# Development of HMPE fiber for deepwater permanent mooring applications

<table>
<thead>
<tr>
<th>Name</th>
<th>Company</th>
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<tbody>
<tr>
<td>Sérgio Leite</td>
<td>Lankhorst Ropes</td>
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<tr>
<td>Peter Davies</td>
<td>Ifremer</td>
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<tr>
<td>Martin Vlasblom</td>
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<tr>
<td>Bill Fronzaglia</td>
<td>DSM Dyneema</td>
</tr>
<tr>
<td>Jorn Boesten</td>
<td></td>
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</tbody>
</table>
Agenda

- Fiber properties
- Rope properties
- Why use it?
- Conclusions
Three world class players teaming up

Lankhorst Ropes
One of the largest rope manufacturers in the world
Almost 2 decades working with Dyneema®
Presence in Portugal and Brazil

Ifremer
French Ocean Research Institute
Over 20 years experience in testing of high performance fibers and ropes

DSM Dyneema
Inventor of the Dyneema®, the world’s strongest fiber™
Dedicated to innovation
Largest global supplier of HMPE fiber
### Development of HMPE fiber for deepwater permanent mooring applications

<table>
<thead>
<tr>
<th>Stretch</th>
<th>2000 m</th>
<th>3000 m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polyester Rope</td>
<td>40 m</td>
<td>60 m</td>
</tr>
<tr>
<td>Rope with Dyneema®</td>
<td>8 m</td>
<td>12 m</td>
</tr>
</tbody>
</table>

- Polyester creates greater horizontal offset
- **Dyneema®** will provide reduced values

![Image of Dyneema® rope](image.png)
**HMPE to PET comparison**

Lighter, compacter, stiffer

- Rope made with DM20, when compared with polyester will
  - Be 60% lighter
  - Have a 30% smaller diameter
  - Offer excellent fatigue properties
  - Be 3-4 times stiffer

<table>
<thead>
<tr>
<th>MBL</th>
<th>Polyester kg/m</th>
<th>DM20 kg/m</th>
</tr>
</thead>
<tbody>
<tr>
<td>630t</td>
<td>14,5</td>
<td>5,9</td>
</tr>
<tr>
<td>1250t</td>
<td>29,0</td>
<td>11,5</td>
</tr>
<tr>
<td>2000t</td>
<td>46,8</td>
<td>18,6</td>
</tr>
</tbody>
</table>
## HMPE fiber grades

<table>
<thead>
<tr>
<th></th>
<th>General</th>
<th>Reduced creep</th>
<th>Further reduced creep</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dyneema® fiber</td>
<td>SK75</td>
<td>SK78</td>
<td>DM20</td>
</tr>
<tr>
<td>Titer</td>
<td>1740 dtex</td>
<td>1740 dtex</td>
<td>1740 dtex</td>
</tr>
<tr>
<td>Tenacity</td>
<td>35 cN/dtex</td>
<td>35 cN/dtex</td>
<td>31 cN/dtex</td>
</tr>
<tr>
<td>Modulus</td>
<td>1160 cN/dtex</td>
<td>1160 cN/dtex</td>
<td>920 cN/dtex</td>
</tr>
<tr>
<td>Elongation at break</td>
<td>3.5%</td>
<td>3.5%</td>
<td>3.6%</td>
</tr>
<tr>
<td>Typical use</td>
<td>Work ropes</td>
<td>MODU mooring</td>
<td>Permanent mooring</td>
</tr>
</tbody>
</table>
DM20 fiber
Step change creep properties – creep elongation

- Accelerated testing are performed at elevate temperatures to provide results in acceptable time frame: 70°C and 300 MPA = 20% MBL
DM20 fiber
Step change creep properties – creep rate

- Creep: 70°C & 300 MPA = load of 20% MBL
- Creep rate DM20 is 50 times lower than SK78 in normal offshore conditions
**HMPE fiber Rope samples**

- 8 strand sub-rope samples (spliced)

<table>
<thead>
<tr>
<th>Material</th>
<th>Ø</th>
<th>Break strength</th>
<th>Test</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>SK78</td>
<td>29 mm</td>
<td>600 kN</td>
<td>Stiffness, Creep</td>
<td>Ifremer</td>
</tr>
<tr>
<td>DM20</td>
<td>34 mm</td>
<td>900 kN</td>
<td>Stiffness, Fatigue</td>
<td>DNV</td>
</tr>
<tr>
<td></td>
<td>52 mm</td>
<td>1800 kN</td>
<td>Stiffness</td>
<td>Lankhorst Ropes</td>
</tr>
</tbody>
</table>
Rope with DM20 fiber
Excellent properties for permanent mooring

- Ifremer – France: Ø 29mm rope: 67 t MBL
- Test conditions: 30°C / 45%MBL
- SK78 creep failure at 30% elongation; DM20 showed 2.5% elongation; only minor part is creep
Rope with DM20 & SK78

Stiffness

- Initially DM 20 is stiffer than SK78
- DM 20 stiffens little after first loading 10% MBL
- After 100 cycles, DM 20 has a stiffness 10% lower than SK78
Rope with DM20 fiber
Dynamic Stiffness

- Increasing mean load
  = increased stiffness

- Increasing amplitude
  = decreasing stiffness
Rope with DM20 & SK78
Dynamic Stiffness

- Increasing mean load = increased stiffness

![Graph showing dynamic stiffness for SK78 and DM20 ropes. The graph includes two linear equations:
  - SK78: Stiffness (N/tex) = 0.87*ML + 101, R² = 0.9752
  - DM20: Stiffness (N/tex) = 0.895*ML + 84.6, R² = 0.9795

Legend:
- SK78
- DM20
- Linéaire (SK78)
- Linéaire (DM20)
Rope with DM20 fiber
Stiffness testing

- After the stiffness testing a permanent strain of 1,5% was recorded
Rope with DM20 fiber
Fatigue

- DNV: Ø 34 mm, after 10,000 cycles between 5-50% MBL – ISO Standard, the obtained break strength result is 118% of the break strength value of the non cycled rope = Excellent fatigue life DM20
Why DM20?
Operational benefits in every project stage

Design stage

- Optimizing between riser type & mooring line stiffness
- More vessels of opportunity for transport & installation
Why DM20?
Operational benefits in every project stage

Installation stage
- Smaller or fewer vessels required for transport & installation
- Lower weights, thus faster & safer installation
- Longer rope lengths, thus fewer connections
Why HMPE
Operational benefits

- The concept balancing OPEX savings & CAPEX investment has been proven by many in many applications....

- MODU mooring lines, seismic lines, offshore lifting slings, deepwater lowering and lifting lines

- Petrobras, Shell, Anadarko, ConocoPhillips, Transocean, Delmar, Statoil, SBM, APL, PGS, Prosafe
Conclusions

- DM20 new product in HMPE portfolio with the known product benefits of HMPE
- Ropes made with DM20 fiber match industry requirements for permanent mooring
- Creep prediction model is again available for DM20
- Mooring ropes with DM20 offer OPEX savings during design and installation stage of deepwater systems.
Thank you

Sérgio Leite
Peter Davies
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