Service life of synthetic fibre ropes in deepwater lifting operations

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Fibre ropes for deepwater lifting

Fibre ropes offer the following advantages

• Lightweight construction is self-buoyant
• Easy to handle
• Possibility to make easy repairs with splices

However

• Fibre ropes for dynamic lifting operations are a relatively new development in the offshore industry
• Greater operational risks for lifting than for mooring
• Little practical experience to base the design of lifting equipment on, thus implementation presents various engineering challenges
Deep water potential of fibre ropes

Example: Offshore Mast Crane

- Single fall 200 ton capacity on the surface
- 92 mm steel wire rope
- Submerged rope weight 36 kg/m
- At 3000 m water depth the rope weight is 108 ton
- Effective capacity at 3000 m is 92 ton

With a steel wire rope the crane capacity more than halves at 3000 m depth

A fibre rope with Dyneema® is self-buoyant thus theoretically the crane retains its 200 ton capacity
Engineering challenges

Fibre ropes show large potential for deep water lifting operation

However for implementation questions have arisen on different issues like

- Service life
- Discard criterion
- Safety factors
- Certification
- Drum spooling
- Abrasive wear

+ = ?
Combined research activity

Huisman Equipment and DSM Dyneema are working together to tackle these challenges

Goals

• Develop deep water lifting equipment that can work with synthetic fibre ropes
• Create a rope manual that can be used for the design of deep water lifting equipment

Current focus on

• Bend-over-sheave fatigue
• Abrasion
• Winch design
Bend-over-sheave fatigue depends on

- Rope construction
- Rope diameter
- Line pull
- Sheave diameter
- Groove radius and shape
- Fleet angle
- Load frequency
- Temperature

Bend fatigue life prediction requires a **consistent** set of measurement data
Bend fatigue test data

- Target rope: fibre rope with Dyneema®, 12x1 braided construction and DSM Dyneema coating
- Rope diameters: 8, 20, 50 and 80 mm
- Line pull: safety factors ranging between 2 to 10
- Sheave diameter: D/d of 10, 20 and 30
- Groove radius: r/d of 0.5 and 0.53
- Low load frequency or cooled rope

Setup a model to predict rope life time within the given range of input parameters
Bend-over-sheave fatigue model

For steel wire ropes the Feyrer equation is commonly used

**Modified version for synthetic fibre rope with Dyneema®**

\[
\log N = a_0 + a_1 \log \left( \frac{F}{d^2} \right) + a_2 \log^2 \left( \frac{F}{d^2} \right) + a_3 \log^3 \left( \frac{F}{d^2} \right) + a_4 \log \left( \frac{D}{d} \right) + a_5 \log \left( \frac{F}{d^2} \cdot \frac{D}{d} \right) + a_6 \log(d) + a_7 \log \left( \frac{r}{d} \right)
\]

Single bends to failure

Influence of:

- Safety factor
- Sheave diameter
- Rope diameter
- ‘Life factor’
- Groove radius
Tuning of model with test data

Model serves as input for rope service life estimation
50 mm tests with Huisman’s test machine

Driven sheave  End connections  Rope path **without** counter bending

Rope path **with** counter bending
50 mm bend fatigue test results

Optimization of fibre construction and coating

<table>
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<th>Number of machine cycles [-]</th>
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<td>Rope with Dyneema® Bend optimised Wet test</td>
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**Abrasion due to spooling**

- Spooling of a rope to and from a winch can lead to abrasion and limit the rope’s service life
- Abrasion results from rope-to-rope and rope-to-flange contact
- This abrasion is similar to drum crushing of steel wire ropes

**This effect was investigated in a combined effort with**

- Huisman
- DSM \(\text{Dyneema}\)
- Jumbo Offshore Rotterdam
Winch spooling test installation

Winches supplied by Jumbo
- 36 mm rope
- Line pull 400 kN up to 6 layers
- Lebus grooved shells
- Filler pieces to reduce width

Winch test tower
- Direct winch-to-winchester spooling
- Winch 1 regulates tension
- Winch 2 regulates speed

Virtually any lifting scenario can be simulated
Abrasive spool test

- Continuous spooling and unspooling of 4 windings
- Varying linepull to create slippage between layers
- Test locations at the center of the 1<sup>st</sup> and 3<sup>rd</sup> layer and at the flange from the 1<sup>st</sup> to the 2<sup>nd</sup> layer
- Residual strength determined after spooling test

Most abrasive wear occurs between adjacent layers
Residual strength measurements

Effect of the number of cycles on the residual rope strength after abrasion test
Estimation of rope service life

Quay Crane at Huisman for in service testing

Identification of system points

Administration of rope movement and occurring bends

n: number of nodes
s: rope section

Hoisting

Winch

s1 s2 s3

s18 s19 s20

Dead end

n-5 n-4 n-3 n-2 n-1 n

F_line pull

n-2

n-1

F_line pull

half bend reversal

full bend reversal

half bend reversal

0 1 2 3 4 5
Estimation of rope service life

Load cycle diagram

Rope condition along rope

Heaviest loaded rope section determines rope service life

Identification of critical sections aids rope inspection

Damage index: \( \text{damage index} = \sum_{i=1}^{n} \frac{N_i}{N_{\text{failure}}(S_i, D_i, d)} \)
Conclusions

- Synthetic fibre ropes with Dyneema® show potential for deep water lifting operations
- Collaboration helps to fill the knowledge gaps and increases confidence
- Consistent bend and abrasion fatigue data makes service life predictions possible
- Combined with a rope monitoring system a bend fatigue and abrasion model can aid rope inspections
Questions