Girth Welds in Newly Constructed Pipelines

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Manufacture of Linepipe Steels

- Lower grades, such as X70, now have carbon less than 0.05%.

Evolution of Chemical Composition

- Reduction in carbon, decrease in HAZ hardness

![Graph showing chemical composition and estimated VHN for different pipe types.](image-url)
- X100, ~2000
- Mechanized GMAW. High level of HAZ softening
HAZ Softening – X70

- X70, ~2000
- Mechanized GMAW. Moderate level of HAZ softening
**Hardness and Strength Distribution near a New Girth Weld**

**Pipe 1**
- YS = 86,000 psi

**Pipe 2**
- YS = 91,500 psi

**E8010 hot pass, fill and cap**
- YS ~ 78,000 psi

**E6010 root bead**
- YS ~ 66,000 psi

- X70, early 2010’s
- GW: Manual SMAW

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Permitted Strength Range – API 5L PSL 2 Pipes

- Range of yield strength = 20-30 ksi
- Range of UTS = 28-50 ksi
Examples of Actual vs. Specified Minimum Strength

- X70, ~1990

Graph: Yield Strength in Mill Certificates (MPa) vs. Measured Yield Strength at 0.5% Strain (ksi)

- Test Temperature = 21 °C

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Potential girth weld failure due to strain concentration along the HAZ while the nominal strain in the pipe is low.
Girth Weld Failure

- Failure in the HAZ at ~0.44-0.50% overall strain in the pipe
- Girth weld was in compliance with API 1104.
Girth Weld Failure

- Girth weld failure in the HAZ from a line constructed in ~2010.
Key “performance” requirements in API 1104
- Indications from NDT are smaller than the set limits (acceptance criteria)
- Maximum stress in the cross-weld tensile test is equal or greater than the specified minimum tensile strength of the pipe.

Implications
- Girth weld strength undermatching against the actual strength of pipe and HAZ softening are permitted as long as the maximum stress in the cross-weld tensile test is not less than the specified UTS of the pipe.

Possible consequence
- Girth welds could fail at low overall strain (less than 0.3-0.5%) due to high strain concentration in the weld area.
When we had steels with high carbon and high hardenability

- No HAZ softening
- There were cases of weld strength undermatching the actual strength of the pipe; but wide smooth weld cap prevented strain concentration

Key drivers to GW failures: vintage vs. modern welds

- Vintage
  - Large flaws remaining after construction (including hydrogen cracks)
- Modern
  - Weld strength undermatch
  - HAZ softening
  - Less-forgiving weld profiles
  - Hydrogen cracks
Why Should We Care?

- Moderate levels of strain can exist even in areas not associated with ground movement
  - Pipe being forced into ditch
  - Crossings

- Most pipelines should have some level of tolerance to longitudinal stresses/strains.

- Longitudinal stresses/strains are typically not actively managed in areas of “stable ground” or no past history of failures, even there are longitudinal stress/strain limits in the design phase.

- The requirements in API 5L/1104 does not guarantee strain capacity beyond ~0.3%.
  - Strain-based design starts at 0.5%. The implications are that current API 5L/1105 is good to 0.5%. This is not the case.
The girth weld incidents cited here are not exclusively a “welding issue.”

The problem can only be solved through proper

- Pipe specifications, and
- Welding procedure design and execution.

Selecting the right welding procedure/process can help.

- Through the understanding the impact of welding on materials surrounding the welds.
- Welding parameters that have impact
  - Mechanized vs. manual welds
  - Heat input level vs. construction speed/efficiency
  - Weld profile, including weld overbuild
Q&A