Influence of Laser Line on Strain Path during Forming of Tailor Welded Blanks

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Project Team

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Outline

Introduction

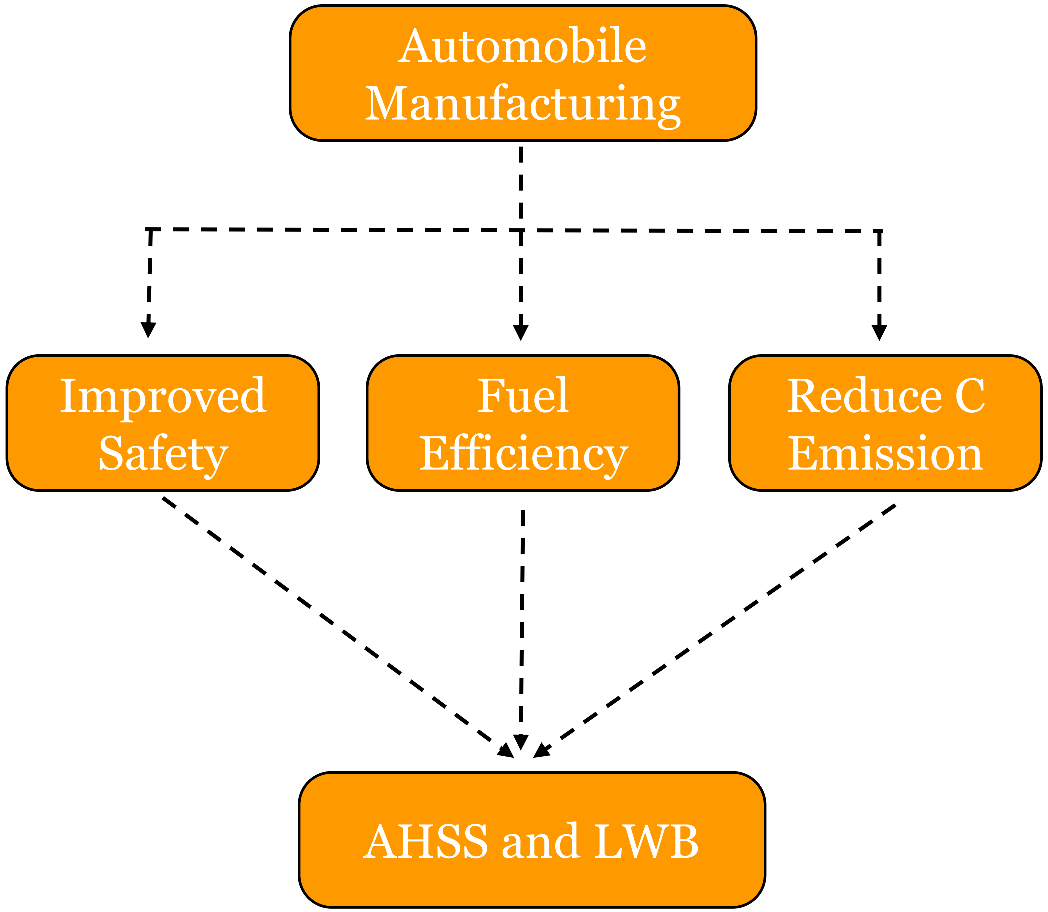
Methodology

Welding Properties

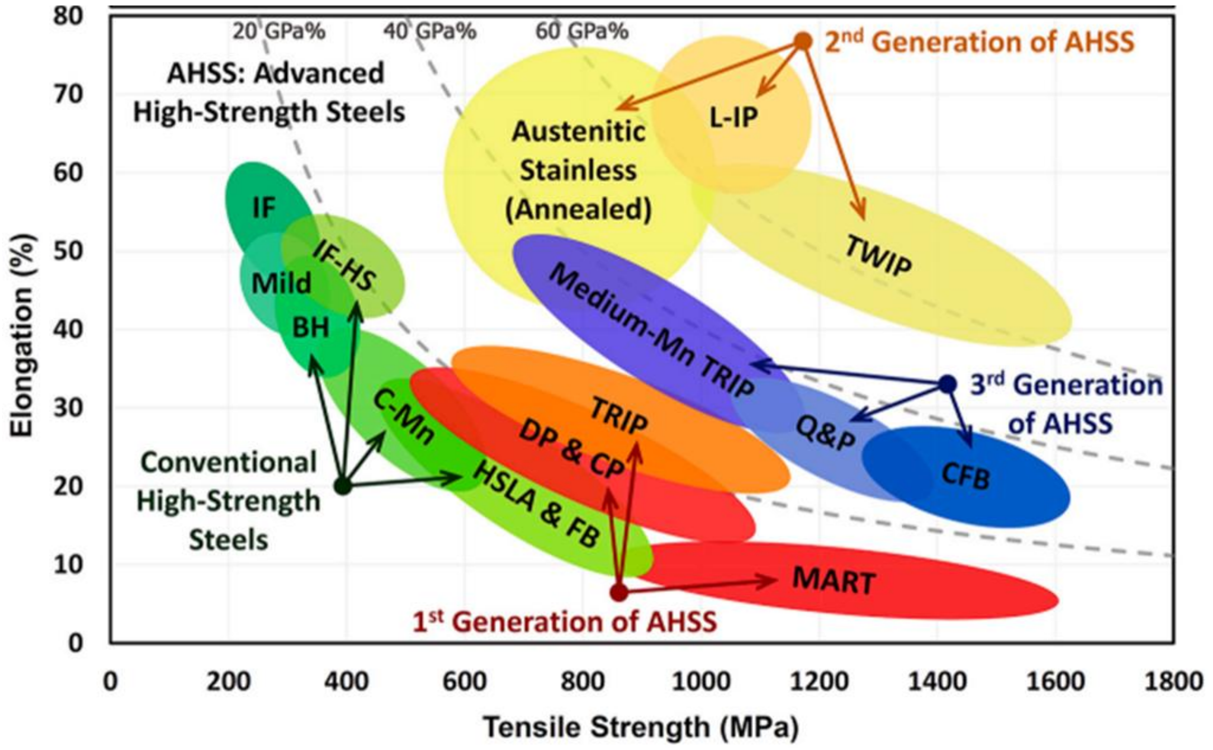
Forming Behavior

Conclusion

Changes in Automotive Construction



Steel strength ductility diagram (banana diagram)

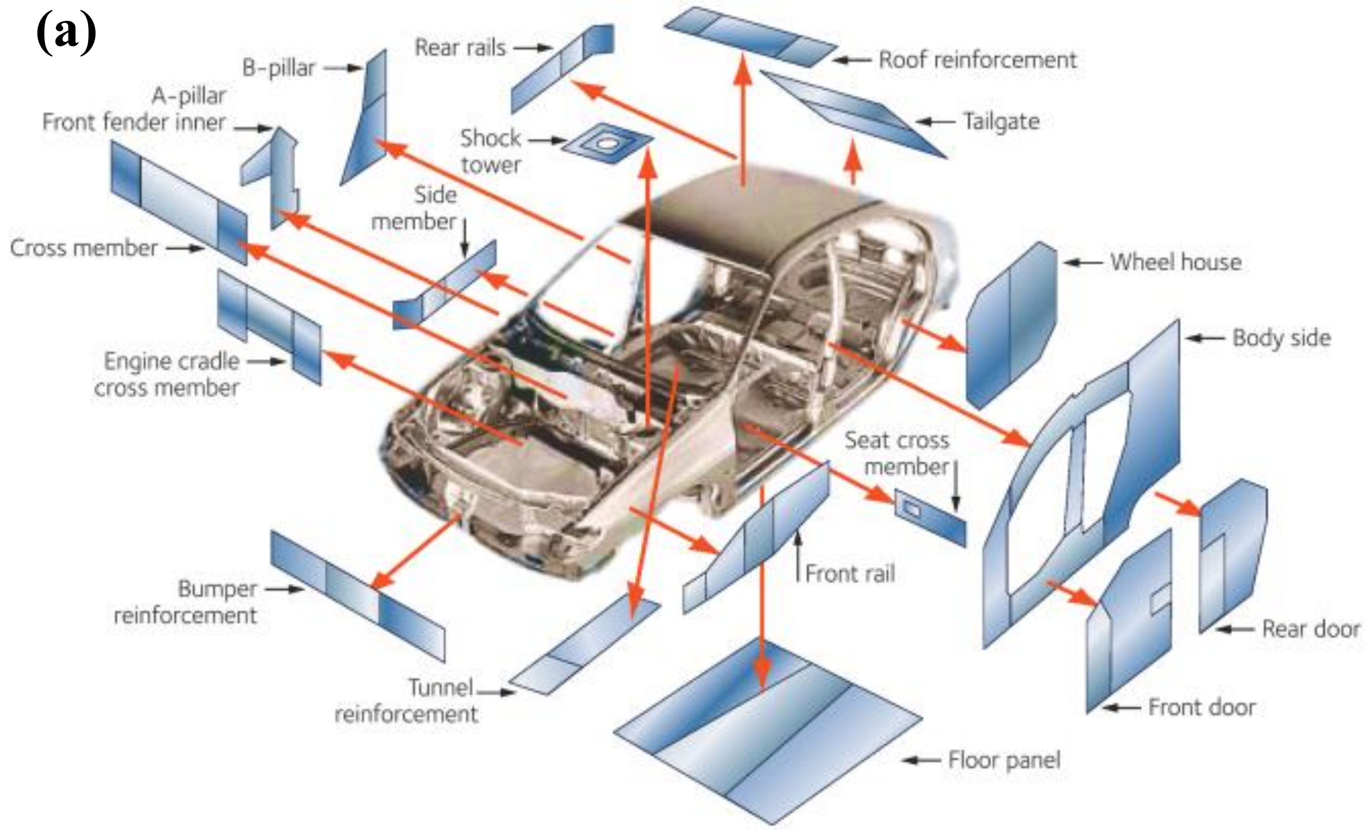


2017_Lesch_Advanced high strength steels (AHSS) for automotive applications
2023_Khan_A review on heat affected zone softening of dual-phase steels during laser welding

Tailor Welded Blanks

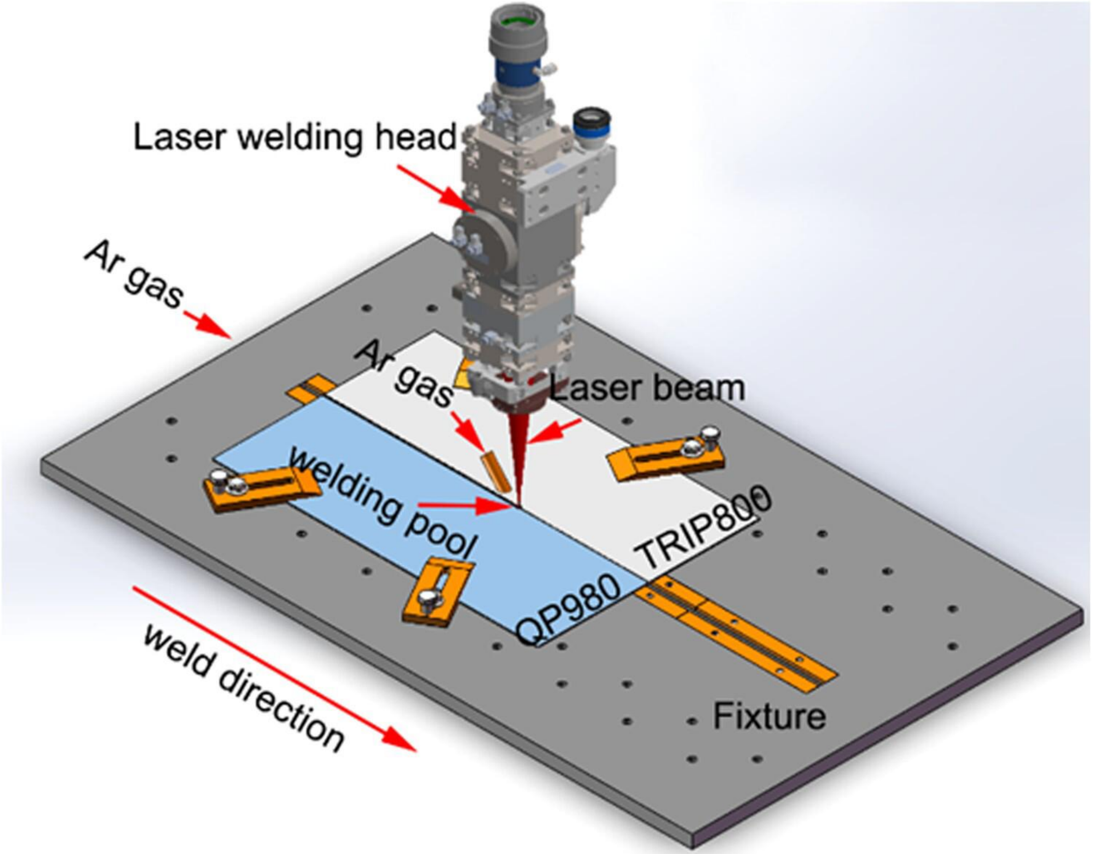
Examples of vehicle components manufactured using laser welded blanks (LWBs)

(a)



2023_Öztürk _Investigation of mechanical properties of laser welded dual-phase steels at macro and micro levels

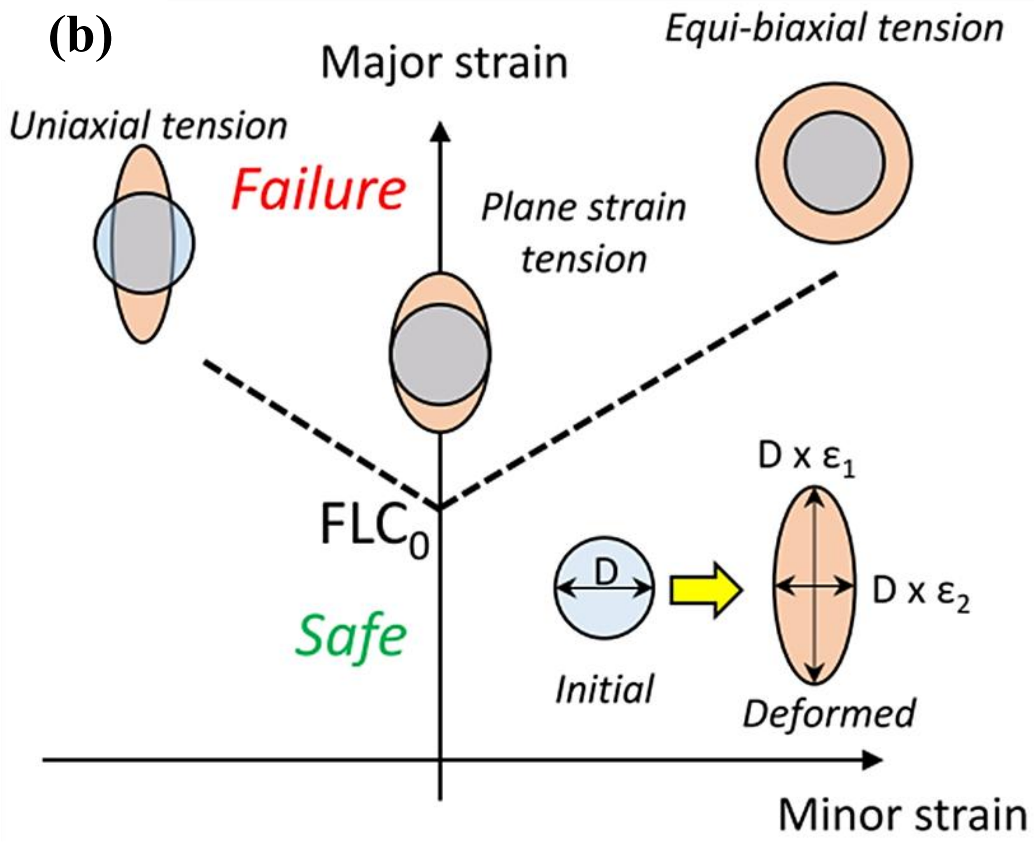
Laser welding (LW) setups without a filer wire



2021_Guo _Investigation on microstructure and properties of dissimilar joint between TRIP800 and QP980 fabricated by laser welding

Monolithic Material Formability

(b)



➢ **Nakazima or Marciniak tests (standard):**

Forming limit curves composed of limit strains of materials deformed under uniaxial, plane and biaxial tension states at acute necking or prior to fracture

(a)

2019_Noder_A comparative investigation into the influence of the constitutive model on the prediction of in-plane formability for Nakazima and Marciniak tests
2022_Noder_Plastic Instability and Failure of Sheet Metals Subjected to Complex Stress States
2014_Jasinski _Application of laser speckles to localized necking and cracking detection in Erichsen cupping test

Development of Local Weld Properties

Laser Welding Parameters

Welding speed
- Low welding speed leads to parent material burn-through
- Very high welding speed leads to expulsion and partially penetrated weld

Laser output power
- Insufficient power leads to partially penetrated weld
- Excessive power leads to parent material burn-through

Beam tilting angle
- 5 to 10° for steels; greater than 10° for Aluminum to maximum material energy absorption

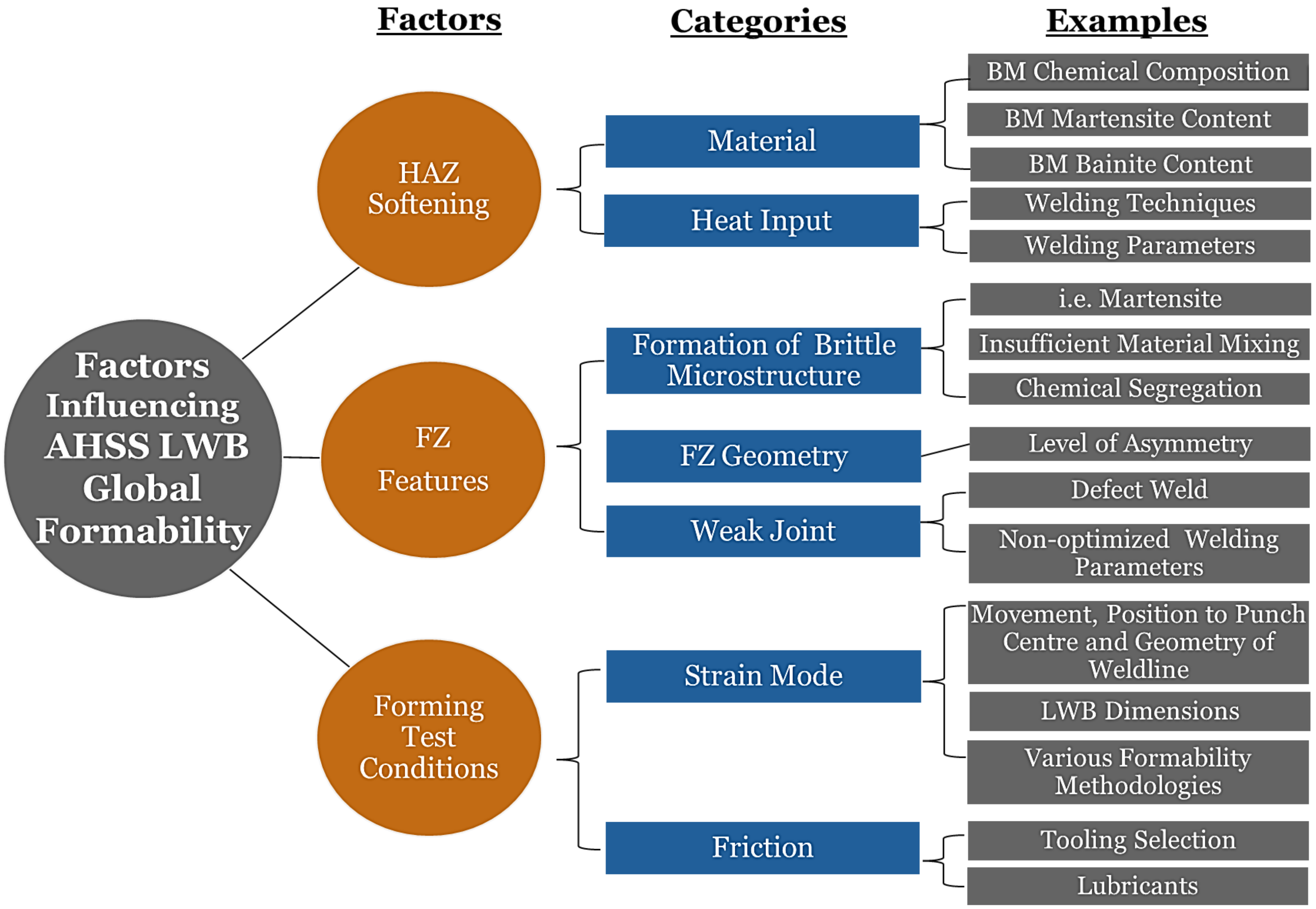
Weld Characteristics

Weld Dimensions
- Fusion zone geometry
- HAZ width
- Surface weld appearance

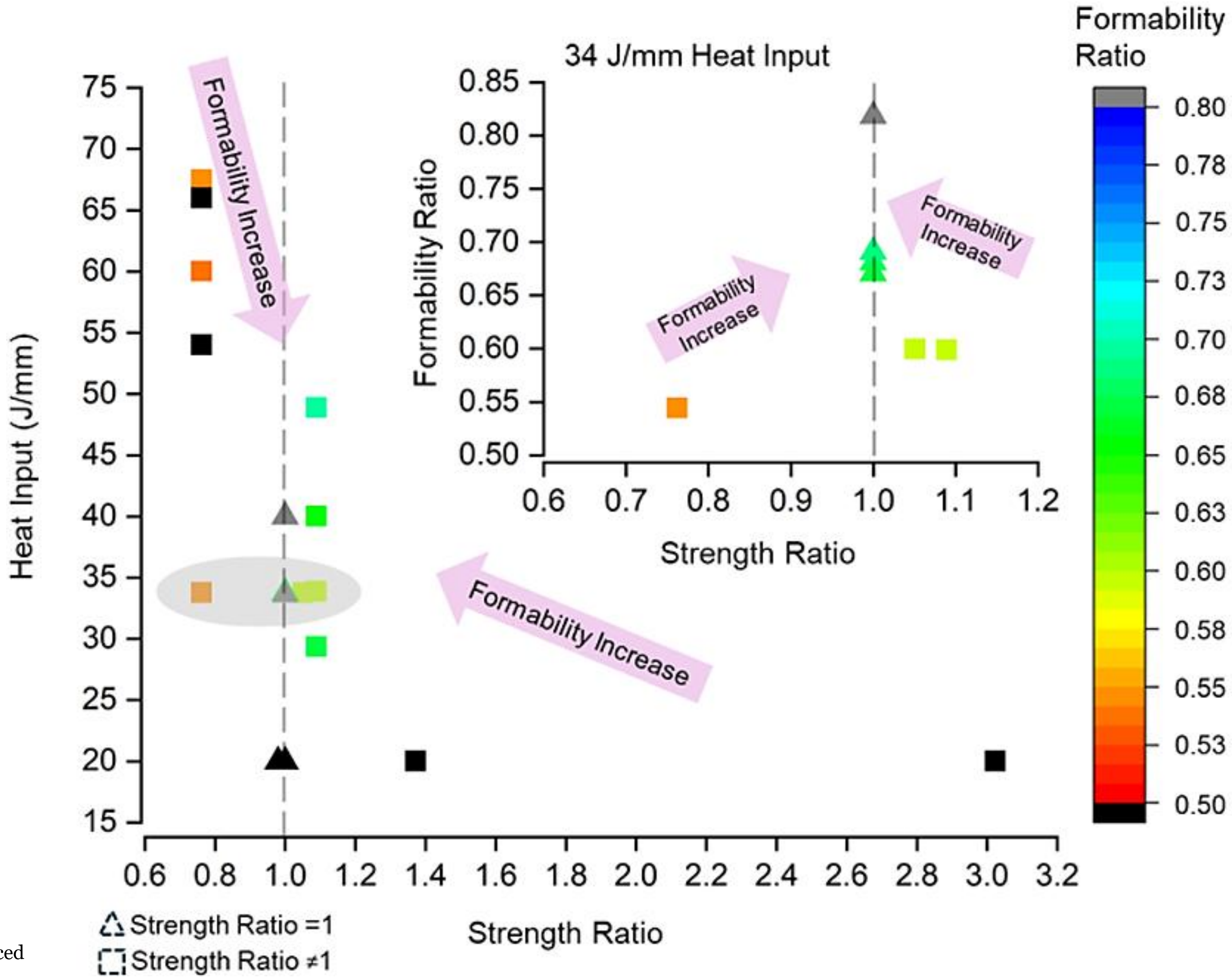
Microstructural & Mechanical Properties
- Hardness profile
- Microstructural characteristics
- Forming behavior: tensile properties, limit dome height and forming limit strain

Failure Tendencies
- Type of failures
- Failure locations
- Fracture surface characteristics

Laser Weld Influence on Formability



Past Results on Laser Blank Formability



2025_Song S, A review of forming behavior and influencing mechanisms in laser-welded advanced high-strength steels, Mater Sci Eng A

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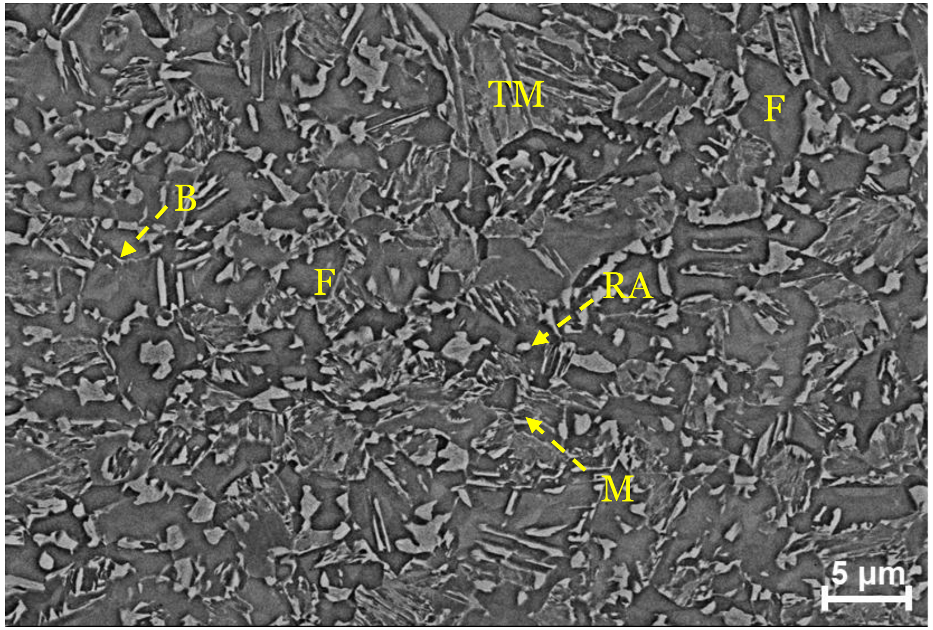
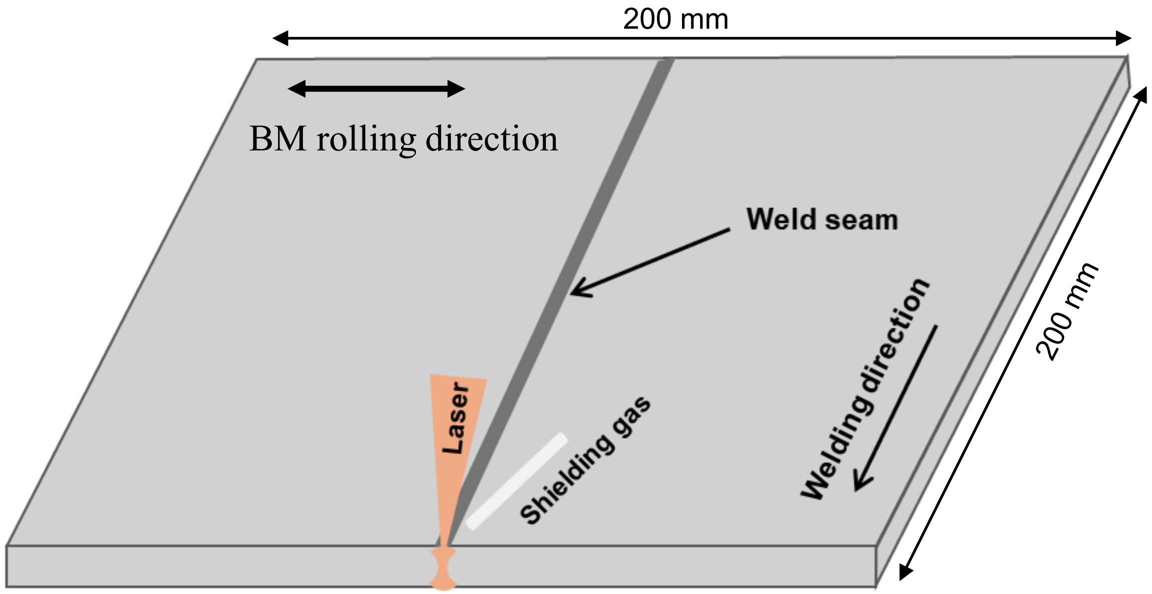
Objectives

How does the presence of the weld line impact the formability of the TWB?

METHODOLOGY

Material and Welding Methodology

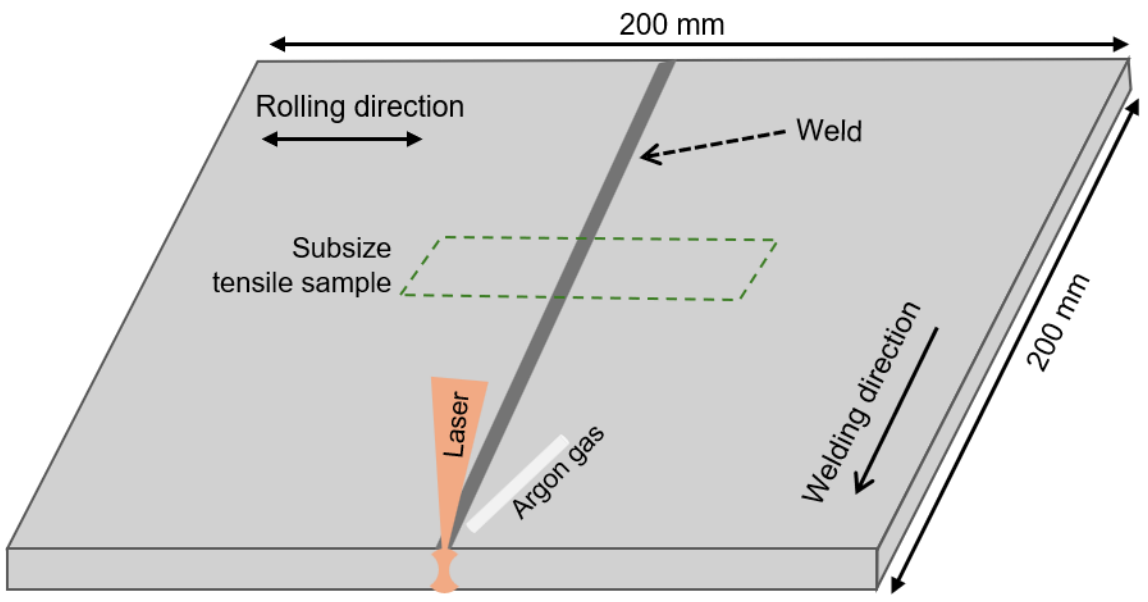


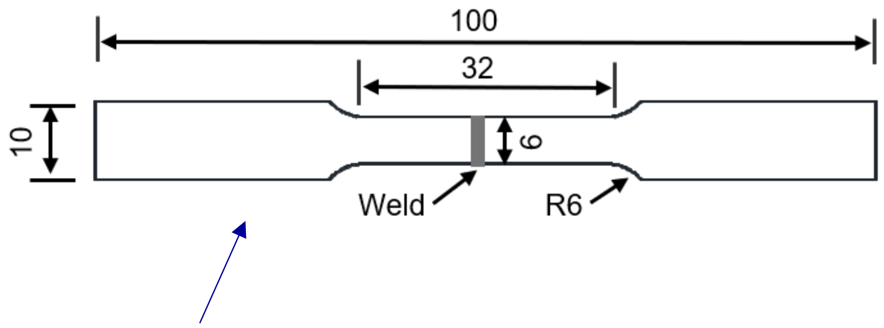


Grade	Thickness (mm)	Composition (Wt%)			
		C	Mn+ Si	Cr+ Mo	Nb+ V+Ti
3G-980 GI	1.65	0.22	3.5	0.05	0.007

Top Surface Spot Size (mm)	Power (kW)	Speed	Shielding
0.3 and 1.2	4.5	Varies	Ar

Tensile Testing Geometry



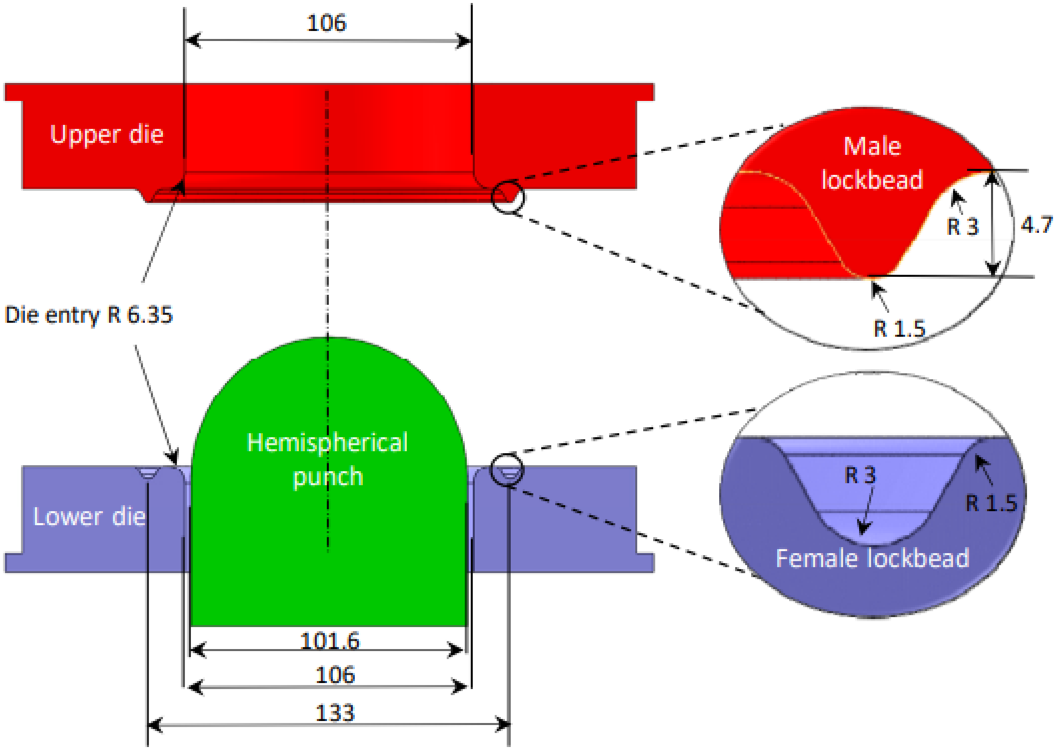


Subsize tensile coupon geometry

- The overall formability of LWBs under uniaxial stretching was evaluated using sub-size tensile specimens.

Forming Test Methodology

Nakazima test tooling



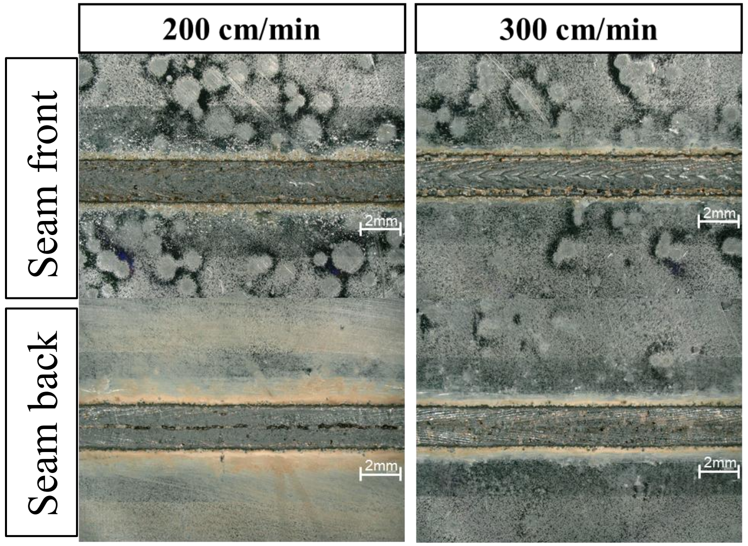
- ➢ The Nakazima dome test does not use a carrier blank but a hemispherical punch that deforms the material out-of-plane so that bending, tool contact and non-linear strain paths.

2019_Noder_A comparative investigation into the influence of the constitutive model on the prediction of in-plane formability for Nakazima and Marciniak tests

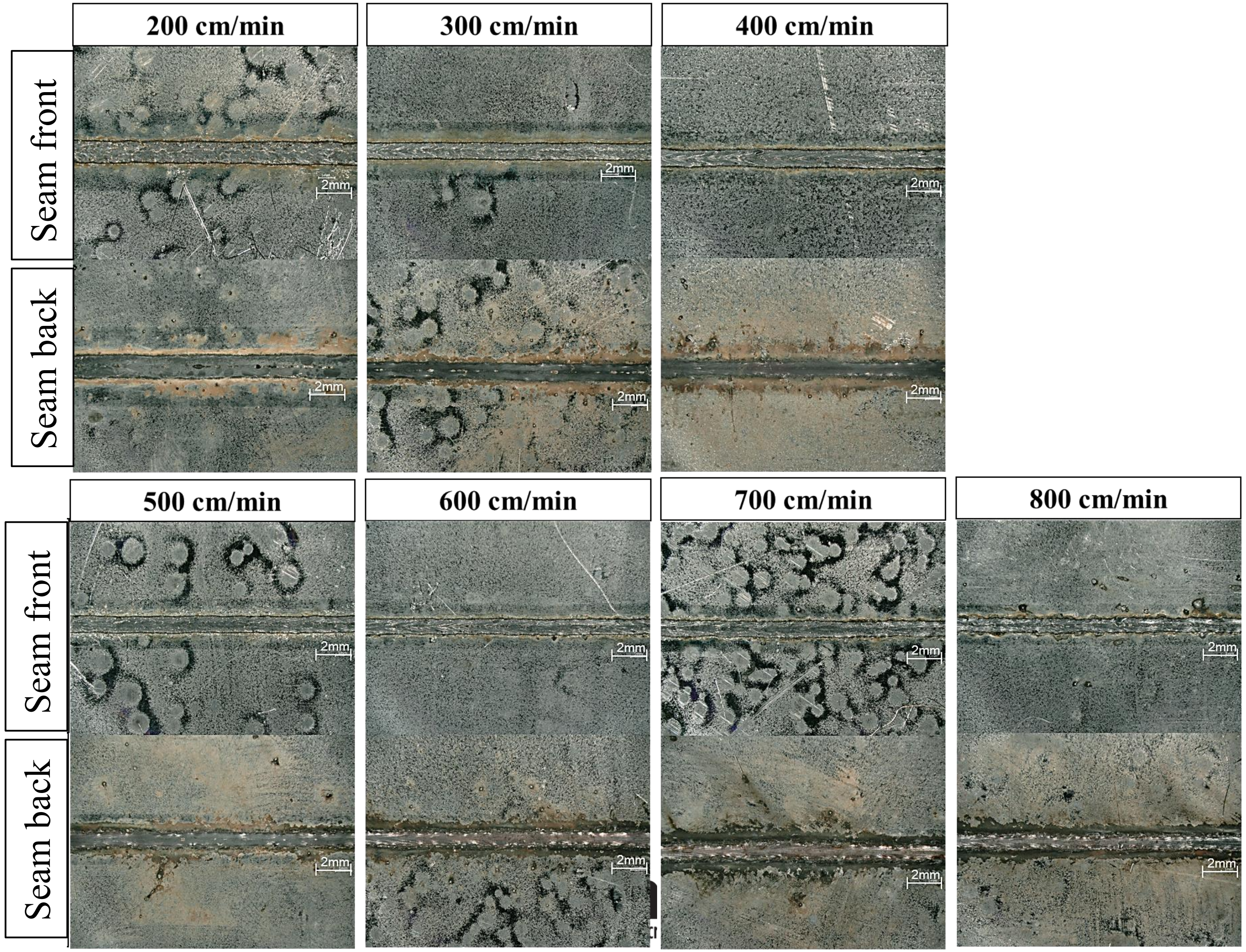
WELD PROPERTIES

Weld Appearance

T3 welds: 1.2 mm laser spot size

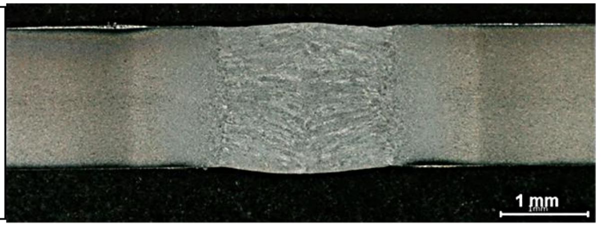


T1 welds: 0.3 mm laser spot size



Cross-Sections of Laser Welds

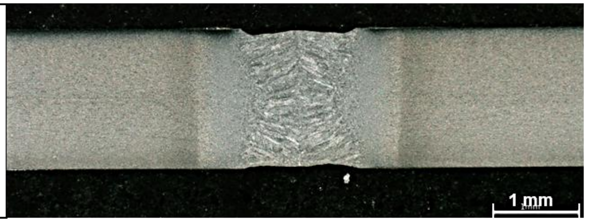
200 cm/min



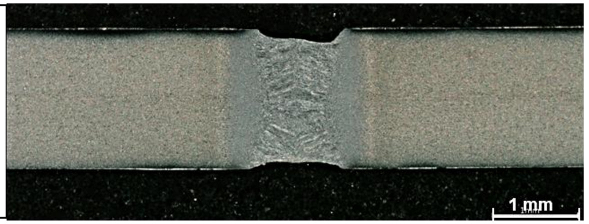
300 cm/min

T3 Welds

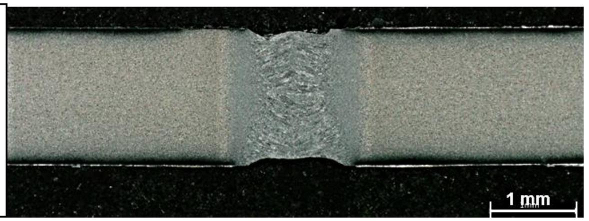
200 cm/min



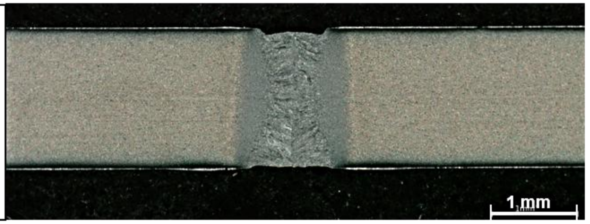
300 cm/min



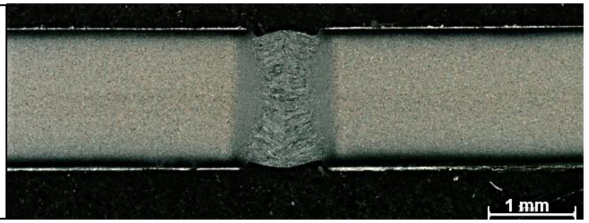
400 cm/min



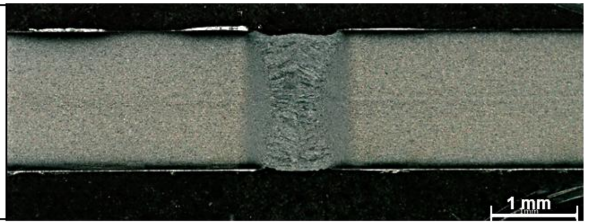
500 cm/min



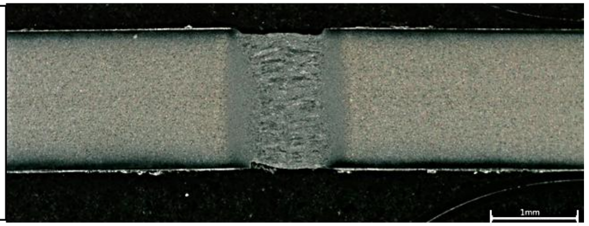
600 cm/min



700 cm/min

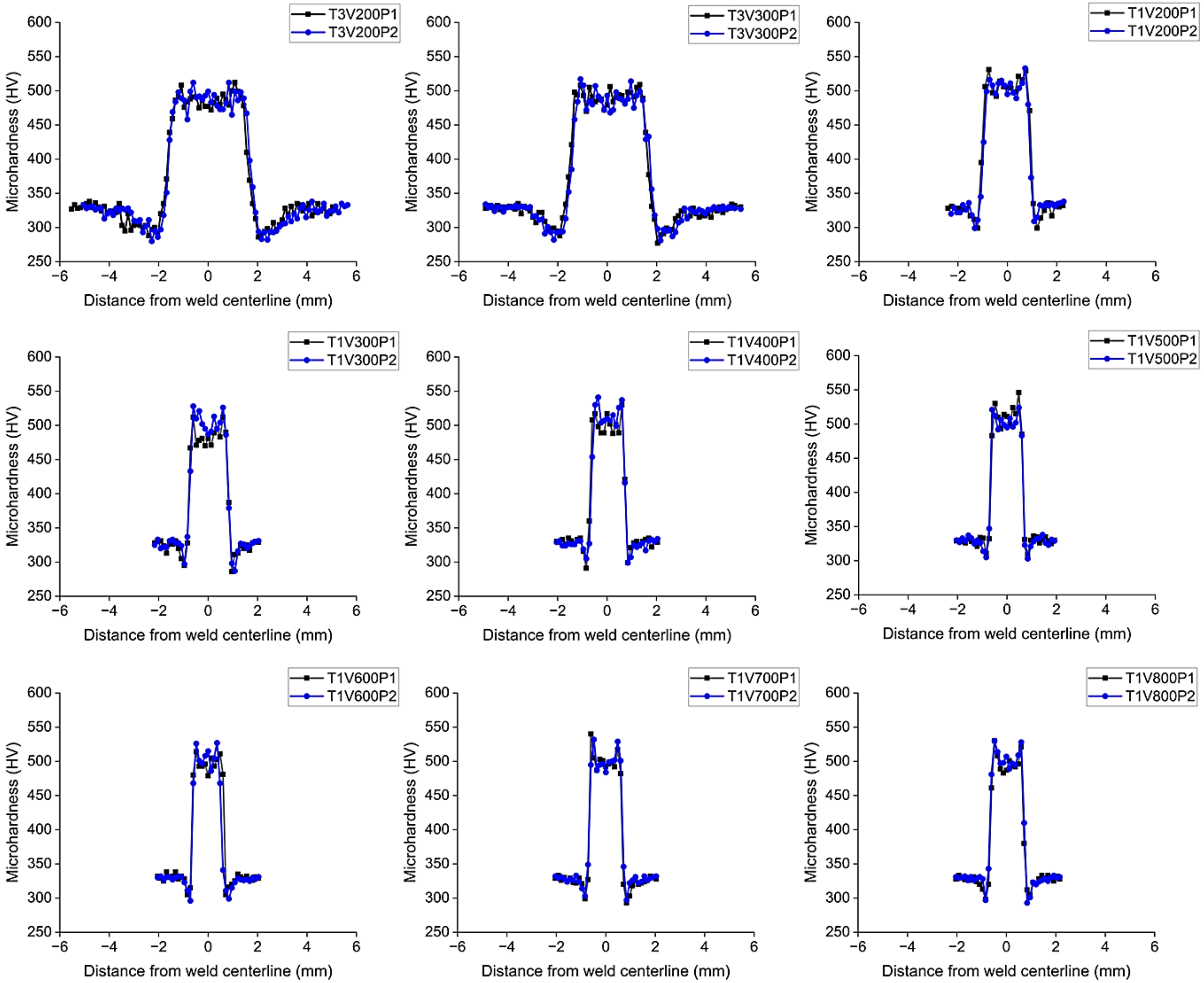


800 cm/min



T1 Welds

Weld Hardness



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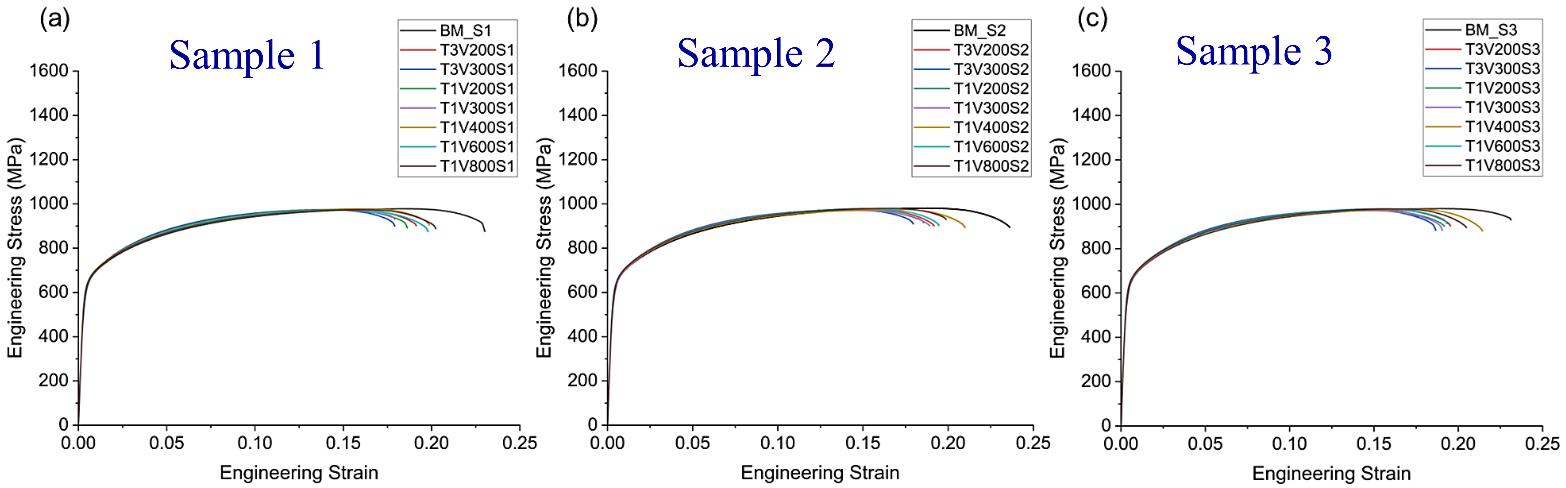
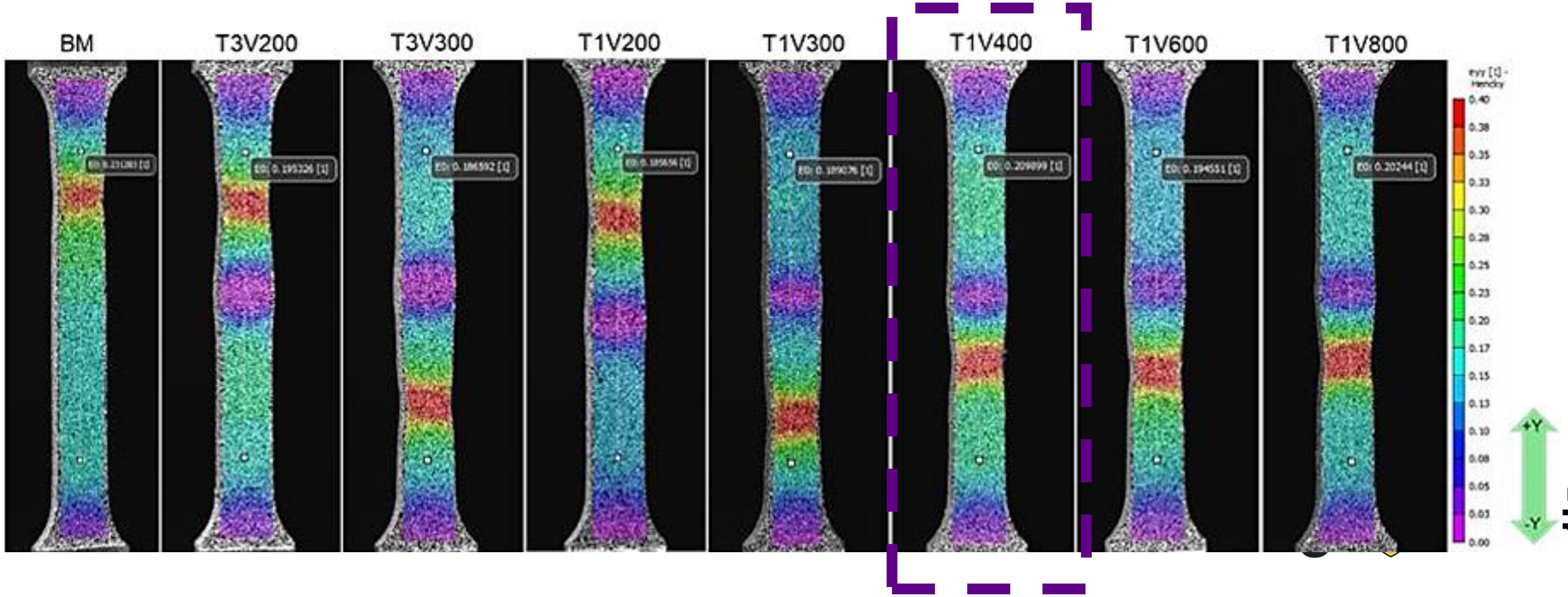
FORMING BEHAVIOUR

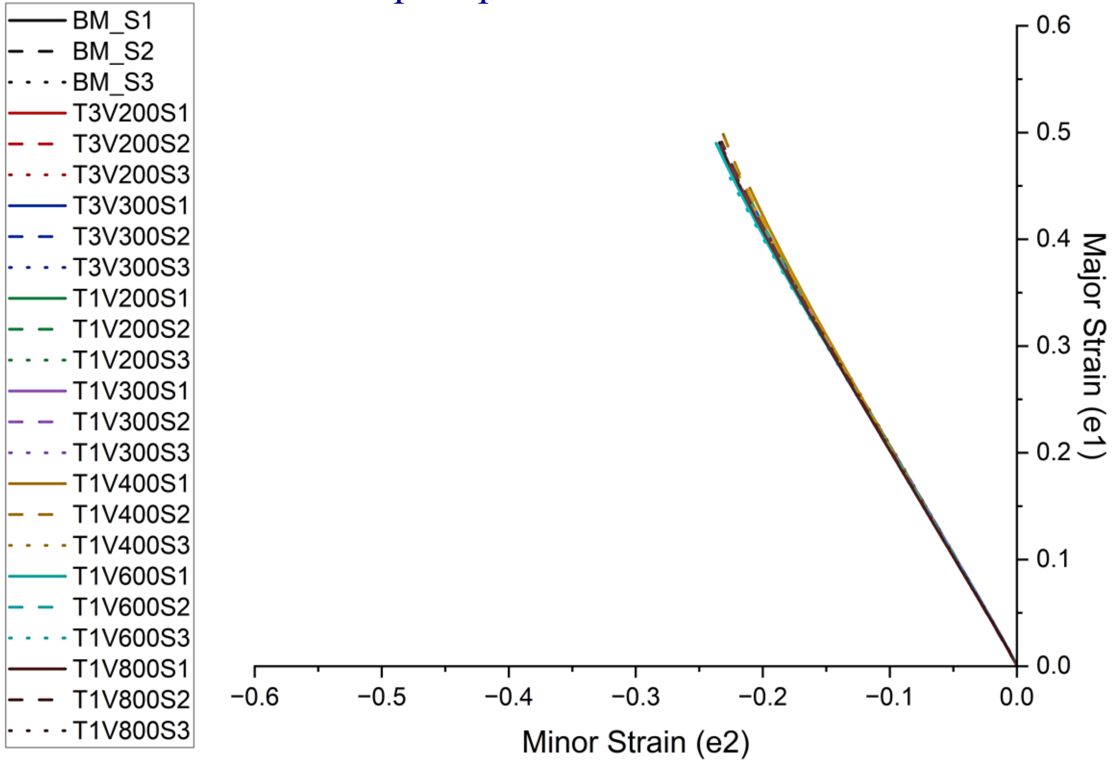
Tensile (Uniaxial Stretch) Behaviour of Welds



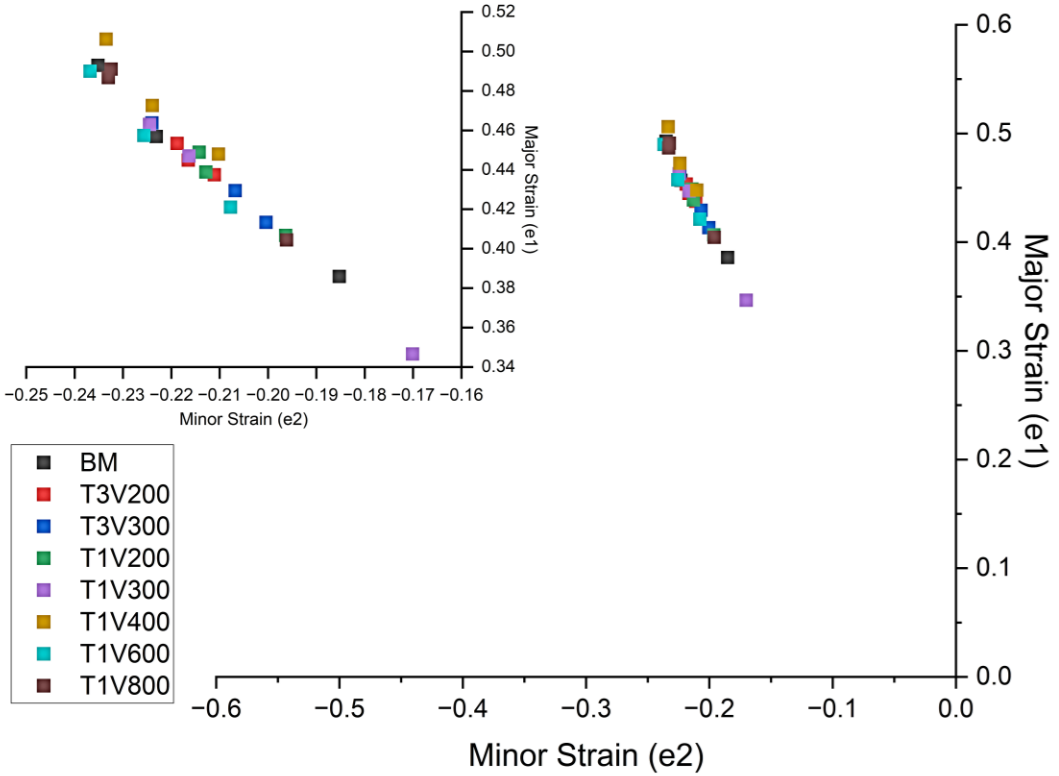


Strain Path of Welds Subjected to Tensile (Uniaxial) Strain

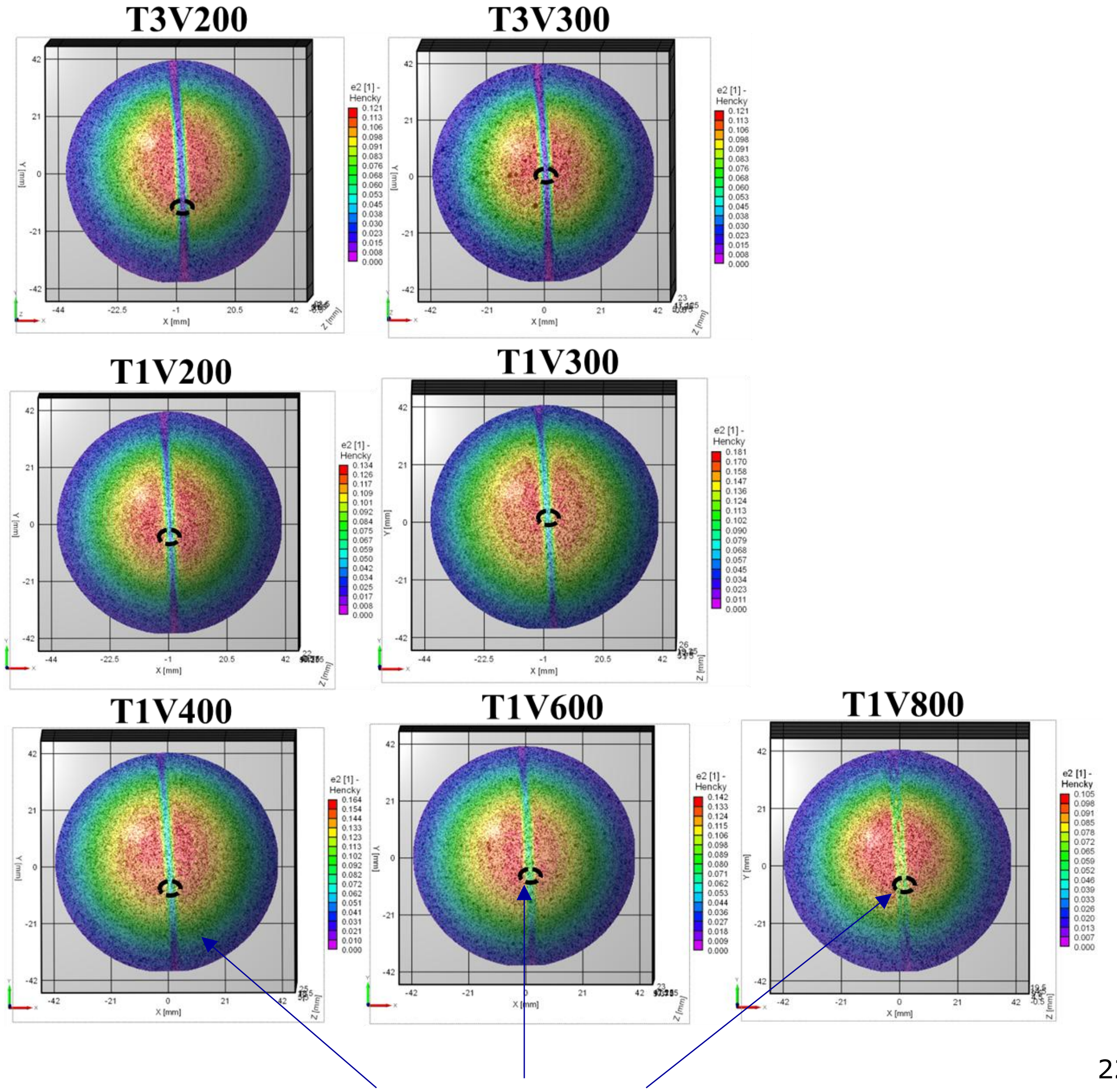
Stain path prior to fracture onset



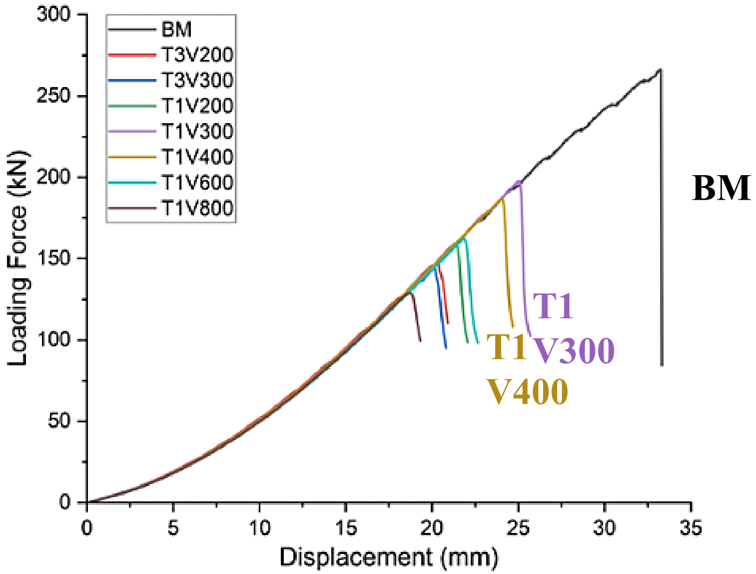
Strain values prior to fracture onset

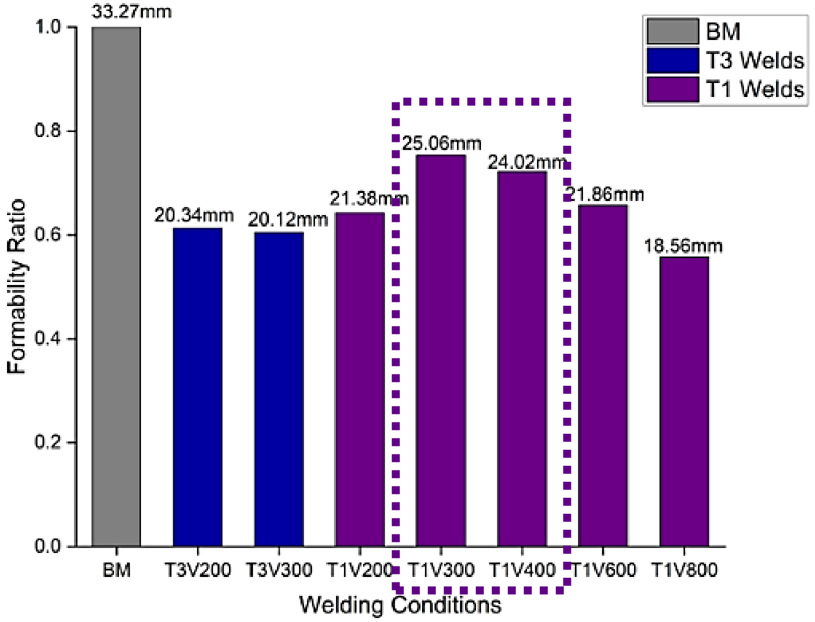


Formability of TWB in Biaxial Stretch



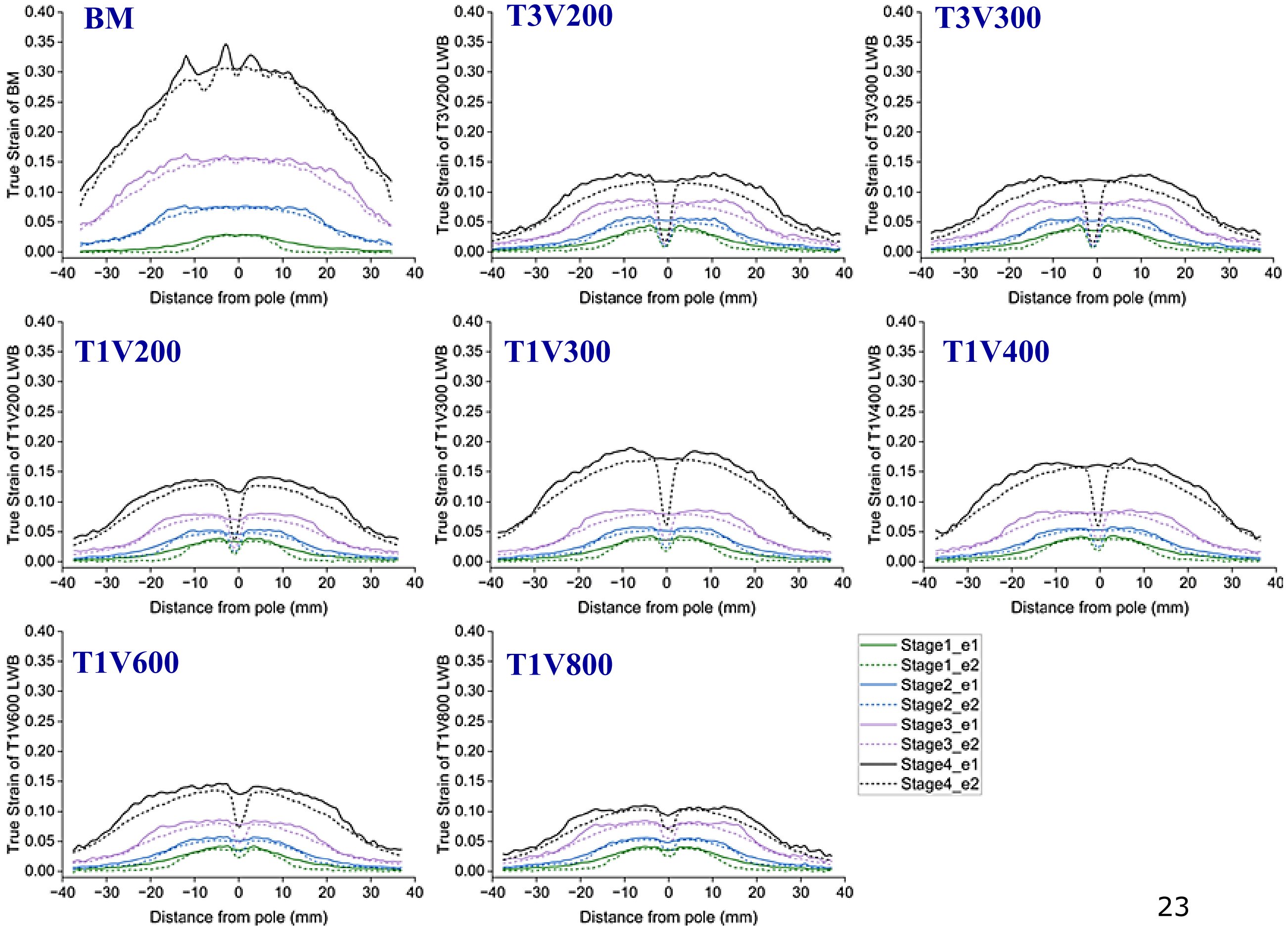
Fracture initiation location



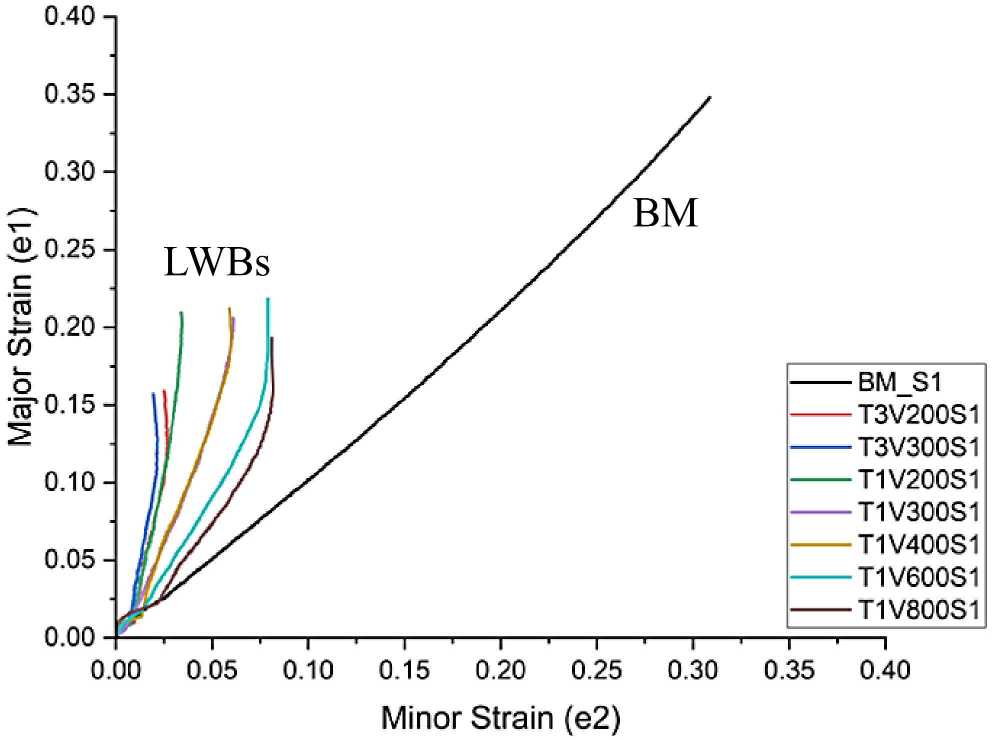


Strain Path During Biaxial Stretch

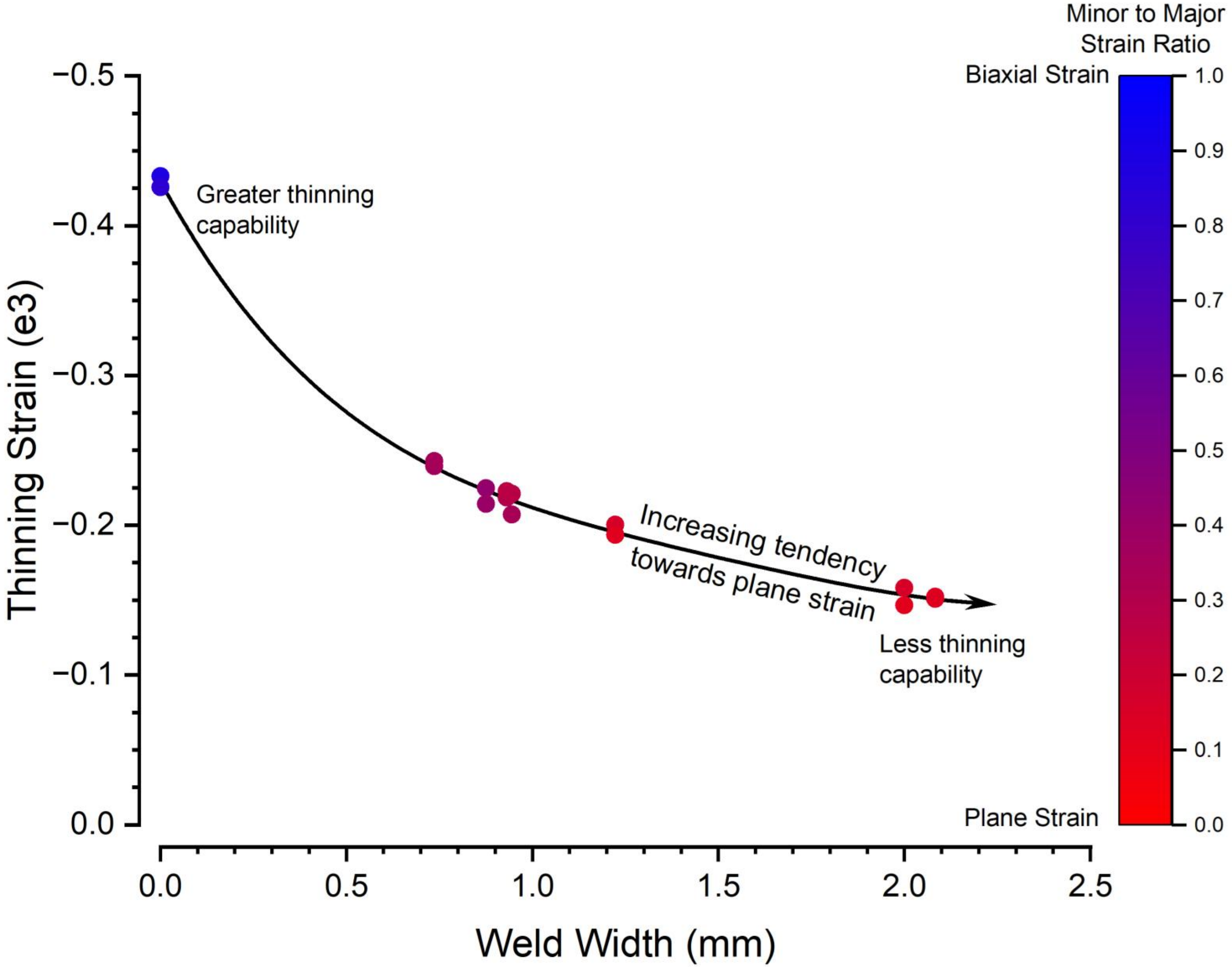
Local strain evolution along the pole and across the weld line over the entire deformation history



Strain path at fracture initiation site prior to cracking



Relation Between Weld Dimensions and Biaxial Formability



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CONCLUSIONS

Conclusions

- Although welds loaded in tension (uniaxial stretch) perpendicular to the weld line showed some (22%) decrease in total elongation there was almost no decrease in joint strength (0.6% drop in UTS) and no change in strain path at the failure location compared to the monolithic blank
  - All samples failed in the base material
- The weld in the TWB changed both the maximum dome height, and strain patch of blanks in formed in biaxial stretch when compared to the monolithic blank.
  - The maximum dome height decreased between 25%-44% compared to the monolithic blank, and strain path approach to the plane strain condition from the biaxial strain conditions
- During biaxial testing all samples failed in the fusion zone
- Weld formability increased as fusion zone width decreased. However, at very narrow fusion zone widths, geometric defects limited blank elongation
- As fusion zone width decreased, the strain path at the failure location because more biaxial and higher thinning strains were achieved

Acknowledgements

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Thank you for your attention!

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