White Paper

Modeling PRCI PR-331 Growth Rate Analysis within Cognitive Integrity Management (CIM)

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oneBRIDGE Flow Forward™

Metal loss from corrosion is one of the more significant threats to pipeline integrity worldwide. Accurately characterizing corrosion growth enables appropriate dig planning, avoiding unnecessary digs on one hand as well as the possibility of missed threats on the other. In this white paper, OneBridge discusses the use and shortcomings of static defect analysis to measure corrosion growth and make informed decisions about anomaly mitigation.

Process Summary

OneBridge has based the depth calibration analysis in this research primarily on the PRCI PR-331[1] framework. The analysis is made possible by aligning every individual anomaly and correlating them with field-measured depths in repair data within Cognitive Integrity Management (CIM).

This white paper describes analysis details and also discusses shortcomings, such as when there is insufficient data for the prescribed calculation. Additional extensions of the PR-331 method are considered in cases where insufficient data exists to perform the calibrations exactly as laid out in that document.

This paper also includes a presentation of several growth calculation methods.

OneBridge has applied the PR-331 method to customer system(s) designated in this paper as System A.

Potential Conclusions

As with all research, certain assumptions and adjustments were made to derive a process that is repeatable, statistically accurate, and can be applied practically, within the confines of CIM, to business decision-making. One takeaway from this analysis is that in-line inspections (ILI) performed in quick succession lead to extremely high variance growth predictions. This is due to the short time interval in a two-point extrapolation calculation. Averaging together these readings reduces this error substantially.

The static anomaly calibration method of PR-331 was successfully implemented for System A, with the conclusion that the ILIs do not show depth calibration magnitudes greater than 2%. Thus, the depth data can be trusted for unbiased growth calculations.

[1] PR-331-063525-S01 Procedures for Comparing Successive ILI Runs to Establish Corrosion Growth Rates

Segment A

There is a large set of ILI records for this segment. Multiple pairs of ILI measurements performed over a short period (weeks) along with a long history of inspections make it challenging to calculate reliable growth rates.

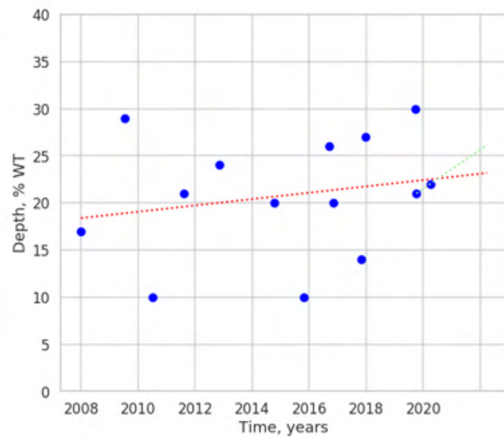

Figure 1: Example anomaly with aligned depth measurements in most ILIs for this segment. The red line is a linear trend through all points.

PR-331 Depth Calibration

When integrity engineers (IE) make decisions about dig plans, one of the things they must do is interpret ILI data. Analysis includes application of tolerance, calculation of failure risk criteria, determination of a corrosion growth rate (CGR), and accounting for ILI-wide effects like significant over- and under-call. This is known as depth calibration.

PR-331 primarily uses *static defects* to calculate depth calibration.

Corrosion calls are said to be static defects if they are not expected to corrode further. An example would be external corrosion that has been mitigated with a non-metallic sleeve or a pipe recoat. Certain product environments, such as dry gas, also allow internal defects to be considered static. In these cases, any change in statistical measures of the static defect depths from ILI to ILI cannot be caused by growth. Instead, they are attributed to tool bias.

The main challenge in calibrating depth using static defects is that there must be enough anomalies to be able to draw statistically significant conclusions. A secondary challenge is that the distribution of depths of static defects may not match that of all ILI depths, leading to incorrect depth-dependent depth calibration.

The PR-331 document outlines an analysis procedure for inspection data. It includes identifying static defects based on the specific details of the line: product, repair history, sleeve type, recoating data. Using the full history of these defects aligned across all ILIs, the next step is to compare statistics regarding the depth distribution in each ILI. It's important to note when there is a large difference in the mean, median, or variance of the distribution, as these indicate a possible tool bias.

In these reports from Segment A ILI, there are enough aligned anomalies with aligned histories (dating to 2016) and repair data to find a sufficient population of static anomalies to calibrate the recent history of this line. External anomalies that have been mitigated with recoating or a non-metallic sleeve are considered static. The distribution of depths of these anomalies can be compared in Figure 2. The mean

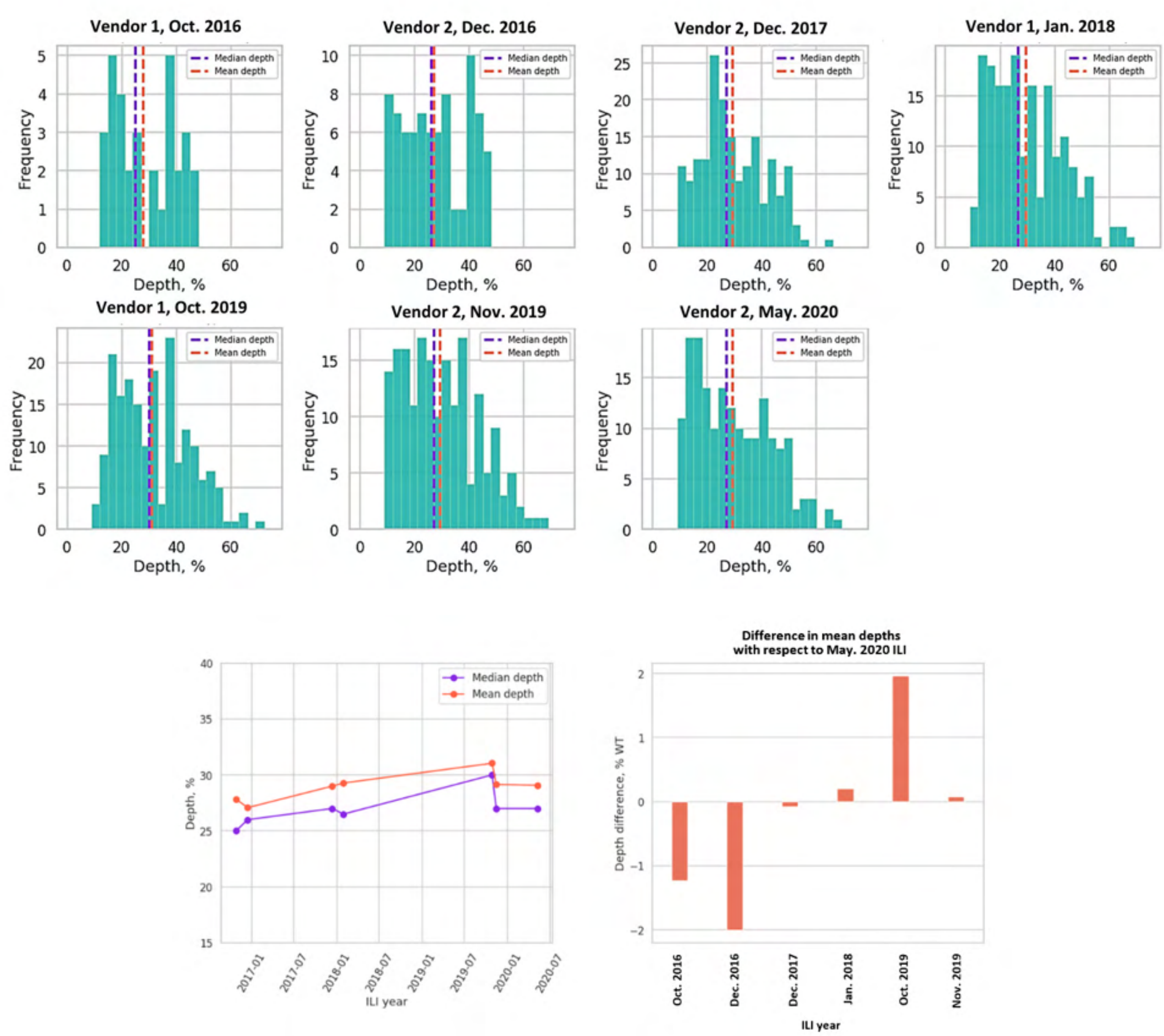

Figure 2: (top) Depth distributions in several ILIs for aligned static anomalies in green (bottom left). Mean and median of these depth distributions across time for each ILI (bottom right). Difference of each distribution mean with respect to the 2020 static anomaly mean depth. The orange bars represent the level of potential tool bias in each run.

and median of these distributions are quite stable over time, indicating that substantial over- or under-call from tool bias is unlikely.

Additional validation comes from comparison with repair data for older ILIs (Figure 3). The two 2016 ILIs are possibly slightly under-called relative to the field measurements but are near or within normal tolerance.

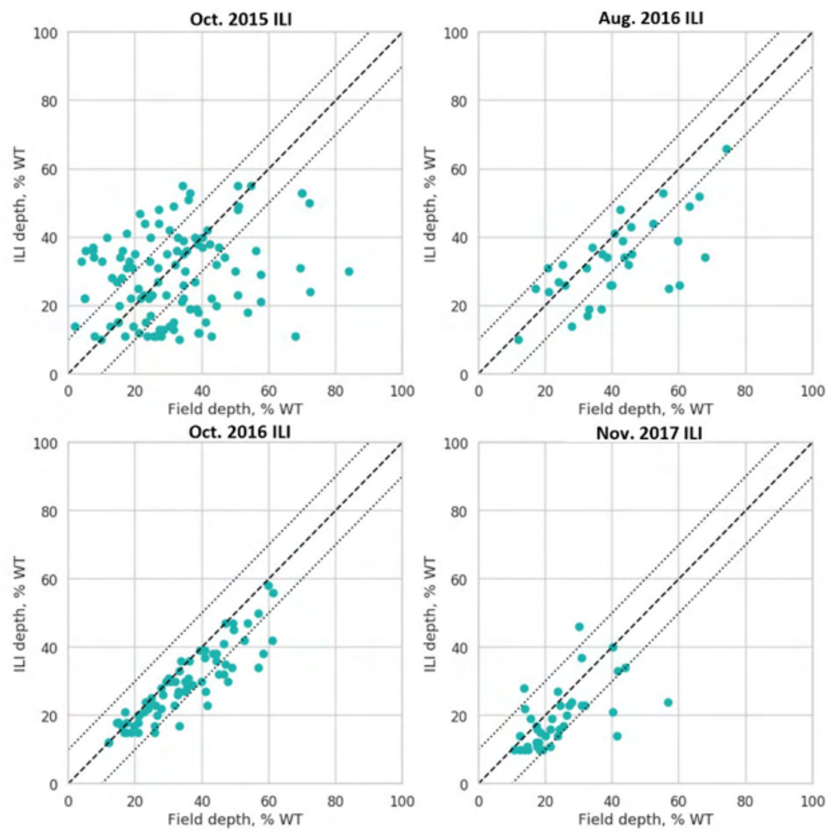

Figure 3: Unity plots of ILI depth vs field depth in repair data for four ILIs. Please note that the ILIs in this figure are not necessarily the same as ILIs in Figure 2 due to difference in selection criteria

Corrosion growth rate calculation

There are several strategies for calculating the corrosion growth rate (CGR) of an anomaly from an aligned history of ILI measurements. The efficacy of each strategy is evaluated by comparing a depth prediction from the calculated CGR to a field measurement or future ILI measurement of the depth. It's important to note that each strategy has different strengths and weaknesses that must be considered, in addition to agreement with future measurements.

No-growth strategy

As a control strategy, assume no growth and the predicted depth is the same as the latest measured depth.

Simple 2-point linear extrapolation

The latest two ILI-measured depths are used to define a linear growth rate over time and extrapolated forward. This strategy is very sensitive to tool noise in the two measurements. The variance in predicted depths will be very high when the time interval between the latest inspections is short. However, for corrosion that has recently started growing rapidly, this method may be the most sensitive.

Many-ILI linear fit

Fit a linear trend to all ILI measurements in the aligned history of each anomaly. The sensitivity to tool noise is greatly reduced when there are several measurements of each anomaly. The method is not sensitive to short inspection intervals in the way that the 2-point linear extrapolation is. A disadvantage is that recent rapid corrosion growth is not as strongly reflected in the calculated CGR as in the 2-point linear extrapolation.

Historical baseline

This method is similar to the 2-point linear extrapolation, but instead of using the second most recent ILI as the initial depth, average all previous measurements as the initial depth and calculate the CGR using this baseline and the most recently measured depth. The average of many points should suppress the variance caused by tool noise.

Short time interval averaging

All these strategies can be modified by averaging together depth measurements when they are within a short time interval, for instance 90 days. This modification mitigates the amplification of tool noise for closely spaced inspections.

In Segment A, there are not enough field measurements from repairs following the 2020 ILI to compare growth predictions. For the purposes of comparing growth methods, the depths from the 2009-2019 ILIs are used to predict a depth in 2020, which is compared to the 2020 ILI.

The short time interval between the 2019 and 2020 ILIs substantially increases the spread of predicted depths, leading to a substantial difference between the strategies that average nearby inspections and those that consider them independently (Figure 4). The two ILIs in 2019 were performed only a few weeks apart and their tolerance errors dominate the growth line.

Beyond this point, however, there is only a slight difference between growth calculation strategies. This is likely because the interval between the 2019 and 2020 inspections is short, total growth over this period is not large, and thus there is not as much opportunity for growth strategies to diverge as there might be for three-year or longer intervals. More repair data following the 2020 ILI would also allow comparison with field measurements, which are expected to be more precise. Another opportunity would be to apply this analysis to a longer time interval, possibly by artificially ignoring recent ILIs.

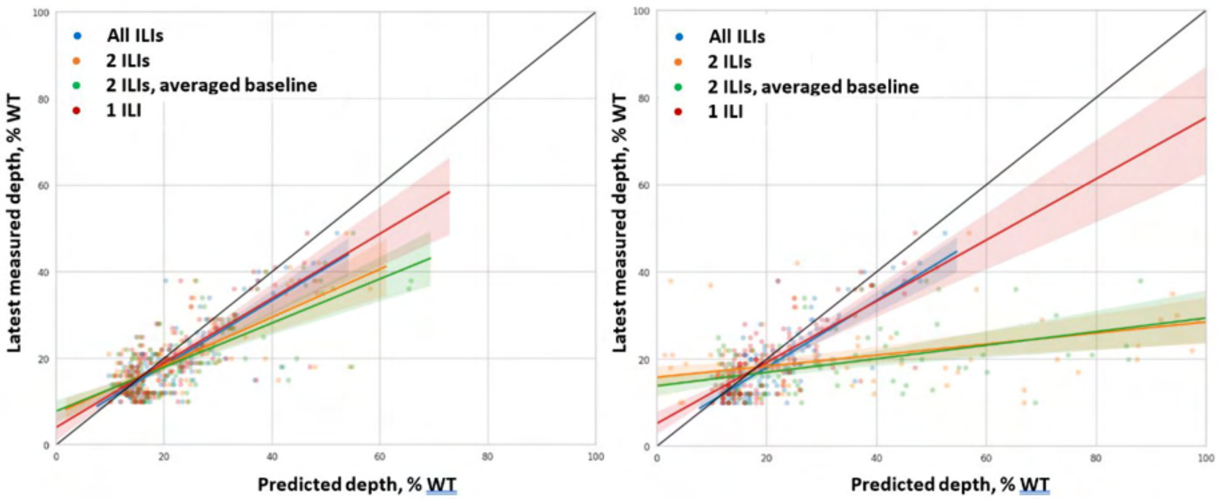

Figure 4: Unity plot of the 2020 ILI depth versus a depth predicted using a CGR calculated using previous ILIs. Lines and error bands are a linear fit. Colors show the different methods used. Red for the No-growth strategy that assumes no growth between the 2019 ILI and 2020, orange for the Simple 2-point linear extrapolation from the latest two measurements, green for the Historical baseline method that averages several previous ILIs as a baseline for growth in the latest measurement, and blue for the linear fit to all ILI measurements. On the left, ILI measurements that are within 90 days of each other are averaged into a single measurement point, and on the right, all measurements are considered individually.

Extensions of PR-331

Static defect analysis according to the PR-331 method elegantly solves the problem of separating run-to-run bias from net corrosion growth, as long as there are enough static defects to draw statistical conclusions. In many cases, there are not enough defects in total or not enough repair records to define a large population of static defects. Creativity in identifying static defects can help; for instance, anomalies that have been dug but not sleeved may be static because of the subsequent recoating.

Additionally, it is possible to analyze non-static defects as a fallback method. Under the assumption that a significant number of corrosion defects are not growing, we expect the growing anomalies to appear near the top when defects are ranked by observed growth rate. We can then observe trends in the median growth rate (or another select percentile) as possibly reflecting measurement bias. Additional validation of this technique can come from comparison with field-measured depths from repair data. In general, the higher accuracy of field measurements permits validation of non-static defect analysis in addition to assessing the overall validity and accuracy of ILI data.

About Cognitive Integrity Management

Cognitive Integrity Management Cognitive Integrity Management™ is a platform that addresses regulatory compliance and internal operational goals. It is a fully integrated enterprise level solution for a complete overview of asset health in the highly secure Microsoft cloud.

OneBridge Solutions Inc.

OneBridge Solutions Inc., develops and markets revolutionary new SaaS solutions that use advanced Data Sciences and Machine Learning to analyze big data using predictive analytics to assist Oil & Gas pipeline operators to predict pipeline failures and thereby save lives, protect the environment, reduce operational costs and address regulatory compliance requirements.

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