Development of HMPE fiber for deepwater permanent mooring applications

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Agenda and opening remarks

- The challenge: Moor production units with HMPE
- Designing a solution
- Results
- Why use it?
- Conclusions

Why?

- Industry likes working with HMPE
- Successes with large global players
- “We like your fiber,
  can we use it for production mooring”
- DSM ready for it

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

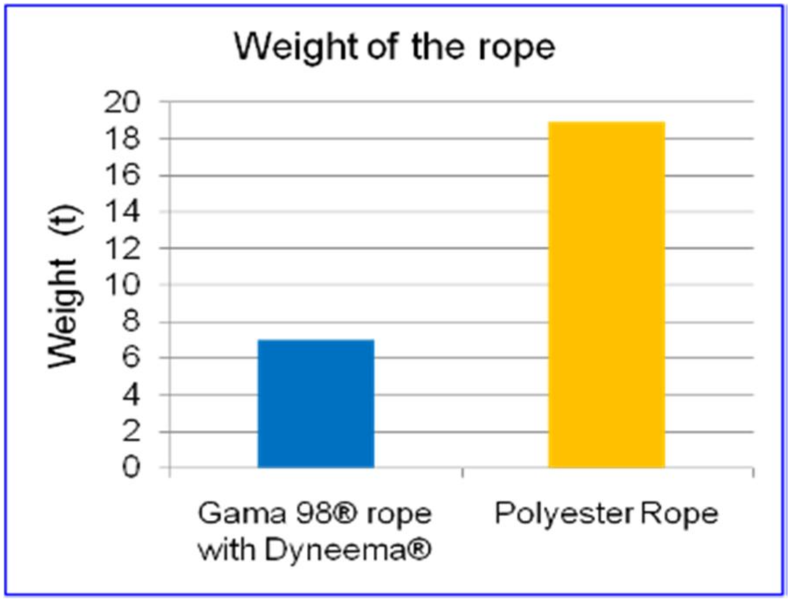
DSM Dyneema

- Inventor of the Dyneema®, the world's strongest fiber™
- Dedicated to innovation
- Largest global supplier of HMPE fiber

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



High dynamic stiffness, but

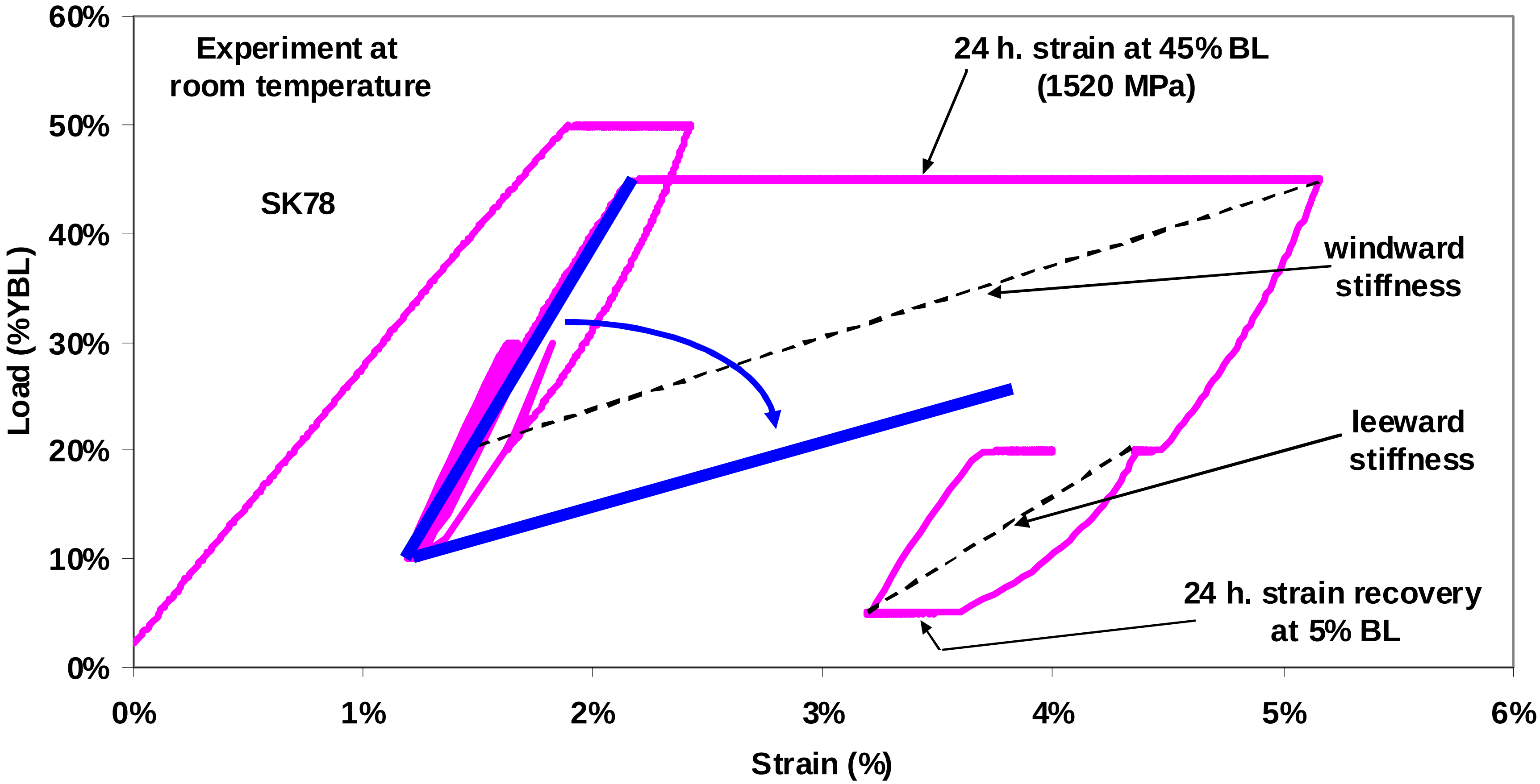
Windward stiffness of standard HMPE grades is low

- 2011 OIPEEC paper by Petrobras (del Vecchio ea)
- Tests proposed
- Dynamic stiffness is high, but quasi static stiffness values are low, due to long interval under static load
- QSS will improve if creep is reduced

Yarn stiffness based on Yarn Break Load	SK78 fiber
Windward 24h.	6.8 x YBL
Leeward 24h.	13.0 x YBL
Dynamic stiffness (10-30%YBL)	43.7 x YBL

HMPE fiber and rope stiffness

Existing SK78 grade – stiffness too low



Design parameters for DM20

Step change in creep performance needed

- 0.5% Maximum elongation of a mooring rope after 25 years in service
- Matching the required creep lifetime safety factor

- These requirements were not achievable with any existing commercial HMPE grade, not even SK78

	SK75		SK78	
	Estimated creep elongation	Creep failure safety factor	Estimated creep elongation	Creep failure safety factor
MODU mooring condition (5 years of 20%BL at 16°C)	6.6%	Can not be met	1.7 %	Can be met
Permanent mooring condition (25 years of 20%BL at 16°C)	Failure		failure	

Norms and guidelines

Guideline	NI 432 DTO R01E	DNV-OS-E303 DNV-OS-E301	Guidance notes on offshore mooring fiber rope	API-RP-2SM	ISO/PDTS 14909
Issuing body	Bureau Veritas (7)	Det Norske Veritas (8), (9)	American Bureau of Shipping (10)	American Petroleum Institute (11)	International Organization for Standardization (12)
Creep prediction	Long-term creep of the rope based on fiber creep data.	Creep failure resistance to be specified by rope manufacturer. Yarn manufacturer to test to yarn creep failure.	Creep analysis to estimate the total creep strain during the design service life. Creep rupture analysis to estimate the creep rupture life. Creep model based on fiber creep data.	Creep analysis based on mean and maximum design loads. Creep failure analysis based on rope test data.	Estimate of creep rate and allowable creep elongations, in operating conditions on most critical area of the rope. Based on model of fiber creep properties.
Method			Number of discrete design conditions to calculated annual creep strain and	Several tension intervals to calculate annual cumulative creep	

95% of initial rope strength or 10% of installed rope length.		Total creep strain limited to 10% of total length of HMPE rope.	
NI 432 DTO R01E	**DNV-OS-E303 DNV-OS-E301**	**Guidance notes on offshore mooring fiber rope**	**API-RP-2SM**
	Creep failure safety factor of 3 for mobile moorings and 5- 8 for long-term moorings.	Factor of safety over the design service life against creep rupture: 5 (creep is monitored) or 10 (creep is not monitored).	Factor of safety for creep failure is10 times the service life of the rope.

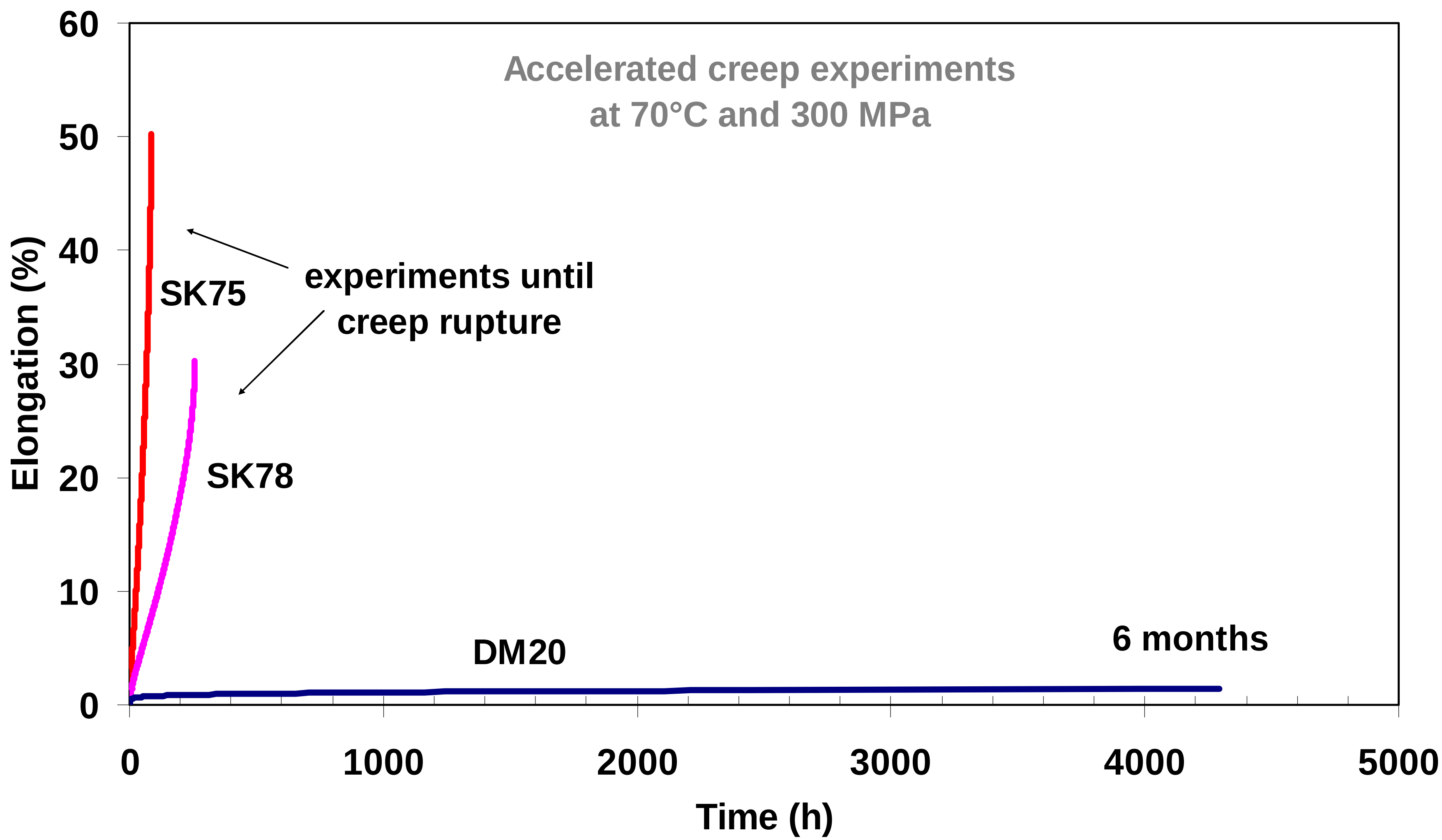
DM20 fiber

Step change in creep properties - elongation

- Elongation as function of time
- Accelerated tests at 70C and 300MPa

DM20 fiber

Step change in creep properties - elongation



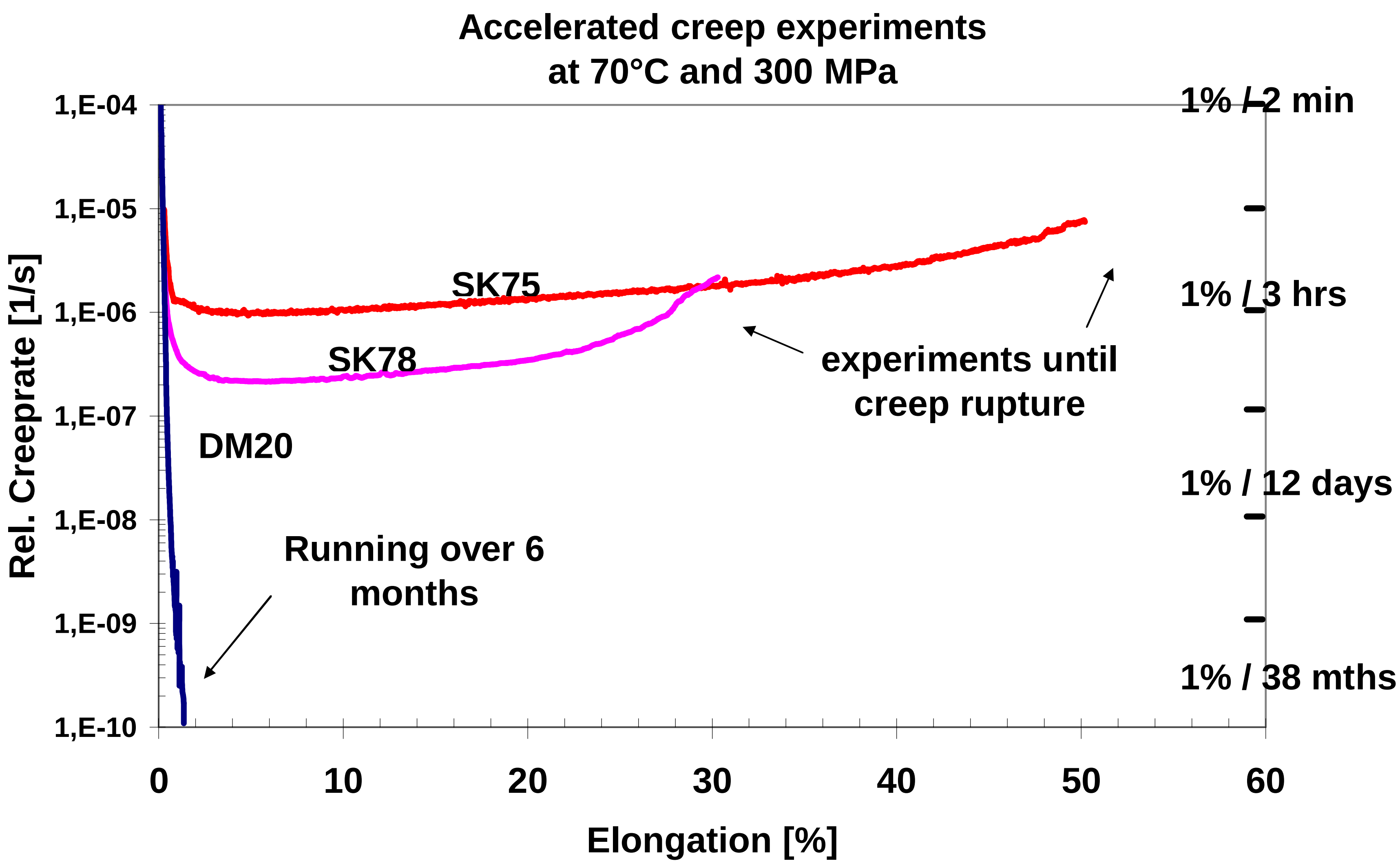
DM20 fiber

Step change in creep properties – creep rate

- Creeprate as function of elongation
- Accelerated tests at 70C and 300 MPa

DM20 fiber

Step change in creep properties – creep rate



Rope with DM20 fiber

Excellent properties for permanent mooring

- 29mm rope, 67 tons break strength
- Tested at Ifremer, France. 30C / 45% rope break load

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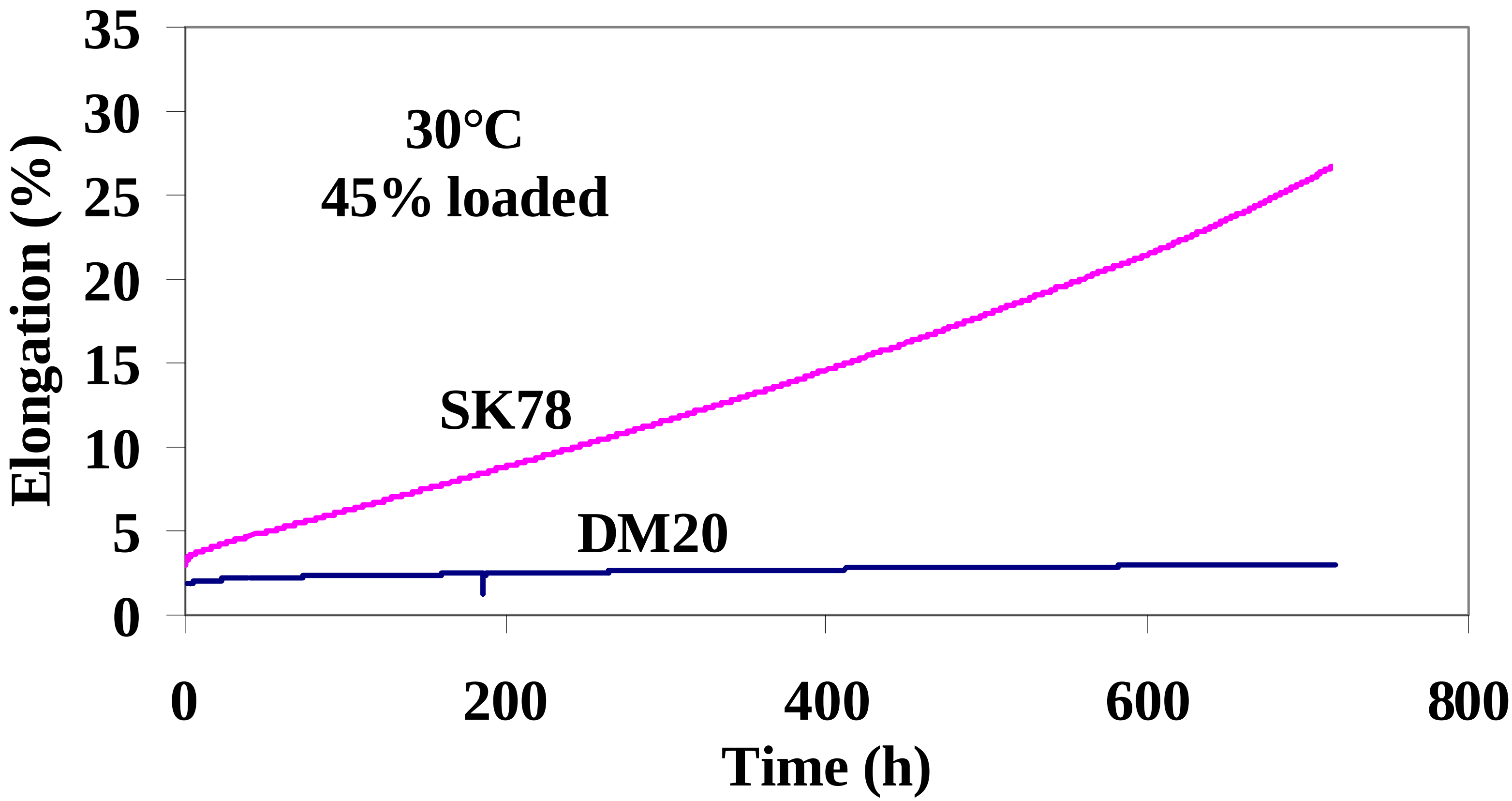


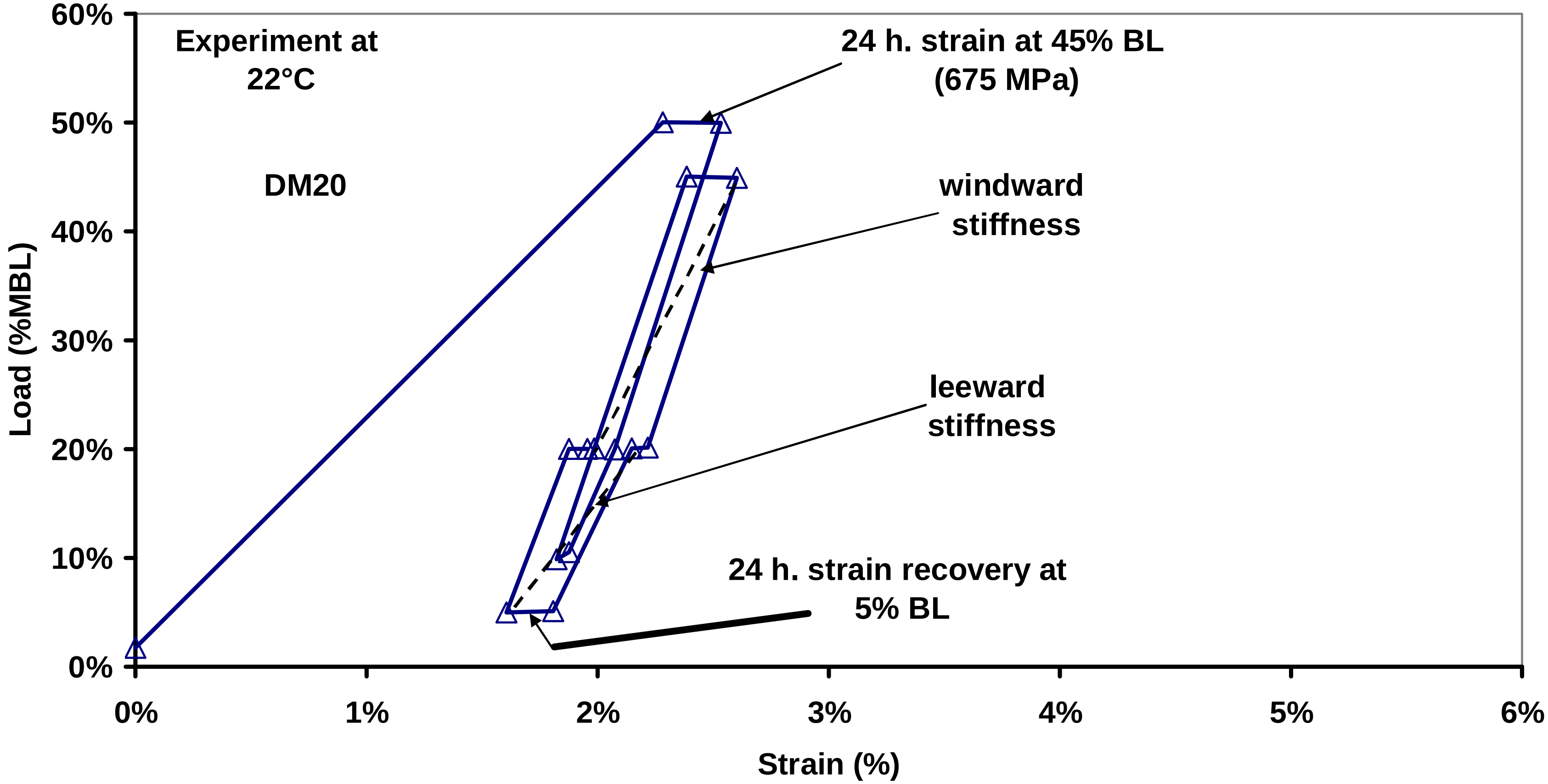
Rope with DM20 fiber

Excellent properties for permanent mooring

- Fatigue test according ISO 14909 @ DNV Bergen (Norway)
- 34mm, 90 tons break strength subrope designed by Lankhorst
- 10.000 cycles
- 5-50% BS
- Followed by tensile test Break @: 106 tons (118%)

Rope with DM20 fiber
Excellent properties for permanent mooring

- Stiffness test



DM20 fiber and rope

Excellent properties for permanent mooring

- Fiber and rope stiffness measured (22C)

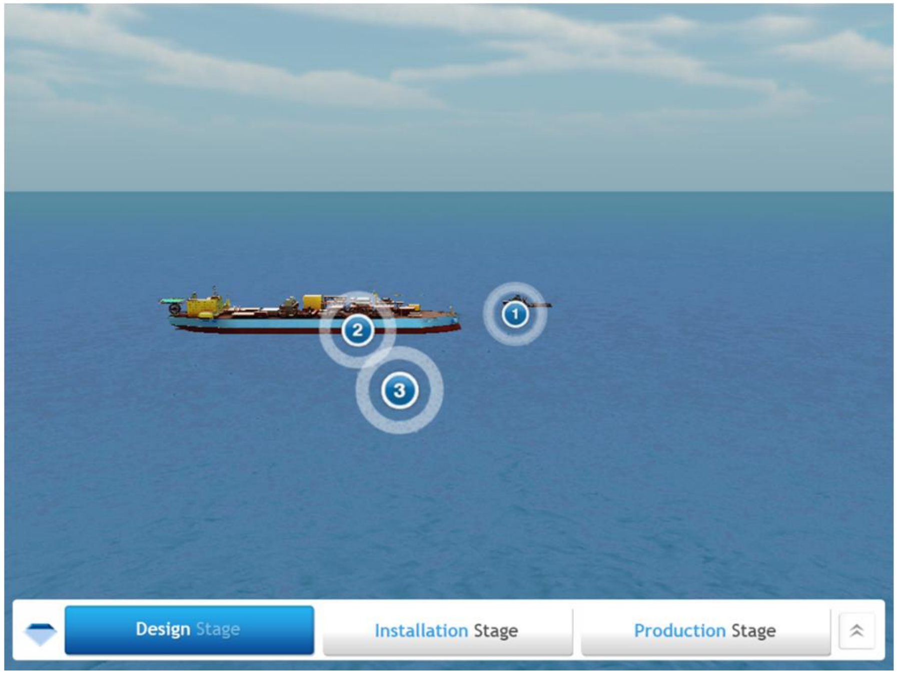
	SK78 fiber	Rope DM20
Windward 24 hour	6.8	40.3
Leeward 24 hour	13	27.8
Dynamic 10-30%	43.7	60

Why DM20 ?

Operational benefits in every project stage

Design stage

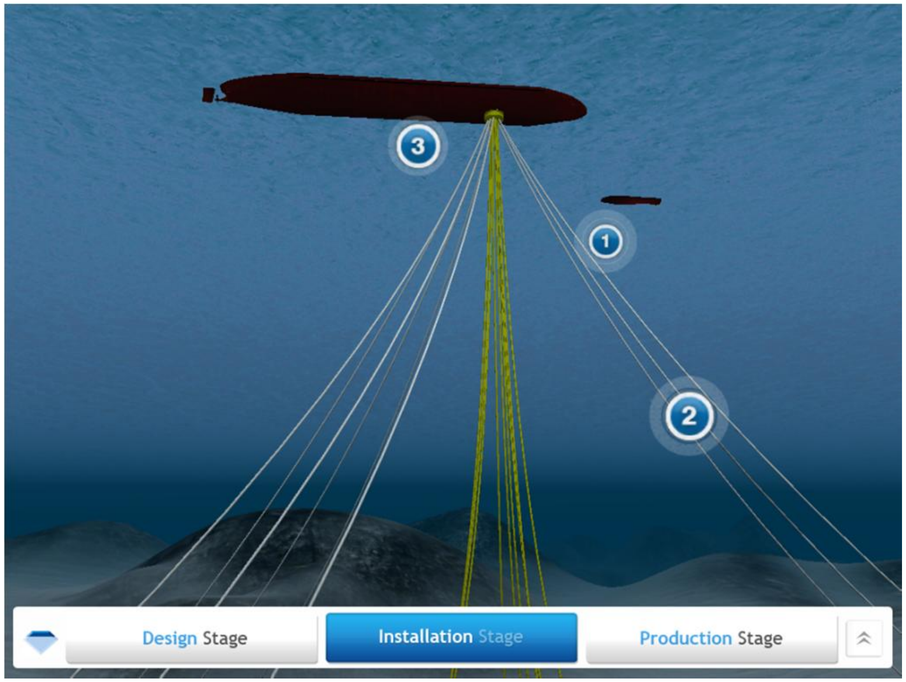
- Optimizing between riser type and mooring line stiffness
- More vessels of opportunity for transport and installation



Why DM20 ?
Operational benefits in every project stage

Installation stage

- Smaller or fewer vessels required for transport and installation
- Lower weights thus faster and safer installation
- Longer rope lengths thus fewer connections



Why HMPE
Operational benefits

The concept of balancing OPEX savings and 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 is a new product in the HMPE portfolio with the known product benefits of HMPE
- Ropes made with the new DM20 fiber match industry requirements for permanent mooring
- Creep prediction model is again available for DM20
- Discard criterion of 10% for creep, that is in several standards, needs to be reconsidered for DM20
- Mooring ropes with DM20 offer OPEX savings during design and installation stage of deepwater systems.

Obrigado / Thank you / Questions

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