Qualification of m-pipe® and Hybrid Flexible Pipe for deployment in Brazil’s pre-salt region: composite materials selection to overcome technical challenges

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Victrex plc / Magma Global Ltd / TechnipFMC

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Presentation Overview

- Brief review of Magma’s m-pipe® (TCP)
- Service Conditions in the Brazil Pre-salt fields
- Magma / TechnipFMC Hybrid Flexible Pipe (HFP)
- Materials Selection and Qualification
PREDICTABLE PROGRESSION

All engineering follows a progressive adoption path

Composite % of aircraft mass

F-111 A310 A330/340 A320 series F-35 Boeing 787

First composites used

Frac balls plugs Rudder Spoilers Airbrakes

Rear bulkhead Keel beam J-nose

Flaps Dry HTP box LG doors Engine cowlings

Hybrid risers Wing skins Fixed skins Engine nacelles Access covers

All-composite risers Structurally almost all composites

Source: Technovation, Sept 2015
M-PIPE’S HIGH PERFORMANCE SIMPLIFIES PRODUCTION

Strength to weight ratio:  
1/6 weight of NB flexible  
1/10 weight of steel

High Pressure/High Temperature:  
≤20ksi  
≤200°C

Corrosion resistance:  
Inactive to oilfield chemicals  
Low gas permeation
M-PIPE MANUFACTURE

Victrex PEEK

Carbon fiber

High quality laser manufacturing

= m-pipe®

- One product for all applications
- Exceptional performance
- Cost effective
Oil-rich offshore reserve below 2000m of carbonate salt in 2000 to 3000m water

Large reserves of high quality light oil.

High levels of CO$_2$ (~12%) and H$_2$S and high temperature and pressure challenge the use of steel.

Most of the ‘well-known’ polymer / composite systems are at the limit of their performance, thermally and mechanically.
MAGMA / TFMC: HYBRID FLEXIBLE PIPE (HFP)
TechnipFMC / Magma Approach

HFP overview

--- Conventional Flexible Pipe ---

--- Hybrid Flexible Pipe (HFP) ---

Thermoplastic Composite Pipe (TCP)

Conventional Armor and External Sheath

TechnipFMC / Magma Approach

HFP overview

--- Conventional Flexible Pipe ---

--- Hybrid Flexible Pipe (HFP) ---

Thermoplastic Composite Pipe (TCP)

Conventional Armor and External Sheath
TechnipFMC / Magma Approach
HFP overview

Today

Conventional flexible

TCP

100

10

Tomorrow

HFP

40

Weight in sea water, filled with water (kg/m)
8” Conventional Flexible

100% Composite TCP

8” Hybrid Flexible Pipe

Hi Flex laminate design (jumper / flowline)

Hi tension tri-axial laminate design (riser)

Low MBR

Medium MBR

Medium to Large MBR

- Laminate design is governing TCP MBR performance (more than matrix polymer material choice)
- HFP concept allow to optimize TCP MBR through clever load sharing
Magma / TechnipFMC Approach

- HFP qualification according to DNV-GL standards
  - DNVGL-RP-A203 – Qualification of new technology
  - DNV-OS-C501 – Composite components
  - DNVGL-ST-F119 Thermoplastic Composite Pipes

- Qualification Plan endorsed by DNV-GL

- Small Scale / Medium Scale / Full Scale pyramidal approach

- Test on Hybrid Flexible Pipe manufactured using Magma Global and TechnipFMC industrial assets

HFP manufacturing in TechnipFMC LeTrait Manufacturing Unit

HFP full scale test – Burst.
Materials Selection

Overview

There are a number of high performing and proven polymers used in SURF applications: PVDF, PA11, PA12, XLPE.

Typically used as liners or internal pressure: the structure combines un-bonded steel armour layers to provide strength and flexibility and polymer sealing layers with low stiffness to provide fluid integrity.

In TCP’s there are (normally) two materials:

- **Polymer** for the internal conduit / liner and the matrix for the composite (ensuring compatibility)
- **Fibre** as the load bearing component of the composite (Carbon)

**Flexibles**

- Chemical and permeation resistant fluid barrier capable of working at temperature.

**HFP**

- Chemical and permeation resistant fluid barrier capable of working at temperature
- Low permeation, chemical resistant, mechanically stable composite matrix able to transfer applied loads to fibres under operational loads
Matrix Material Selection Criteria

The matrix bonds fibres together and transfers the applied load between them.
- Higher temperature composite applications require high temperature polymers to operate effectively.

The matrix properties also determine the degradation / failure mechanism of the composite:
- Chemical degradation
- Water absorption
- Creep (especially at elevated temperature)
USEFUL FEATURES OF PEEK / CARBON FIBRE COMPOSITES

Molecular structure of PEEK superposed on a graphite plate\(^1\)

Hybrid Flexible Pipe
Polymer Selection

Advantages of PEEK based composite

- PEEK-CF: inherently good bonding between PEEK and CF
- PEEK mechanical properties stable within HFP operating temperature range
- Best in class chemical resistance. PEEK already known as suitable choice for O&G most demanding application (HPHT sealing). Tested against NORSOK / ISO 23936-1 standards.
- Very low permeation compared to thermoplastic materials already used in conventional flexible pipe. Barrier against corrosion.
Hybrid Flexible Pipe
Polymer Selection

Advantages of PEEK based composite

- PEEK mechanical properties stable within **HFP operating temperature range**

<table>
<thead>
<tr>
<th>Crush Strength</th>
<th>PEEK-CF TCP</th>
<th>PVDF-CF TCP</th>
</tr>
</thead>
<tbody>
<tr>
<td>20°C</td>
<td>100%</td>
<td>20°C</td>
</tr>
<tr>
<td>110°C</td>
<td>40%</td>
<td>110°C</td>
</tr>
<tr>
<td>20°C</td>
<td>60%</td>
<td></td>
</tr>
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<td>110°C</td>
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</tbody>
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TechnipFMC
Advantages of PEEK based composite

- **Very low permeation** compared to thermoplastic materials already used in conventional flexible pipe. Barrier against corrosion.

![Diagram showing permeation comparison between PVDF and PEEK](image)

Corrosion resistance

- 30 x less permeable to CO₂


Supercritical CO₂ environments

- CO₂ becomes supercritical above 31°C and 73.8 bar
  - Here density is that of the liquid while diffusion properties are those of the gas

- CO₂ at high pressure is a powerful solvent which can influence polymer performance

- CO₂ effects can be reversible (swelling effects) but can also remove additives and low molecular weight content.

- The low solubility of CO₂ in PEEK polymer and its high chemical resistance provide a good basis for matrix and liner selection

![Phase diagram of CO₂](https://upload.wikimedia.org/wikipedia/commons/thumb/2/23/Carbon_dioxide_p-T_phase_diagram.svg/609px-Carbon_dioxide_p-T_phase_diagram.svg.png)
Effects of Supercritical CO$_2$ on PEEK Polymer
The Brazil pre-salt region poses significant materials challenges.

HFP combining Technip FMC and Magma Global technologies is a promising solution to these challenges.

The function of the polymer in a TCP differs from that in a flexible: in a TCP, as the matrix polymer it is important that the polymer retains its mechanical properties at elevated temperature and in a SCCO₂ environment.

A Victrex PEEK polymer solution clearly exhibits the capability of performing in these environments whereas other thermoplastic polymers have reached the limit of performance.
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