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TECHNICAL ACCEPTANCE ASSURANCE LIMIT OF IFL™ PIPELINES

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ABSTRACT

With a worldwide aging pipeline infrastructure and increasing economic and regulatory constraints for pipeline operators, pipeline integrity issues need to be solved. While pipeline regulations not only demand inspections or monitoring of structural integrity at certain intervals, but a continuous process of verification of pipeline integrity and fitness-for-purpose. In-Field Linear Hose (IFL) offer complemented solution for both maximizing pipeline integrity preventing; corrosion, wear, leakage etc. as well as, a health monitoring tool.IFL has short rehabilitation times and rapid re-commissioning, and thus represents not only an inexpensive alternative to open rehabilitation, but also a high-quality method for the renewal of pressure petroleum pipes with an anti-corroded solution. Although, IFL structure can be coiled or uncoiled several times, it embedded optical fibre for health monitoring tool assessing pipeline integrity by inspecting the pipe corrosion, metal loss, deformations, and position. Technical Acceptance Assurance for IFL™ over its 20 years of design life are key deliverables of this study. Whereas, IFL failure mode is typically caused by a succession of defects or degradation that leads to loss of structural integrity. IFL Collapse, Burst, Tensile failure, Torsional failure, Fatigue failure, and Erosion are failure mechanisms expected cause potential IFL failure and need to scrutinize. This paper focuses on wrinkling of IFL under verities loading, deformation and its interaction with the outer pipe. Stresses and strains will scrutinized throughout the deformation stage, detecting possible detachment of the liner from the outer pipe and minimum loads induce wrinkles.

Keywords: flexible hose, composite hose, laminated hose, carcass hoses and high-pressure hose.

INTRODUCTION

a) General

PETRONAS Carigali Sdn Bhd Sarawak Operations (SKO) is currently operating and managing a total of 175 production pipelines assets which is the highest numbers as compared to Peninsular Malaysia Operations (PMO) & Sabah Operations (SBO). Table below summarize the total quantity of operated pipelines in SKO.

Table-1. Total quantity of operated pipelines in SKO.

Sarawak Operations Pipelines (1902km, 240 Nos.)				
Size (in dia)	6 to 36			
Age (yr)	<20	20-30	>30	TOTAL
Operating	35	65	75	175

The pipeline assets in SKO cover approximately 1902 km, made up by Full Well Streams Pipelines and Gas Lift Pipelines. The distribution of pipelines sizes ranges from 6 to 36 inches in diameter.

From 2001 to 2007, SKO embarked on quick fix activities which focused on pipeline services, repairs whilst setting the scene for pipeline replacement projects from 2007 onwards [1,5].

b) Current situation

As part of business integrity requirement of securing long-term production goals, predictive maintenance project shall eliminate threats and necessarily low in operational cost. Thus, it has to begin with finding solutions to prolong the pipeline operations life with low capital and operational costs [3].

The Annual Integrity Assessment carried out by the SKO Pipeline and Structural Section is a crucial exercise to gather, evaluate, analyse and plan for the integrity management of SKO pipelines. Based on key testing and criterion, all of SKO pipelines were rated in five categories, Very High, High, Medium, Low and Very Low risk. Based on this assessment, focus will be given in managing the pipelines with Very High and High risk respectively. Maintenance and replacement project was planned and done in reducing the potential of problems [6].

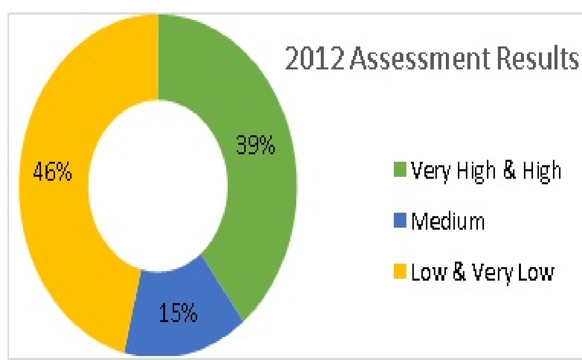

Figure-1. Number of pipeline per risk category 2012.

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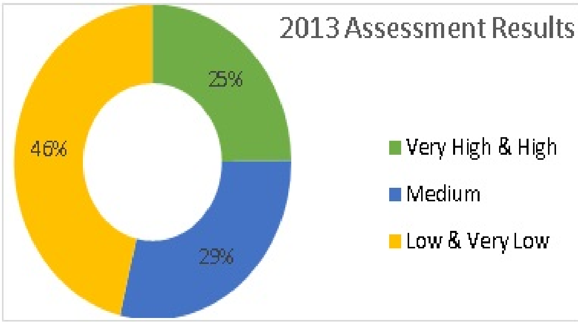

Figure-2. Number of pipeline per risk category 2013.

The bar charts above summarize the number of pipelines based on risk category. The 2013 Annual Integrity Assessment results shows that, between 2012 and 2013, there is a decrease in number of Very High and High Risk pipelines from 71 to 43. However, the medium risk category shows an increasing value [7].

IFL DESIGN JUSTIFICATION

The development of initial design was built based on various factors. Firstly, the forces needed to pull the hose inside a host pipe, which exceed distance of 10 km. Therefore, the hose must withstand these forces: tension and bending, acting on it during the installation. By referring to Figure-3, the hose designed to have circulated cuffs provides very thick wall to easies insulation proses and offer proper strength allow hose to withstand the wrench load during insertion in host pipe. As well as these cuffs will accommodate the full interior surface of host pipe during expanding process.

The hose has small circular tubes scattered around the hose circumference to allow the placement of optical fibre and Armor fibre. This allow the hose to exert the forces applied and prevent it from breaking. Nevertheless, the thickness of the hose is also a crucial factor, which needs to be taken in consideration. The commonly used pipe diameter in oil and gas is around 10 inches to 12 inches. The hose must have a small thickness so that it will not have a huge effect on the inner diameter of the host pipe. In addition, small thickness translates to flexibility in handling, transportation and installation of the hose.

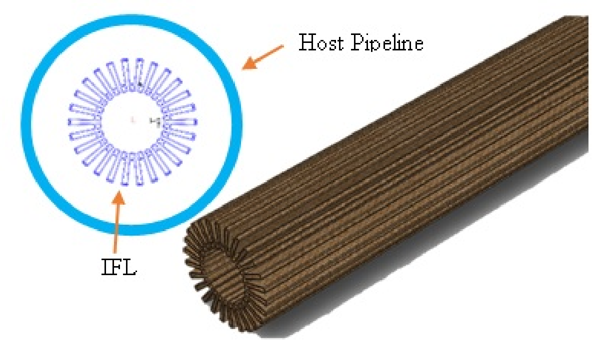

Figure-3. 3D Hose model.

Design claim

- A IFL hose comprising composite layer made of vinylester resin reinforced by carbon matt fiber.
- An elongated body including a number of layers which extend along the elongated body, said layer having varying pressure resistance leading to reduction in weight of the system.
- The IFL hose of claim 1, wherein said layers include an optical fibre.
- The IFL hose of claim 1, wherein said layers include an elongated element in a form of one or more of cable, or heating wire.
- The IFL hose of claim 1, including at least one reinforcement member embedded in and fully bonded to internal wall of the hose.
- The IFL hose of claim 1, wherein said layers control expansion, collapsing, and tension of the IFL hose.

Analysis setup

To estimate operational limit of possible detaching, wrinkling, and collapsing of IFL. Furthermore, the specific behaviour of IFL needs careful examination to understand the influence of the global plastic deformation caused by mechanical contact between IFL outer layer and host pipe see Figure-4. As well as the capacity on the liner to survive operational process without local buckling. Motivated by this challenge, significant efforts have been undertaken to establish the extent to which host pipe can be safely bent, to identify the main factors that influence IFL liner detaching or wrinkling, and also to find ways to prevent any deformation or detachment within the host pipe. Current work begins with modelling the gripping force of the IFL, focusing on determining the critical curve, which causes IFL liner detachment and wrinkling during the spooling-on phase. The post buckling responses of IFL liner wrinkling may also investigate by 3D FE models. This paper, include a comparative analysis on the wall thickness influence of IFL outer layer, as well as pitting and irregular corrosion, see Figure-5.

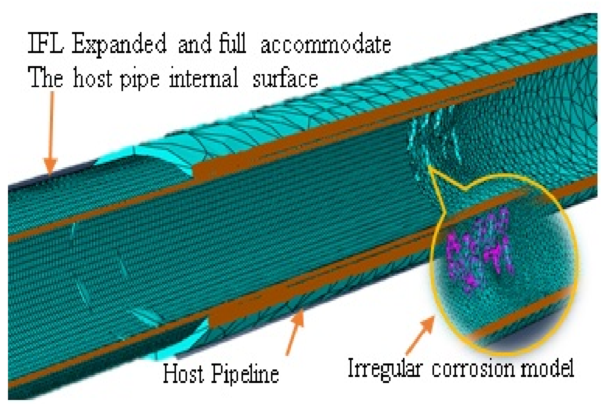

Figure-4. Equivalent elastic strain of hose.

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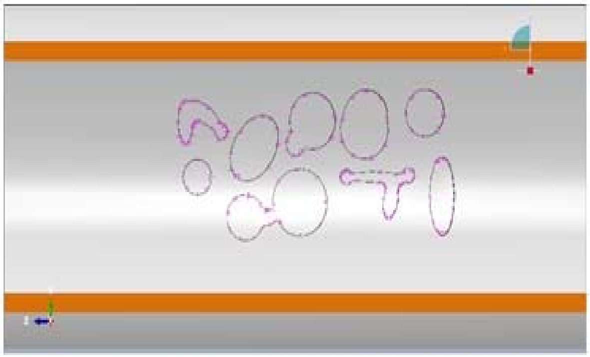

Figure-5. Irregular corrosion model on host pipeline.

DEDUCTION ON IFL DAMAGES CLASSIFICATIONS

1. Collapse of IFL is when the pressure sheath fail by collapsing inwards to cause severe problems for flow assurance and integrity. The failure mechanisms that may lead to collapse are different, but the common denominators are excessive force or pressure, fabrication anomalies, erosion, and transport and installation damage.
2. Burst is opposite of collapse, burst is caused by internal pressure or excessive forces where IFL materials will rupture outwards. The probability of IFL burst is largely increased by anomalies in the IFL layers. IFL fabrication errors, erosion or external abrasion will decrease the burst resistance and create weak spots, see Figure-6.

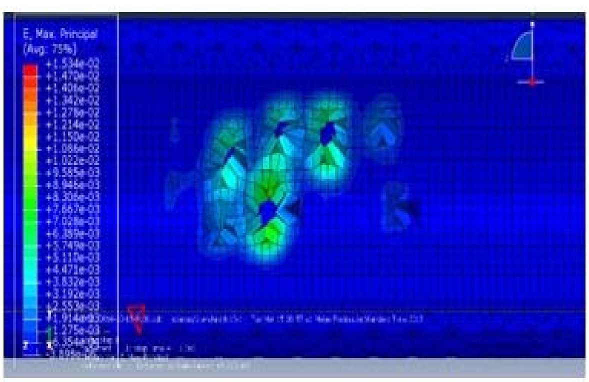

Figure-6. IFL undergo burst failure near pitting zone.

3. Tension forces are mainly affect the IFL at riser portion as it hangs from the platform and all the weight is distributed to the top of the IFL.
4. Compressive failure: When IFL is installed its temperature and host pipeline are equalized with the temperature of the ambient seawater. After starting production, warm gas and fluids conveyed in the pipeline raises the temperature. This causes the IFL materials in the hosted pipeline to expand and if it is restricted by friction with internal hosted pipe surface, compression forces will build and may cause wrinkle.
5. Torsional failure: IFL may during installation are configured in a helical pattern. Therefore, it may subjected to tension or compression as the IFL is twisted. Excessive tension loads due to twisting may form wrinkle then rupture of IFL, see Figure-7.

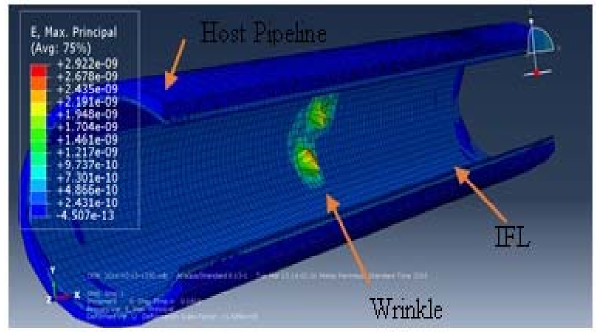

Figure-7. IFL undergo torsional failure.

6. Fatigue failure: In service the different layers of the IFL will be subjected to several different stresses. This can be tension, compression, torsion, erosion, abrasion and temperature variations. A single load cycle of the mentioned stresses may not be large enough to damage IFL, but the accumulated cycles can wear down IFL composite layers.
7. Erosion: in IFL is when particles in the produced fluids collide with the internal wall of IFL and over time causes thinning of IFL layer. Failure mechanisms when solids (sand) are produced and conveyed through a production pipeline erosion can be a problem. Especially for gas production the solid fragments have high velocity and collide with the inner wall off the IFL. Some areas will be more endangered by this problem as the lay route of the pipe cause certain areas to experience more erosion than others (bends and curves). Erosion alone does not usually cause failure of IFL, but the erosion process wears down the corrosion protecting layer of IFL wall. If erosion and corrosion act together the thinning of IFL may be sufficient enough to cause collapse or rupture.

8. Wrinkles is a geometric imperfections of the liner at different patterns and sizes if the external circumference of the IFL liner exceeds the internal circumference of the host pipe. Influences of wrinkle configurations on loading bearing, cyclic loading and circumferential strength of IFL liner need to scrutinize. Wrinkle may reduce the ultimate hoop strength of IFL up to 23% and depending on the occurred wrinkle pattern. Effecting the cyclic loading corresponding, service life, and the ultimate strength of the liner may reduce by 16% as well, see Figure-8.

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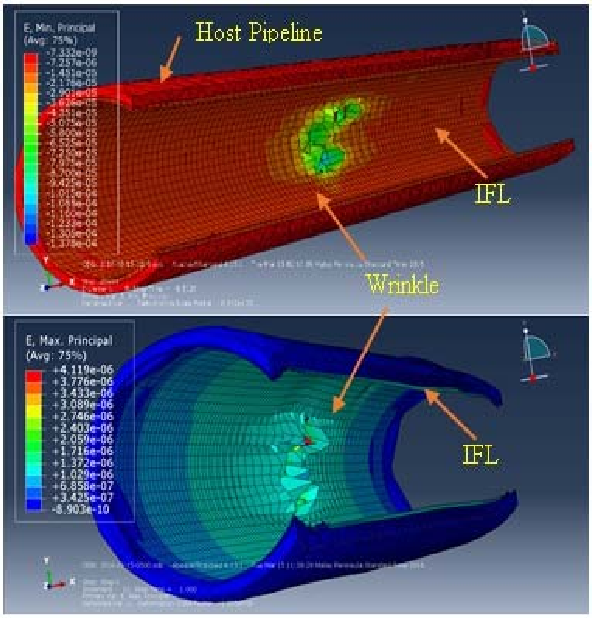

Figure-8. IFL undergo wrinkles imperfections.

9. Stress Crack Growth (SCG) is a phenomenon in IFL materials whereby slow growing cracks can occur due to the presence of stress in the material. Therefore it is required to scrutinize IFL durability as it dependent upon IFL structural integrities and resistant to inhibit the initiation and slow growth of cracks.

Ductile failure, may results in IFL yielding and reflects a material's propensity to undergo large-scale, irreversible 'plastic' deformation when under operational stresses, see Figure-9.

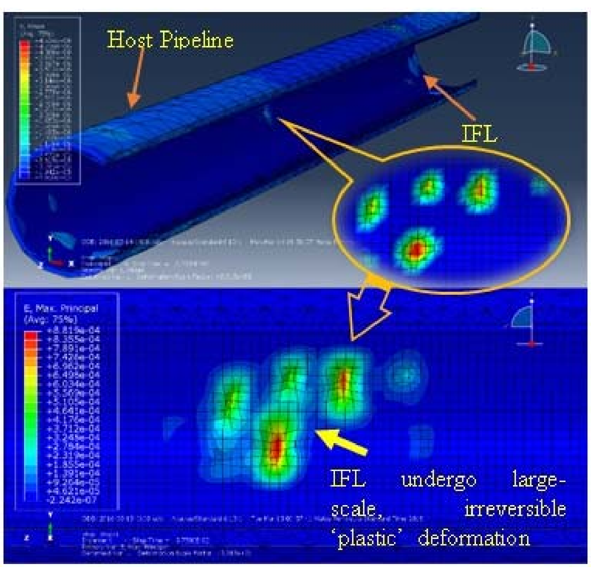

Figure-9. IFL undergo ductile failure.

The mechanism results in localized expansion of IFL wall section and final rupture of the deformed zone. This failure mode is associated with Creep, Creep Rupture and SCG. Creep is time dependent, non-reversible deformation, when IFL exposed to a constant tensile stress. Creep rupture is the terminal event of creep and is a measure of the time that IFL material under a constant, applied tensile load takes to fail, see Figure-10.

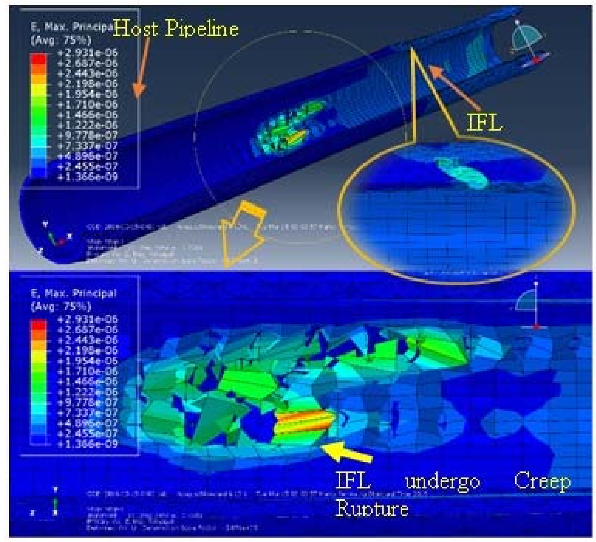

Figure-10. IFL undergo creep rupture.

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