OrcaFlex Friction Effects

The seabed friction force has magnitude up to μR, and acts tangential to the seabed plane towards the 'previous unsheared point of contact' with the seabed. Here μ is the user-specified friction coefficient and R is the seabed normal reaction force.

To explain what is meant by 'previous unsheared point of contact', we must first explain how the friction force is ramped from zero to the full friction force of magnitude μR.

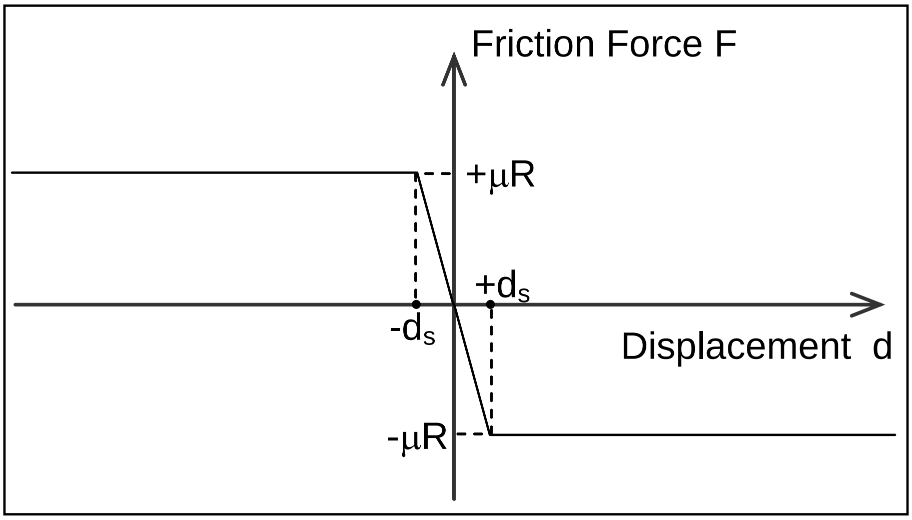
Consider a line lying in the XZ plane on a horizontal seabed, and measure values +ve in the +ve X-direction. If the node is pulled in the +ve X-direction then the friction force is up to F = -μR (-ve since friction opposes the direction of pull, and we are measuring forces as +ve in the +ve X-direction). If it is pulled in the -ve X-direction then the friction force is up to F = +μR. And if it is not pulled then the friction force is F=0.

In common with other programs, OrcaFlex does not apply the full friction force magnitude μR immediately any displacement of the node occurs. It 'ramps' the friction force from zero to magnitude μR over a small distance. This is done partly to enable the equations of equilibrium to be solved, since if the friction force was immediately stepped from zero to μR then this would give a discontinuity in the force on the node, making solving of the equations very hard. But this ramping of the friction force can also be thought of as a simplistic representation of real physical effect, namely the fact that a surface will shear slightly when an object is dragged across it.

OrcaFlex uses simple linear ramping of the friction force from zero to μR. The friction force F is given by

$F = - K_s.A.d$ up to a limit of being no more than μR in magnitude

where d is the displacement from the 'unsheared' position, K_s is the user-specified seabed shear stiffness, and A is the contact area of the object that is in contact with the seabed. For a node of a line, A is the user-specified contact diameter multiplied by the length of line represented by that node. The friction force is illustrated in the following graph:



The distance d_s over which the friction force is ramped from zero to μR is therefore given by $d_s = \mu R/(K_s.A)$. It is small if a high seabed shear stiffness is specified, but larger if a low stiffness is specified. If the object was lying on the seabed with no other forces applied then its 'free' seabed penetration would be $R/(K_n.A)$, where K_n is the user-specified seabed normal (i.e. penetration stiffness). So the shear distance d_s can be written as:

$$d_s = (\mu.K_n/K_s) \times \text{(free penetration distance)}$$

and if the seabed shear stiffness is set to '~', which means 'same as seabed penetration stiffness', then this simplifies to:

$$d_s = \mu \times \text{(free penetration distance)}$$

This shows that if the specified shear stiffness is of the same order as the penetration stiffness, then the shear distance, over which friction is ramped, is of the same order as the penetration distance, which of course is typically quite small.

Friction in Statics

As-laid Position

Friction can be included in the OrcaFlex static analysis for lines. When this is done OrcaFlex needs to know the previously position of the line, in order to know what direction friction should act. This is referred to as the 'as-laid' position and it can be given by the user specifying a lay azimuth and as-laid tension. See OrcaFlex help file for details.

Rate of Change of Tension

If the as-laid position is specified by giving the as-laid tension and azimuth, then friction in statics acts to try to maintain that as-laid tension. However if a line end is no longer in the as-laid position, then the line will typically be pulled away from the as-laid position to some extent.

Consider the simple case of a line lying on a horizontal seabed, with no current, and just one end lifted from the as-laid position. That end of the line will be pulled, increasing the tension at the touch-down point, so it is typically greater than the as-laid tension. The part of the line still in contact with the seabed will therefore be pulled in the same direction, and the friction forces on that in-contact part will try to resist this.

If the line has uniform properties, then the maximum friction force available on a unit length of line will be uniform and equal to μR. And so if the full friction force is active then the tension in the in-contact part of the line will vary linearly at rate μR per unit length, from its touchdown value to the as-laid tension.

Note, however, that this will only happen if the shear stiffness is very high. For lower shear stiffness values the increased tension towards the lifted end of the line will only pull the line a short distance. If this distance (which depends on the axial stiffness) is less than the shear distance d_s, then the friction force applied will be within the friction ramping zone and so the full friction force μR will not be applied, and so the tension will not change as fast. This effect means that the rate of change of tension, along the in-contact part of the line, will often be less than μR.

The active friction force per unit length, and so the rate of change of tension, can also turn out to vary along the line, due to variations in how far each node on the line has been pulled. So the tension variation along the line might not be linear. Increasing the shear stiffness reduces this effect, since ramping is over a smaller displacement range.

OrcaFlex Friction Effects

Effects of changes in line properties or penetration in the contact zone

Suppose the line properties change at a given point P within the in-contact part of the line. For example suppose the contact diameter increases after point P (say with no change in weight in water). Then the line penetration beyond P will be smaller and so the line centre will be higher. This lifting of the line will cause a very small increase in strain near that junction, which in turn increases the tension and pulls the line near P towards P. This is a very small effect, but if the axial stiffness of the line is high then the tension change it causes can sometimes be noticeable as a small rise in tension near P.

A similar thing can happen at a fixed or anchored line end. If the line end is fixed or anchored at a slightly different level to the free-lying level of the adjacent line, then the line is effectively being lifted up (or pushed down, depending on the relative level) by a small amount. This will again pull the line a small amount towards that end, causing a small rise in tension near that line end.

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

The Orcina Team
orcina@orcina.com