RISK MANAGEMENT

Damage vs failure:
a risk assessment needs to know the difference

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Since several of our recent columns have dealt with management-of-risk issues, let's go back now to the technical side. That is, let's take a deeper look into an aspect of the mechanics of good risk assessment – the measuring of risk.

Recall that proper probability of failure (PoF) estimation requires independent measurement of three components: exposure, mitigation, resistance. Without the independent measurement of each of these, we cannot fully understand PoF. When threatened by failure mechanisms (as all pipelines are) a pipeline survives by either:

1. Defending against or blocking the attacking mechanism, or
2. Absorbing or resisting the threatening force.

Let's discuss the last of these: resistance.

Resistance is the amount of damage a component can withstand without failure. Resistance measurements tell us the difference between damage potential and failure potential.

To measure resistance in a way most useful to a risk assessment, we must estimate the possible presence of weaknesses, the rate of emergence of future weaknesses, and the role of each weakness in strength reduction. As to the last issue – the role of each weakness type – the central question to be answered is: what has been lost due to the presence of this feature? For instance, how many overpressure events, longitudinal stress loadings, fatigue cycles, vehicle impacts, etc., can now no longer be resisted, due to the presence of this weakness? How much shorter is the time to failure from cracking or material degradation?

Varying levels of rigour are available to the risk assessment designer. The underlying engineering, physics, and material-science concepts can be complex. However, approximations often provide sufficient accuracy and will be appropriate for many types of risk assessment.

When more precision in resistance estimation is desired, pairings of specific weaknesses with specific potential loadings can be analysed using solutions up to robust finite-element analyses. For example, issues related to longitudinal-seam susceptibilities or girth-weld imperfections have dramatically different weakness implications for various loadings such as internal pressure, external forces, or cyclic fatigue.

For more approximate assessments, resistance can be efficiently captured by modelling a pressure-containing component's effective wall thickness. Wall thickness is a very strong determinant of strength and therefore is a useful surrogate for all other strength-influencing factors.

Increasing forces or defect severities will each reduce effective wall thickness and, hence, the ability to resist additional forces. As wall thickness is reduced, implications for component strength include:

- Less capacity for pressure containment
- Faster time-to-failure (TTF) for degradation mechanisms
- Higher D/t leading to reduced buckling capacity
- Lowered resistance to external forces including localised (such as puncture) and uniform (for example, subsea hydrostatic pressure) loadings.

Therefore, weaknesses can be efficiently modelled in terms of equivalent reduction in wall thickness. More reduction in effective pipe-wall thickness is the same as forecasting increasing failure rates under assumed loading scenarios. As a modelling convenience, we 'translate' each weakness type – metal loss, dent, girth weld defect, axial seam crack, etc. – into an equivalent loss of wall thickness.

Whether a more robust or more modest assessment is desired, it must take into account the probabilities of various weaknesses coinciding with various loading scenarios. The general process calls for an estimate of potential loads, stresses, and strains which is overlaid with estimates of known and suspected weaknesses due to previous damage or questionable manufacturing/construction processes (see also our previous column on *Threat interaction: a case of confusing terminology*).

Resistance is especially highlighted in regulatory Integrity Management Plans. Inspections and integrity assessments are essentially measurements of resistance. They may imply aspects exposure and mitigation, but they are predominantly telling us about system strength. Recall our previous example illustrating this point:

> *External metal loss on a typical pipeline, usually detected by inspection such as in-line inspection, actually tells us several things about every location where it is found:*
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> - *Some damage has occurred. We should now know remaining wall thickness and, hence, available strength against future loads. Even if the metal loss is not actionable, some incremental strength, perhaps inconsequential, has nonetheless been lost.*
> - *Both of the typical mitigation measures, coating and cathodic protection, have failed.*
> - *At least some exposure, usually soil corrosivity, exists.*

The most compelling and certain of these is the first – the measure of resistance. Some knowledge of exposure and mitigation is also now available and should be included in the risk assessment, but it carries more uncertainty. For instance, when did corrosion begin? When was each of the mitigation measures lost? Was the exposure level (the soil corrosivity) constant?

Understanding that resistance prevents failure, but does so in a different way from how mitigation prevents failure, provides enormous insights into failure potential and opportunities to reduce risk.

Even though we may have few opportunities to significantly change resistance for an existing pipeline, this understanding is critical. In the design phase of a pipeline, we have the opportunity to choose the balance between mitigation and resistance levels for the changing exposure levels along the route.

This is an exercise in risk management. When done well, it ensures the safest design at the lowest cost. P

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