Validating Snapback Risk

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Abstract
An overview of the work undertaken by Holmes Solutions, an engineering design and testing facility, to understand the nature of, and risk posed by, mooring line failure (snapback) events, with the goal of developing validated protection systems; specifically line arresting structures. The paper focuses on the collaboration with BHP Mitsubishi Alliance (BMA) at Hay Point Coal Terminal, Queensland and looks at the full-scale testing undertaken in partnership with Geobrugg AG, as well as some of the results of those tests and conclusions for ports looking to address this issue.

Keywords: Snapback, mooring lines, life safety, ports, arresting structures

1. Introduction

Mooring line failure, also known as mooring snapback, accounts for over 50% of all recorded mooring incidents and constitutes some of the most serious injuries. One in seven reported incidents result in a fatality and over one in five in often serious, life-changing injury (UK P&I Club, 2009) (Australian Maritime Safety Authority, 2015). Protecting workers from a snapback event remains a challenge, given the unpredictable and poorly understood nature of these events. Research shows that snapback events are caused by a variety of factors, rather than a single event (Australian Maritime Safety Authority, 2015). This makes them difficult to control for and to prevent. Eliminating the risk completely can only be done by removing lines altogether, which in many circumstances is neither practical nor possible. For scheduled maintenance, this can lead to long periods of offline, greatly affecting production efficiency.

Mooring line snapback is one of many maritime safety areas identified, where incidents tend to be under reported. This means that control measures may not be adequately identified and implemented across the industry. There are currently no mandatory standards for protection structures, indicating that existing structures may not provide the level of protection expected. The control measures implemented are mostly focused on procedural controls such as PPE, line management plans and snapback zones (Australian Maritime Safety Authority, 2015).

The likelihood of future mooring incidents may also be adversely affected by climate change. Severe weather events (high winds, storm surges etc.) are one of the risk factors identified in snapback events and are predicted to become more frequent with the effects of global heating (IPCC, 2022). The increased size of ships is another area of concern. Over the past decade, container ship sizes have grown from an average of under 3,000 TEU to around 4,500 TEU (Baraniuk, 2022), with the largest now reaching over 24,000 TEU. In the Australasian region, only Port of Tauranga is currently able to moor vessels over 10,000 TEU (Kemp, Chen, Morrison, & Lo, 2019). Many Australasian ports are currently not designed to safely moor the larger vessels, increasing the risk factors for mooring line failure.

2. Project Background

BMA Hay Point Coal Terminal management were proactive in implementing a range of control measures such as hook tension monitoring, reducing rub zones, mooring analysis, snapback zones and line management protocols across their port. However, in 2020 a high-speed line failure was captured on camera crossing a usually busy work zone and vehicle right of way. This highlighted the need for more than just procedural controls.

Figure 1 Showing impact zone of parted line crossing the walkway at speeds of up to 1000km/hr.

BMA developed a temporary barrier which they installed onsite to protect workers whilst they were developing a permanent solution. They initially approached Holmes Solutions to validate their proposed solution, due to Holmes' experience of designing and testing of structures built to absorb large dynamic energies. Holmes reviewed the proposal, which raised a number of potential issues with the proposed inputs to the design and consequently it's suitability. This led to a collaboration with Geobrugg AG for their high-tensile mesh expertise and consultation with Wilhelmsen for their line testing knowledge, to conduct an extensive redesign, testing and validation process. Holmes then conducted a series of tests and underwent an iterative, evidence-based design process which resulted in the validated solution, now installed as the permanent solution at Hay Point.

The full-scale testing was first-of-its-kind and the results demonstrated that the effectiveness of many existing protection solutions and controls used on ports need to be reconsidered.

3. Customer Requirements

BMA were looking for a free standing and fixed foundation barrier, able to safely arrest and contain a snapback at 60% MBL (minimum breaking load) for an 85t mooring line. The expected performance criteria (PC) for the validated fence is highlighted in Table 1 below:

Table 1 Performance criteria for protection barrier validation testing

PC1	No part of the fence system shall be found more than 1.5m behind the original location of the fence system.
PC2	Fence System captured the rope within 1.5m of initial impact.
PC3	The resulting maximum dynamic deflection of any part of the fence system, measured as the distance between the fence section's foremost point before and rearmost point under impact, must not exceed 1.5m.

4. Testing Process

Testing played a critical role here, allowing Holmes to assess designs through a limit-based program. This is where we tested the upper and lower limits of the design to gauge performance.

Holmes replicated the spring line failure that occurred at BMA, utilizing the purpose-built full-scale snapback test platform on the ground at our testing facility in Christchurch, NZ. The test facility consists of purpose-built infrastructure used for high energy, dynamic impact testing of various test article types. The site infrastructure includes a customised 30m drop tower, asphalt runways, reaction anchors and a range of bespoke testing set ups used for impact testing. The site provides a safe location for this type of testing that is isolated from public and neighbouring properties. This enabled the team to test a variety of ropes and protection structures in a variety of configurations.

Standard engineering practices perform poorly for this type of testing, so we relied on research, hypothesis, testing and data to inform design and enhance solutions. For this initial project, 25 full-scale tests were carried out. Tests were carried out both with and without barriers to improve understanding of line behaviour.

4.1 Test Configuration

Two mooring arrangements were used throughout this program, a direct inline configuration and a redirected (sweeping) configuration. These reflect the commonly published snapback zones (Figure 2).

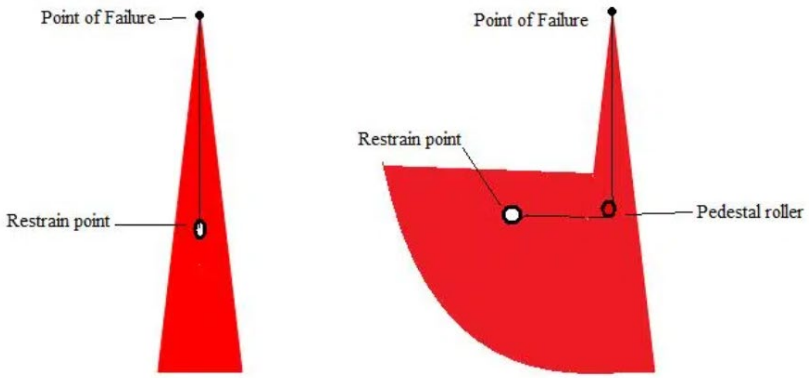

Figure 2 Typical published snapback zones

The direct, inline testing involved parting the rope in a straight line back to a point of restraint, whereas redirected tests had the rope running around a bollard. The bollard configuration was selected to represent typical fairleads used on the sides of ships (Figure 3).

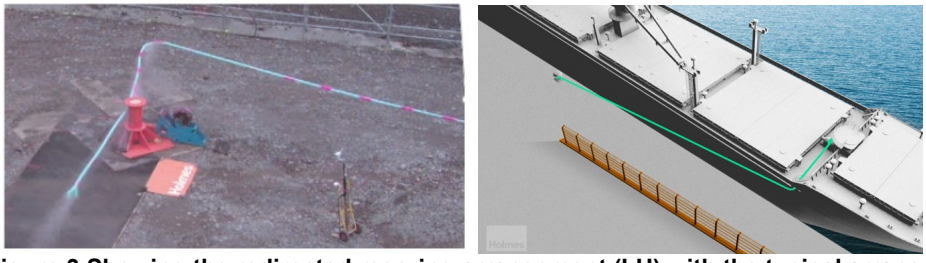

Figure 3 Showing the redirected mooring arrangement (LH) with the typical arrangement at berth (RH)

Testing replicated the “worst case scenarios” most likely to be encountered at the port, where lines may be directed around bollards and close to heavy foot traffic areas. One angle of redirection was used in the testing program, that being of 90 degrees. This represents a typical spring line mooring arrangement. Testing was conducted at various heights to represent the likely critical points of impact on the barrier, resulting from lines failing at different points and whilst under different mooring configurations, including varying angles. The effect of different angles on snapback severity will also be considered in future studies.

4.2 Test Specimens

A selection of commonly used commercial mooring lines and advanced mooring line technologies was tested in this program. The line size and rating were determined to what is commonly used when mooring vessels at BMA’s berthing locations. All lines tested were brand new and previously unused.

4.3 Testing Apparatus

The snapback testing apparatus consists of powered, moving, and static elements used to tension, and subsequently part, a mooring line in a controlled and repeatable manner. The powered elements are used to extend, tension, and sever the line, while the static elements provide restraint and redirection of the mooring line. The basic configuration is representative of the conventional use of mooring lines; one end is statically restrained while the other end is connected to a movable object that subjects the line to deflection and loading. The severing of the line is targeted through deliberate intervention with a custom-fabricated guillotine. The overall test set up occupied a relatively flat, rectangular area of approximately 140m by 50m. Data is recorded using multiple load cells and high-speed cameras. Post test analysis is then undertaken using video software analysis to describe the snapback event fully.

5. Results from Testing

5.1 Rope Behaviour

5.1.1 D/d Ratio

Testing found that actual line efficiency is typically much less than industry expectations. Some lines tested broke well below their stated MBL (minimum breaking load), resulting in unpredictable outcomes. We now know that line efficiency is highly variable due to factors such as the line diameter ratio (D/d ratio) and line wear and tear (see Fig. 4 and Fig. 5 below). Additionally, when lines are tensioned above 50% of their MBL, invisible damage occurs to lines adding to the unpredictability.

With the D/d ratio, the lower the ratio, the greater the reduction in MBL. The diameter of the fairlead significantly influences (reduces) the actual line efficiency and failure load of the mooring line. Further, where tensions are monitored within a redirected mooring configuration, actual values may vary upwards of 10% when comparing failure points to the points where data is being collected.

Figure 4 D/d schematic for lines around bollards

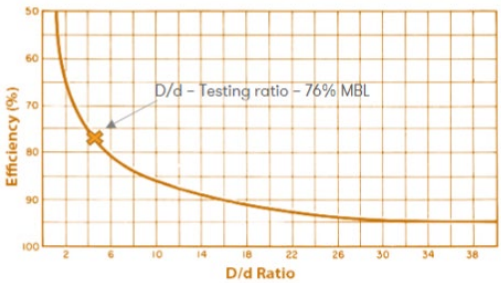

Figure 5 D/d efficiency of % MBL graph.

The unpredictability of the outcomes highlighted that some recommended control measures may not accurately reflect reality. For example, the line rupture location can dramatically change the snapback zone. Therefore, a marked snapback zone may not include all the risk areas, exposing personnel to risk.

5.1.2 Rope speeds

Testing also found that the speeds reached by the parted lines were much higher than previously thought, particularly for redirected ropes.

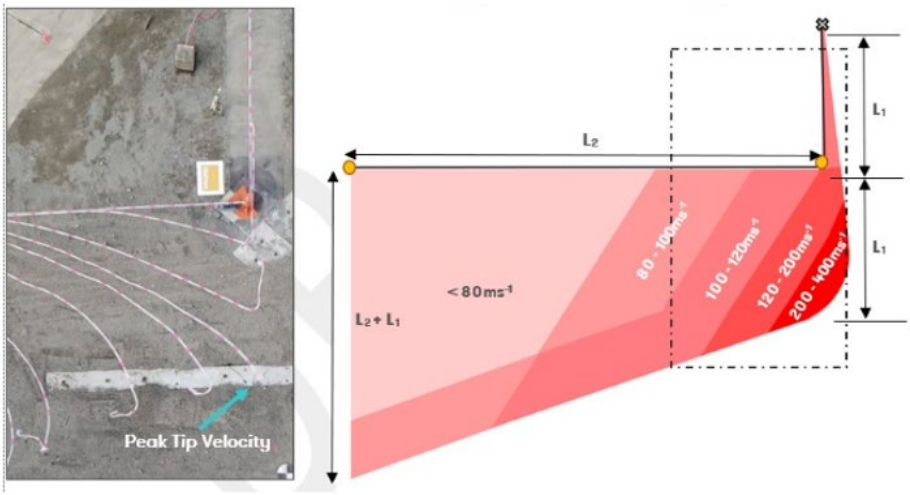

Figure 6 Redirection snapback zone example showing tip velocity observed of 85t line parted at 60% MBL.

The peak tip velocity (Figure 6) reached speeds upwards of 1000 kph. Even for line breaks at lower tension, we recorded speeds of 200-300 kph. Testing recorded velocities of 296 m/s or 1065 kph. Where impacts with a structure occurred (lasting 15-20 milliseconds), 220-300kJ of energy were released, depending on the length of the ruptured end of line impacting the structure (up to 5-10 metres). By comparison, a 10,000kg truck going 90km/hr impacting a road safety barrier at 15 degrees, has an impact energy of 210 kJ.

5.1.3 Deflection

Obstacles may exist in a true mooring snapback scenario that affect the motion of line travel during such an event. During tests, it was observed that lines connecting with ramped surfaces caused the line to be deflected upwards, away from the bollard, extending the snapback zone (Figure 7).

Figure 7 Contact with a ramped bollard surface deflects the line of travel upwards.

5.2 Summary

From testing, it was observed that snapback zones can be much larger than suggested due to the possibility of deflection in a sweep snapback event. They do not just occur on a 2D plane and ramps or other structures within the snapback zone can significantly alter the anticipated path of travel of the line. The point of rupture may also occur anywhere along the length of line and can also alter the snapback zone. The speeds reached by the parted lines are also far higher than previously understood. Fig. 8 below illustrates previously published snapback zones (LH image) alongside the observed snapback zone (RH image) for the given parting point, as a function of L1 and L2 and the redirected angle.

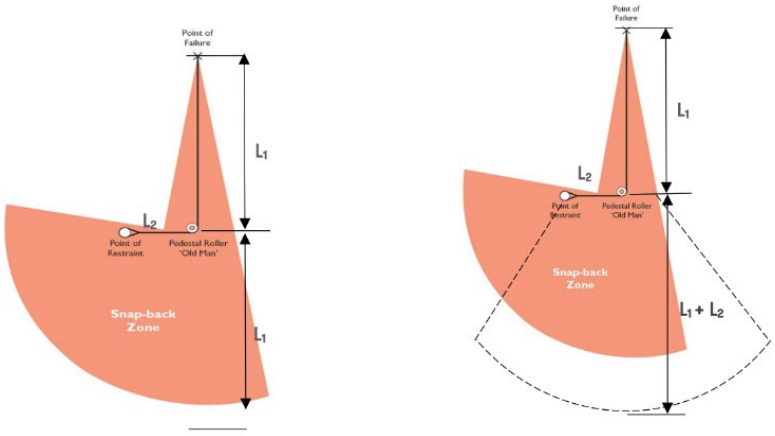

Figure 8 LH image showing previously suggested snapback zoning and, RH, showing observed deflected snapback zoning during testing.

Further testing of different line types and configurations is recommended to enable a more complete understanding of line behaviour and snapback zones.

5.3 Barrier Tests

Geobrugg are a developer and manufacturer of safety protection meshes for large dynamic events such as rockfall or debris from motorsport crashes. Our initial barrier test used an arrangement of Geobrugg's proprietary high tensile mesh system. This system has been designed and tested to capture debris, parts or even whole vehicles of up to 1000kg approaching at 20 degrees and travelling 120 km/hr, as well as large debris of 780kg at 90 degrees travelling up to 60km/hr. This test was of a sweeping impact with the line parted at 50 tonnes. The resulting snapback had the tip impacting the fence at velocity of about 700 km/hr. As shown below in Figure 9, this initial mesh fence was unable to contain the rope.

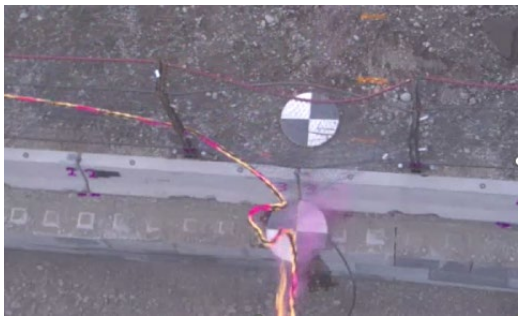

Figure 9 The parted line easily penetrates the Geobrugg high tensile mesh

For the final test (Figure 10) we undertook a sweeping impact test on BMA's existing, temporary structure. The fence was designed according to best engineering theory available at the time.

Figure 10 Showing testing of existing temporary protection structure. A clear fail.

The testing was designed to assess performance across the structure, with the line impacting at different points and speeds (Figure 11)

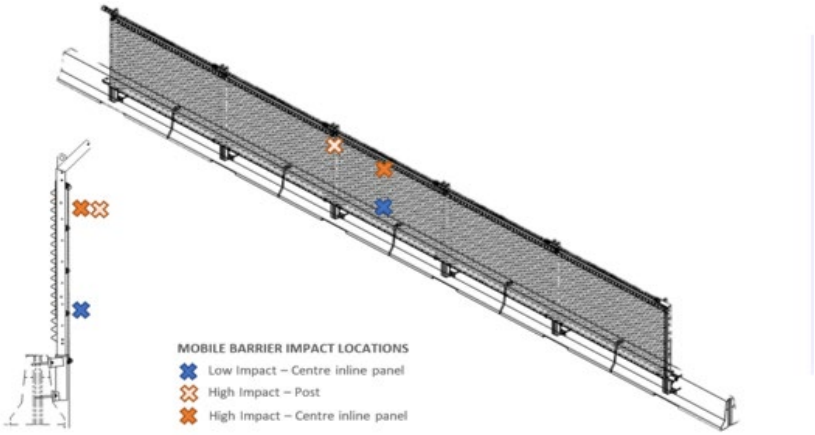

Figure 11 Impact tests were carried out to validate snapback effects on different points on the barriers and at different speeds.

The tests clearly illustrated that existing theory did not work in practice, however our increased understanding of rope behaviour through the testing, enabled an iterative, data-based design process, eventually resulting in a successful design.

6. Custom Solution

Using a science based and data driven approach, Holmes and Geobrugg were able to design, test and validate a custom protection solution; tailored to meet the specific BMA requirements for this site (Figure 12). The successful final solution is now installed at Hay Point Coal Terminal.

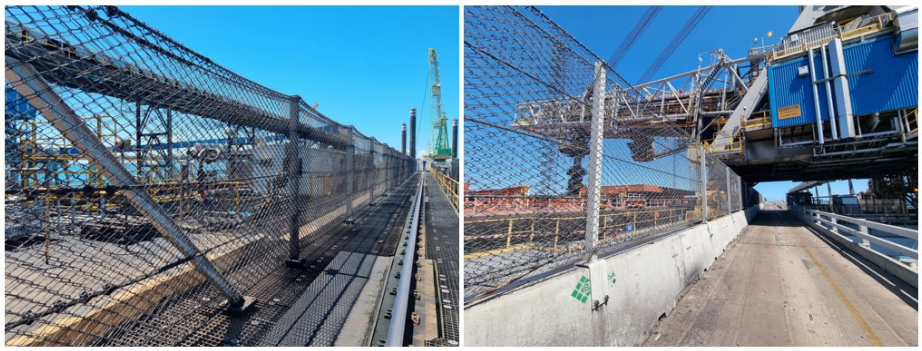

Figure 12 Custom Solution for BMA in place at Hay Point Coal Terminal

7. Future testing and product development

Further testing now is being carried out by Holmes and Geobrugg to explore different barrier configurations and to deepen understanding of the behaviour of the parted lines in a variety of contexts. The goal is to develop a suite of protection structures (permanent, temporary, mobile and modular) that can cover most critical areas across most ports.

8. Conclusion

Every port is different. Developing an effective protection structure requires a close understanding of the conditions faced on the ground. Due to limited understanding of their behaviour, the speed and trajectory of a parted line in any given situation can be difficult to predict. However, we can assume the worst case and plan for that. More varied testing will enable a more effective, nuanced response. The current responses from industry are mainly focused on procedural controls such as PPE and admin, which may not effectively address the root causes or mitigate the outcomes of a line parting event. Protection barriers, when used, are currently not required to be tested or validated, which also means that they cannot be guaranteed to safely arrest a snapback event.

OCIMF guidelines recommend that mooring lines are identified as “critical equipment or systems” (OCIMF, 2018). The first step for ports and shipowners is to acknowledge the risk of snapback. Secondly, a mix of controls may be needed to meaningfully reduce risk. Some control measures, such as identified snapback zones, may not be adequate. Finally, as it is not always possible to eliminate the risk altogether, and lengthy shutdowns can severely impact production efficiency, protection structures are an important factor in the mix. These should be validated, ideally through full-scale testing, and need to be tailored to fit the conditions at your port.

9. Acknowledgements

Holmes would like to acknowledge the team at BMA Hay Point as well as Wilhelmsen’s Timm Ropes and Geobrugg AG for their input and collaboration on this project.

10. References

Australian Maritime Safety Authority. (2015). Maritime Safety Awareness Bulletin Issue 2, Shaping shipping for People, Thinking- Mooring Safety . Canberra: Australian Government.

Baraniuk, C. (2022). Why container ships probably won't get bigger. London: BBC. Retrieved from https://www.bbc.com/future/article/20220629-why-container-ships-probably-wont-get-bigger?zephr-modal-register

IPCC. (2022). Summary for Policymakers In: Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, UK and New York, USA.: Cambridge University Press.

Kemp, A., Chen, T., Morrison, S., & Lo, C. (2019). Containerised trade trends and implications for Australian Ports, A report for Port of Newcastle. Sydney: HoustonKemp.

OCIMF. (2018). Mooring Equipment Guidelines, Fourth edition. London: OCIMF.

UK P&I Club. (2009). Understanding Mooring Incidents. London: Thomas Miller.

11. Other Sources

Dent, J.M, (2020) “Hay Point Coal Terminal Mooring Line Snap-back Risk Assessment,” Sydney: Baird.

Smith, A.S, (2021) BHP Mitsubishi Alliance Snapback Barrier System- Validation Testing Mobile and Fixed Barrier Fences. Christchurch: Holmes Solutions.