Inspection Data Management

Brian Gates

Kecheng Shen
School of Mechanical Engineering

Darryl Godfrey
BP Kwinana Refinery

Abstract

This project investigates thickness measurements and corrosion rates within refinery piping circuits through a statistical analysis. Knowledge of the pipework condition and its rate of deterioration allow the inspection team to make reliable predictions on the remaining life until the piping circuit is no longer fit for service and requires replacement. In fitting measurements at some locations of the piping circuit to probability distribution functions, it is possible to assess the total condition of the circuit with a degree of confidence. This confidence is a function of sample size as the more locations are included; the greater percentage of the piping circuit can be monitored. The objective is to optimise the required amount of inspection locations to achieve the required confidence. The deliverables will be two practical inspection management tools. The first tool will have the inspector's input piping circuit conditions, measurements and the location of the measurements and this will return a minimum thickness and a confidence reading. The second tool will return a corrosion rate for the circuit. Ultimately the project should lead to the inspection management program being more efficient with its resources and the process being more reliable, leading to reduced financial costs and increased plant integrity and safety for the refinery.

1. Introduction

The BP Kwinana Refinery can process up to 138 000 barrels of crude oil a day. This is enough to supply most of Western Australia's petroleum requirements from aviation fuel, gasoline, diesel and oils to asphalt for the road. The piping onsite at BP Kwinana deteriorates as the circuits are exposed to corrosive substances and conditions. Thus the inspection department undertakes an inspection program to monitor the condition of the piping circuits. The inspectors need to know how many Thickness Monitoring Locations (TMLs) will return a good assessment of the piping circuit condition and at what rate the circuit is deteriorating.

The present inspection management program consists of the inspectors taking measurements at set number of TML's along a circuit. As a general rule the inspectors inspect bends, the inlets and outlets to bends, tees, high turbulence areas and areas where there is sometimes no flow. Where the circuit is straight they inspect approximately once every two metres. If the piping is supported by external brackets it is inspected every second bracket. All this depends on features of the pipe (length, diameter, etc), available knowledge on the likely deterioration mechanisms, where they are likely to occur and the experience of the inspector. From this the inspectors may add TMLs if they, or other BP Refineries, have experienced events in the past that leads them to believe that there may be a problem in the future or where the piping condition is approaching the minimum allowable thickness.

As for the corrosion rates, the inspection team incorporate a linear model. They divide the difference in thickness measurements by the time between inspections. From the evaluated corrosion rates, the greatest rate of change is then utilised to assess when the piping circuit will fall below the required integrity requirement. This covers a “worst case” scenario as it assumes the piping continues to deteriorate at the quickest rate.

The world has been exposed to the problem of corroding assets for many years now. Refineries have had inspection management programs since they started operating and a core foundation of this is inspecting the piping circuits to get a good assessment of the circuit condition. Thus it is not a new idea - it would have crossed the minds of many inspection engineers over the years.

This project considers the representation of real life data sample with various standard statistical models to give an estimate of the condition of the whole system. This application of statistics is not restricted to engineering but is being used in fields such as, but not limiting to, medicine, biology and finance (Shaw, 1999).

Fitting random samples and attempting to fit a standard distribution model was suggested by Wirsching, (1992). The parametric analysis may be carried out on the thickness measurements (HSE, 2002 and Khan, 2007) and the corrosion rates (Sparago, 1999 and Abernethy, 2009) data for a piping circuit. The known distribution that accurately represents the system can then be used to ascertain the probabilistic estimates of thickness measurements and the expected rate of change.

CorrSolutions, (2001) and Sparago, (1999) highlight the necessity of identifying similar environments within the piping data. Once the data are grouped together within these environments a better fit will be obtained. These environments are defined through combinations of size, type, and operations.

The circuits can be assigned into risk catagories using Risk Based Inspection (RBI) consequence levels. Each level will have a required confidence level that must be obtained from the analysis to guarrentee fitness for service.

To investigate the effect of changing sample size (number of TMLs) on the confidence levels of the estimate CorrSolutions (2001) suggest Monte Carlo simulations can be employed to estimate and optimise the required number of TMLs for the confidence required and specific environment.

2. Process

The initial step was to transcribe the real life thickness measurements from onsite into a table format. These values are then used to evaluate corrosion rates (R) using:

$$R = \frac{C - P}{t} \tag{1}$$

Where C = Current recorded measurement (mm)
P = Previous recorded measurement (mm)
t = Time between inspections (years)
R = Corrosion rate (mm/year)

The actual thickness measurements and the corrosion rates are then analysed using the statistical software Minitab. Corrosion rates from the same time period apart were grouped at and graphed using this software.

The probability plot creates an estimated cumulative distribution function (CDF) from the sample by plotting the value of each observation against its estimated cumulative probability. The estimated CDF is evaluated using the Median rank method given as: (Minitab, 2007)

$$CDF = F(y) = \frac{i - 0.3}{n + 0.4} \tag{2}$$

Where "i" is the rank of the maximum wall loss reading/ corrosion rate and "n" is the total number of data points in the sample.

There are many possible distributions available to represent the inspection data. The functions considered for this project have been used in previous similar situations, being the 2-parameter Weibull, Maximum Extreme Value (MEVD), and the log-normal distributions.

Minitab uses two Goodness of Fit tests: Anderson Darling (AD) and p-value. The AD measures how well the data follows a particular distribution. The better the distribution fits the data, the smaller this statistic will be. The p- value determines the appropriateness of rejecting the null hypothesis in a hypothesis test. The smaller the p-value, the lower the probability that rejecting the null hypothesis is a mistake (Minitab, 2007). Both these tests can be used to compare multiple distributions that model the same data. In general a small AD and a p-value over 0.1 will demonstrate that the data fits the distribution well.

The accuracy of the estimates derived from the probability function depends on how well the data fits the statistical distribution. Sparago (1999) suggested that getting a good fit is essential as a poor fitting distribution will not provide reliable estimates. A closer fit may be obtained by separating the TML's into similar environment blocks.

Issues such as the accuracy of the readings and the TMLs not inspected in the exact same locations as these may contribute to errors in data. All negative corrosion rates were not included in analysis as it is practically impossible to have a piping that is growing in thickness.

3. Results and discussion

The thickness measurements were graphed but the plots did not return good fits for any probability function. It was discovered that when piping is installed there is a minimum required thickness but not a maximum. This is a problem as some measurements are larger than they should be (by up to 5 mm) and this led to a large spread of data with little relationship between them.

Instead of using the absolute thickness measurements it was decided to use indirect thickness measurements. That is, the amount of wall loss at the TML since the last inspection. From here it was also easy to calculate corrosion rate as it is the wall lost over the time between inspections (equation 1).

In applying the analysis to the test circuit line P1417 on the Vacuum Distillation Unit (VDU) 2 the following results were obtained. (The normal distribution was included in these results to show a standard statistical function that is familiar to most engineers).

Figure 1 shows that the Normal and Largest Extreme Value graphically look like they have the most suitable fit to the data. Comparing Goodness of Fit tests AD and p-values it confirms that graphical interpretation as they have the smallest AD and p-values over 0.1. Although the Normal distribution indicates the strongest fit, historically it is not the best choice for this type of analysis.

As stated above, from a good fitting distribution it is possible to estimate values. For example reading from figure 2 it can be said that with a 95% confidence, the 80th percentile for the population will be between 0.6 and 0.95 mm/yr.

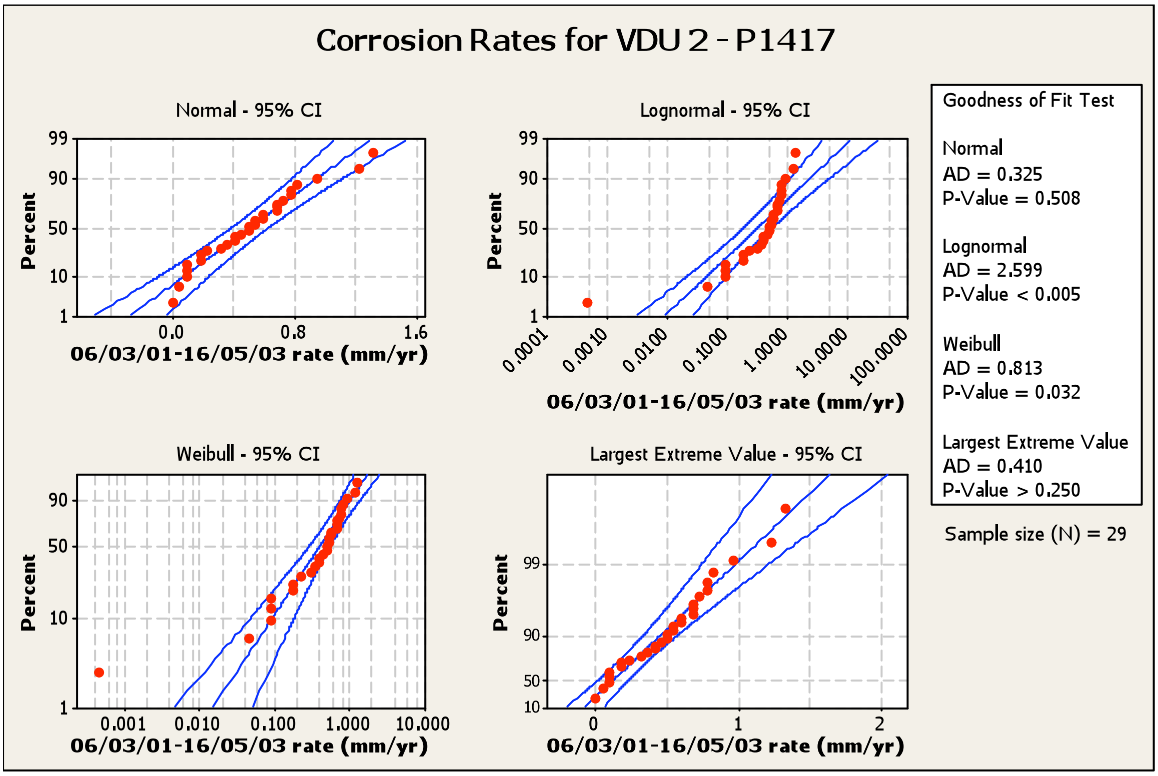

Figure 1 Plotted corrosion rates - VDU 2 Circuit P1417

4. Conclusion and future work

The project has confirmed that the inspection data can be fitted to statistical distributions. The results also supports the concept that if required, the breaking the circuit into “blocks” of similar environment (defined by size, type and operations) can produce a better fit. The greater the fit then the more reliable the information obtained from the graph is.

The next stage will be to finalize a rule for if and how the circuits need to be broken into the blocks. The other area needing to cover is to investigate the effect of increasing and decreasing sample size on the confidence interval. With this and the use of RBI the optimum amount of TMLs will be known for a circuit under different conditions.

Finally, the above methodology will be incorporated into one or two simple tools that may be operated by onsite inspectors to allow them to establish how many TMLs are required for a certain circuit.

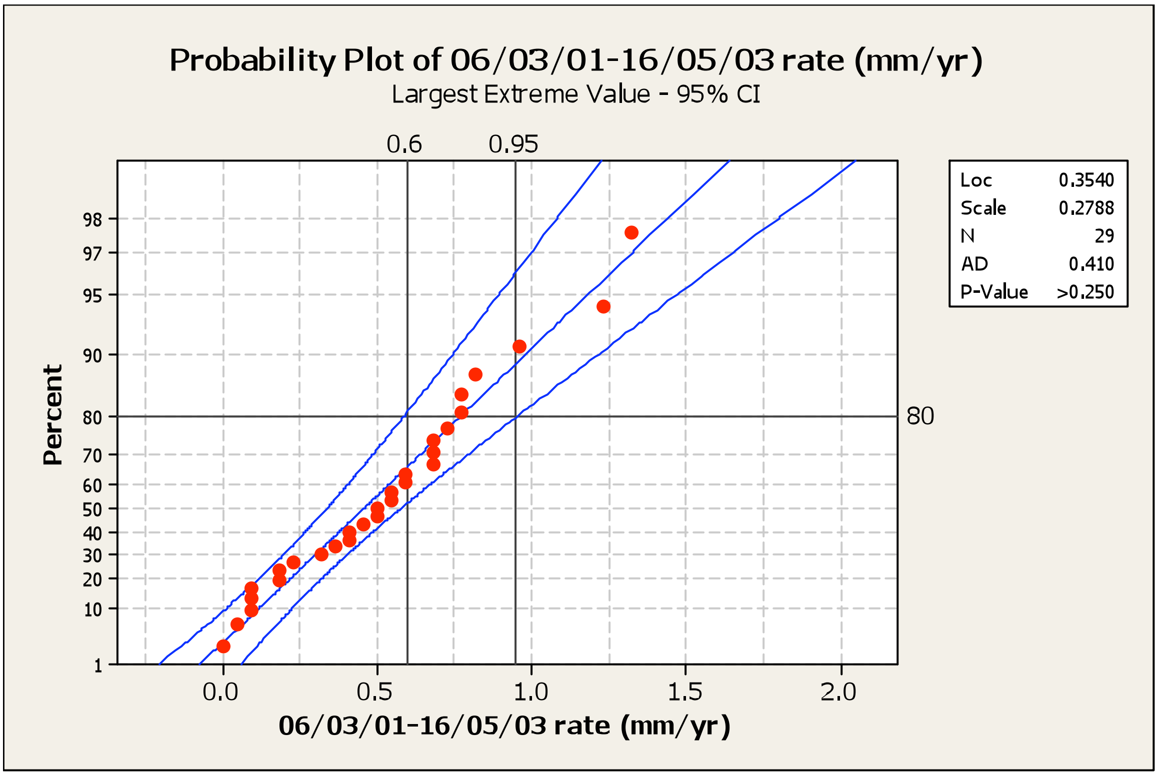

Figure 2 Largest Extreme Value with 95% confidence bounds - VDU 2 P1417

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