

Dynamic Loads on Ship's Lines

A recent issue of Professional Mariner reported the death of a deck hand who was knocked overboard when a line parted under strain. This tragedy invites a review of the basics of line loads and breaking strength. The main function of mooring lines is to hold a ship fast to her berth against the effects of wind and current or other forces. If the mooring lines are properly adjusted, wind or current loading on the lines is a static load. If you try to use a line to stop a moving ship that is a dynamic load. The difference between these two types of loads is significant and should be well appreciated by the mariner.

Here's a simple illustration. If you tie a line to an object and lift it off the ground the load on the line is equal to the weight of the object. If you drop the same object from some height and try to keep it from hitting the ground by holding onto the line, that is a dynamic load and it will be much greater than the weight of the object. Dynamic loads can be calculated using Newton's Second Law of motion as expressed in the formula $f = ma$ (force equals mass times acceleration). Deceleration is the reverse of acceleration and Newton's Law could just as easily be expressed as $f = md$. That is, the force required to decelerate moving object = the mass of the object multiplied by the rate of deceleration.

The rate of deceleration depends on the initial speed and distance traveled while coming to a stop. The more abrupt the stop (shorter distance, less time) the greater the rate of deceleration and the greater the dynamic force. This is why shock absorption mechanisms such as airbags in cars, crumple barriers on highways, landing cushions for pole vaulters, etc. are designed to lengthen the stopping distance and reduce the dynamic force on the person or thing being brought to a halt.

In the case of using a mooring line to stop a ship approaching a berth the velocities are relatively small but the masses are very large. Consider a ship approaching a berth at one knot. If we put a line over to a bollard on the pier and then make it fast to a cleat on deck, as soon as the line starts to become taut the rate of deceleration will depend on how much the line stretches before we stop. A low stretch line such as Spectra or Kevlar will result in a much greater rate of deceleration (quicker stop) than a more elastic line such as Nylon. Skillful "checking" of the line – letting it take a strain and then easing it out – will reduce the rate of deceleration.

Here's some numbers. If we put over 100 feet of line and hold it, a typical nylon line will stretch 20%, to about 120 feet, before reaching it's safe working load at which point we hope the ship is stopped – beyond that we risk damaging or parting the line. A high strength/low stretch line such as Spectra or Kevlar may stretch only 2% or about 102 feet. If the ship is moving 1 knot, the dynamic load on the nylon line as it stretches to 120 feet would be about 5 lbs per ton of vessel displacement¹ while the dynamic load on the Spectra line as it stretches to 102 feet (a ten times faster rate of deceleration) would be about 50 lbs per ton. These seem like small numbers

¹ A general formula to approximate the dynamic load on a line (in pounds of force) is

$$Load = \frac{T * 100 * V^2}{d}$$

where T is tons displacement of the ship, V is the initial velocity in knots and d is the distance traveled in feet while stopping.

until you realize that if you're dealing with a 10,000 Ton ship, you're loading the nylon line to 50,000 pounds and the Spectra line to 500,000 lbs. The minimum breaking strength of a typical 1.75 inch diameter nylon line is going to be about 100,000 lbs while that for the same size Spectra line will be about 225,000 lbs. In this example, the nylon line, because of its elasticity is going to have a better chance of stopping the ship, than the Spectra line which will probably fail (or rip out the cleat). Of course, one great advantage of the low stretch lines is that they don't snap back when they part.

Bottom line – The function of mooring lines is to hold a stopped ship in place. Using mooring lines to bring a moving ship to a stop is inherently unsafe. The greater the mass of the ship, the faster the ship is going and the shorter the stopping distance, the more unsafe this maneuver becomes. Lines can be effective in removing very small amounts of “way” but it is vital that the lines be “checked” (i.e. slipped a little at a time) to increase the stopping distance and slow the rate of deceleration. This is especially important when using low stretch lines.