Dynamic Load Monitoring and Analysis of Mooring Lines used by Wave Energy Converters.

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Polyurethane-steel belts offer a promising solution for mooring lines in WEC systems, showing stable tensile performance and predictable viscoelastic response. Accurate force monitoring requires sensor calibration and accounting for load dissipation, critical for ensuring reliability in offshore dynamic environments.

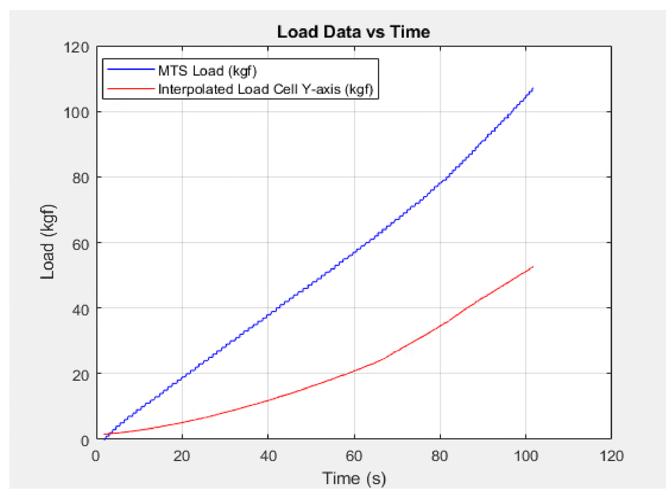
Introduction

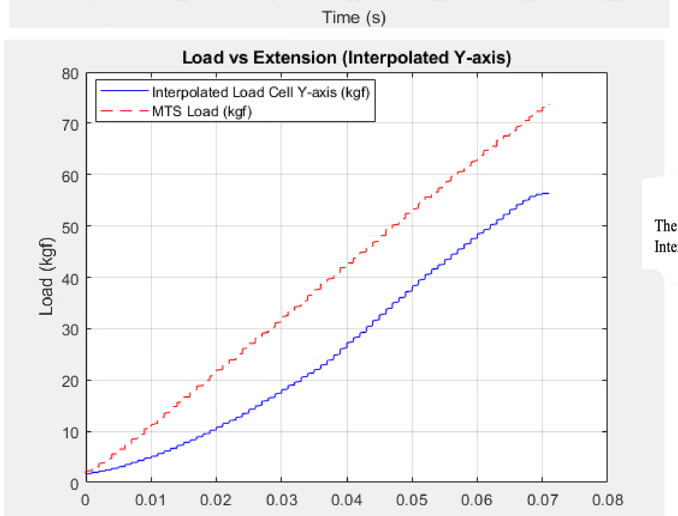
As wave energy converters (WECs) technology is becoming more mature, a new generation of units developed by private industry has emerged and is expected to become a common feature of the blue economy. The majority of these WECs is moored to the seafloor, and the ability to produce energy both efficiently and reliably is tied to the very design of the mooring mechanism. This research explores several methods to determine experimentally the dynamic characteristics of a polyurethane-steel tension belt for rotary power take-offs (PTO) systems and wave energy converters. Polyurethane-steel tension belts are steel-cord-reinforced polyurethane belts that offer high longitudinal stiffness, minimal post-elongation, and high pitch accuracy, which are crucial for synchronous drives. A prominent application concern is the unpredictable behavior and unknown life predictions of polyurethane belts when used for power transmission under winching elements and harsh underwater conditions [1]. The focus of the work presented is to compose a structural analysis of the belt under dynamic loading conditions. Continuously monitoring mooring load provides information on whether anchoring forces remain within safe thresholds, which helps reduce the risk of structural failure during harsh sea conditions.

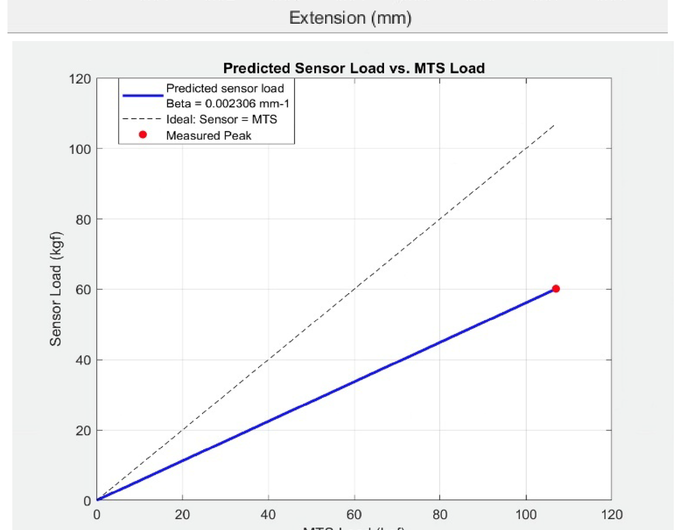
Load cell-based belt tensile testing performed on the MTS machine:

The test conducted was a tensile test performed under controlled laboratory conditions to evaluate the mechanical behavior of the 3100 µm Synchro-Power flat [4] belt under uniform load increase and to assess the sensitivity of two data acquisition systems—PADLOC [2] and the MTS machine—operating simultaneously. The PADLOC is connected to the 500 [kN] Interface load cell (model LPXX-50MT-DB) mounted [2] at the bottom end and connected to a computer to record load measurements. The MTS machine controls the extension rate, and it is manually configured in the input section of the program. The extension rate was set to 0.000165 mm/s, and the test was conducted until a maximum load of 100 [kg-f] was reached. A slow rate ensures that the viscoelastic composites like polyurethane-steel belts have time to respond to the applied load without introducing dynamic or rate-dependent effects like viscoelastic lag [6]. On the other hand, high extension rates may experience inertia, causing noise, overshoot, and inaccurate load readings that could mask true material responses. Especially when monitoring with two systems (like MTS and PADLOC), a slower rate ensures both systems can sample at appropriate resolution and synchronize readings with minimal lag.

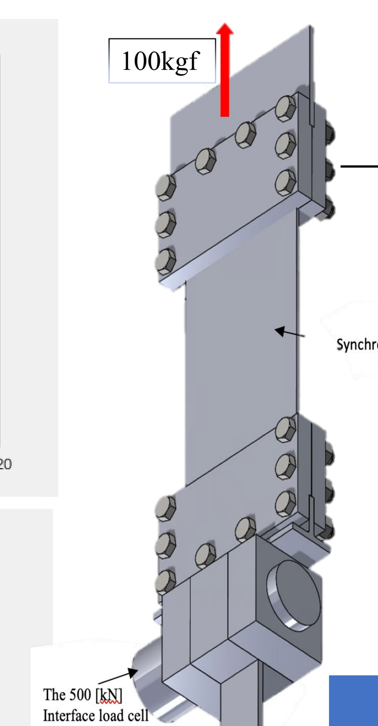
RESULTS



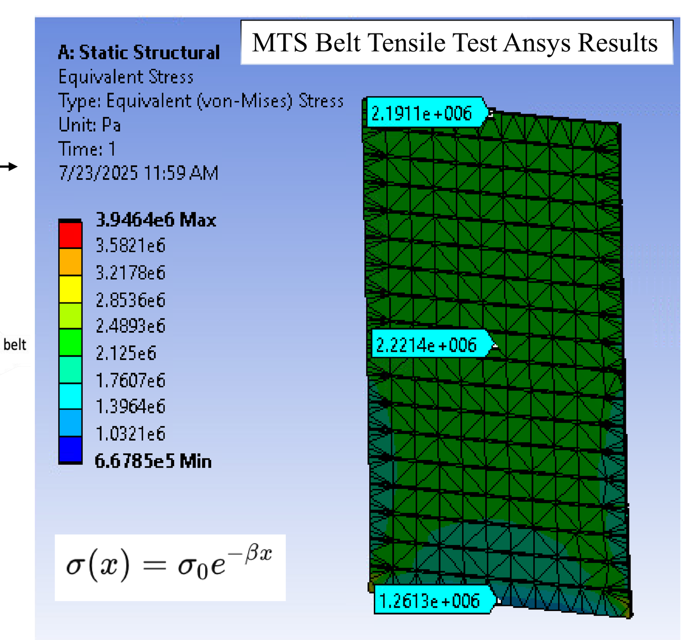




$$T_{out} = T_{in} \cdot e^{\mu\beta} \quad (1)$$
$$F_{sensor} = F_{MTS} \cdot e^{-\beta L} \quad (2)$$
$$F_{sensor} = F_{MTS} \cdot 0.5618 \quad (3)$$



MTS Belt Tensile Test Ansys Results

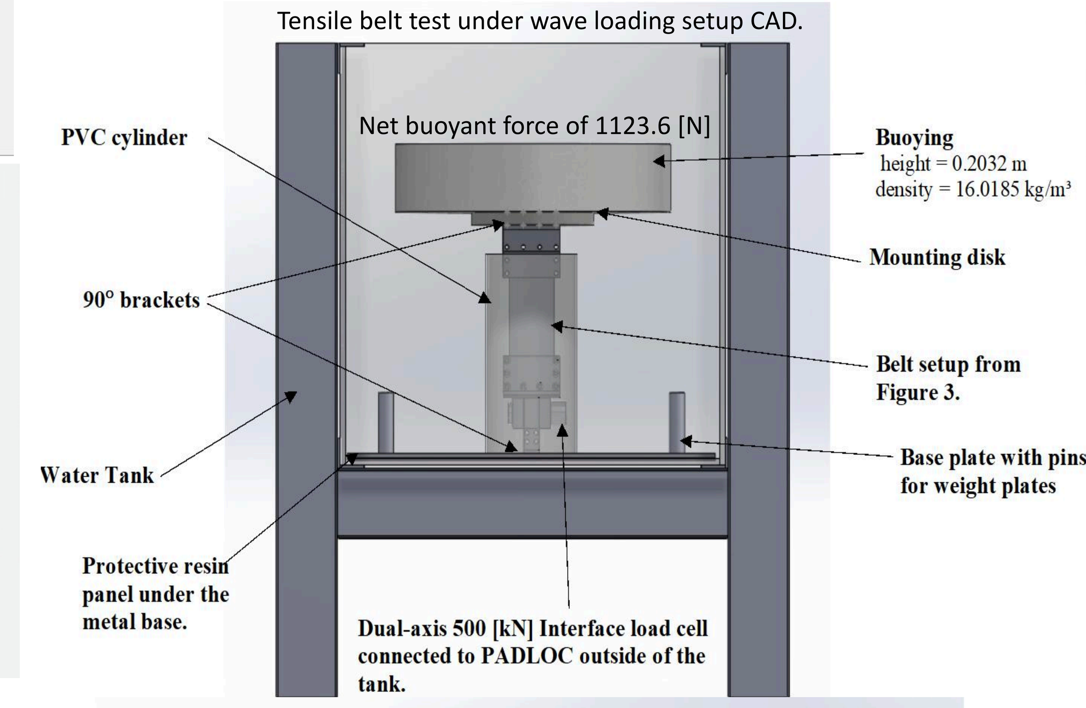


$$\sigma(x) = \sigma_0 e^{-\beta x}$$

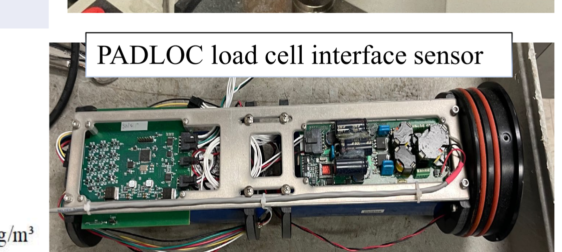
	MTS (Top)	PADLOC (bottom)	Difference (%)	Ansys (top)	Ansys (bottom)	Difference (%)
Stress (Pa)	2.15e6	1.20e6	44.2%	2.1911e6	1.2613e6	42.44%
Extension (mm)	0.107			2.509		

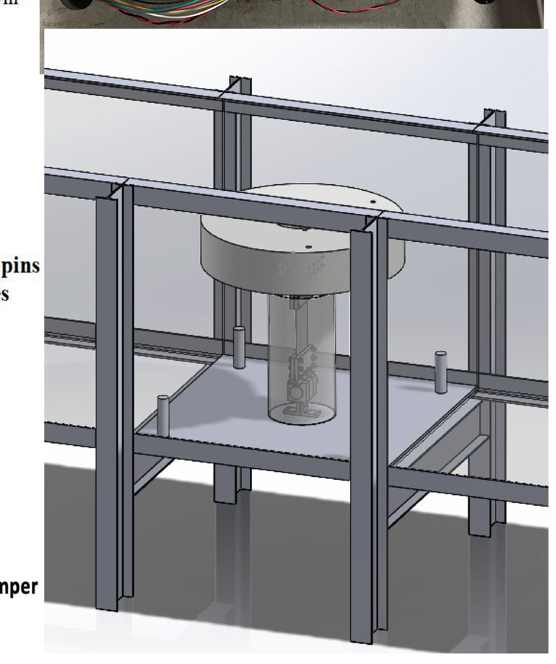
MTS Belt Tensile Test In FAU Lab

Tensile belt test under wave loading setup CAD.

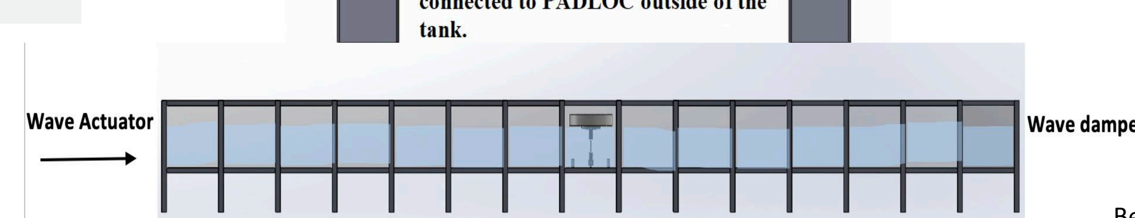


PADLOC load cell interface sensor





Belt tensile test at 0 degrees setup under wave load dimetric profile.



Tensile belt test under wave loading lab setup CAD.

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Conclusions

Both the MTS and Interface (Y-axis) load cells follow a similar trend, confirming consistency in the tensile testing setup. This test shows that the belt exhibits a smooth load increase over time. Furthermore, the maximum extension recorded in the test dataset was 0.07 [mm], indicating limited elongation under load. Together, these observations reinforce the conclusion that the belt behaves as a composite with limited range of elasticity capable of distributing tensile load without abrupt deformation or failure. However, for accurate load assessment in practical systems, sensor placement must be considered, and calibration models, such as the exponential decay correction [7], should be applied to reconcile differences between sensor readings. The sensitivity of the data acquisition method relies on the position of the sensor, as it was observed that there was a mismatch of 56.2% of load readings from both load measurement sensors. Exponential decay model reconciles sensor discrepancies.

Tensile belt test under wave loading in a controlled environment:

This experimental setup is designed to evaluate the mechanical response of the Synchro-power flat belt under simulated wave loading in a controlled lab environment. The system features a vertically mounted water tank housing the belt setup that is clamped between a submerged buoy and a fixed base plate. The buoy, introduces an upward buoyant force that mimics dynamic wave interactions. The belt can be positioned at varying orientations—0°, 45°, and 90°—to evaluate how different angles affect its performance under simulated wave conditions. The dual-axis 500 [kN] interface load cell is integrated in-line with the belt to precisely measure both vertical and lateral load components during testing. The load cell is interfaced with PADLOC data acquisition outside the tank, allowing real-time monitoring of tension fluctuations as hydrodynamic forces act on the system. This configuration enables repeatable testing of tensile belt performance under controlled, wave-like conditions, making it highly suitable for offshore mooring or subsea tether system analysis.

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