Evaluating Screening Methods as an Alternative to Dent Strain Assessments?

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Abstract

Operators utilize the calculation methods prescribed in ASME B31.8 Appendix R [1] to predict the likelihood of cracking during the dent formation process. ASME B31.8 Appendix R provides acceptance limits for calculated strain levels below which there is a limited likelihood of crack initiation. Dent strain calculations require detailed caliper measurements, data smoothing, and shape-based analysis for each dent. The industry has been attempting to develop streamlined dent screening criteria based on dent characteristics available in ILI-reported feature listings. These dent characteristics, such as depth, length, and width can be implemented in a screening methodology that does not require the same level of data and assessment as a detailed strain analysis to estimate the likelihood of dent formation cracking.

One such screening criteria that has been used in the industry to assess the sharpness of dents is the length to depth ratio. A length to depth ratio less than 20 has been used by the industry as a predictor of dent sharpness. Logically, a smaller length to depth ratio would indicate a sharper dent and; therefore, a higher strain value. Various studies have compared this ratio to strain estimates with mixed results. This study aims to build on previous studies by incorporating additional data from multiple ILI vendors and tool technologies. Existing screening criteria and industry presented results are explored, along with additional parameters, to identify correlations between dent measurement characteristics and strain results.

If a dent screening methodology based on readily available ILI-reported characteristics is possible, this would result in a valuable tool to enable more efficient assessments, while still maintaining the confidence of a dent strain assessment, to predict the likelihood of cracking during dent formation. This study will share learnings and provide guidelines to be used when considering the development of a dent screening methodology.

Background

Dents in buried pipelines remain a leading contributor to pipeline releases. Whether caused by third party damage or during construction, they pose an integrity threat. The amount of strain can be calculated in a dent, and is typically done using the methodology provided in ASME B31.8 (2020) Appendix R. This has been widely applied by the pipeline industry to assess the amount of damage caused during the indentation process. The more damage caused during the indentation process (higher strain) is an indicator of a crack initiating within the dent. In order to calculate dent strain, the entire profile of the dent is needed. In-line inspection (ILI) caliper tools can provide this information and is typically used. Direct examination can also be utilized to capture the dent profile through things such as physical measurements or laser scanning.

Obtaining dent profile measurements and performing subsequent strain calculations can be costly. The pipeline industry has been seeking conservative screening criteria for dent strain as a simplified

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alternative. CSA Z662:19 [2] takes into account the sharpness of a dent as an alternative to strain assessment, namely length to depth ratio (L/d). The American Petroleum Institute (API) RP 1183 [3] is in the process of revising the first edition. Members of the task group have discussed whether dent screening can be incorporated into the second edition of API RP 1183 [4].

Introduction

A previous study [5] investigated the effect of applying the CSA Z662 dent screening criteria to 4,450 dents reported by a single ILI service provider on multiple pipelines and concluded that the dent screening criteria "can be considered conservative" as long as three criteria are evaluated: dent depth, dent length to depth ratio, and dent width to depth ratio.

This paper extends the analysis performed in the previously referenced IPC paper by evaluating 1,891 ILI-reported dents from six pipelines inspected by a different ILI service provider. The ILI-reported dimensions (axial length, circumferential width, and depth) as well as the ASME B31.8 (2020) Appendix R estimated strain were provided by the ILI service provider.

1,777 of the 1,891 dents are in 273.05 mm (10.75 inch) outside diameter (OD) pipe with the remainder in 406.4 mm (16 inch) OD pipe. The predominant OD to wall thickness (t) ratio is between 30 and 40. The dataset includes dents within the pipe body as well as those that interact with either a girth weld or a long seam weld, specifically 1,657 and 234, respectively.

Existing screening criteria (i.e., CSA Z662:19) focus on dent depth and "sharpness", where sharpness is estimated using the ratio of the dent length to the dent depth. The lower this ratio, the short the length is compared to the depth, suggesting a sharper dent. The analysis in the previously referenced IPC paper additionally reviewed the potential impact of the width to depth ratio.

The distribution of dent depths as a function of the dent location (i.e., in the pipe body or interacting with a weld) is provided in Figure 1. The average ILI-reported depth of dents within the pipe body is 0.83% OD and 0.87% OD for dents interacting with a weld. Most dents are less than 2.0% OD in depth. The average length /depth ratio (L/d) is 46.3 and 42.3 for the pipe body and interacting with weld, respectively (see Figure 2). The majority of dents have a ratio greater than 20.0. Similarly, as depicted in Figure 3, the majority of dents have width / depth (W/d) ratios greater than 20.0, with averages of 30.6 and 27.1 for the pipe body and interacting with weld, respectively. The distribution of 2020 ASME B31.8 (2020) Appendix R strain is shown in Figure 4 with averages of 3.5% and 3.7% for the pipe body and interacting with weld, respectively. Table 1 presents a summary of pertinent parameters.

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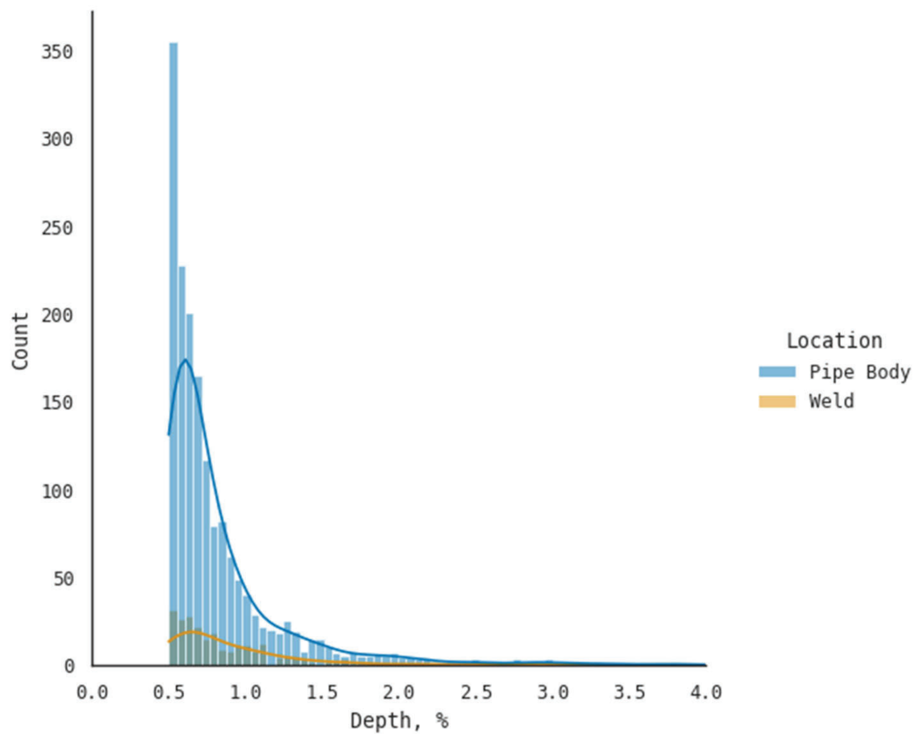

Figure 1. Depth (% OD) distribution

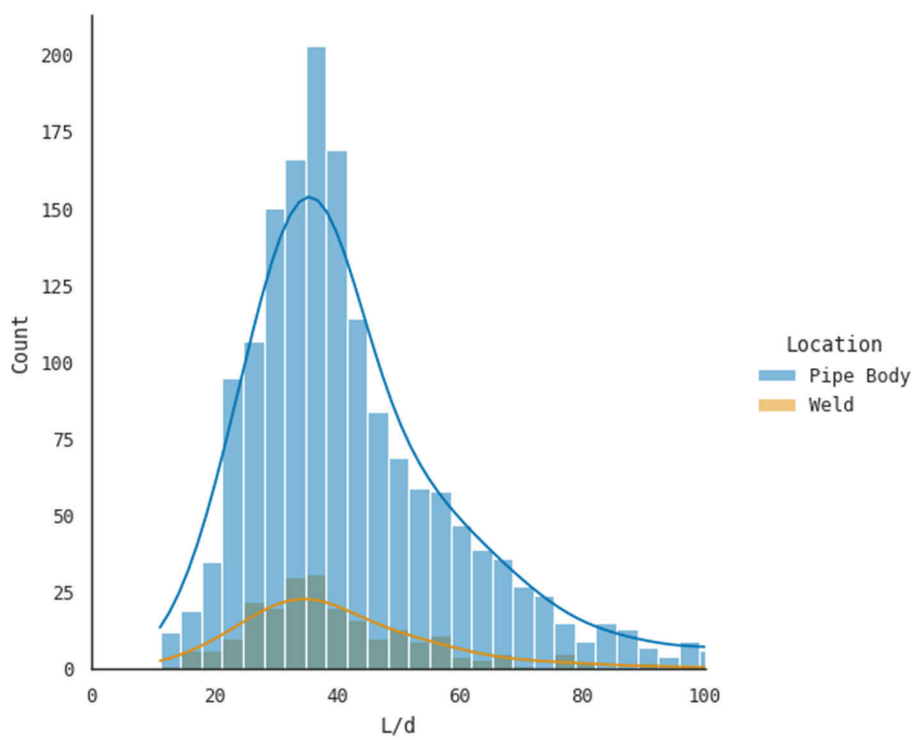

Figure 2. Length / depth distribution

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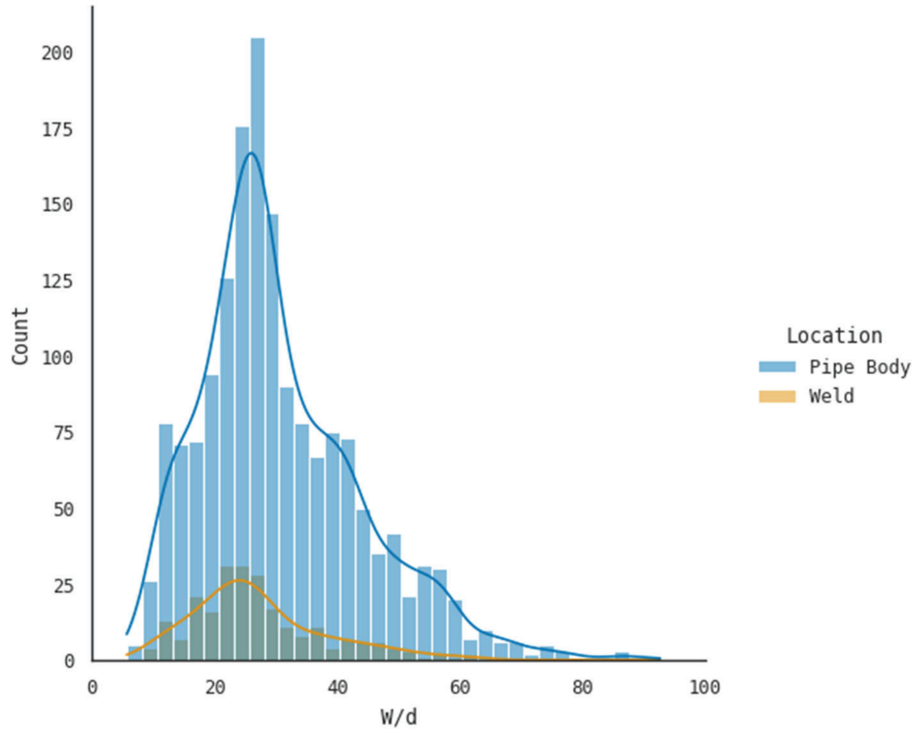

Figure 3 Width / Depth distribution

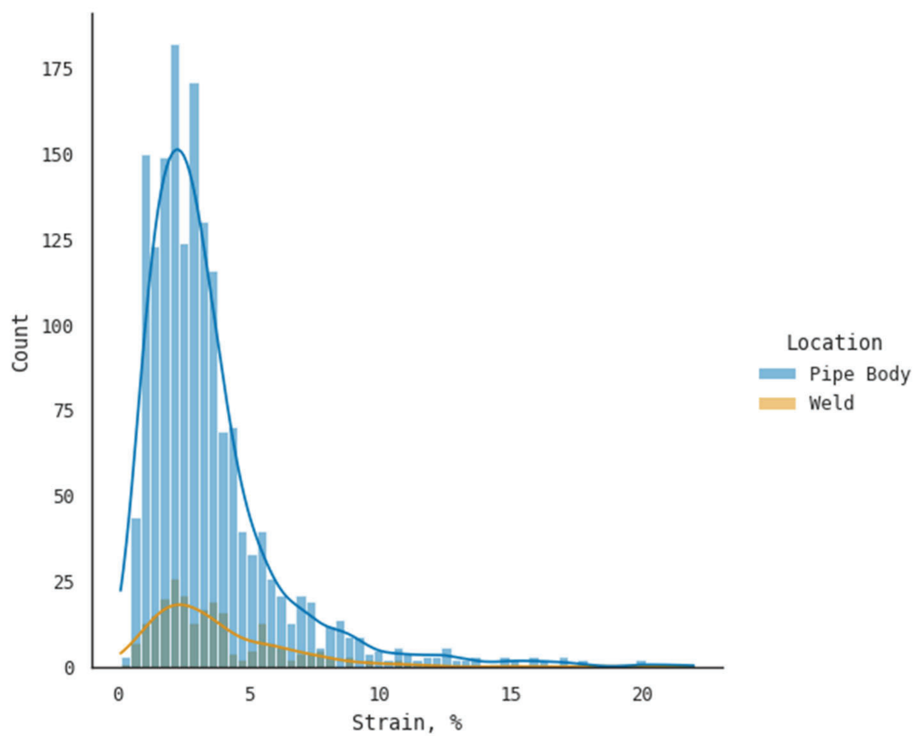

Figure 4. Estimated strain distribution

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Table 1. Pertinent Parameter Summary

Parameter		Range / Count
Pipelines		6
OD, mm		273.05 – 406.4
OD/t		21.17 – 62.52
Interaction		
	None	1,458
	Feature†	199
	Weld‡	188
	Weld‡ & Feature†	46
Location		
	Pipe Body	1,657
	Weld‡	234
Shape		
	Complex	208
	SinglePeak	1683
Depth (d), %		0.5 – 7.75
Length / Depth (L/d)		11.13 – 312.09
Width / Depth (W/d)		5.67 – 92.59
Strain, %		0.1 – 22
Matched to Previous ILI		762

† E.g., metal loss, crack related feature
‡ Long seam weld and girth weld

A total of 762 dents were matched to reported dents in a previous inspection, with 558 of those reported by the same ILI service provider in both ILI surveys. The ILI-reported depths between the inspections appear the most consistent followed by depths, L/d ratio, and W/d ratio, as shown in Figure 5, Figure 6, and Figure 7, respectively. In Figures 5 through 7, the reported measurement from the previous ILI survey is on the x-axis and the most recent ILI survey on the y-axis. The scatter around the dashed line (representing unity) is the smallest for depth and largest for the W/d ratio. The scatter around unity does not appear to be significantly different for dents reported in the pipe body compared to those interacting with a weld.

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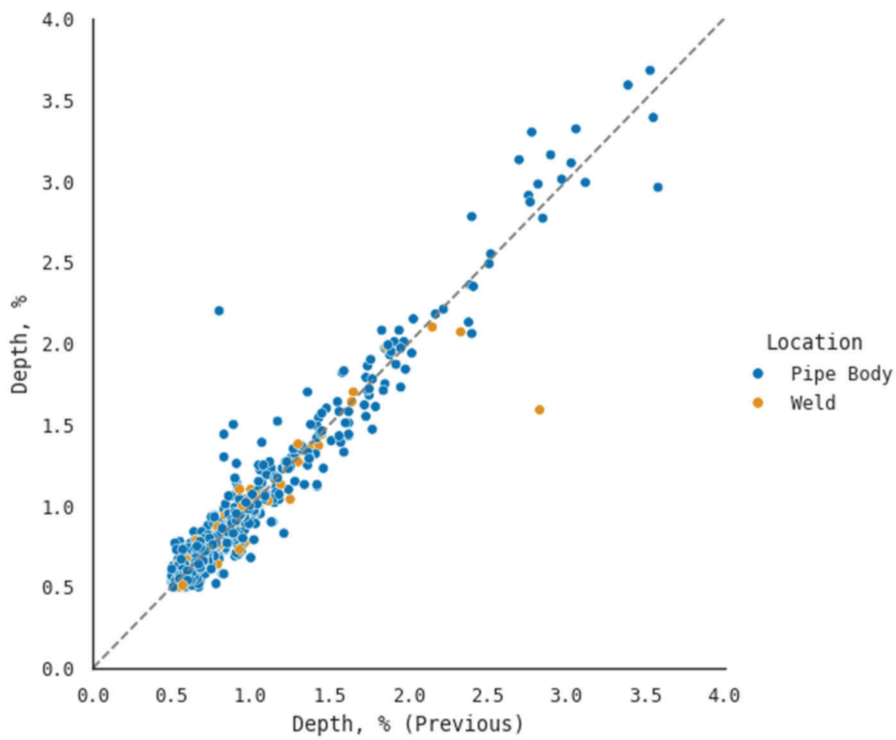

Figure 5. Comparison of ILI-reported depths from multiple ILIs

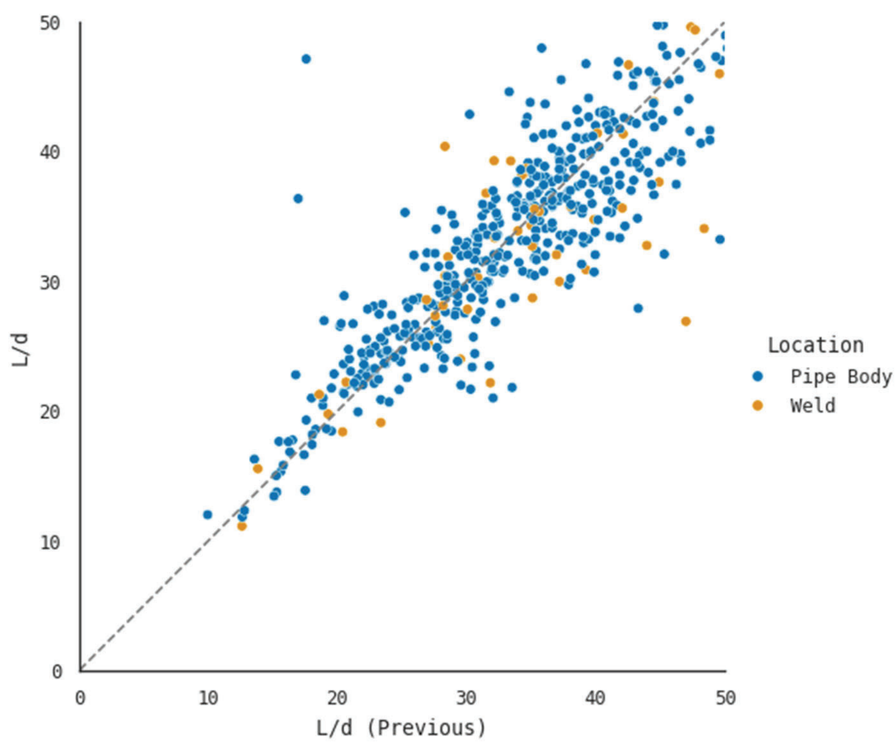

Figure 6. Comparison of ILI-reported L/d ratios from multiple ILIs

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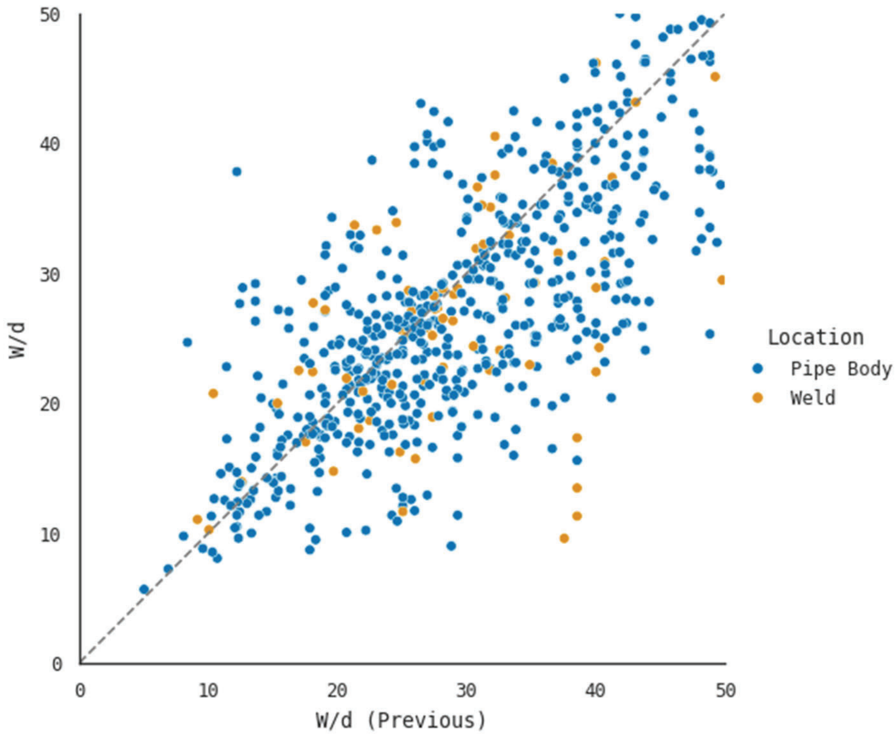

Figure 7. Comparison of ILI-reported W/d ratios from multiple ILIs

Results Summary

The intent of screening limits is to identify those dents with estimated curvature strains exceeding specified strain limits, thereby reducing the number of dents with a higher likelihood of cracking. As discussed above, three of these criteria are evaluated herein. CSA Z669:19 provides curvature strain limits at 4% and 6% for dents interacting with a weld and those in the pipe body, respectively. There are 187of the 1,657 dents in the pipe body with curvature strains over 6% and 71 of the 234 dents interacting with a weld exhibiting curvature strains above 4%.

The corresponding dent depth screening limits in CSA Z662:19 are 2% and 6% OD (interacting with a weld and on the pipe body). In Figure 8, the ILI-reported dent depth vs strain values are compared. In Figure 8, the shaded region highlights dents where the estimated strain is above the CSA Z662:19 limits, but the depth is not. In other words, dents with undesirable estimated strains that would not be identified using only the depth criteria (i.e., are within the shaded regions). 185 dents in the pipe body and 65 dents interacting with a weld are within the shaded area. In general, there does not appear to be a correlation between deeper depths and higher estimated strains. Further demonstrating that depth alone is an insufficient screening criterion.

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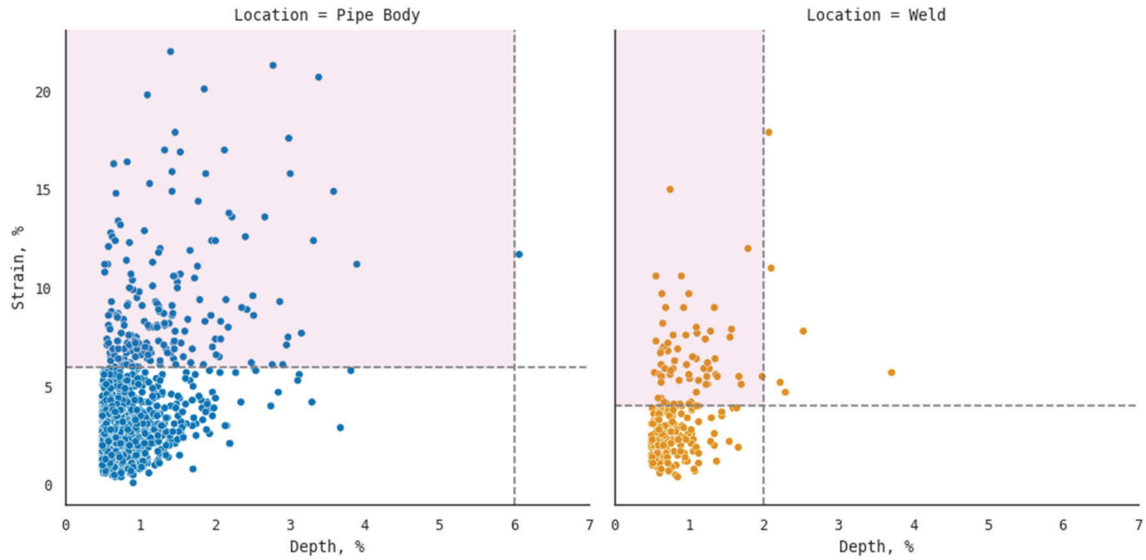

Figure 8. Strain vs depth – dents within pipe body and interacting with a weld

The other screening limit provided in CSA Z662:19 is a L/d ratio less than 20.0. Dents with ratios below 20.0 are expected to be sharp and therefore have high curvature strain. The capability of this ratio limit to solely identify dents with high strain is demonstrated in Figure 9. Again, the shaded region highlights dents where the estimated strain is above the CSA Z662:19 limits, but the L/d ratio is not. Within the shaded region there are 141 dents in the pipe body and 60 dents interacting with a weld. As the L/d ratio decreases the estimated curvature strain tends to increase.

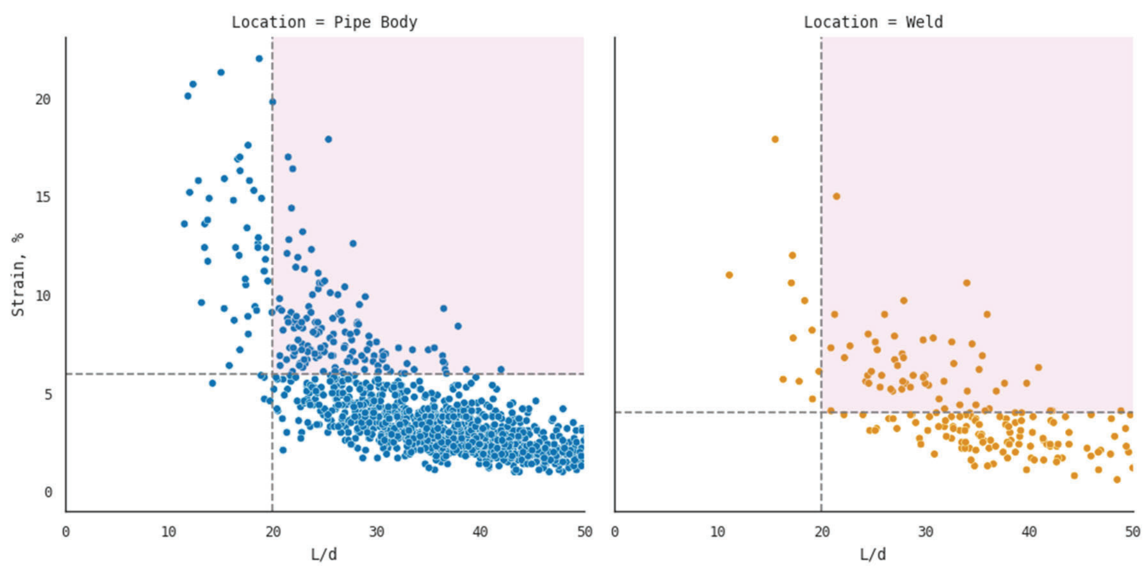

Figure 9. Strain vs L/d – dents within pipe body and interacting with a weld

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The analysis in the previously referenced IPC paper also reviewed the potential for the W/d ratio to identify dents with strain levels above the critical limits. There are 47 dents in the pipe body and 34 dents interacting with a weld with curvature strains above the specified limits and a W/d ratio above 20.0; if W/d by itself were used as a screening criterion, these dents would not be identified. Similarly to the L/d ratio, as the W/d ratio decreases the estimated curvature strain tends to increase.

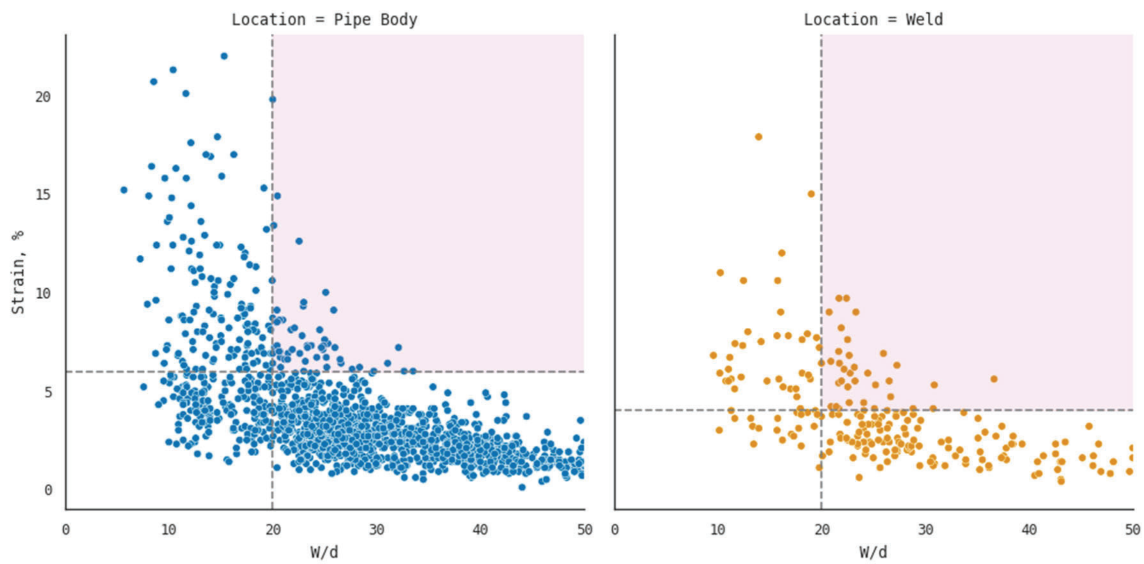

Figure 10. Strain vs W/d – dents within pipe body and interacting with a weld

Figure 11 and Figure 12 present a graphical representation of the combination of the L/d and W/d ratios as a potential screening process for dents in the pipe body and those interacting with a weld, respectively. Dents with curvature strains above the respective criterion from CSA Z662:19 are represented by the circles. Both Figure 11 and Figure 12 demonstrate that dents within the dataset evaluated have a tendency to have higher strain at smaller combined L/d and W/d ratios. Despite this apparent trend, there are multiple dents with combined L/d and W/d ratios above 20.0 that also exceed the curvature strain limits in CSA Z662:19, which are depicted by the circles within the shaded region of Figure 11 and Figure 12. In total, there are 44 dents in the pipe body within the shaded region and 34 interacting with a weld.

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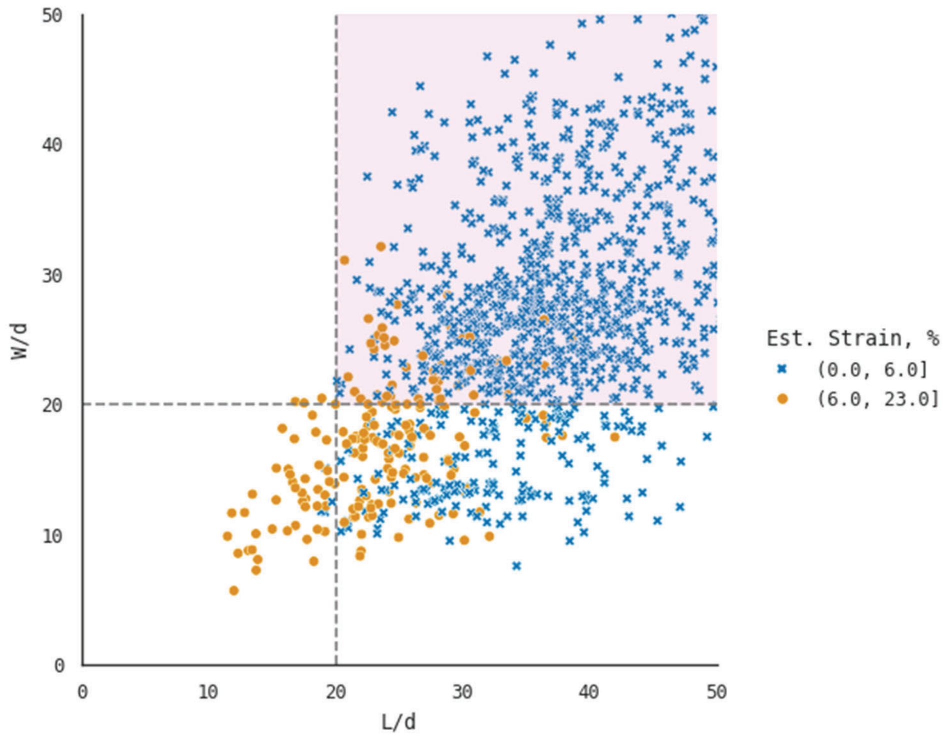

Figure 11. L/d vs W/d –dent strain within pipe body

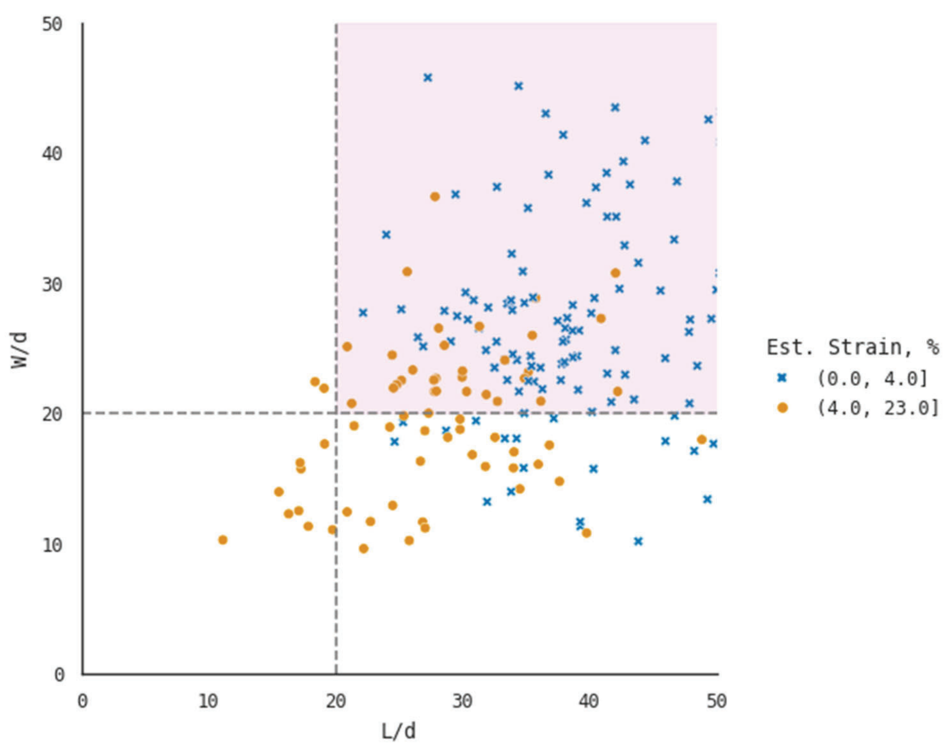

Figure12. L/d vs W/d –dent strain interacting with a weld

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A summary of the analyses discussed above is provided in Table 2. Specifically, Table 2 presents the number of dents within the dataset with strains above the CSA Z662:19 limits that would not be identified by the various potential screening criteria. Even if the three criteria are combined (depth, L/d and W/d ratios) then a large portion of the dents with high strain would not be identified properly. Table 2 also provides the results of a modified set of criteria, specifically increasing the ratio limits from 20 to 30. As expected, the number of dents incorrectly identified decreases.

Table 2. Summary of High Strain Dents Not Identified by Potential Screening Criteria

	Number (% of Total†)	
	Pipe Body	**Weld**
Analyzed Dents	*1,657*	*234*
Strain > 6% or 4%‡	187	71
Depth <6% OD or 2% OD‡	185 (99%)	65 (92%)
L/d > 20	141 (75%)	60 (85%)
W/d > 20	47 (25%)	34 (48%)
L/d > 20 & W/d > 20	44 (24%)	32 (45%)
Depth <6% OD or 2% OD‡ & L/d > 20 & W/d > 20	44 (24%)	32 (45%)
L/d > 30	27 (14%)	27 (38%)
W/d > 30	2 (1%)	4 (6%)
L/d > 30 & W/d > 30	0 (0%)	2 (3%)
Depth <6% OD or 2% OD‡ & L/d > 30 & W/d > 30	0 (0%)	2 (3%)

† Percentage of dents above CSA Z662:19 strain limits
‡ Dents in pipe body and dents interacting with a weld, respectively

Conclusion

This study was performed to take an additional review of the performance of ILI tools to predict high strain dents through a screening process. While the results of this study had similar trends to previous studies, the results were not as favorable to predict high strain dents. The conclusions made by the authors of this study are that given different ILI vendors, tools, technologies, pipelines, etc., its difficult to use feature reported dimensions to determine a singular strain screening criteria, or combination of criteria. It is recommended that if similar screening methods are utilized, the user should demonstrate the performance on their pipeline system(s) with the ILI vendor who performed the inspection(s) in order to establish confidence in a conservative approach.

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References

[1] ASME B31.8-2022, Gas Transmission and Distribution Piping Systems, American Society of Mechanical Engineers, 2022.

[2] CSA Z662:19, National Standard of Canada, Oil and gas pipeline systems, June 2019.

[3] API RP 1183, Assessment and Management of Pipeline Dents, November 2020.

[4] (2024, September 11-12), API TG 1183 In-person Meeting, American Petroleum Institute, Houston, TX.

[5] Krystin Cousart and Chris Holliday, A Study on the Conservatism of the Dent Screening Criteria in the Candial Standards Association (CSA) Z662:19 Oil and Gas Pipeline System Standard, IPC2022-88266.

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