

Effective Implementation of Subsea Integrity Management

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Abstract

Strong Integrity Management (IM) systems have been implemented by Operators around the world for all underwater components including subsea equipment. Pioneering work has recently been carried out in developing best practice for IM of subsea equipment components which is providing a solid foundation for Operator's Integrity assurance activities.

The paper describes the systematic risk based integrity process for both new installations and ageing facilities, specific to subsea equipment such as trees, jumpers, umbilicals, manifolds, sleds, etc, in all water depths including deepwater field developments. It not only looks at the general requirements of an Integrity program but also outlines the issues specific to subsea equipment which need to be taken into account including:

- Consideration of IM early in field development
- The value of monitoring in conjunction with inspection
- Development of suitable Technical and System Performance Measures
- Emergency preparedness
- Competency of personnel

Introduction

Lessons learned in industry have been instrumental in the change from a prescriptive inspection and test regime into a goal setting Integrity Management (IM) regime. The trend is seen to have gathered worldwide acceptance after being adopted in the UK in the aftermath of the Piper Alpha tragedy, which led to the overhaul of UK legislation.

The body responsible for the introduction of the IM regime in the UK, the HSE, undertook a study between 2004 and 2007 covering 40% of the UK offshore assets, and issued a report (Asset Integrity Programme, KP3 [1]) highlighting a number of areas where UK Operators were required to place additional focus, including:

- Wide variation in the performance of management systems between assets in the same company;
- The condition of plant was often not understood;
- Overdue maintenance and inspection;
- Significant improvement could be achieved without major capital expense through better planning;
- The role of asset integrity was not well understood;
- The concept of barriers in major hazard risk control was not well understood;
- Cross organisational learning to secure corporate memory needed improvement;
- Better key indicators of performance were needed to keep senior management aware;
- Many senior managers were not making adequate use of IM data.

Subsea equipment is no different to any other offshore assets and therefore in order to have an effective IM system for subsea offshore facilities, it is essential that these general concerns be addressed to protect asset value, and ensure safety and environmental protection.

2H have been working with Operators to develop risk based IM processes and systems for deep water subsea equipment which are recognised as being pioneering [2]. These systems and processes when viewed against the areas highlighted in the UK HSE KP3 report can be seen to effectively address the general concerns raised. As a result, the systematic risk based integrity process for subsea equipment assists in identifying and rectifying potential shortcomings through:

- Implementation of justifiable and auditable IM plans

- Regular issue of performance metrics to management (both technical and process)
- Coordinated planning of all IM activities
- Ensuring involvement throughout the process with Operations personnel
- Clear risk assessment methodology providing monitoring and mitigation requirements in conjunction with inspection
- Centralised data management
- Technical performance measures linked to all monitoring and mitigation needs
- Delivery of IM data in a user friendly manner providing ongoing asset health check, and with clear recommendations to ensure onward integrity

The need for the implementation of an Integrity management program is well recognised in the offshore industry. This paper outlines the issues specific to subsea equipment which need to be considered for an effective subsea integrity management system.

Consideration of IM Early in Field Development

In order to maximize the returns from an IM program, IM activities should best be tied into the asset development path as shown in Figure 1. Conducting a risk assessment during the subsea equipment design phase helps to identify potential risks to the long term integrity of the system. The monitoring plan developed with the risk assessment may be included in the design and can be integrated in the subsea systems. Following the fabrication of the subsea equipment, a detailed inspection package can be developed based on the as-built information and used for a baseline inspection following installation. Benchmarking the condition of the subsea equipment following installation and tracking its status over time can provide a history of the equipment for external structural damages.

Setting an IM plan from the very start will lead to fewer surprises during the life of field and helps eliminate gaps in important data transition from development teams to operations personnel. An early implementation of IM plan will facilitate tracking and

remediation of age-related anomalies for the subsea system and hence extension in the life of field can be achieved as shown in Figure 2.

System designers can dramatically improve the ability to perform conditional monitoring by planning for and providing in the system designs the necessary instrumentation to permit better conditional monitoring. Additional subsea measurements would enable more precise fault detection and source identification than is possible with most systems today. For example, more accurate hydraulic flow rate measurement from the hydraulic power unit would improve the fluid consumption algorithms used to detect leakage. Additional pressure sensors combined with strategic isolation valves within the subsea hydraulic distribution termination assemblies would permit isolation of hydraulic anomalies associated with blockage or fluid leaks in complex subsea system architecture.

Monitoring along with Inspection

Integrity management of subsea systems goes well beyond simply inspection or inspection management, although these are key requirements. Inspection activities alone provide a fraction of the information required in order to give an informed opinion in integrity assurance. A carefully developed condition monitoring plan must be developed and implemented to manage integrity and ensure the ongoing performance of a subsea system.

Setting up inspection and monitoring in isolation of each other is seen not to be the most useful way to look at risk management. Inspection and conditional monitoring go together, as an effective approach to controlling offshore risks over the long term of the facility infrastructure.

Inspections provide a snapshot of the visible structural health of the system. An ROV inspection of a deepwater subsea system can provide visual evidence of potential wear, impact damage, external corrosion signs, valve status, potential leaks, vibration, and structural damage. Benchmarking the condition of subsea equipment following installation and tracking its status over time can provide a history of the deterioration rate. Unfortunately, limited information can be obtained in this manner to assess the

internal integrity of the subsea system, and visibility due to marine growth and inaccessibility can also play a role in the reliability of inspection results.

Threats relating to the internal health of subsea systems are numerous and varied including grounding in the electrical system due to water ingress, poor communications, blockages or small leaks in the hydraulic or chemical injection systems, and critical control valve failure, for example. All of these can go undetected by inspection potentially leading to subsea system downtime. Similarly fatigue performance would go undetected until too late when external visual cracking would be evident, if relying on inspection only.

Monitoring systems can include generic condition monitoring or system specific response monitoring. Condition monitoring targets the essential parameters required to ensure the safe operation and verify the condition of the system, while system specific response monitoring targets the critical areas which typically are only relevant to the specific operation being conducted at a specific point on time. Conditional monitoring examples include pressure, temperature, flow rate, environment, sand erosion, corrosion coupons, fluid sampling, and environmental loading resulting in vessel motions. Examples of typical system specific response monitoring include hydraulic reservoir level alarms, valve command failure alarms, data readback communication outages, low hydraulic pressure alerts, and computer malfunctions.

Safety, criticality and economy of subsea system demands designers' attention to provide provision for long term condition monitoring. Most subsea production systems are designed for adequate system specific response monitoring, but very few, if any, have been designed to extract the most in terms of system conditional monitoring.

For integrity management purposes, instrumentation may be installed at locations on the subsea structure identified to be fatigue critical or high risk during the design stage. At these locations, stresses are measured and rainflow stress cycle counted to track the fatigue damage accumulation over time. However, it is not always possible to install monitoring devices at the fatigue critical location. For such cases, finite

element analysis is conducted to determine transfer factors for converting stresses measured at instrument location to those at the critical locations. Hence, damage rates at multiple critical locations can be tracked by installation of a single monitoring device, Figure 3. In addition fatigue damage accumulation can be tracked over time to identify potential failures ahead of time.

A large amount of sensor data exists within the subsea field that is extensively used for making the production decisions. Opportunities exist to employ algorithms in conjunction with selected specific response sensor data to yield system health information. For example, production operators refer to sensor readings to maintain production at a desired level with flowing pressure up and down stream of an adjustable tree-mounted flow choke indicating the rate of production from a well. This same data combined with the choke position sensor reading can indicate the condition of the choke trim and give preliminary notice of incipient choke insert replacement requirements.

Subsea communication efficiency monitoring provides another opportunity to gain early warning of an impending failure, or reduced capacity, when combined with a software algorithm. Most subsea production control systems are programmed to monitor successful communications between surface and subsea and are set to annunciate a notice to personnel when the communications error rate reaches a preset level. While this monitoring method serves well to indicate a communications anomaly which has already occurred, the annunciation alarm level is set to prevent nuisance trips and only indicate when the integrity of communications is severely compromised. An algorithm can be implemented which closely trends the same communication error information, compares the current trend to historical trends previously collected and logically determine if an increasing error indication could be a leading indicator of incipient communication channel failure. An early warning of this type of anomaly allows time to prepare cost-effective remedial measures before actually losing communication with the subsea equipment and thereby forcing a production shut-in.

Technical and System Performance Measures

For both mitigation and monitoring, key performance measures should be defined to provide a rapid form of assessment on potential integrity issues, i.e. lack of chemical injection, or increased stress levels above pre-determined warning levels. Suitable alert levels in the form of Key Performance Indicators (KPIs) assigned to each monitored parameter highlight when these parameters reach critical or near-critical levels, providing the ability to automatically notify appropriate personnel if a measurement exceeds the preset alert level, facilitating any required remedial measures.

Monitoring and inspection execution is conducted and reviewed by offshore personnel with the results relayed to onshore IM team for full review and evaluation. A formal process should be established for measuring the effectiveness of the technical and operational integrity of the equipment and is seen to be fundamental to the success of an IM strategy. A set of technical and operational Key Performance Indicators (KPIs) are defined for the IM process and are tracked and reported by the IM team to Operator Management on a periodic basis. Any potential threat to the system identified by the IM program is recorded in the form of a deviation, or anomaly, report and agreed actions tracked to closure in a timely manner dependant on the revised potential risk to integrity. With the anomalies graded against risk to the asset, required actions are then able to be prioritized accordingly, with an assigned responsible person and completion timeline.

Performance indicators comprise an appropriate balance of leading and lagging indicators. Leading and lagging key performance indicators are established for maintenance, inspection and testing programs to measure compliance and drive continuous improvement. These indicators should include the following:

Leading indicators:

- Overdue inspections and tests for each equipment class
- Open inspection or test deferrals
- Outstanding actions from peer assists/reviews and audits
- Outstanding inspection and test reports and records updates

Lagging indicators:

- Number of equipment test failures
- Reliability/availability of facility/plant or equipment items
- Number of interventions or notifications by regulatory authorities pertaining to inspection and test programs
- Closure of corrective work or actions and anomalies in accordance with agreed time limits

Emergency Preparedness

The value of IM may only be recognised when its application averts unplanned shutdown, or damage to the environment or injury to personnel. Even one day of lost production for an asset can affect its sustainability given the volatile hydrocarbon prices in recent years. Given the time delay in ordering and installing specialist replacement subsea equipment, lost revenue alone can potentially run into millions of dollars, in addition to the cost of replacement components and their installations costs. Maintaining production with minimal downtime is critical to investors.

A well designed IM program may identify weaknesses in the facility early on so they may be addressed before an extreme event. The spares philosophy for subsea equipment may be driven by the IM risk assessment to ensure vulnerable equipment whose loss would have an immediate effect to production, has suitable contingency or replacements available.

Some of the elements of a comprehensive IM program that relate to extreme event, such as a hurricane, preparedness and response are:

- Automated response following the breach of technical KPI limits
- Emergency planning for both preparation for such an event and post response activities
- Operational phase verification of design
- Verification of the facility with respect to new environmental load requirements
- Management of change processes

- Inspection and monitoring to verify condition with respect to system integrity
- Maintenance of records relating to system integrity and documentation of configuration
- Maintenance of analytical models for quick evaluation of the system and the associated risks

Competency of Personnel

It is important to emphasize the quality of the personnel conducting all aspects of the IM process. Integrity engineers and inspectors should be evaluated and trained to ensure a thorough understanding of the subsea systems involved, including the systems function, their potential failure modes and suitable repair/ replacement methodologies. Competence should therefore be evaluated at all stages in the integrity process, including assessment of risk, interpretation of monitored data, and inspection execution.

Assessment of risk and interpretation of data is dependent upon system knowledge and understanding of IM processes. Adequate time must be allotted to personnel for familiarization with the IM process. Full understanding of the operation of equipment and clear lines of responsibility is required to ensure there are no potential gaps in the IM system.

In order to maximize the returns from a subsea inspection, it is important to have trained personnel to carry out inspection work. Training and experience are required in order to reliably assess the visual significance and translate what can be viewed into an accurate estimate of equipment condition.

Conclusions

While the normal IM process may be applied to subsea equipment, the tools available for integrity assurance are more restricted, with visual inspection by ROV or diver providing only limited information on the condition of components. As a result greater reliance is placed on condition and load monitoring along with mitigation measures. Associated with these activities key performance measures with predefined alarm levels are essential. Regular reporting of these key performance indicators

ensure that personnel are aware of the value of the barriers put in place and static and dynamic load levels within components compared with design parameters.

Implementation of risk based integrity management plans for subsea systems have resulted in significant value to the operators. An effective Subsea IM program includes risk based integrity (RBI) assessment, monitoring and inspection plan, key performance indicators to provide alert levels, and anomaly tracking and resolution. The advantages gained include reduced asset downtime, improved understanding of subsea structure performance to extreme loading conditions, clear estimation of remaining life, confirmation if an event resulted in damage to the structure (and therefore rapid confirmation of ability to resume production), improved anomaly tracking with clear management strategy on schedules, improving cost efficiency by targeting inspection on critical areas, evidence of poor material selection leading to anomalies which can be avoided/better engineered for future projects.

Looking ahead, system designers can dramatically improve the ability to perform conditional monitoring by planning for and providing in the system designs the necessary instrumentation to permit better conditional monitoring. A few additional, basic subsea measurements would enable more precise fault detection and source identification than is possible with most systems today.

As a result of implementing the systems described and initiating continuous challenge and improvement, the following benefits are recognised:

- The condition of subsea equipment is relayed to all relevant personnel in the form of anomaly reports, performance measure reports, and regular periodic integrity status reports, keeping everyone fully informed on asset health;
- Any overdue integrity items are highlighted to management within performance metrics requiring appropriate approvals for any deferrals;
- Integrated planning through the IM process;
- Regular meetings between IM personnel and operations personnel ensure a thorough understanding of what is required and why throughout the integrity process;

- The concept of barriers in major hazard risk control is backed up with suitable performance, response and mitigation measures;
- Cross organisational learning to secure corporate memory is provided through ensuring the central database of information is kept up to date;
- Key indicators on performance are provided and continuously reviewed;
- IM data is delivered in a user friendly manner therefore providing instant update on asset integrity.

Therefore the specific IM systems outlined addresses the issues raised by the UK HSE while effectively managing risk to the assets.

References

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2. Cook, H. (BP), Dopjera, D. (BP), Thethi, R. (2H), Williams, L. (iicorr), (2006), “Riser Integrity Management for Deepwater Risers”, Proc of Offshore Technology Conference (OTC), Houston, TX, OTC 17891
3. Maheshwari, H., Natarajan, S., Falconer, P., (2009), “Managing Integrity of Subsea Assets”, Proc of IORS 2009, Mumbai, India

Figures

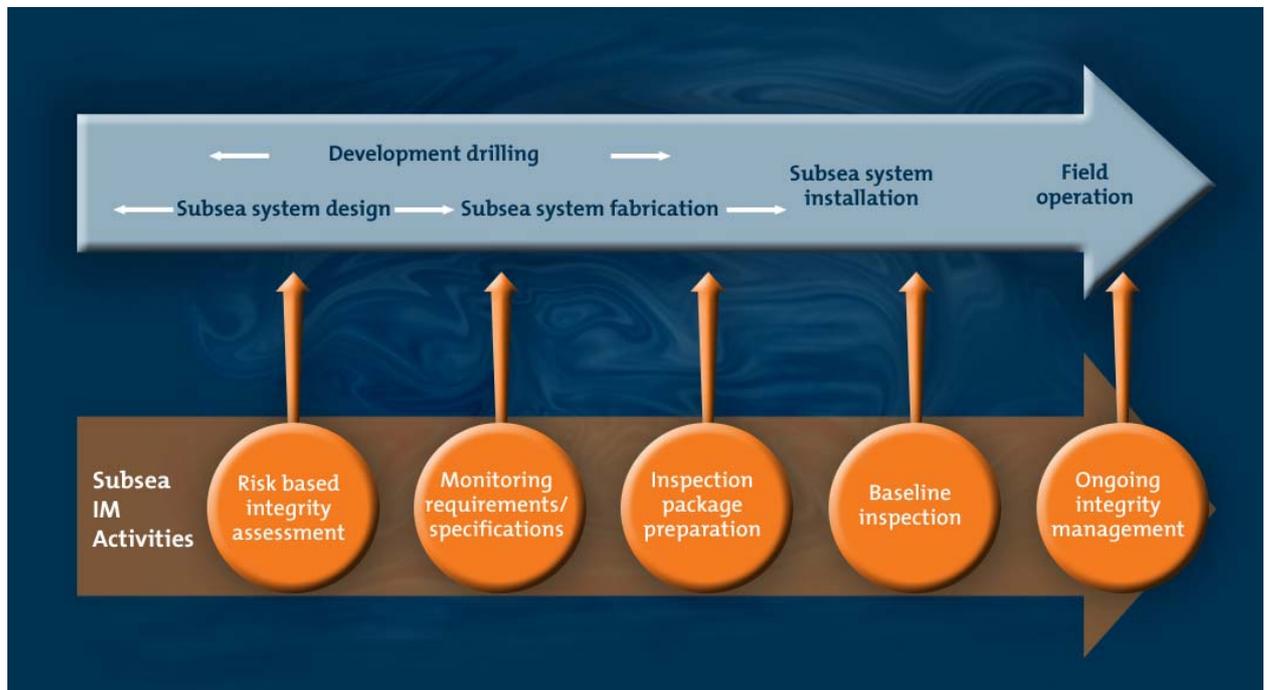


Figure 1 – IM Integration Timeline for New Fields

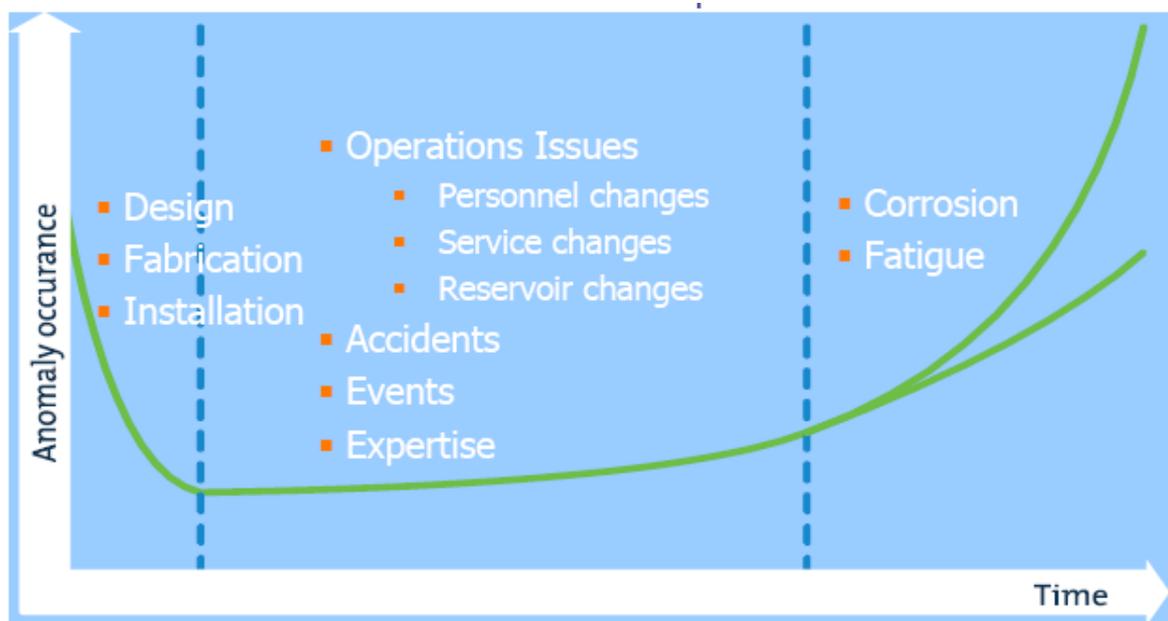


Figure 2 – Life of Field Anomaly Incidents

Fatigue Life Usage (Service Life = 5 years)

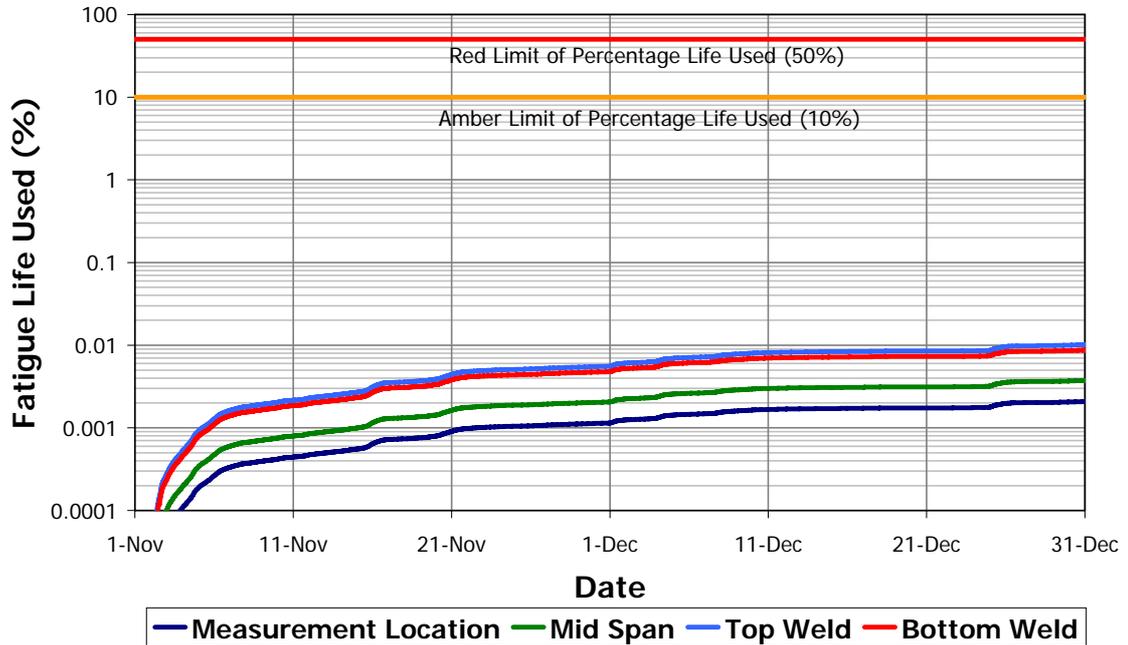


Figure 3 - Alert Levels Set on Monitoring Data