TRELLEBORG

Bending Restrictors

Engineered Systems

Trelleborg Offshore

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Applications

Flexible pipes, flowlines, power cables and umbilicals are usually connected to a rigid structure such as a subsea riser base, PLEM or wellhead.

To prevent these pipes from overbending at the interface between flexible and rigid structures, Bending Restrictors are often installed on the pipe.

A Bending Restrictor or BR as it is more commonly known is specifically used where static (or quasi static) loads act on a pipe, rather than dynamic loads when a Bending Stiffener would be more suited.

The Restrictor usually comprises a number of interlocking elements which articulate when subjected to an external load and lock together to form a smooth curved radius known as the locking radius. The locking radius is chosen to be equal to or greater than the minimum bend radius of the pipe.

Once the elements have locked together the bending moment present is transferred into the elements and back through a specially designed steel interface structure into the adjacent rigid connection (i.e. wellhead, PLEM etc), therefore protecting the pipe from these potentially damaging loads.

Trelleborg CRP are able to offer either a bespoke design or make use of a vast array of existing designs of Bending Restrictor elements to suit a wide range of pipes, umbilical and cables. CRP are also able to design and manufacture the steel interface structures required.

The Trelleborg CRP Bending Restrictor design offer three advantages:

- Split design, allowing installation of the Restrictor after pipe termination.
- Ease of installation onshore and offshore.
- Neutrally buoyant in water, eliminating self weight loading on pipe.

Pre-installed Bending Restrictor on flexible pipe reel

Overboarding complete Bending Restrictor

Design and Engineering

Trelleborg CRP has assembled a design and engineering team with significant technical knowledge and experience gained over many years in the offshore and oceanographic industries, designing and even installing flexible pipelines.

Our team work very closely with clients to understand in detail a particular task or set of parameters under which the system will operate - handling, deployment, operation and recovery.

The physical parameters are then converted into numerate data with the completion of a Design Data Sheet (DDS) – these are available from the CRP Sales Department on request.

Important information required is:-

- Minimum bend radius.
- Pipe outside diameter.
- Loads (bending moments, shear loads).
- Length of coverage.
- Operating temperature.

From this information, Trelleborg CRP's engineers can either select a suitable existing design of Bending Restrictor element, or use an in-house software design tool - RESTRICTOR to design a bespoke element, which comply with both the geometrical and loading requirements specified by the client.

Having understood the application and mechanical interfacing requirements to satisfy the specification, the Restrictor is designed to meet in service condition in the most cost effective way.

Interface Structure

Once the Bending Restrictor elements have been designed/selected it is necessary to design a suitable steel structure to attach the elements to the adjacent rigid connections.

This item often requires complex interface engineering with the pipe/umbilical supplier, subsea equipment designers and installation contractors all wishing to have an input into the design process to ensure ease of construction and installation and integrity in service.

The interface structure comprises a split steel component which has a housing which fits around the 'heel' end of the Bending Restrictor element, and then bolts or clamps to the adjacent structure. This is known as a 'Female' connection and is suitable for applications where the Bending Restrictor is fitted to the pipe at the 'second end-off' the reel.

Alternatively a Male connection can be used where the Bending Restrictor elements fit over the steelwork - this is suitable for 'first end-off' applications.

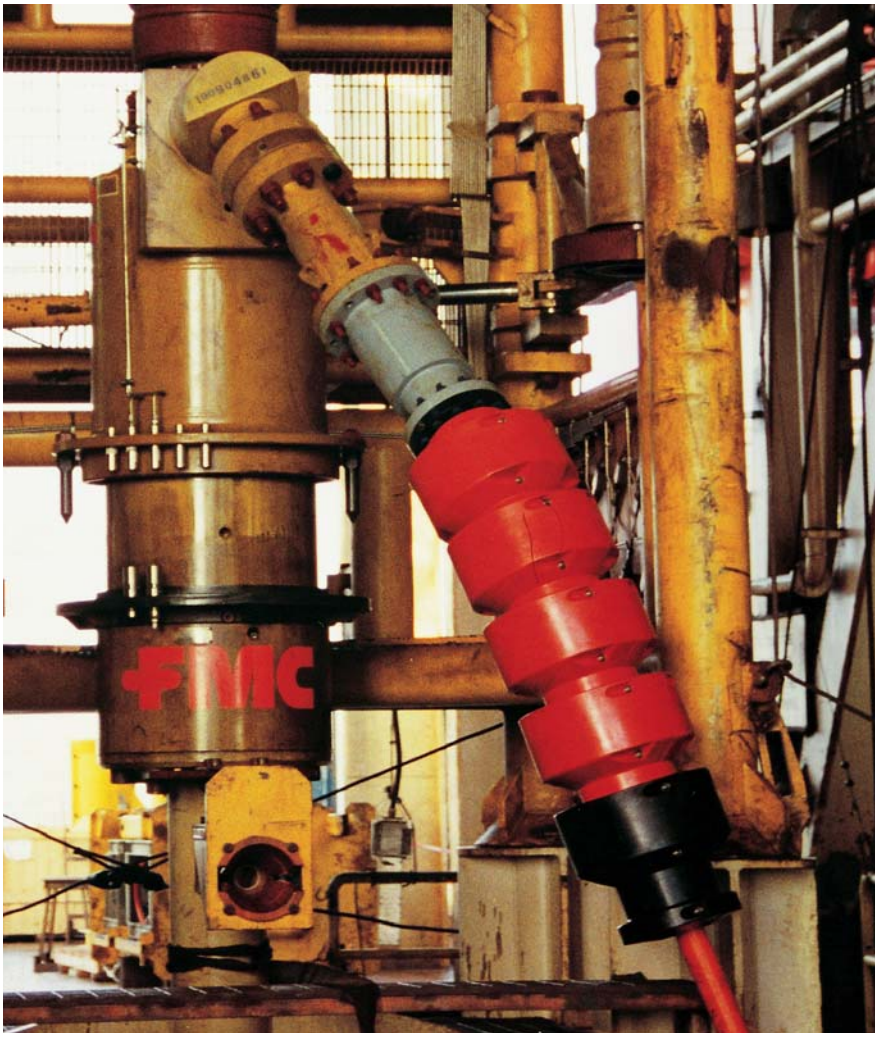
Either the Male or Female connections can be attached to the adjacent rigid structure by two main methods:-

- **Reaction flange**
- **Reaction collar**

The reaction flange has a simple split flange arrangement which bolts directly to the adjacent structure, whereas the reaction collar is a split shell configuration which clamps around the keys into the pipe end fitting/termination head.

Trelleborg CRP also have experience of designing and building additional adapter flanges, extension spools and pull-in connectors which may be required for particular applications.

All design is conducted in accordance with the relevant codes and specifications (e.g. NORSOK, DNV, API etc) and fabrication is conducted in accordance with approved weld documentation and fully qualified welders using ASME IX (or equivalent) procedures.



Diverless Bending Stiffener Connector System

Materials

The materials used in the manufacture of the Bending Restrictor components are as follows:-

- **Elements -**
  structural polyurethane.
- **Element fasteners -**
  super duplex stainless steel.
- **Interface steelwork -**
  high strength structured steel.

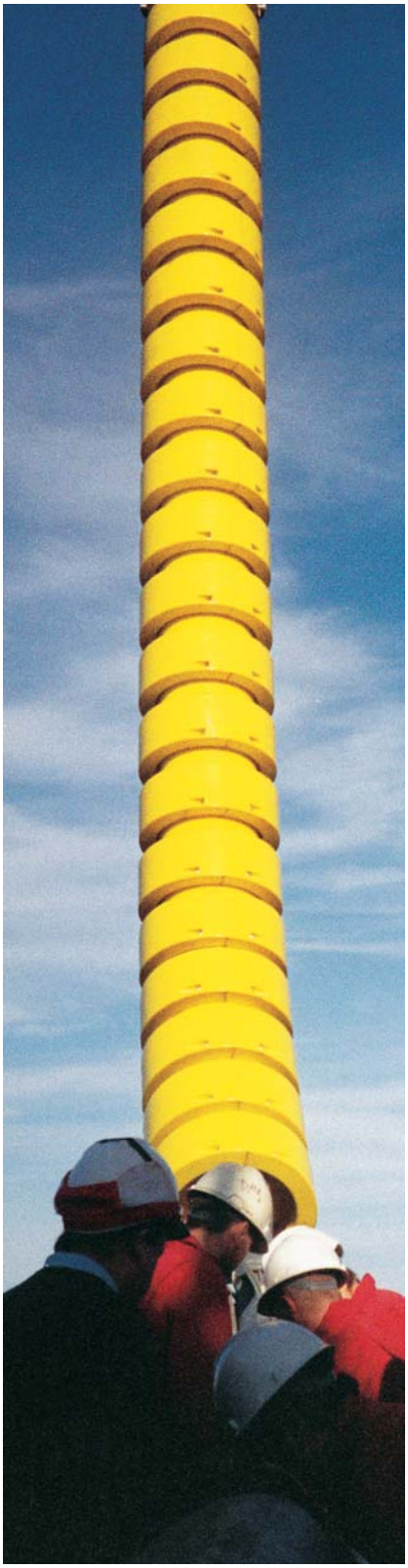
As the polyurethane elements and super duplex fasteners are inert/corrosion resistant in seawater the only part of the structure requiring corrosion protection is the interface steelwork. This is usually provided by a suitable subsea coating system (e.g. NORSOK, System 7) and either connection to an adjacent cathodic protection system or by attachment of it's own dedicated anodes.

For particular high temperature applications (i.e. production flowlines) the use of titanium or Alloy 625 Element fasteners may be considered.

The Polyurethane elements are usually moulded yellow or alternatively orange.

Both colours provide excellent visibility when the Restrictors are subsea.

Typical material properties of polyurethane used to manufacture Bending Restrictor elements are presented in the tables below.



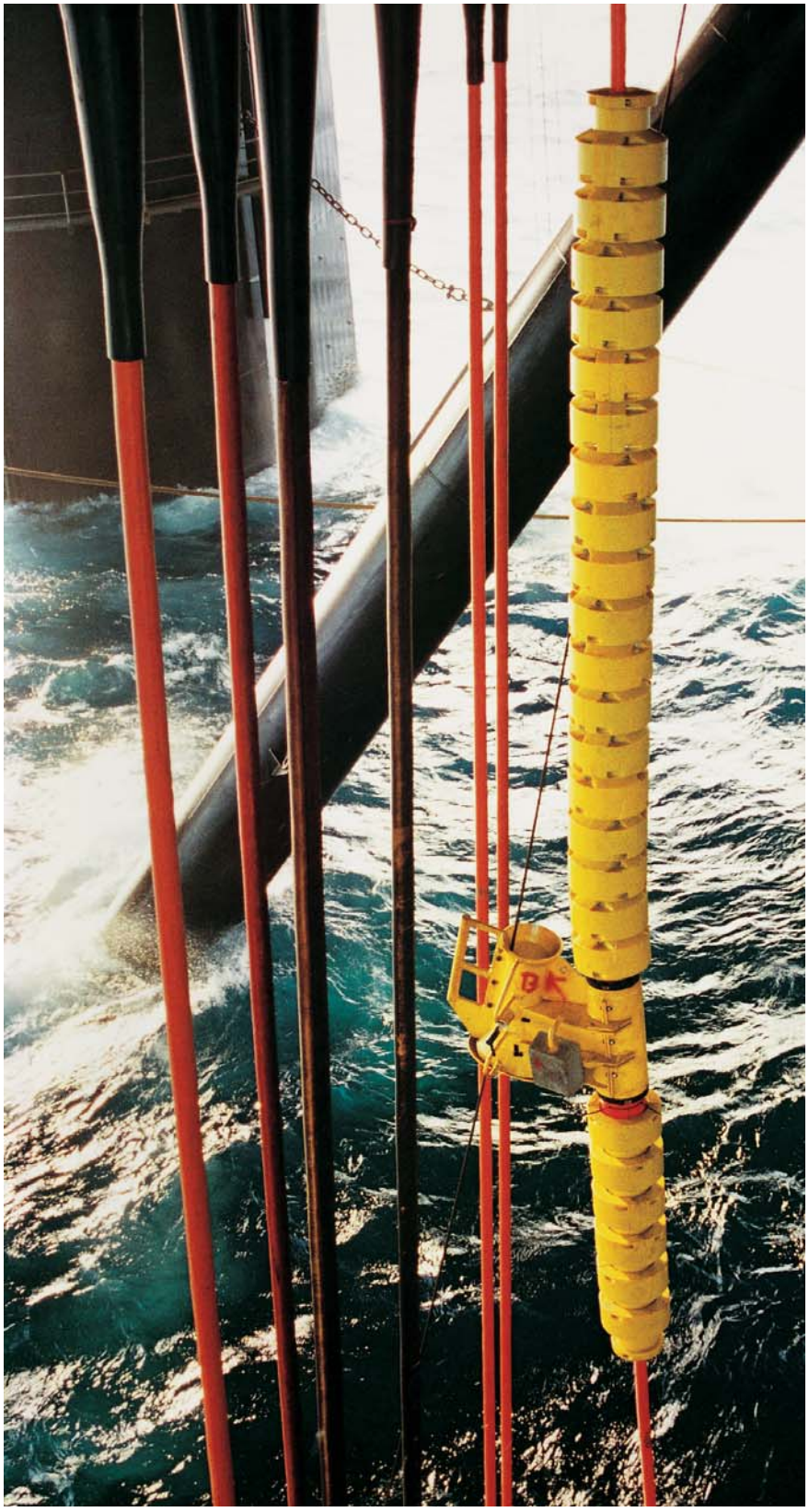
TYPICAL PHYSICAL PROPERTIES AT 23˚C			
Property	**Test Method**	**Value**	**Unit**
Shore Hardness	BS 2782 Pt 3	80	˚D
Tensile Strength	BS 903 Pt A2	45	MN/m^2
Elongation at Break	BS 903 Pt A2	20	%
Heat Distortion Temperature	BS 2782 Pt 1	70	˚C
Izod Impact Strength (Notched)	BS 2782 Pt 3	8	KJ/m^2
Specific Gravity - cured	–	1.150	kg/m^3

All values are typical

TYPICAL PHYSICAL PROPERTIES AT 60˚C			
Property	**Test Method**	**Value**	**Unit**
Shore Hardness	BS 2782 Pt 3	74	˚D
Tensile Strength	BS 903 Pt A2	21	MN/m^2
Elongation at Break	BS 903 Pt A2	64	%
Heat Distortion Temperature	BS 2782 Pt 1	70	˚C
Izod Impact Strength (Notched)	BS 2782 Pt 3	13	KJ/m^2
Specific Gravity - cured	–	1.150	kg/m^3

All values are typical

Manufacture



Trelleborg CRP make use of their modern state of the art production techniques and their many years

of experience processing polyurethanes to manufacture high quality Bending Restrictor element mouldings.

The mouldings are manufactured by injecting liquid polyurethane into a mould tool which then solidifies and is demoulded prior to being oven cured.

The mould tool utilised is of critical importance to the final product quality and is precision machined from aluminium castings to meet very tightly controlled dimensional tolerances.

The tools modular configuration allows easy change-out of parts which allows quick and cost effective modification of existing designs to suite a new application.

The tool is usually mounted in a large semi-automated hydraulic press, which greatly improves the turnaround time for manufacture of mouldings.

Trelleborg CRP's experience of processing large volumes of polyurethane, whilst maintaining the strictest of quality control procedures is second to none. Large investments in modern efficient dispensing equipment and storage tanks has made this possible, which together with round the clock shift working means that short lead times are possible to suit the most pressing of client requirements.

Testing

Factory acceptance testing of Bending Restrictors can be divided into three main categories:-

- **Materials testing**
- **Fit-up, assembly testing**
- **Load testing**

Materials Testing

Very strict quality control checks are performed on all batches of polyurethane material used in the manufacture of Bending Restrictors. This includes both goods-inward and in-process checks to ensure that only raw materials with the correct material properties are put into production and that these properties remain consistent throughout the manufacturing process.

Trelleborg CRP have a modern well equipped QA/QC laboratory which allows most material testing (tensile, compressive etc) to be conducted in-house.

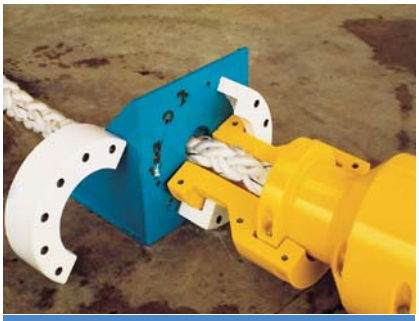
Alternatively if Third Party Approval test results are required CRP have free access to a local NAMAS Approved Test House.

Fit-Up and Assembly Testing

Generally the first time a client will open the packing case he will be offshore on an installation vessel. It is therefore vital that in order to prevent expensive delays, all the components of the Bending Restrictor fit-up and assemble together as requested.

As a matter of routine the Bending Restrictor elements will be fully assembled in a string using the correct fasteners prior to release for despatch from Trelleborg CRP.

In addition the elements will be assembled onto the particular interface steelwork component, which in turn will be fitted up to either the real or a mock-up of the rigid interface structure.



Fit up and assembly testing

Load Testing

To ensure that the Bending Restrictor has a suitable load capacity, many clients specify that a load test is undertaken.

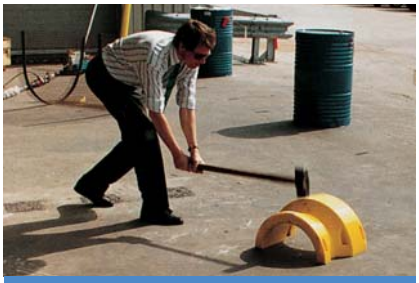
Two types of load test can be conducted:-

- **Proof load testing.**
- **Destructive load testing.**

With the proof load test, a fully assembled string of elements is subjected to the calculated maximum in service loading.

The load is held for a defined time period and the restrictor is then examined for any signs of damage.

If a destructive load test is specified the Restrictor is first proof load tested then the load is increased until failure of one or more of the element occurs. The failure load is recorded and compared to the load anticipated by calculation methods.



Oil company representative conducting some basic impact testing

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