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REVIEW OF METHODS FOR PIPE WALKING & LATERAL/ UPHEAVAL BUCKLING DETECTION SUBSEA INSPECTION, MAINTENANCE & REPAIR

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Abstract

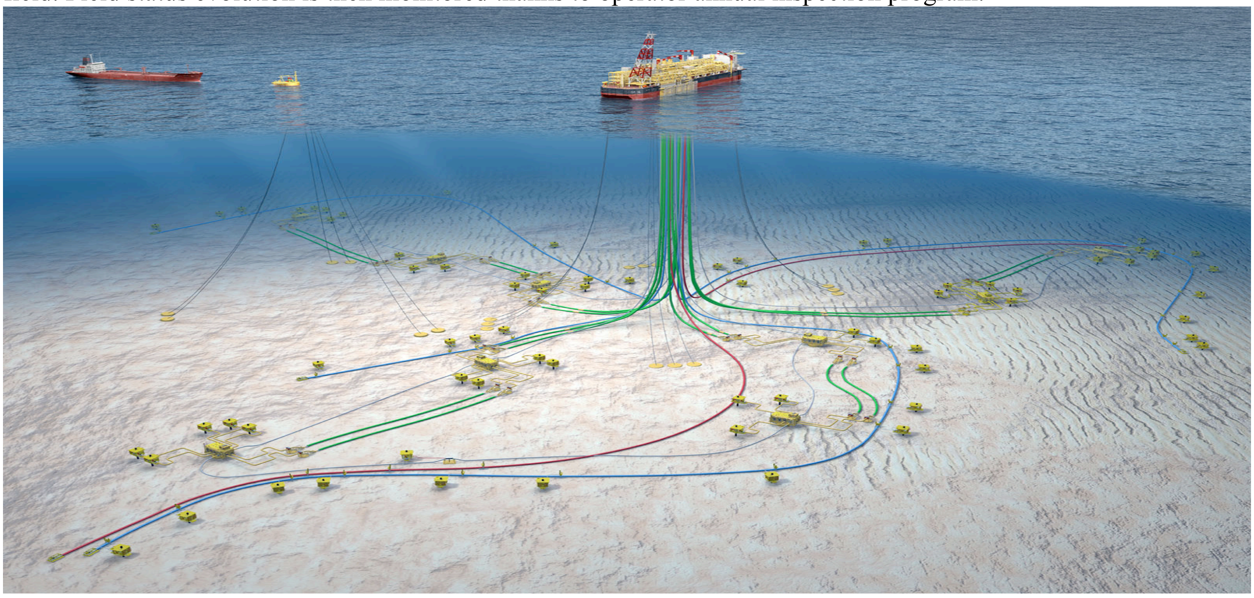
IMR tasks of deep water field built with steel pipeline, require to monitor various effects which may occur upon sealine laydown, during pressure testing (construction phase) or during the exploitation of the field (Production phase). Three kind of phenomenon must be monitored : free span in excess of admissible length, Lateral & upheaval buckling and Pipeline walking. Initial IMR survey information are collected during as-laid/ as-built survey, then information is collected during annual inspection.
This paper proposes an in-depth review of the Methods to be used for detecting and identifying Pipe walking & lateral/ upheaval buckling effect and finally a first analysis of field results.

1. Inspection Requirement and Method overview

IMR tasks on steel pipeline, typically include visual inspection, Cathodic protection monitoring and excessive constrains & fatigue applied on sealine evaluation.. This last item requires to first identify & monitor 3 kind of phenomenon:

- free span in excess of admissible length
- Lateral & upheaval buckling (lateral, Vertical displacement)
- Pipeline walking (axial displacement)

Initial IMR survey information are collected during as-laid/ as-built survey, this provides the reference status of the field. Field status evolution is then monitored thanks to operator annual inspection program.



2. New Field Typical Survey & Inspection program:

During the course of the field installation and prior to sealine flooding, an As-Laid Survey is performed in order to confirm the status of the general sealine status.

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2.1 As-laid survey (Post-lay survey)

The aim of this survey is to provide the following information:

- Integrity of the coating
- Integrity, functioning and Eastings, Northings of all CP anodes
- Evidence of any anomaly such as damage to coating, anodes, obstructions or obstacles within the corridor.
- Attitude, orientation, position and depth of any specific feature such as: SDU, ILT, FLET, manifold, suction anchors, etc…
- Continuous Eastings, Northings and depth of sealine
- Relative position of sealine to seabed, identification of buried sections, free-spans,
- Accurate identification, visual inspection and metrology of free spans (KP, length, max height, profile. This inspection is repeated once remedial work has been carried out.

This survey is performed by Work ROV, deployed from a DP2 vessel, equipped with High definition sonar, dual head scanning sonar, dual boom cameras, bathy-system, pipe tracker (when required) and positioned with Vessel USBL system or LBL duly deployed and calibrated LBL array.

<u>As-laid survey is usually carried-out immediately after completion of the installation of each sea line.</u>

2.2 Final As-built Survey

Upon the completion of a new field development project, an As-built dossier is issued including all COMPANY required information. This As-built dossier includes As-Built Survey results:
For large Deep water field development, As-built survey usually comprises inspection and survey of all installed systems, including inline structures, sealines, umbilicals, risers, export lines, mooring lines of permanent floating structures (FPSO and OOB), final position and heading of permanent floating structures. Most of the time , it includes Cathodic Protection survey (CP survey).

The aim of this survey is to provide the following information:

- Integrity of the coating
- Integrity, functioning and Eastings, Northings of all CP anodes
- Evidence of any anomaly such as damage to coating, anodes, obstructions or obstacles within the corridor.
- Attitude, orientation and Eastings, Northings and depth of any specific feature such as: SDU, ILT, FLET, manifold, suction anchors, etc…
- As-built of crossings, free-span correction and all remedial work, anchoring system etc.
- Eastings, Northings and depth of sea line
- Relative position of sea line to seabed, buried sections, free-spans,
- Final visual inspection and metrology of free spans (KP, length, max height, profile.)

This survey is currently carried out by Work ROV, deployed from a DP2 vessel, equipped with High definition sonar, dual head scanning sonar, MBE, bathy-system, dual boom cameras, pipe tracker (when required) and positioned with Survey Vessel USBL system or LBL duly deployed and calibrated LBL array.

<u>This survey is carried-out after flooding, pressure test of the lines, free-span correction, etc…</u>

2.3 Cathodic Protection survey

CP survey aims to confirm that all assets are correctly protected against corrosion.
CP survey is part of the final As-built Survey. Both Potential and Electrical field gradients are monitored and anodes output/ life duration estimated. CP survey results are fully detailed in a dedicated CP report.

This survey is currently carried out by Work ROV, deployed from a DP2 vessel, equipped with High definition sonar, colour video system, dual head scanning sonar, CP probe assembly, bathy-system, pipe tracker (when buried) and positioned with Support Vessel USBL system.

<u>CP survey is carried-out once all installation work has been completed, that lines have been tested and are ready for production.</u>

2.4 Periodic sea-line Inspection

For years, periodic Sealine inspection scope of work was typically similar to As-Built & CP survey scope of work These inspections were carried-out on an annual basis, as per IMR inspection program.

3. New IMR Survey Requirement:

Initially, IMR survey information were collected during As-Built and CP survey, which are in line with IMR program survey requirement.
With the new deep water field developments and the extreme cost & complexity to perform intervention and repair in deep water, new Inspection and monitoring requirements were adopted by Companies: Lateral/ Upheaval Buckling, free spanning and pipe walking identification and monitoring.

3.1 Engineering based methods

* Buckling, spanning and walking engineering study
As part of the IMR program definition, location of possible flowline and structures displacement are identified by running engineering programs allowing the prediction of spanning, buckling and walking phenomenon. This study takes into account all pertinent parameters such as soil conditions, seabed profile, sealine characteristic, route design, presence of inline structure, anchoring system, etc…

3.2 Lateral and Upheaval Buckling identification Methods

* "Heading" Survey
Lateral buckling and up-heaving effects are identified by routine "Heading survey", allowing to detect small lateral displacement of lines, mainly high pressure/ high temperature injection pipes, before and after first pressure tests, then regularly during the life of the field.

Heading survey are conducted during the 3 steps of inspection program :

- First, as part of the as-laid survey carried out immediately after flowline laying.
- Second as part of the as-built survey carried out upon completion of all connection, and after pressure tests.
- Then, as a routine inspection following IMR program, during the whole life of the field.

Heading survey are carried-out with ROV equipped with 4 wheels undercarriage, "rolling" on top of the line. This survey is fully compatible with As-laid and as-built surveys. It can be run at the same time. This survey is based on the acquisition of heading raw data versus position, DCC and KP. For upheaval, laser cross shape, accurate depth, seabed profile and relative position of the pipe/seabed.

* "Foot Print" Survey
Soil is usually very soft, influence of currents and waves is very low, soil will work as a memory of the movement of the sealine. Raw Detection shall be done during video and DHSS survey, where seabed profile is highlighted visually or by visual laser cross section on the video, and by symmetry analysis of DHSS profiles. Detailed inspection can be made by MBE, 3D sonar or high resolution SSS.

3.3 Refinement of the standard method

When magnitude of phenomenon is small, all methods have to be refined and detection threshold have to be analysed due to the limit of each method. Most of the time, combination of various method will allow to detect and confirm the occurence of the phenomenon. LBL enhanced systems such as DVL and/or INS may be used as required.
For some specific sections (inline structure, etc…), when a permanent LBL reference system is in place LBL positioning will be used as required. SLAM method can be used for accurate positioning, enhanced Inertial
Note that the use of DVL/ INS will allow precise analysis of flowline out-of-straightness over a short section.
The speed of the ROV can be ideally maintained below 1 km/h in order to allow the ROV pilot to keep the 4 ROV wheels in close contact with the pipe.
Upheaval buckling detection can be studied during routine Heading survey, by upgrading standard free-span detection methods based on DHSS, multi-beam systems or tri-dimensional sonar.

The use of Inspection AUV (Alistar or similar) may reduce the cost of inspection and then, allow to increase the frequency of inspection. Due to the lack of contact between AUV and pipe, refined methods will then to be implemented.

3.4 Structures Position & Attitude survey & Pipe walking effect

The aim of this survey is to detect small axial displacement of the HP/HT injection and production lines, before and after first pressure tests then, later, during the field life.
This Survey requires the use of the following techniques:

- Prediction of possible/ probable movement areas using calculation models.
- Structure attitude and heading measurement based on underwater gyrocompass and inclinometers
- Accurate depth measurement and reliable scour/embedment description of structure base
- Various Visual/ acoustic alignment checks methods, requiring the installation of a semi-permanent network of steel markers.
- Structures LBL positioning based on the existing permanent array of stands

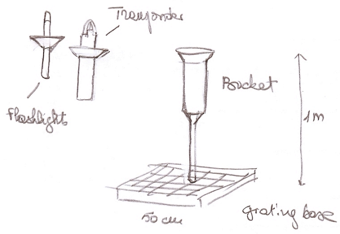
Initial survey comparison can be based on the as-built results and inspections collected during subsea structure installation, basically: pitch, roll, heading, accurate Eastings & Northings derived from LBL, accurate depth derived from digiquartz sensors, height above seabed, integrity proven by full detailed video inspection.
Further inspections can be performed as per the IMR program requirements

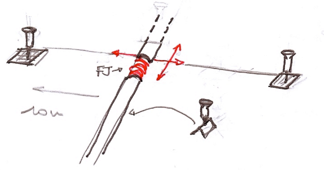
The following information shall be collected:

- Subsea structures attitude (Head, pitch & roll) and height above the seabed
- Accurate depth/ height measurements and reliable scour/embedment visual survey of structure base
- Subsea structures KP, DCC, depth and Eastings, Northings, position derived from LBL positioning, as required
- Subsea structures displacement based on visual alignment check and LBL range measurement using semi-permanent markers
- Video, sonar image of seabed up to 5/10 m around subsea structure when a walking is suspected

<u>* Specific Marker Network Deployment</u>
Specific displacement measurements shall be carried out at various point of interest as determined by numerical model prediction. Alternatively routine measurement shall be performed as per the IMR program.

Precise measurement of structures and flowlines displacement will require ROV deployment of a semi-permanent network of light steel markers equipped with buckets for acoustic or visual systems, at all section where buckling or walking is anticipated.





These markers shall be deployed 10m each side of an easily identifiable point of the pipe/ structure, in order to be able to detect small displacement using either top or lateral visual alignment or acoustic metrology using in this case, a saddle placed on the pipe.
Reference point can be an anode or a field joint of a specific part of a structure. Should subsea structure have a transponder bucket, it will be used as the structure reference.
Note that, for large displacements, the existing permanent LBL array stands will be used for supporting acoustic methods.

<u>* Spool piece and Jumper inspection</u>
Spools and Jumpers are good markers of pipe walking and SLED displacement.

Survey of all spool and jumper are carried out as per IMR inspection plan, based on suspected or identified displacement, scour or embedment.

The aim of each survey is to monitor the following information:

- Spool/ jumper span/ embedment measurement
- Spool/ jumper visual inspection and snapshot of specific area of interest
- Spool/ jumper end structures attitude, heading and height measurement
- Spool/ jumper end structures scour/embedment visual survey of structure base

when required, a systematic bathymetric survey of spool/ jumper area will be performed by running cross-lines at 5 m intervals perpendicular to the spool piece/pipeline, acquiring data from the ROV MBE (SeaBat or similar), 3D sonar, DHSS and pipe tracker. Cross lines extend for a minimum of 10 m either side or the area,

<u>* Method improvement: Spool piece and Jumper instrumentation</u>
Spools and Jumpers being good markers of SLED displacement, could be instrumented using robust, specific fiber optic sensors (FBG, other…).

4. Conclusion

These small and complex phenomenon are difficult to highlight with a standard method.. Repeatability of measurement is one of the main problems to be solved. The use of complementary method allows to put in evidence some occurrence. Refinement of method is mandatory, using more accurate sensors or innovative metrology methods.

<u>Note on the author</u> : Jacques SCHOELLKOPF is an Expert in Deep Water Survey Construction Support. He is the President and Founder of the ADVANCED SUBSEA Group of companies, deeply involved in Services, Consulting, & innovation in the domain of Deep Water Subsea operations.
He worked successively with C.G.DORIS, S2O a R&D Company, ACERGY (ETPM), TECHNIP (Coflexip) then with SAIBOS, being in charge for several years of Survey Construction Support for CASTORO OTTO and SAIBOS FDS.
For several years, ADVANCED SUBSEA was involved in survey method development & validation for TOTAL E&P DeepWater projects: Canyon Express (GoM), Girassol (Angola), Matterhorn (GoM), Dalia, Rosa (Angola), Moho-Bilondo (Congo), Akpo, Usan (Nigeria).
Jacques is currently focusing on Advanced Subsea do Brasil development, a new AS subsidiary established in Rio de Janeiro, dedicated to deep water Services of Rig Positioning, Metrology and Survey Construction Support based on AUV.