

Assessing the Bendability of Ultra High Strength Steel (UHSS) in Plane Strain Conditions

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1. Abstract

Inconsistent behaviour and premature failure are common when bending UHSS. Practicality limits laboratory testing to smaller samples, which may not replicate the conditions of production, and larger volumes of material used in manufacturing may increase the likelihood that material inhomogeneities will cause failure.

A rig was developed, capable of replicating the size and scale of production. Tests have been undertaken on a grade of UHSS (S960MC) at 5 forming radius/thickness ratios with strains measured using digital image techniques. Results show that punch separation occurs on specimens that ultimately fail, causing bend severity to increase unexpectedly. Separation occurs more frequently when the bend line is parallel to the rolling direction. Upcoming investigations will focus on behaviour at this deviation point to try and better understand this separation.

2. Experimental Setup

Bendability is assessed using a custom bending rig designed for the 1000kN press located in the WMMG IMC.

The new bending rig is capable of bending high strength material with a maximum bend length of 400mm.

Directly Measured Parameters:

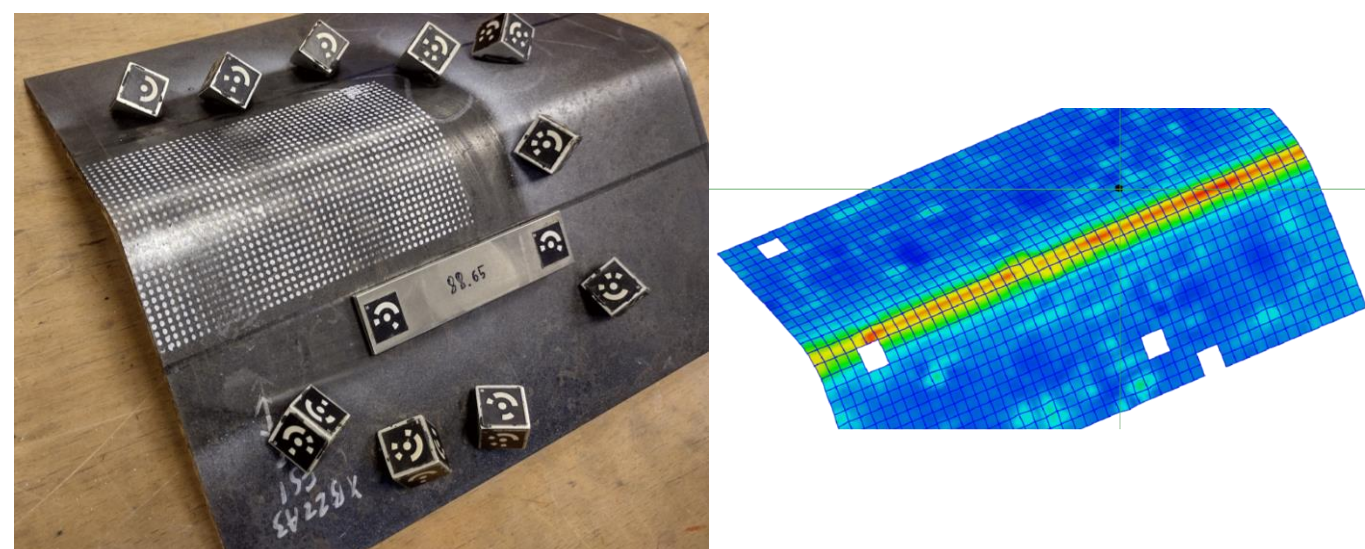
- Force – Displacement
- Edge strain throughout test using Digital Image Correlation (DIC)
- Bulk strain after testing using Circle Grid Analysis (CGA)

Test Variables

- Sheet Thickness (4-6mm)
- Punch Radius (15-25mm)
- Sheet Orientation in regards to rolling direction



Left: View from DIC equipment. Right: Painted sheet and punch for analysis



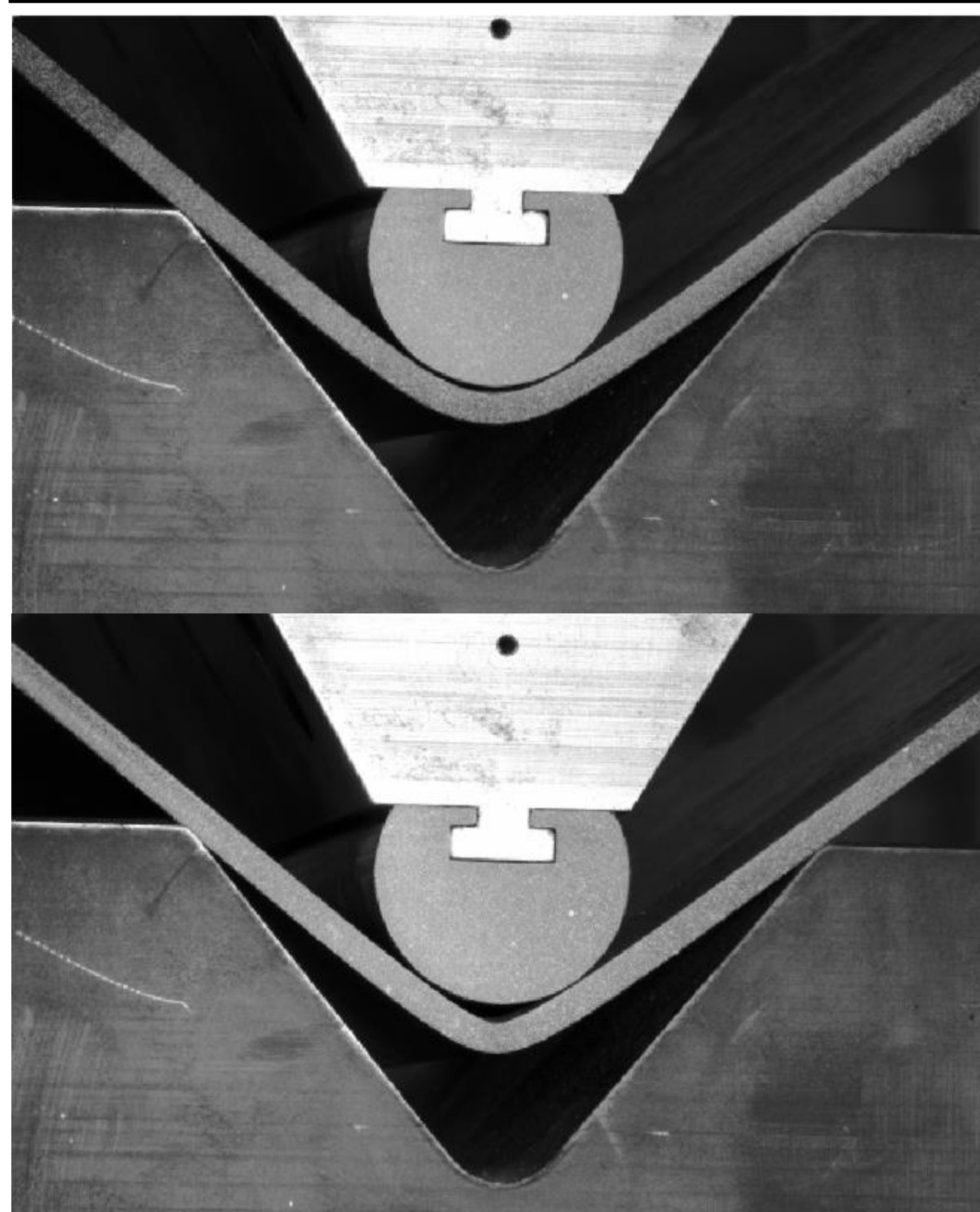
Left: CGA setup with position markers. Right: Generated grid from CGA

Strains measured on the outside edge (in Plane Stress) are compared to the bulk strain as measured using the CGA method. As the bending die is used, DIC equipment cannot be used to measure bulk strains during the test.

3. Results

Punch-sheet separation was a common occurrence during bending, and occurred more frequently when the bend was parallel to the rolling direction.

Separation is the cause of geometric inaccuracies in the finished part and leads to premature material failure due to rapid strain development.

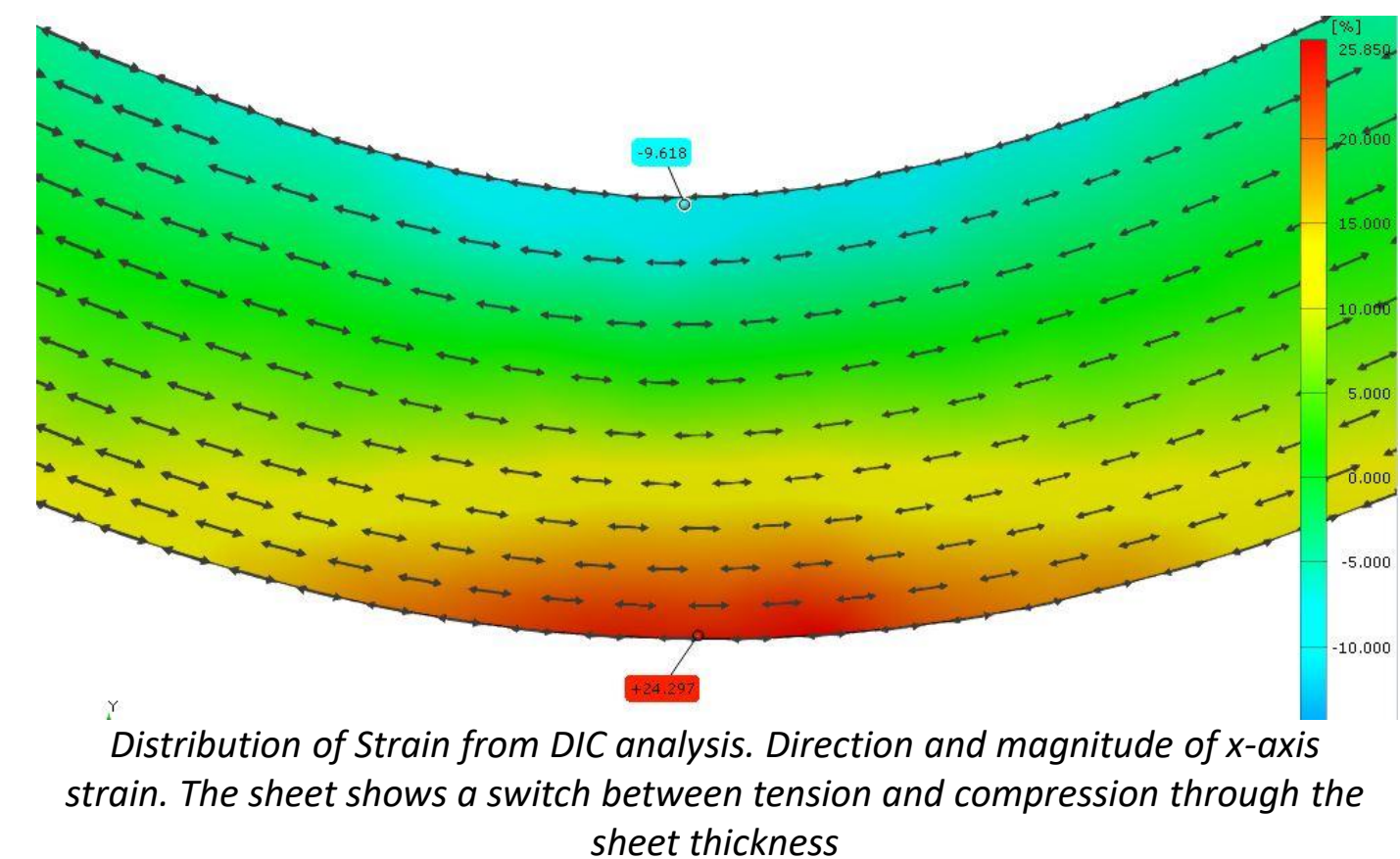


TOP: Sheet not separating from the punch during the bending test – ideal scenario. R20 Punch – 5mm sheet.

BOTTOM: Sheet separating from the punch during the bending test – causing increased strain and geometric inaccuracies. R20 Punch – 5mm Sheet.

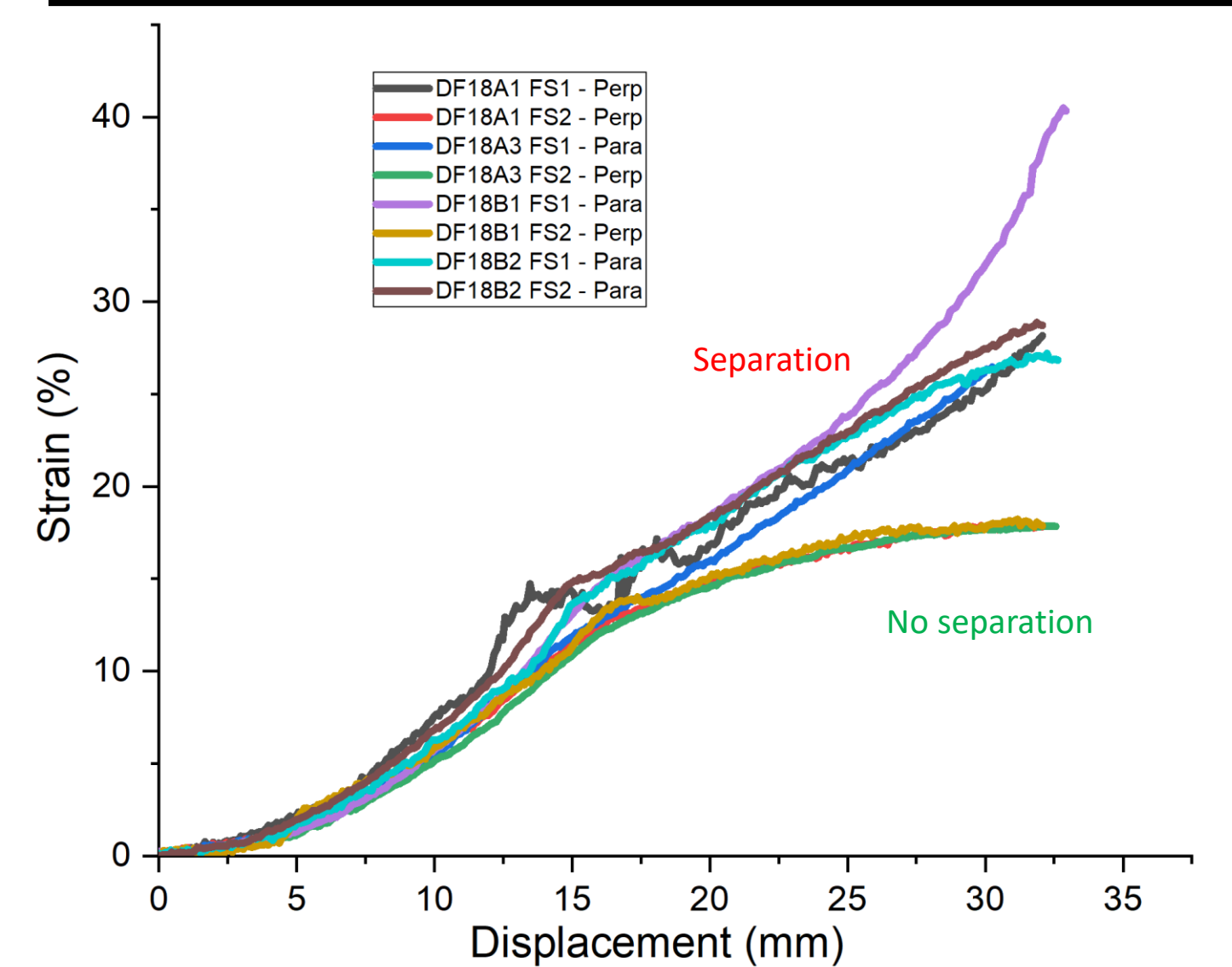
DIC was used to measure strain during bending – measuring the spread of tension and compression through the sheet thickness. The technique was also suitable for the measurement of achieved bending angle and springback.

CGA allowed not only the analysis of maximum strain, but measurement of width of the strain affected zone.



Distribution of Strain from DIC analysis. Direction and magnitude of x-axis strain. The sheet shows a switch between tension and compression through the sheet thickness

Maximum Strain was tracked through the bend tests. At small punch displacements, strain is consistent between specimens. At a consistent punch displacement specimens showing punch separation increased strain rapidly.



Maximum strain from DIC against punch displacement – 5mm sheet, R20 Punch.

4. Conclusion

- DIC is a suitable method for measuring outer edge strain and bending angles.
- Separation in the material tested is more common when bending parallel to the rolling direction
- Separation occurs at a set punch displacement for a given bending configuration
- Further work will focus on this deviation point.