Mooring Line Barriers – Better Understanding the Risks We're Mitigating

Nicholas A. Deussen[1]
[1] Wallbridge Gilbert Aztec, Perth, Western Australia; ndeussen@wga.com.au

Summary
WGA has recently undertaken several projects aimed at reducing risks associated with snapped mooring lines for a ship at berth. During that work, it's been a common theme that the publicly available literature available for assessing and reducing these risks is limited. Further, the unique nature of an event means there is little appropriate guidance to be found through traditional structural, maritime or mechanical design approaches. The most recent approaches by WGA seek to analyse these events in a way where we can start to quantitively assess these risks and their likelihoods.
Keywords: Mooring Lines, Port Safety, Risk Management, Structural Engineering, Mechanical Engineering

1. Introduction

Mooring lines are used to secure a ship against a wharf. When tension is applied to a mooring line, the line stores potential energy through the elastic elongation of this line. Each line has a given breaking load which is determined by the manufacturer and expressed as a Minimum Breaking Load (MBL). As a line is used its capacity diminishes, whether due to exposure to UV, wear and chafe, or other methods. The actual capacity of a line is expressed as a percentage of the MBL. Changes in tension in a line after securing due to vessel movements can increase the tension in the line, which may exceed the capacity of that line. Alternatively, local wear or chafe of the line as it passes through a fairlead, chock, or around a bollard can reduce the capacity of a line such that the pre-existing tension in the line will cause failure.

That failure of a mooring line results in the stored energy within the line being converted into a kinetic energy, often with a tremendous amount of energy concentrated in the tip of the line. This tip can strike personnel working on the wharf, with a study finding that one in every seven snapped mooring line events will result in a fatality [1].

Following the traditional hierarchy of controls, it is an accepted practice to simply eliminate the hazard by removing personnel from the line of fire during mooring operations. However, this approach limits access to the berth for inspection and maintenance purposes, and also does not account for operations during mooring procedures. Alternatively, safe shelters or barriers can be constructed on the berth that provide a safe working area for personnel in a discrete location. However, the design of these structures varies, and without industry guidance, may be under designed and provide a false sense of safety that can actually increase the consequences of a snapped mooring line incident.

2. Alignment With NCC and Reliability Standards

WGA's most recent work has sought to consider a snapped mooring line event with reference to the probabilistic methods presented within the National Construction Code (NCC) Structural Reliability Handbook and ISO2394: General Principles on Reliability for Structures. This approach is consistent with the limit state design principles adopted by most Australian Standards used in the design of ports assets within this country.

Specifically, the approach has taken development of separate action and resistance models with which to determine the design actions to be applied to any barrier structures used to protect personnel working on the wharf. The results of the action model are also quantified as a probabilistic distribution for the establishment of a risk-based approach to assess and manage potential design events that may occur over the life of the structure(s), against known structure resistance criteria.

The accompanying paper presented by Jordan Butler of WGA describes the development of the action model and shows the wide range of uncertainty in quantifying the design actions to arrive at a singular 'design event'. The variance in geometry, line type, condition and other variables finds that the final energy for a given design action can be almost meaningless unless the designer has a sound understanding of the likelihood of that design event. That paper shows that the traditional approach for designing a mooring line barrier using limit state structural design - even if a design force is translated to an equivalent kinetic energy - is flawed.

3. Framework for Quantitative Risk Assessment

As an outcome of this work, the assessment undertaken using a risk based framework can move from an entirely qualitative assessment closer to a quantitively understanding of the risks. This allows a port operator to begin to develop a more targeted body of work to measure and then mitigate their risk exposure. This framework is undertaken by asking a series of questions:

3.1. Does a Broken Mooring Line Event Happen?

In its simplest form, broken mooring lines are an understood event that happens in a port environment. The contributing factors to this may relate to:

- An increase load in the line as a result of vessel movement at berth, whether from wind, wave, tidal movements, passing vessels or other effects.
- A reduced capacity of the line due to age, wear, chafing or other effect.
- Use of load monitoring or load reducing devices such as load pins, Shoretension™ devices or vessel monitoring systems.

The likelihood of these events depends greatly on the environmental factors and are often port or even berth specific. Many ports subject to long period waves or seiching events have a greater frequency of broken line events as vessel movements cause significant increases in line tensions.

3.2. How Much Energy is in that Mooring Line?

Much of the work included in the accompanying paper by Jordan Butler of WGA has concentrated on a determination of the energy associated with a broken mooring line.

By far the biggest contributors to this value are the overall length of the line, and the tension in the line expressed as a percentage of the minimum breaking load. A longer line can store more energy, and a line under more tension has more potential energy. These variables can be somewhat rationalised through an understanding of the berth geometry and historical data obtained from similar berths of broken line events where load monitoring devices are used.

3.3 Does a line strike a work area, and is there a barrier?

The assessment of where a line strikes will depend on the arrangement of the berth, the locations of personnel and the introduction of any barriers to protect them. These factors are overlayed over the possible path of a mooring line, which varies greatly depending on the location and nature of the break. Traditional approaches consider either cones or arcs over which a broken line may travel, but a closer understanding of the dynamics of the rope will help provide guidance as to the likelihood of any given path.

3.4 What is the residual energy in a line at the time it reaches a barrier?

It is one thing to consider the peak velocity, but the transient nature of the rope as it approaches and then passes its terminal velocity are relevant for any assessment. The large energies result in high acceleration, but the low mass and high velocities mean that the peak velocity is reached only instantaneously. This variance occurs both temporarily and spatially, and mean that the resultant energy for assessment of a strike varies depending on the location on a berth.

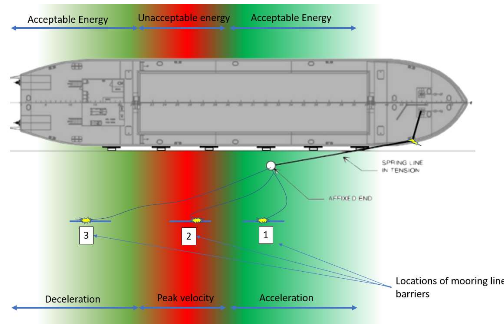

Figure 1: Indicative diagram of the velocity of a snapped mooring line plotted spatially. Note this is indicative only and does not represent a true plot

3.5 Is the mooring line barrier effective at stopping a broken mooring line?

The assessment of this question is dependent on the outcomes of the questions above, particularly Questions 2 and 4, and the work described in the accompanying paper. For many of the mooring barriers designed using static loads approximating the resultant force from a strike, neither the input kinetic energies nor the dynamic capacities of the barriers are well enough understood to answer this question.

Summary and Conclusion

The work in this field is ongoing, and these questions must be raised and answered for any facility on its own merits. What is known is that to take conservative approaches to the answers of each of these questions will often yield an answer that is unacceptable in most risk assessment tables used within industry. This finding is backed up by industry experiences, where major incidents and fatalities are a known and sobering occurrence.

These questions form the framework for future work to be undertaken to implement more targeted controls for reducing these risks, whether through work practices and procedures, active engineering management, continuous monitoring or the implementation of appropriately designed engineered barriers.

References

[1] AMSA, Shaping Shipping for People – Thinking – mooring safety, 2015.