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All Companies under the Jurisdiction of the Canada Energy Regulator

Safety Advisory SA 2020-01 –
Girth Weld Area Strain-Induced Failures:
Pipeline Design, Construction, and Operation Considerations

Please find attached Safety Advisory SA 2020-01.

The Canada Energy Regulator (CER) expects regulated companies to take all reasonable care to ensure the safety and security of persons, the safety and security of regulated facilities and abandoned facilities, and the protection of property and the environment.

Safety Advisories are issued periodically in order to inform the oil and gas industry of an identified safety or environmental concern with the goal of preventing the occurrence of related incidents. A Safety Advisory serves to highlight CER requirements, and to convey the CER's expectation that regulated companies take appropriate action to mitigate any potential impacts to people or the environment.

This letter is to notify you that the CER is aware of several incidents related to failures in girth weld areas on high strength pipe. While no incidents associated with this type of failure have been reported in Canada, the CER is of the view that similar incidents could occur under comparable conditions.

The CER directs your attention to the attached safety advisory and expects that it will be given wide circulation to company personnel and contractors involved in construction, integrity, maintenance and operation.

If you have any questions regarding this Safety Advisory please visit the FAQ webpage at https://www.cer-rec.gc.ca/sftnvrnmnt/sft/dvsr/sftdvsr/index-eng.html or contact the Director of Research and Innovation through our toll free number at 1-800-899-1265.

Yours sincerely,

Original signed by Peter Watson

C. Peter Watson, P.Eng., FCAE
Chief Executive Officer

Attachment

Safety Advisory
SA 2020-01
12 February 2020

Girth Weld Area Strain-Induced Failures: Pipeline Design, Construction, and Operation Considerations

Purpose of the Safety Advisory

The Canada Energy Regulator (CER) has become aware of several incidents outside of Canada where failures have occurred at the girth weld area (deposited weld area and heat affected zone (HAZ[1])) on high strength pipe. While no incidents associated with this type of failure have been reported in Canada, the CER is of the view that similar incidents could occur under comparable conditions.

The CER understands that the mechanism of failure in these incidents was ductile fracture of the girth weld area due to strain accumulation under loads which resulted in longitudinal strains that exceeded the strain capacity of the girth weld area, even though the applied global strains to the piping were of the order of 0.4 to 0.6%[2]. The failures occurred when longitudinal strain, resulting from issues such as settlement or slope movement, accumulated in a lower strength[3] weld area on pipelines which had higher strength pipe material. There are no indications that the failures required the presence of flaws to occur.

The CER is releasing this Safety Advisory to ensure a broader awareness of these types of incidents in order to prevent occurrences of this nature on CER-regulated pipelines. The CER expects that regulated pipeline companies design welded pipelines to withstand those loads that result in longitudinal strains in meeting the requirements of Clause 4.2.4 of CSA Z662-19, and that companies can demonstrate they are in compliance with those requirements of the Clause.

Background

The CER has reviewed available investigation reports, summaries, and industry presentations dealing with these international girth weld failures where the failure could be attributed to strain accumulation in the girth weld area. The following examples were attributed to the subject failure mechanism and are provided as background information.

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[1] The HAZ is identified as the non-melted region adjacent to the weld deposit that has had its microstructure and mechanical properties altered by welding.

[2] In general, modern line pipe can accommodate strains much higher without failures.

[3] "Strength" as used in the discussion of accumulation of strain in the girth weld areas is actual yield strength.

In 2015 an in-service NPS 20 X70 ERW pipe failed at the weld area less than two years after the pipeline was put in service (References [1] and [2]). The shielded metal arc weld (SMAW) girth weld was made with E6010 electrodes for the root pass and E8010 electrodes for the remaining passes. Field evidence and post-failure strain capacity analysis indicated that the weld area failed at a global strain level of 0.4-0.5%. The yield strength of the pipe base metal and ultimate tensile strength (UTS) were above the specified minimum values and there were no flaws found in the failed weld area.

Other examples were observed in 2014 and again in 2018 on a NPS 36 X70 onshore natural gas pipeline that was constructed in 2013 (Reference [3]), and a NPS 32 X80 gas pipeline (Reference [4]).

Incident summaries identified that the welding procedures of the failed welds met the requirements of API 1104, indicating that a qualified weld procedure can pass testing but still be prone to a failure in the weld area. Similar to API 1104, Clause 7 of CSA Z662-19 has no explicit requirement for designing welds to withstand all the loads applied.

The cause of these failures has been consistently linked to combinations of the following contributing factors:

1. High strength pipe with actual tensile strength exceeding specified minimum tensile strength as reported (e.g. in a material test report (MTR)).
2. Weld HAZ softened as a result of the welding process used.
3. Loads applied to the pipeline that result in longitudinal strain, such as in areas of slope movement or subsidence.
4. Pipes welded with a standard bevel (i.e. using SMAW or flux core arc weld (FCAW) method) and the approximate alignment of the heat affected zone of the weld area with the root bead in the 45 degree shear plane (Reference [1]).
5. Portions of the weld where the strength of the deposited weld consumable was below the actual yield strength and tensile strength of the pipe base metal (i.e. under-matched weld).

Softening of the HAZ has been highlighted as a particular issue when coupled with the use of high strength line pipe (Reference [5]) since softening can be influenced by low carbon equivalent line pipe manufactured by a thermomechanically controlled process to increase steel strength (Reference [5]).

Preventive Actions

The CER expects that regulated companies can demonstrate that longitudinal strains resulting from loadings such as those described in Clause 4.2.4 of CSA Z662-19 have been accounted for in the design, construction, and operation of pipelines where strain could potentially accumulate in under-matched girth weld areas.

The CER notes that welding procedure qualification requirements are detailed in Clause 7 of CSA Z662-19. However, the CER would like to highlight that there exists the possibility that girth welding procedures conforming to Clause 7 may result in welds that are still susceptible to ductile fracture in the weld area due to the mechanism described above, since testing for weld strength under-match is not a requirement in the Clause, nor is the requirement to qualify welding procedures using pipe representative of the strongest pipe to be used on the project.

Companies may wish to consult the references, published papers, and summarized contributing factors to determine susceptibility to failure in the girth weld areas and possible mitigation measures. This may include a review of the Welding Procedure Specifications (WPSs) and the supporting weld Procedure Qualification Records (PQRs) together with the actual mechanical properties of the pipe material to determine the potential for weld under-matching and HAZ softening.

Further information

If you have any questions regarding this Safety Advisory please contact the Director of Research and Innovation through our toll free number at 1-800-899-1265.

References

[1] Y.-Y. Wang, S. Rapp, D. Horsley, D. Warman and J. Gianetto, "Attributes of modern linepipes and their implications on girth weld strain capacity," IPC2018-78809, Calgary, Alberta, Canada, 2018.

[2] PHMSA DOT, "Failure Investigation Report - Enterprise Products Operating, LLC: ATEX Ethane Pipeline Failure, Follansbee, West Virginia," 2016.

[3] W. A. Wan Hamat, W. M. M. Wan Ismail, K. A. Ibrahim, G. M Zin and N. S. Md Aris, "High Strain Weld Solutions for Geohazard Active Environment," AIM-PIMG2019 1068, Houston, TX, USA, 2019.

[4] C. Hongyuan, F. Hui, C. Qiang and H. Chunyong, "Failure Analysis Of A Stress-based Pipeline Under Plastic Strain," AIM-PIMG2019-1028, Houston, TX, USA, 2019.

[5] W. A. Bruce, "Pipeline Girth Weld Strength Matching Requirements," *Welding Journal,* no. October, pp. 56-60, 2019.

Additional Published Papers

The following sources could be helpful in further investigating the failure mechanism and history of this issue:

Det Norske Veritas AS, "OS-F101: Offshore Standard: Submarine Pipeline Systems," 2013, pp. Appendix C, Clause F 304.

European Pipeline Research Group (EPRG), "EPRG Guidelines on the Assessment of Defects in Transmission Pipeline Girth Welds – Revision 2014".

D. Fairchild, J. Crapps, M. Panico, W. Cheng, M. Cook and M. Macia, "Tensile Strain Capacity Model, Full-scale Testing, Safety Factor Derivation, And Benchmark Example Calculations," AIM-PIMG2019-1039, Houston, TX, USA, 2019.

PHMSA DOT, "Pipeline Safety: Girth Weld Quality Issues Due to Improper Transitioning, Misalignment, and Welding Practices of Large Diameter Line Pipe," *Federal Register,* vol. 75, no. 56, PHMSA-2010-0078, 24 March 2010.

PHMSA DOT, "Pipeline Safety: Potential Low and Variable Yield and Tensile Strength and Chemical Composition Properties in High Strength Line Pipe," *Federal Register,* vol. 74, no. 97, PHMSA–2009–0148, 21 May 2009.

PHMSA DOT, "Pipeline Safety: Potential for Damage to Pipeline Facilities Caused by Earth Movement and Other Geological Hazards," *Federal Register,* vol. 84, no. 85, PHMSA-2019-0087, 2 May 2019.

J. Shimamura, K. Yasuda, S. IGI, R. Muraoka and J. Kondo, "Development Of High Strength High Strain Linepipe Steels," AIMPIMG2019-1020, Houston, TX, USA, 2019.

Y.-Y. Wang, "Strain-based Design And Assessment – Concepts And Gaps," AIMPIMG-1067, Houston, TX, USA, 2019.

Y.-Y. Wang, D. Horsley and S. Rapp, "Evolution Of Linepipe Manufacturing And Its Implications On Weld Properties And Pipeline Service," IPC2016-64632, Calgary, Alberta, Canada, 2019.

Y.-Y. Wang, D. Jia, S. Rapp and D. Johnson, "Low Strain Capacity Girth Welds Of Newly Constructed Pipelines And Mitigative Approaches," AIMPIMG-1064, Houston, TX, USA, 2019.

Y.-Y. Wang, B. Liu and B. Wang, "Tensile Strain Models And Their Applications," AIMPIMG-1066, Houston, TX, USA, 2019.

Y.-Y. Wang and S. Rapp, "Low Strain Tolerance in Some Newly Constructed Pipelines," Center for Reliable Energy Systems, San Antonio, 2018.

G. Wu, L. Wang, T. London and H. Pisarski, "Pipe Girth Welds Under Plastic Straining: Full-scale Testing And Strain-based Approaches," AIM-PIMG2019-1013, Houston, TX, USA, 2019.