Neutron diffraction studies of residual stresses around gouges and gouged dents

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The residual stress pattern surrounding gouges and gouged dents in oil and gas transmission pipelines is complex and, to date, has not been accurately modeled using stress modeling software. As such, measurement of these stress distributions is necessary. Neutron diffraction is the only experimental method with the capability of directly evaluating residual strain throughout the entire thickness of a pipe wall, in and around a dent or gouged regions.

Neutron diffraction measurements were conducted at the Chalk River NRU reactor L3 beamline on three gouged dents, contained in three separate 24" diameter pipeline sections. These pipe sections were a subset of samples examined as part of a comprehensive collaborative project co-funded by the US DOT Pipeline Hazardous Materials Safety Administration (US DOT PHMSA) and the Pipeline Research Council International (PRCI). A description of the defects and the pipe grade is included in Table 1. Samples BEA161, BEA154 and BEA159 were all created under "high impact" conditions, using the GdF Suez Pipeline Aggression Rig (PAR). As shown in Figure 1, in this high impact case the gouges were created by the PAR swinging through an arc and then striking the pipe wall at a grazing angle. Conversely, BEA178 and BEA179 were created by the PAR pressing a gouging tool into the surface and dragging it axially along the pipe wall.

To date, neutron diffraction experiments are complete for all 5 samples indicated in Table 1. Analysis of the data has been done for all but sample BEA179. An example of the analysed results is shown in Figure 2, for the severe, high impact gouge BEA159.

A comparative analysis of the results thus far for the high impact gouges indicates the following:
(1) Comparison of "medium" gouges in two different pipe grades: Stress distributions are similar – along gouge centerline the outer wall is in a state of neutral to moderate tensile stress, while the inner wall is compressive. Trends are similar in the two pipe grades but the X70 pipe generally exhibits higher tensile and compressive stress values.
(2) Comparison of the "medium" and "severe" gouges in the same pipe grade: These gouges display very different residual stress characteristics:

- Medium gouges, with minor tensile outer wall and very compressive inner wall;
- Severe gouges, with significantly tensile all through wall (except just past gouge end) and maximum tension is at inner wall.

Work continues with the comparative analysis of BEA178 and BEA179. Further neutron diffraction measurements are now underway at NIST and planned for CNBC on gouges created in "vintage" pipe. This pipe is from a stock of older, relatively low strength and toughness material (50+ years old) which was held as stock material. Its behaviour is expected to be representative of much of the older pipe material which is still in service and approaching the end of its lifetime.

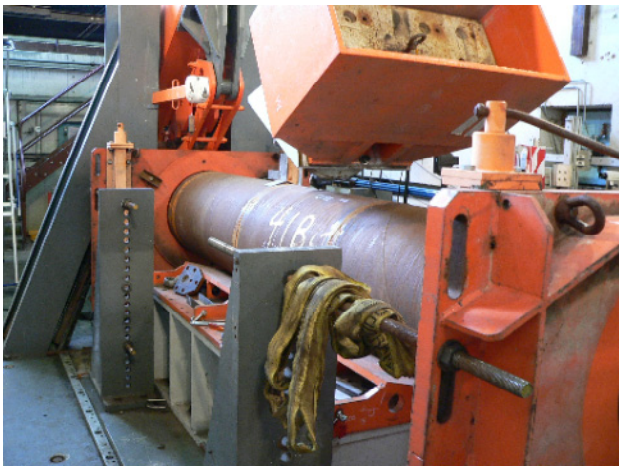

Fig. 1 the PAR (experimental backhoe) setup in the GdF Suez laboratory in St.Denis, France. The PAR is shown in action, creating a gouge in a pressurized pipe. The large orange box is a simulated backhoe bucket, swinging in an arc before impacting the pipe wall at a grazing angle.

Table 1. A summary of the gouge defects examined in the larger study, including whether the strain measurements were conducted at NIST or CNBC.

Defect	Pipe Grade	Gouge Type	Dent Type	Facility
BEA161	X52	Medium: 25% depth	Shallow: 1.1% depth	NIST
BEA178	X52	Medium: 27% depth	Severe: 5.7% depth	NIST
BEA154	X70	Medium: 22% depth	Shallow: 1.5% depth	CNBC
BEA159	X52	Severe: 43% depth	Medium: 2.6% depth	CNBC
BEA179	X70	Medium: 20% depth	Severe: 4.7% depth	CNBC

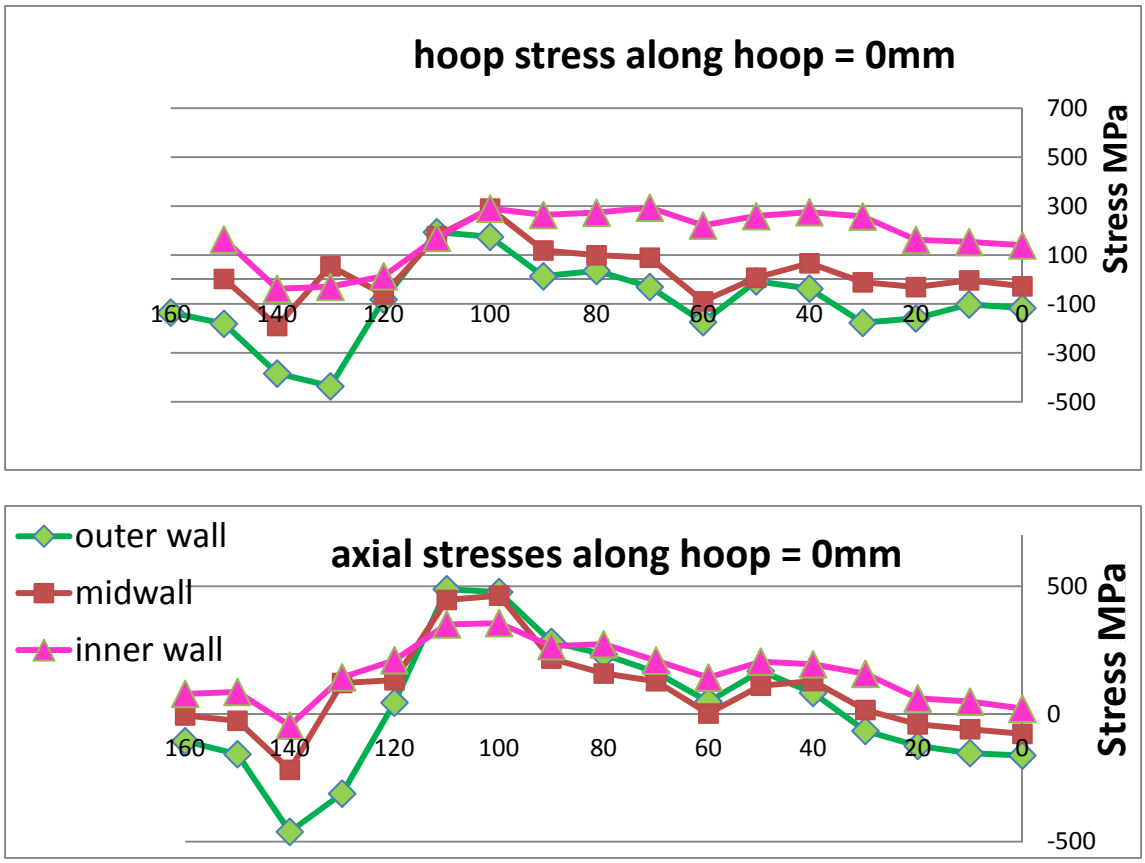

Fig 2 Hoop stress and axial stress results for locations along the hoop = 0mm position in the BEA159 gouge. This is a "high impact" severe gouge produced in a pressurized X52 grade pipe section. A sketch of the gouge, which is approximately 11cm long, is reproduced at bottom, with the measurement locations shown and the hoop = 0mm line indicated. The measurement locations "line up" with the corresponding results in the plots above. Results are shown for outer wall, midwall and inner wall positions at each measurement location.