Flexible Pipe-Polymer Coupon Monitoring
Application

Flexible risers are now more common in recent years due to the increase in deep water oil and gas exploration. The flexible riser is a connection between typically a floating production system, and the subsea well or pipeline and often a means of transporting Oil & Gas. A Flexible Riser is composed of both metallic and polymer layers designed for optimal strength, weight, and flexibility under high pressures and temperature variances. The polymer sheath layer contains the process fluid and consists of certain types of polymers to form a pressure barrier that has to be resistant to chemical and mechanical degradation over time.

To maintain the integrity of the flexible riser it is important to monitor the condition of the polymer in the pressure barrier sheath. The Cosasco® Polymer Monitoring System can be used for determining the potential breakdown or ageing of the polymer material under operating conditions. A number of Polymer coupons of the same material as the sheath are inserted into the flow for a certain period of time and then removed one at a time and analysed to evaluate the condition of the pressure sheath. Based on a quantitative analysis of the coupons, an estimate of the remaining service life of the pressure sheath may be determined along with any changes to the molecular structure or chemical properties that may affect the overall strength and structural integrity of the sheath.

Typical Unbonded Flexible Riser Composition

- Carcass (304, 316, duplex,..)
- Polymer (PA11(nylon), PDVF, XLPE,PE) Pressure Sheath
- Hoop strain armour (Z,T,C..) Axial armour (2 or 4 layers)
- Outer polymer sheath (PA11, PE)
- Outer carcass/fire protection
The Cosasco® Polymer Monitoring System

The Cosasco® Polymer Coupon Monitoring System consists of a polymer coupon holder and solid plug assembly installed in a standard 2” Access Fitting that would normally be located in a topside rigid pipe, downstream of the flexible riser end connection.

Installation of polymer monitoring equipment, in the form of retrievable polymer material samples, will increase the confidence of the ‘in the service life prediction’ at some point into the future life of the pipe. The coupon is required to be manufactured from the same polymer material as used in the flexible pipe. A sample of the polymer pressure sheath(s) or coupons will be required prior to installation of the coupon holders. This will be provided from the riser manufacturer and coupon cut by use of non heating methods eg a mechanical stamp or water cutting. Heating of the coupon should be avoided as well as avoidance of solvents and UV light.

For the coupon holder design, details of the piping at the mechanical access fitting eg fitting type, pipe diameter and wall thickness, is required to ensure that the coupon assembly has sufficient room for insertion into the pipe. In addition, there is a requirement for information on possible slug flow, including, details of pressure, temperature, GOR, density, velocity, etc. to ensure that calculations can be done to verify the coupon holder integrity.

Shown to the left, disc coupon holder assembly including the solid plug/holder, the rack of Disc coupons, and the shroud.

The design allows for a similar process fluid environment as would be encountered in the riser pressure sheath and the carcass.
Hydraulic Solid plug and coupon holder

Polymer Coupon Rack

Coupon holder housing (Shroud)
## Polymer Coupons

There are several designs available for polymer coupon monitoring with different applications:

<table>
<thead>
<tr>
<th>Item</th>
<th>Name</th>
<th>Description</th>
<th>Material</th>
<th>Issues</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Disk coupons</td>
<td>Disks with the full thickness of the polymer pressure sheath</td>
<td>PA-11 PVDF PE XFLEX</td>
<td>Small dimension available 2=28mm limits the possible tests. Suitable for PA-11 with small sample tests, and blistering tests with the thick sample. Provides an effective thickness ( \frac{3}{2} ) of the sheath thickness, double side exposure</td>
</tr>
<tr>
<td>2</td>
<td>Dog Bone</td>
<td>Pre-machined dog bone shaped bars for mechanical tests based on torsion or tension measurements. Approximately: 8 x 2 x 60 mm(^3)</td>
<td>PA-11 PVDF PE</td>
<td>Mechanical test species, provides possibility to retrieve 1 or several depending on criticality. The number of samples is “high”. Simulates the inner wall surface with the thin sample, and the two-sided exposure</td>
</tr>
<tr>
<td>3</td>
<td>Notched</td>
<td>Notched coupons, clamped in either end, to simulate the thermal stresses occurring in a pressure sheath of a flexible pipe</td>
<td>PVDF</td>
<td>Visual inspection of stress concentrated region. Requires that the stress is maintained.</td>
</tr>
<tr>
<td>4</td>
<td>Bars</td>
<td>~10x10mm bars of approximately 60mm length</td>
<td>PA-11 PDVF PE</td>
<td>Provides a fewer number of samples, but with the pressure sheath thickness, and flexibility on the possible tests. Well suited for cases where one is uncertain on the tests to run.</td>
</tr>
</tbody>
</table>
Applications of Corrosion Management

The notched type coupon systems are not shown as they are best suited for PA degradation and PVDF thermal cycling issues respectively.

The options for either coupons for pure chemical analysis (CIV tests) or a combination of chemical and tensile tests. A combination of Dog Bone and a thermal stress coupon can also be offered as an option. The thermal stress coupon has a notch cut in the coupon surface which can be visually inspected to determine any propagation due to the effects of temperature cycling, as a simulation of a cut in the polymer material.

For the case of PVDF and PE pressure sheaths, bar shaped coupons provides an advantage, as this provides large material sections where one can perform a broader range of tests. The trade off to Dog Bone type coupons is the number of separate samples available. This can however be amended by inserting fresh coupons when a sample is retrieved. The bar shaped coupons will be similar to the disc coupons and provide the thickest possible sections of the pressure sheath, which is one of the parameters important for the explosive decompression failures.

The bare shaped coupons will provide 8 separate pieces in one coupon holder. The length of the solid plug adapter is adjusted so that the coupons are exposed to the medium.

A) Disc coupons: typically 8-10, spaced, with full exposure all sides

B) Dog Bone coupons: 16 pieces, spaced, full exposure all sides

C) Bar coupons: 8 pieces, min 1 mm clearing between sides

Sketches of the coupon assemblies.
Polymer Coupon Installation/Retrieval

The assemblies will be installed in 2” access fittings and one coupon from each holder will be removed after a programmed interval eg initially after 1 year and 2 years thereafter. The number of coupons that will be fitted into the holder will be dependent on the spool pipe diameter, polymer thickness, results of WFC calcs and desired monitoring programme.

The coupons removed will be according to special handling procedures and stored in a suitable container to avoid heat, UV light and solvents. They can then be subjected to a mechanical strength and/or chemical analysis to determine and changes to the molecular structure or mechanical properties. The results can be used to determine the future point of failure in the service life prediction model for the polymer material, operating under the field conditions.

The polymer coupon assembly may be installed and retrieved under pressure using a Cosasco RSL or RBS/RBSA Retriever and Cosasco Single or Double Block and Bleed Service Valve.

Polymer Coupon Analysis

The analysis of polymer coupons is a specialised task and requires the services of a third party laboratory / test organisation, who specialise in polymer material analysis. The results will form part of a flexible pipe integrity management programme that will be provided by the operator. The following is for information purposes:

1. Carry out polymer testing on coupons
   a. Confirm test selection with flexible manufacturer(s).
   b. Identify accredited independent test laboratories.
   c. Conduct tests and supply test results.

2. Review results, assess and recommend actions
   a. Review and assess laboratory test results against acceptance criteria from industry standards (API 17B, API TR 17TR2 and API TR 17TR1).
   b. Propose recommendations on service life or monitoring interval, for example, based on test outputs.
   c. Have assessments and recommendations reviewed by an independent 3rd Party.
### Laboratory Tests

Details of laboratory tests for assessment of polymer aging and performance (Step 1) are listed in Table 1.

<table>
<thead>
<tr>
<th>No.</th>
<th>Test</th>
<th>Description</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>CIV Test (PA-11)</td>
<td>Determine change in molecular weight due to polymer ageing using solution viscosity.</td>
<td>Destructive (API 17TR2 Appx D)</td>
</tr>
<tr>
<td>2</td>
<td>Molecular Weight Determination Test (PVDF)</td>
<td>Molecular Weight Determination of PVDF Samples Using Gel Permeation Chromatography (GPC).</td>
<td>Destructive (API 17TR2 Appx C &amp; relevant ASTM standards)</td>
</tr>
<tr>
<td>3</td>
<td>Mechanical Test&lt;sup&gt;©&lt;/sup&gt;</td>
<td>Ductility or fracture toughness.</td>
<td>Destructive</td>
</tr>
</tbody>
</table>

*© The type of mechanical test will depend on the suitability of the polymer coupon dimensions (disc coupons unlikely to be appropriate).*