

RISK MANAGEMENT IN THE OPERATIONS OF A SUBSEA PIPELINE

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This paper presents the Integrity Management (IM) of a relatively new and significantly sized subsea pipeline, focussing on seabed dynamics and pipeline freespans. The control of known/expected risks through Risk Based Inspection (RBI) Assessment, the inspections themselves, the sensitivities involved in the anomaly assessment through application of industry recognised practices and the considered actions to control these resultant risks are all demonstrated.

The findings and results when implementing the chosen (through risk based selection) remediation program and how this in turn has provided knowledge that must be employed in the future IM of the pipeline are discussed leading to a conclusion that will be of general benefit to those involved in risk management in highly dynamic projects and not be limited to Oil & Gas or Pipeline Operators.

OVERVIEW

Pipelines have undeniably become a necessity in our respective regional and even global infrastructure by providing an efficient and cost effective means of transporting significant volumes over long distances at low cost, that "low cost" of course being relative to alternative means of transportation if any exist.

As with all things however, technical and commercial gains of this nature have associated risks that must be managed to protect the people associated both directly and indirectly with the pipeline, the environment in which it is located and of course the value and sustained operation of the asset itself.

The intent of this paper is to discuss not only some of the specific risks that can often be faced by a subsea pipeline operation but go a stage further to demonstrate how the interpretation and assessment of risk plus the actions taken to manage the risks themselves can create threats.

Most pipeline operators and regional legislative bodies have effective minimum standards on what systems and strategies must exist to ensure risk management is efficiently in place but it must be appreciated by all that the presence of these systems itself does not make any measure towards minimising or controlling risks and as such can be considered as only part of the Integrity Management (IM) Lifecycle.

It should also be said that whilst the technical content of this paper is specific to that of subsea pipelines, the principle that risk management is essentially a dynamic activity and can require input on a frequent basis is inherent of any equipment type, discipline or application.

In order to adequately convey the sources of the primary risk in this case study, some basic principles of subsea pipeline management must be briefly provided.

SUBSEA PIPELINES – BRIEF INTRODUCTION

During the design and pre-construction phases of a subsea pipeline, extensive effort and resource is placed upon determining and assessing the seabed conditions which will essentially form the working environment of the installed pipeline.

The basic variances involved range from seabed soil conditions and stability (including topographic and geographic local phenomena) to on-bottom and surface current and wave influences.

Factors such as material selection, fluid type, corrosion mitigation, third party interaction, protection and design life are some of the obvious other areas examined but this paper focuses on the seabed dynamics and specifically that of pipeline 'freespans'.

As the very name would suggest this is a section of the subsea pipeline spanning two contact (or "touchdown") points with no support in between. In any discipline, the mechanical stresses in this situation can immediately be recognised and appreciated. However, in a marine environment, the variable forces (primarily current and those as a result of soil stability) increase the complexities involved in accurately predicting the extent and duration of such dynamics when considering design tolerances.

Therefore, within the designed specification of an installed pipeline, freespan tolerances must be determined and observed during the assets operation phase.

Figure 1 provides a visual representation of a subsea pipeline span scenario where the span dimensions are within design tolerances.

These design tolerances are again affected by the many contributing factors from the design stage and can, as a result, vary along the pipelines entire length due to items such as coatings specification changes and marine environment condition extremes.

For the purposes of completeness, it should be noted at this point that in some instances, freespan tolerances can be 'zero' mainly due to the pipeline location and/or regulatory requirements for particular subsea areas such as high user traffic areas and shipping lanes. The primary reason for the absence of an acceptable tolerance is to protect the pipeline and indeed the other sea users in the immediate area surrounding the pipeline from snag potential due to interaction from fishing gear or vessel anchors.

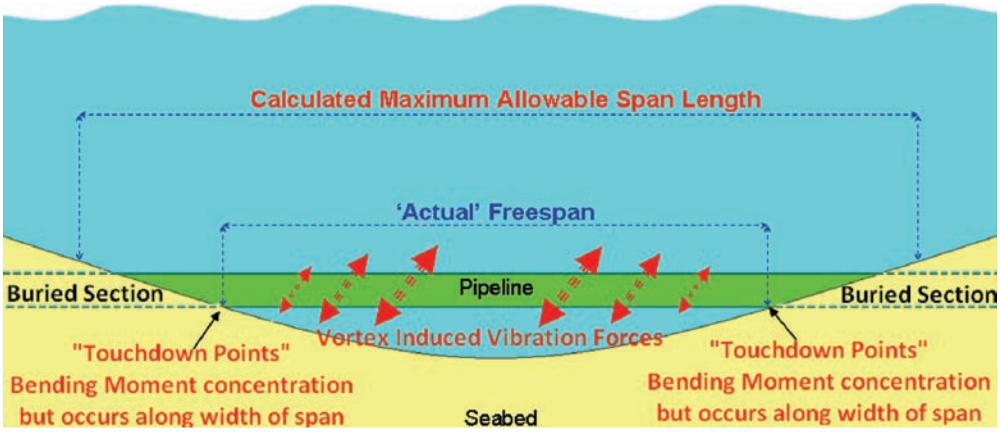

Figure 1. Subsea Pipeline with 'Freespan'

Again whilst referring to Figure 1. some specific risks to a pipeline in span can be described.

1. The stresses developing at the touchdown point at either end of the span from the associated unsupported mass of the pipeline (and of course its contents).
2. Vortex Induced Vibration (VIV) stresses can also occur due to the passing of subsurface current over the pipeline span resulting in a vortex on the opposite side of the current direction.

Either of these instances can create significant risks to the longevity of the pipelines 'assured' safe operation.

RISK IDENTIFICATION

PRE SURVEY RISK BASED INSPECTION ASSESSMENT OR "RBI"

It is not the intent of this paper to detail the techniques, methodologies nor specifics of RBI Assessment in neither its generic sense nor specifically the study that was undertaken for this particular pipeline but the basic steps in RBI Assessment and the outcomes relative to this content are covered respectively as follows:

1. *Identification of risks* specific to the component under assessment.
2. *Determination of the Failure Probability* i.e. Likelihood of the risk becoming realised in a predefined timeframe (e.g. "Design Life of component").
3. *Determination of the Consequence* and consequence type (i.e. People, Environmental, Asset damage costs, Reputation Impact).

   Risk = Probability × Consequence therefore to control the risk

4. *Identification of the most suitable inspection type and frequency* so as to control those risks to ALARP (As Low As Reasonably Practicable).

Of the risks identified from the pipeline RBI Assessment, Freespan was considered to be one of the most predominant at given points along the pipelines length due to its location (and experiences gained from other pipeline users in the same area) and specifically, the known presence of the seabed phenomenon referred to as 'sandwaves'. Again, the title explains that sandwaves are 'rolling' peaks and troughs of the seabed.

Whilst there is little that can be done past the design and construction phases of a pipeline to provide a risk prevention to these occurrences, the inspection activity and frequency does provide a means of risk control or mitigation in that if a span is encountered, remediation activities can be planned and executed if deemed necessary.

The appropriate techniques and annual frequency of inspection were therefore presented as the output of this particular RBI Assessment although this was partly influenced by a lack of asset specific inspection history (the pipeline being less than 6 months in operation and having had no inspection since it's as-laid post construction/pre-operational survey) that in application provides a great deal towards confidence factors in frequency determination.

INSPECTION SURVEY

The results of the inspection in 2007 displayed the presence of nearly 100 spanning areas of the pipeline, the majority of which were of no immediate threat mainly due to their dimensions being within the designed tolerable limits.

The spans themselves were graded as being one of three types the most significant expectedly being – "unacceptable" and was primarily restricted to spans that had formed from previously buried sections within shipping lanes. Being of this nature, little or no further assessment was required and the recommendations were passed on to remediate at the earliest opportunity taking into account (a) the ability to effectively remediate with an appropriate vessel and (b) in a season which would not have a high likelihood of unworkable weather.

QUANTITATIVE RISK ASSESSMENT

Of the spans which displayed parameters out-with the design specifications, further finite assessment was required to quantify the extent of the risk and therefore allow remediation requirements (method and criticality) to be determined in an 'informed' manner.

Given the specific nature of this assessment type, the scope was subcontracted to a recognised industry expert group who applied the now extensively developed '*Recommended Practice DNV-RP-105 Freespanning Pipelines*'.

It is now that the sensitivities can be demonstrated not only in the application of the guidance within DNV RP 105, but also as a result of the information from the survey and even the communication of the resultant output. These factors play a vital role towards an accurate determination of risk being presented and thus, allowing a recommendation to be made.

It is important to ensure that the communication of the remaining content of this paper does not result in the very same mis-interpretation that has led in part to its very development so this element shall be tackled first and deals solely with the principle of 'acceptable risk'.

DNV-RP-105 is based upon the industry recognised value that 'an acceptable probability of risk is equal to $<1/10{,}000$ i.e. an event shall not occur within the first 10,000 instances 'instances' – any probability greater than this is considered un-acceptable. For clarity it should be noted that in chronological terms the period of time is entirely relative and dependant on the frequency of said 'instances'.

The calculation output itself (in its most basic representation) is displayed as an 'estimated duration'. The possible clear mis-interpretation that can be made is that the 'estimated duration' presented is an estimated 'time to failure' whereas it is in actual fact the estimated time before the level of probability of failure increases to greater than $1/10{,}000$ and is therefore considered unacceptable.

The basic elements that are required in order to perform stress analysis of this nature are

- pipeline (and coating) material specification.
- temperature.
- pressure.
- surface wave direction and force (average, peak and predicted worst case).
- subsurface currents direction and force (average, peak and predicted worst case).
- touchdown definition or type.

It may already have been noted by some that the factors of 'temperature' and 'pressure' do not specify whether this is the design specification or the 'current' operational parameters. This omission is deliberate as it presents the second area that must be explored.

The initial calculations that were undertaken utilised the design specifications which are always constant throughout a pipeline section's length and it is not uncommon for these values to be greater than the operating values particularly in relatively new assets where capacities and associated inventories are still being 'ramped up'.

When the same calculations were repeated but using a protracted operating temperature and pressure relative to the location of the spans in question (the expected pressure drop along its route and the thermal differentials due to the line being subsea in relatively cold waters) the results were not solely that the "estimated durations" dramatically altered but more that the nature of the threat changed from being an issue of static stress (i.e. stress at the touchdown point/s) to one of VIV induced stress failure. This alone has potentially huge implications for the remediation plan that may be required. The comparative values with the temperature and pressure changes can be seen in Table 1.

As previously described, the acceptability criteria for the calculations was pre-determined as anything $>1/10{,}000$ being unacceptable.

To try and quantify this, sensitivities were conducted of the acceptability through varying the acceptable probability to $1/5{,}000$ and $1/1{,}000$. The results can be seen in Table 2.

The final variable that had impact in this specific case was what can only be described as the 'confidence factor' applied to the calculation which is directly formed from the knowledge and understanding gained during the survey as to how the pipeline interacts with the seabed at the touchdown points. The resultant effects of this confidence level can be seen in Table 3 and shows not only how it could influence the decisions made towards providing integrity assurance but also how critical it is to ensure that this information is gathered when the span is first identified i.e. at the time of survey.

QUALITATIVE RISK ASSESSMENT

With the information available as presented in Tables 1, 2 & 3, a qualitative approach had to be employed to look both at other influencing factors but also the suitable remediation methods.

As was said previously, it is widely acknowledged that this particular region is subject to highly dynamic

Table 1. Design vs operating conditions effect

Calculated period until is probability reaches 'unacceptable' (Acceptable probability = 1/10,000)	
Maximum design conditions	*Estimated operating conditions*
6.2 days	120 days

Table 2. Probability sensitivities

Acceptable probability		
1/10,000	1/5,000	1/1,000
Calculated period until is probability reaches 'unacceptable'		
120 days	1.1 years	4.1 years

Table 3. Span definition 'confidence' effect

Span Definition (Confidence in the nature of the touchdown and the stabilisation properties it can provide)	*Probability 1/5,000*
	Calculated period until is Probability reaches 'unacceptable'
A) Very well defined span	2.9 years
B) Well defined span	1.1 years

seabed soil movements and in some areas, sandwave migration, which therefore had direct influence on the probability of the spans being of exactly the same dimensions or even location as was identified during the initial survey. This aspect itself was what was believed to be (and was later proven to be) the most significant aspect of the entire situation.

What could not be quantified with any kind of certainty however (without further survey at least) was the knowledge as to whether the span would have increased or decreased let alone moved along the pipeline.

In house expertise was engaged to determine whether any known instances of pipeline failures had occurred as a result of unmanaged freespans as an indicative measure of confidence and whilst no instances were known (excluding risers) it could not be ascertained as to whether this was indicative of the inbuilt conservatism in design span tolerances or simply due to the fact that in span instances out with tolerance, the respective operators had undertaken remediation hence prevented any failure occurrence.

Consideration also had to be given to the remediation type. As has been seen, two very different failure mode predictions were presented and as a result, differing remediation options would be employed.

It was perhaps the only area whereby the resultant actions of both could be relatively accurately understood – if an intervention were undertaken based upon the calculations at 'operating conditions' then there was a residual threat that these would then become the 'operating maximum' tolerances with respect to pressure and or temperature.

This combined with the inability to monitor the span locations for these variables meant that any decision to plan a remediation program must be done in view of restoring full pipeline design functionality.

Ultimately the options that were available were mobilise a vessel equipped to re-survey:

- the spans of specific concern as soon as possible
- the spans of specific concern at a later date when seasonal weather limitations would be minimised
- and undertake remediation on the spans of specific concern as soon as possible
- and undertake remediation on the spans of specific concern at a later date when seasonal weather limitations would be minimised.

OUTCOME

The resultant recommendation made was to re-survey as soon as possible therefore gaining an up-to-date status of the pipeline spans. Once the stability status was fully appreciated any executive actions required could be undertaken whilst an effective intervention program was prepared for execution on a second mobilisation.

Following presentation and review of these options and the recommendation by the pipeline owner, the route of re-surveying plus remediation during the same mobilisation with an intervention program based on the findings of the previous survey was selected.

The remediation options, given the required timeframe, were evaluated for practicality, readiness to execute (i.e. fabrication time etc.) and cost.

The remediation method selected was to utilise subsea 'air-chutes' or 'inflatable bags' that would be evenly distributed along the span length then inflated to provide sufficient buoyancy to lift the pipeline to a predetermined height. Then allowing the insertion of fabric formworks supports that would be 'pumped-up' with cement to the required elevation off the seabed, allowed to cure and finally surrounded by suitably sized rock to prevent the seabed at the bases of the formworks from being eroded through seabed scour.

Within three weeks of this decision, the vessel mobilised with all the equipment, personnel, procedures and risk assessments required for what was considered to be a relatively unique undertaking and was in no ones opinion, considered the easy option albeit it was the most favoured.

Upon arrival, the weather conditions both on surface and as a result, subsurface, were far from conducive towards such a delicate operation and almost immediately the poor visibility experienced proved challenging in simply gaining survey data therefore on-board back-up acoustic devices were employed.

The results of all three critical span surveys demonstrated that they (and the areas immediately adjacent to them) were clear of any conditions that could be considered out with allowable span tolerances and in most instances the pipeline was found to have either partially or fully reburied. Three further spans identified during the 2007 inspection were re-surveyed to provide further data and again were found to be no longer evident in the same area.

With the expected dynamics of the seabed demonstrated and the urgency for any immediate intervention to stabilise at the areas of concern became nil.

It was however known that these areas had been subjected to span stresses previously and any future exposure, as a result of the cyclic spanning patterns along areas of the pipeline (i.e. 'sandwaves') was probable. Given the extensive equipment mobilisation undertaken to allow remediation against the conditions as originally surveyed, efforts were made to protect these areas but again attempts in such the poor visibility (where sonar equipment could not be employed for this task) were impossible to achieve without introducing an immediate risk through impact potential.

Post survey interpretation and collation of this data plus the data from the original survey, the construction survey and indeed the pre-installation route survey provided a valuable overview where rolling peaks and troughs of the seabed could be seen over the relative timeframe of 3 years. This provided not only assurance and base understanding as to the mobility of specific regions concerning the pipeline but also a quantifiable reference for when updating the RBI assessment.

It is hoped that this can go some way towards providing the previously unavailable confidence in survey findings where freespan is identified and as a result, the decision basis for the management of known spans.

This very area has been trialled on other seabed regions over a period of many years with relatively high levels of accuracy and confidence should be high that local knowledge and pipeline specific familiarity will have a significant impact on the IM assurance of the asset in question.

CONCLUSIONS

The conclusions are brief given the previous content and two main areas are highlighted, firstly that of communications regarding data handoff/interpretation and secondly regarding the dynamics of a seabed region.

1. It is hoped that this paper conveys the absolute criticality of ensuring that not only the correct data (design, survey, assessment, operating conditions etc.) is available but also that all interpretations, assumptions and expectations are fully communicated to all parties involved in any exercise similar to this. Failure to do so may only result in lost time but potentially the implications could be far worse. Primarily in this example, the local knowledge of seabed dynamics was largely un-quantifiable and demonstrating 'experience' is a difficult task for any recognised organisation. The interpretation of the presented assessment outcome data also caused immediate (and understandable) concerns when 'the period until acceptable probability breach' was initially understood to reflect 'duration to pipeline failure prediction' so the secondary key learning is in ensuring that when information of this nature is presented, it is done in a way that guarantees the correct interpretation by the recipient in the correct.
2. Secondly the development of seabed topography prediction software may not be that far away but like all modelling suites, the only means of calibrating or verifying a prediction is to actually undertake the task. In any event, the sharing of regional information through regulatory bodies and public forums is vital in ensuring all operations that can potentially have adverse effects, have as much experience based content as is available.

ACKNOWLEGEMENTS

Specific appreciation must be extended to Mr. Mark Wilson at iicorr Ltd for both allowing me to continue developing this paper, career mentoring and indeed for the continual support during its development.

Also my thanks to both the internal iicorr staff and external personnel who were involved in the steps discussed in the previous pages. It was a challenging time but in a short duration an event went from being a potential risk to a situation of integrity assurance due to their professionalism and commitment.

Finally, to the Hazards XXI committee.

REFERENCE

1. Recommended Practice: DNV-RP-F105 – FREE SPANNING PIPELINES (Det Norske Veritas, FEBRUARY 2006).