Dyneema® 3T rope model for accurate mooring analysis with Deeplines Wind™
- the key to improved accuracy and reduced risks -

Introduction:

A specific type of properties for Dyneema® DM20 ropes has been implemented into DEEPLINES. Input data provided by DSM are introduced as an external encrypted file (Dyneema® 3T rope model).

This file contains information which allows an automatic update of the Dyneema® rope dynamic stiffness and structural damping during a time domain simulation accounting for the temperature, the loading frequency and the average axial strain experienced by the rope.

To get access to this feature, you have to:

- Use DEEPLINES version V5R7 (contact: deeplines@principia.fr);
- On the DSM website a request can be submitted to obtain Dyneema® 3T rope model as an encrypted file.

  https://www.dsm.com/dyneema/en_GB/company-info/other-request.html

Model input data:

The mooring model is defined as a classical mooring pattern in DEEPLINES. A mooring line may be composed of segments of different types. Segments made of Dyneema® fiber ropes are given dedicated properties.

As illustrated below, Dyneema® fiber rope properties are associated with classical bar elements in DEEPLINES except that:

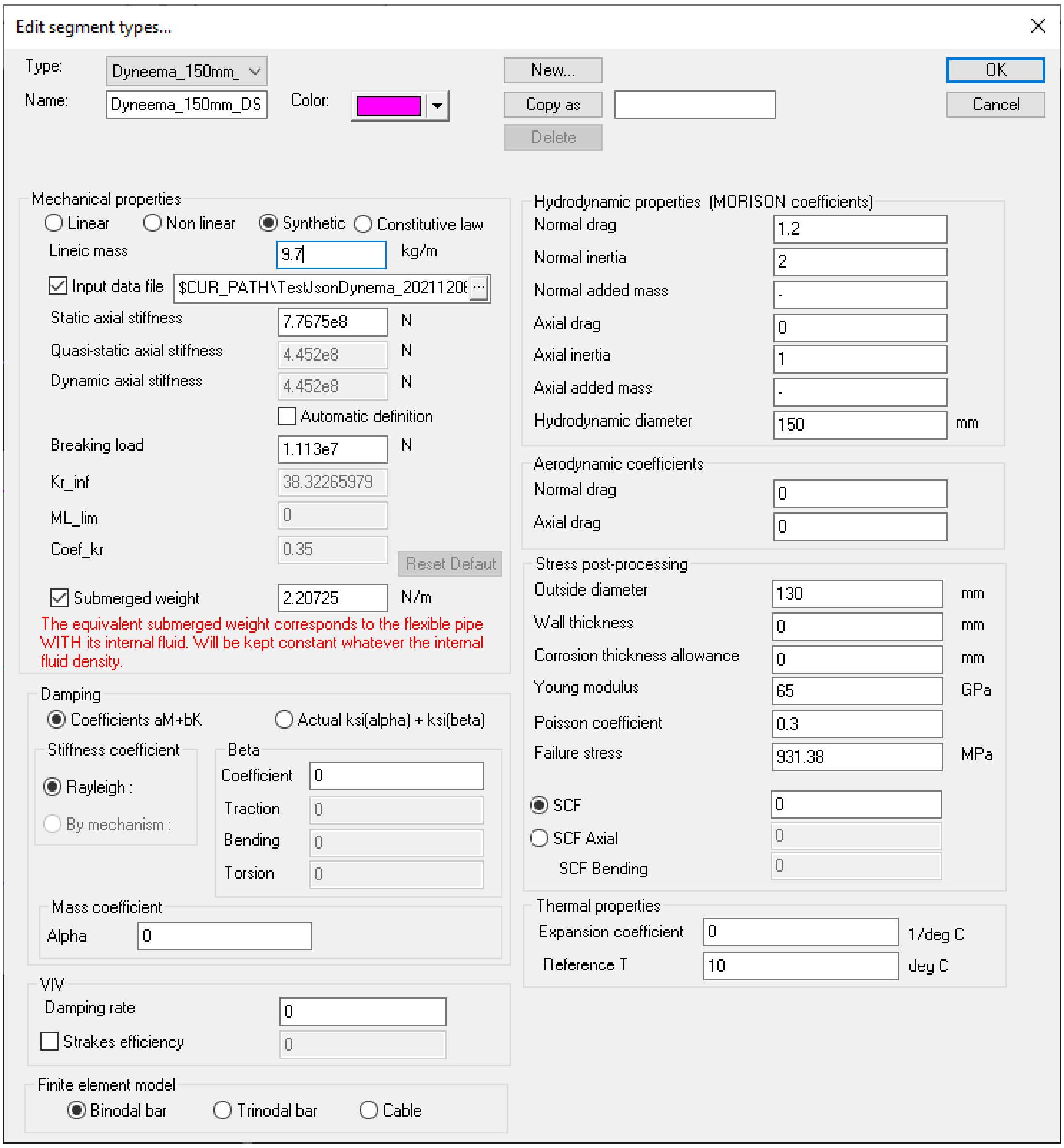
- Option Synthetic is checked.
- A specific input file is selected (encrypted file provided by DSM).

In addition to this encrypted file, users must define:

- The linear mass (kg/m),
- the so-called "static" axial stiffness (N): This reference stiffness value to be defined in accordance with DSM. Unless otherwise specified, the reference stiffness is the dynamic stiffness of the rope at 23°C, 1Hz and mean strain of 1%, i.e. $EA_{dynamic=}AE_{ref,23°C,1Hz,1\%}$. A classical value of 65MBL is often considered. More accurate input to the reference stiffness can be obtained by DSM or with your rope or tendon producer of choice.
- the outer diameter and the hydrodynamic (or aerodynamic) coefficients to compute hydrodynamic (aerodynamic) loads,

Other data may be defined as options:

- the submerged weight in N/m,
- temperature and thermal properties,
- post-processing data.



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DSM
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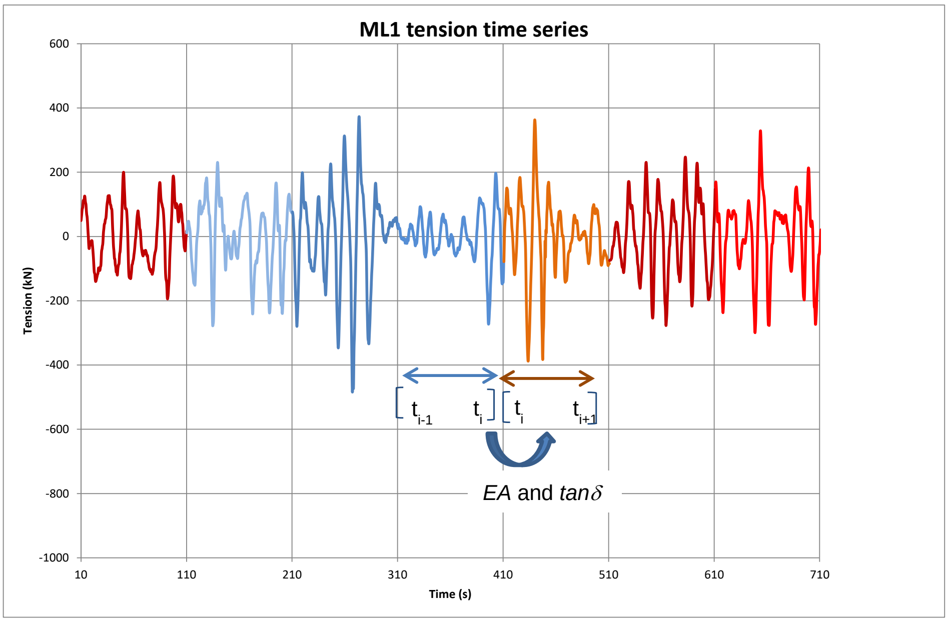
Computation principles:

From a practical point of view, the simulation is split into time windows, which duration is to be fixed by the user, and results of a time window [t_{i-1}, t_i] are used to determine the dynamic stiffness and damping for the next sequence [t_i, t_{i+1}] as illustrated below.



Note: the sequence duration is to be defined by the user with a dedicated keyword.

Example:

**SYNTHOPT*

Ioption_dyneema Tstart Tend Twindow

1 0 1000 200 0.

When computations start, the reference stiffness (static stiffness) is used. Then tensions and strains computed at all arc lengths of a line are stored during each sequence [t_i, t_{i+1}].

At time step t_{i+1}, the dynamic stiffness and damping to be used for the next sequence [t_{i+1},t_{i+2}] are evaluated as such:

- Get the zero up-crossing period T_z over [t_i, t_{i+1}] at each arc length along the line;
- Get the temperature T(°C) at t_{i+1} in case a variation in depth or in time is defined ;
- Get the average strain over [t_i, t_{i+1}] ;
- By convention, f=1/T_z is supposed to represent the average loading frequency;

- Compute the updated axial stiffness as such :

$$\mathrm{EA} = \mathrm{EA}(\mathrm{T}, \mathrm{f}, \varepsilon)$$

Where $\mathrm{EA}(\mathrm{T}, \mathrm{f}, \varepsilon)$ is function derived from DSM input data

- Update the damping term considering a Rayleigh damping matrix $\boldsymbol{C}=a\boldsymbol{M}+b\boldsymbol{K}$, with: *a* and derived from DSM input data
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- Use updated values for sequence $[t_{i+1}, t_{i+2}]$

Sequence	Axial force N_x	Axial stiffness	Damping
Static / Quasi-static	Tension = $EA_S\ e_S$	EA_S	0
Sequence $[t_o,t_1]$	Tension(t) = $EA_S\ e_S + EA_{QS}\ (e_{QS} - e_S) + EA_t\ (e(t) - e_{QS})$	EA_{to}	$\tan(\delta_{to})$
Sequence $[t_1,t_2]$	Tension(t) = $EA_S\ e_S + EA_{QS}\ (e_{QS} - e_S) + EA_{to}\ (e_{to} - e_{QS}) + EA_{t1}\ (e(t) - e_{to})$	EA_{t1}	$\tan(\delta_{t1})$

$T_{temp}(t_1)$ & $\{f, \varepsilon\}_{average\ [t_o,t_1]}$

DSM encrypted file