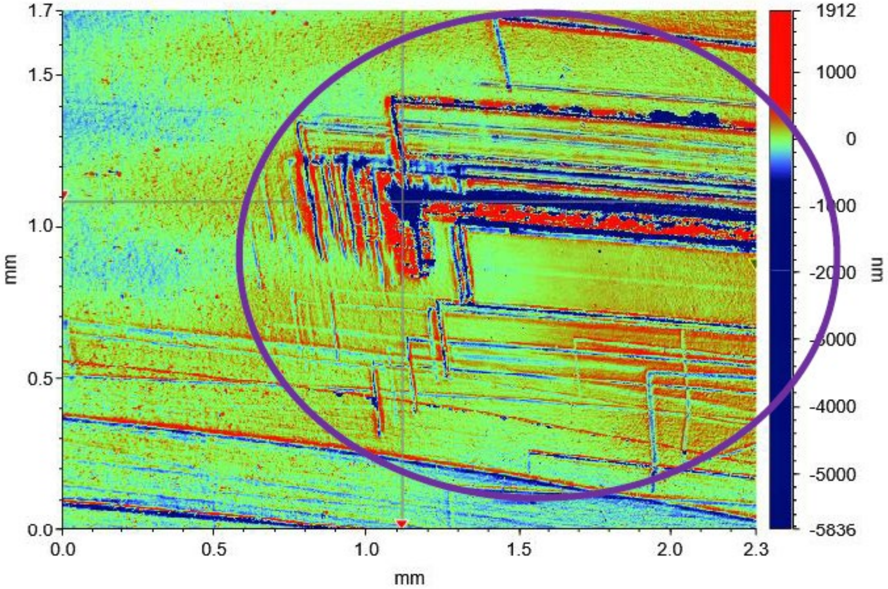
50k cycles

- Scratches in the edges of the blank
  - Mostly similar between AM and D2 materials





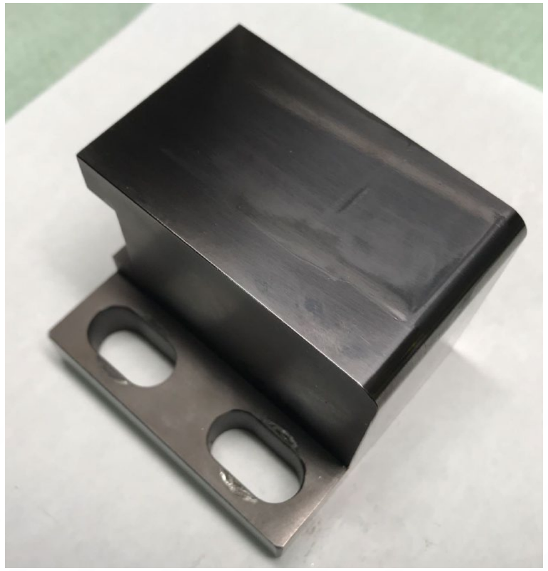
D2



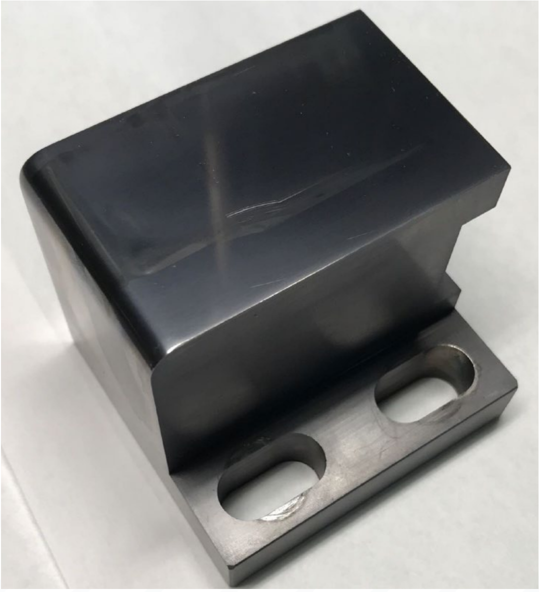
AM

SUMMARY OF PROFILOMETRY RESULTS

- AM insert exhibits deeper and wider scratches in the general contact zone but produced samples of better surface finish than the D2 inserts and less degradation in the forming surface of the insert
- D2 insert shows more wear in the forming surface near the radius of the insert. Less wear was exhibited in the general contact zone.
- No scratches of critical concern were exhibited in either of the samples



D2



AM

DISCUSSION

Advantages:

- AM can enable reduced lead times compared to conventional manufacturing, in some cases
- AM can enable unique conformal heating/cooling designs that can improve quality and cycle time for applications such as hot stamping

Disadvantages:

- The AM process is relatively slow, and therefore difficult to create a large number of components
- This relatively slow process, in addition to expensive capital equipment, leads to higher costs than conventional manufacturing, typically
- There has been relatively less focus on material development specifically for tooling applications, therefore few options exist for tool material selection, in some cases creating sub-optimal material choices

SUMMARY

- Based on the results of this study, AM tool steel materials can be considered for future stamping applications
- Considerations should be made for the build orientation when designing and building additive inserts

FOR MORE INFORMATION

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More Questions? Meet Paul at the Auto/Steel Partnership booth after this presentation.

A/S P Auto/Steel Partnership