Friction Effects and Shear Stiffness

Tension along a line on the seabed changes due to friction. In an ideal model the theoretical rate of tension reduction would be $\mu R/L$. This document discusses situations in OrcaFlex where this rate is not generated and how this relates to the non-ideal real world.

1 Friction Ramping

1.1 Physical Mechanism

When a horizontal load is applied to a line on the seabed it will initially resist displacement. This resistance is due to friction and shear stiffness of the seabed. When the line initially starts to displace it is because the seabed is shearing slightly. Soon however the yield stops and further displacement is due to the line sliding.

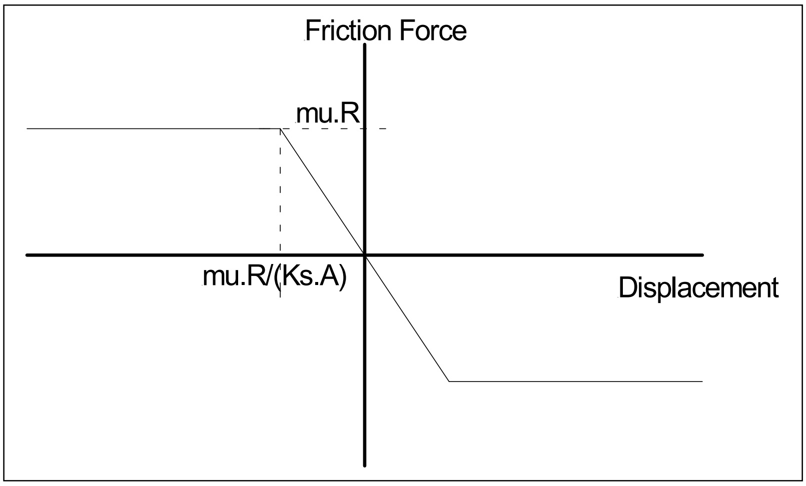
The displacement therefore has two components, shear and slip.

1.2 Application in OrcaFlex

OrcaFlex models this two stage slip. See the plot below.

When a point on the line initially starts to slide forward it moves along the slope, increasing friction as the seabed increasingly resists yield. The slope itself is defined by the seabed shear stiffness (Ks) and the contact area (A). The effective μ in this region is less than specified by the user so tension change along the line length is less.

Further displacements move the point off the slope, onto the constant μR part of the curve. There is no more seabed yield and full friction is applied. The effective μ in this region is as specified by the analyst.



1.3 When Friction Ramping is Significant

This ramping of μ has a significant effect on tension distribution when the seabed has low shear stiffness, the line has high axial stiffness and the line is experiencing a low load.

The low shear stiffness results in the slope extending over a long displacement range. The high axial stiffness means the line will only make small displacement changes due to the applied load.

With this combination it is possible for the line to remain within the ramping region under the applied load. The friction will therefore not reach the maximum value and tension reduction along the line length will be less.

This is of importance when identifying end termination loads where the line is slipping right up to the termination. The loads reported by OrcaFlex, and experienced in reality by the termination will be greater than indicated by a simple hand calculation based on Fr= μR.

The simple hand calculation assumes the line is laying on a surface that does not yield (infinite shear stiffness) so the full friction force is immediately available when displacement starts. In reality the seabed will yield to a degree and so the hand calculation overestimates friction, underestimating the load experienced by the end connection.

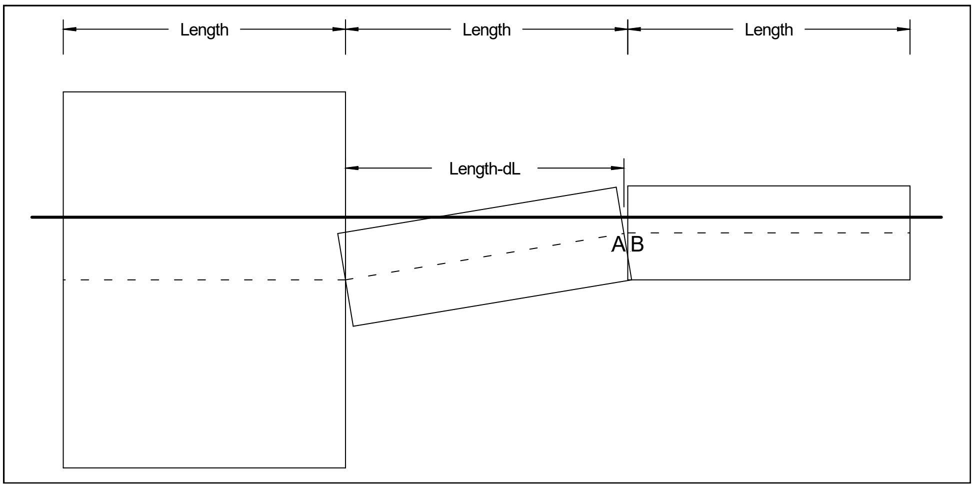
2 Defining Displacement

Displacement is defined as the distance from the “previous unsheared contact point”, the target position. This position assumes the line lies on the seabed and remains parallel to the seabed surface.

If the line diverges from parallel due to one node sinking or being pushed up then there will be a shift in node position from the target and this will be seen as a displacement. The result is a step change in the effective tension as the friction, shear stiffness and axial stiffness act to rectify this displacement. These step changes are generally small and not significant to the results.

In the figure below, the change in diameter and weight have resulted in the middle section rotating. The right hand node is at Position A, where as the target position is B. The difference is small but with a high axial stiffness this could result in a noticeable step change in effective tension.

Similar effects can be observed by fixing the anchored end of the line higher or lower than the “free laying” level of the adjacent line. The adjacent node would be at the “free laying” level so the segment must rotate to reach the specified end position.



We hope that the information in this article is useful, but do contact us if you have any comments or questions.

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