Simulation of Tensioning Systems with the Belt Drives library in SimulationX®

TNO-0008

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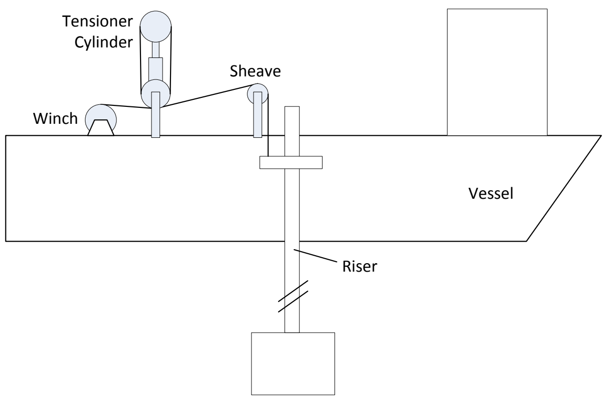
Visualize the solution – Remove the risk

1. Introduction

SimulationX® is graphically based software for modeling and simulation of dynamic systems. The software is developed by ITI GmbH in Germany and has been well received in the offshore industry because of its extensive library, simple user interface and high flexibility. This article describes a model of a tensioning system developed with the Belt Drives library in combination with the Planar Mechanics library both available in SimulationX® release 3.5.



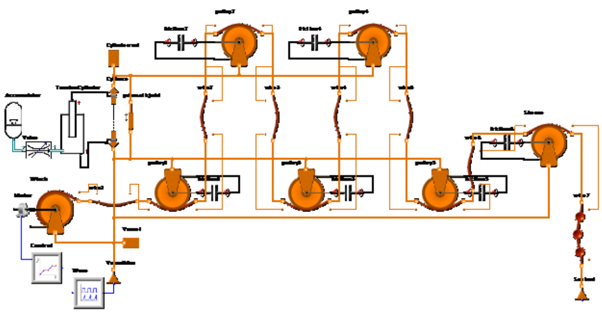
The figure above shows a simplified riser tensioning system on a floating production vessel holding with the purpose to keep constant tension in the riser.

Connecting the tensioner cylinder with gas accumulators with large volume it is possible even with a passive system to have a high tension force in the wire with only small force variation during operations in waves.

Tensioning systems are widely used in offshore operations and typically consist of a number of sheaves and a wire. Even though the tensioning system consists of simple mechanical components, the dynamics of a such system is quite complex due to compliance and mass of the wire, contact between wire and sheaves, friction in sheaves and highly nonlinear behavior of the gas accumulators.

2. SimulationX® Model

A system model of the tensioning components with two parts, including control signals, in SimulationX® is shown.



The model contains a combination of elements from the Hydraulic, 1D Mechanics, Planar Mechanics and Belt Drives library together with control signal boxes.

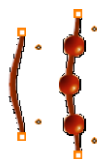
The Planar Mechanics library in SimulationX® allows the user to develop 2D mechanical models fast and efficient and couple it to i.e. hydraulic cylinders. The Belt Drives library is an extension of the Planar Mechanics library

that include elements for modeling wire systems belt drives. Some of them are briefly described here.

The winch element can be parameterized with a mass, moment of inertia and a drum diameter. The wind-up kinematics can in details be specified by number of windings per layer and an initial wound-up length or

number of windings together with wire thickness. The winch can be driven by any rotation motor element in SimulationX®.

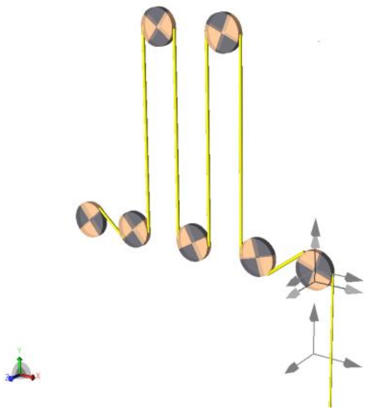
The sheave element can be parameterized by inertia properties and diameter. And there is an option to include slip between sheave and wire. For both winch and sheave it is possible to introduce damping or friction by connecting the two black lines through a damper or friction element from the Rotational Mechanics library. In this simulation model a continuous



transition friction depending on the wire force are introduced in each sheave.

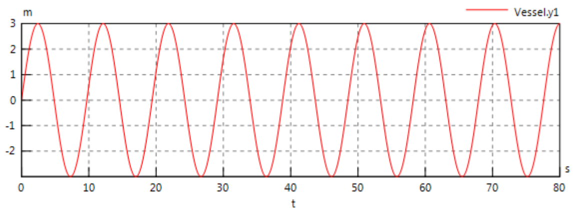
Two kinds of wire exist in the library. The first is a mass less wire specified by a stiffness constant (E-modulus times cross section area) and a damping factor. The second is furthermore specified by a distributed density (mass per length). The length of each wire section is calculated automatically and continuously updated during simulation if the sheaves are moving relative to each other. Hence, all kinematic relations including compliance of the wires are handled by SimulationX®.

The wire can be attached to any kind of 2D mechanical body or as in this model to the riser which is fixed to the seabed. An isometric view of the wire system is shown below.

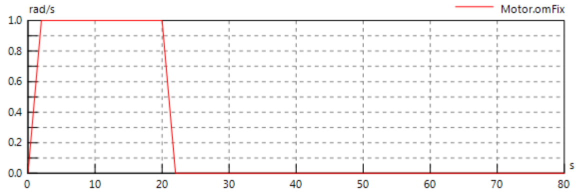


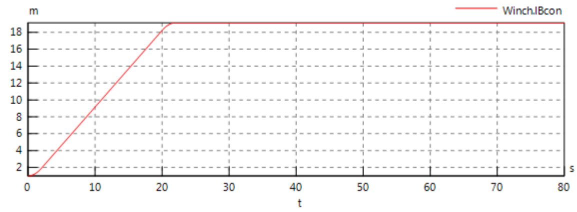
3. The system analysis

In this example the tensioner cylinder has a stroke of 8 meters and the vessel is moving up and down with a wave height of 6 meters with a period of 9.7 seconds which is shown in figure below.

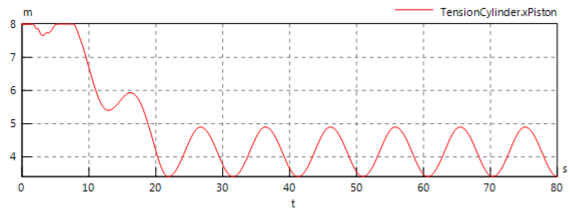


Initially the wire is unloaded and during the first 20 seconds the motor of the winch is activated. The figure below shows the control signal to the winch engine and the length of the wound-up wire on winch.

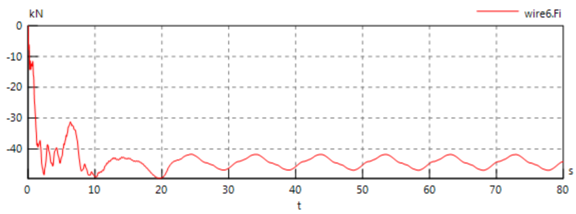




Because of prefilled pressure in hydraulic circuit the tensioner cylinder is initially fully extracted and then tensioned by the winch when the vessel is in motion. The cylinder extraction is shown in the figure below. When the tensioning system is in operation the cylinder is oscillating 1.5 meters which is one fourth of the vessel movement due to the gear ratio given by the topology of the tensioning system.



The figure below shows the wire force measured at the last sheave, which initially is unloaded then strengthened by the winch and oscillates between 42 and 47 kN.



It is here demonstrated how the Belt Drives library in SimulationX® can be applied for simulating wire systems. The model can easily be expanded to more complex assemblies and different combinations of cylinder, valves and accumulators can be tested.

SimulationX® simplifies the modeling and simulation and makes this technique available for more engineers.

The systems can be tested in a different manner than what is possible in a real test and the system limits can be verified without the risk of damage. It is important to remember that no software can ever be so good that system knowledge is no longer necessary.

If SimulationX® is used together with good system knowledge in the design process; it will give the end user better and more stable systems and also more optimized systems for the system producers regarding cost/performance.

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