WGA

BREAKING POINT: UNDERSTANDING THE DYNAMICS OF PARTED MOORING LINES AND PROTECTION BARRIERS

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PARTED MOORING LINES – AN INTRODUCTION

What is a parted mooring line?

A mooring line is a tensioned line used to secure moored vessels, typically to a wharf or dolphin.

Occasionally, mooring lines will break, either due to errant behaviour of the vessel or due to poor maintenance and inspection regimes.

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PARTED MOORING LINES – AN INTRODUCTION

These events can be catastrophic and are often

lethal

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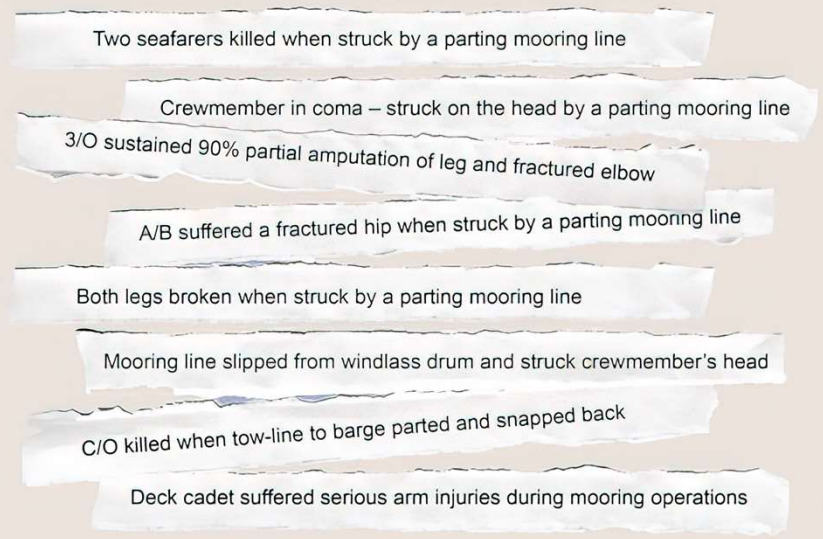
PARTED MOORING LINES – AN INTRODUCTION

The Numbers

- The number of events at Australian Ports vary, from as little as less than one event per year, through to as frequently as once a fortnight.
- It is estimated that 1 in 7 events that interact with personnel results in a fatality (UK P&I Club, 2009).
- Australian Port safety is much better than the rest of the world, but it is still estimated that a fatality occurs every 5 years due to parted lines (AMSA, 2015).



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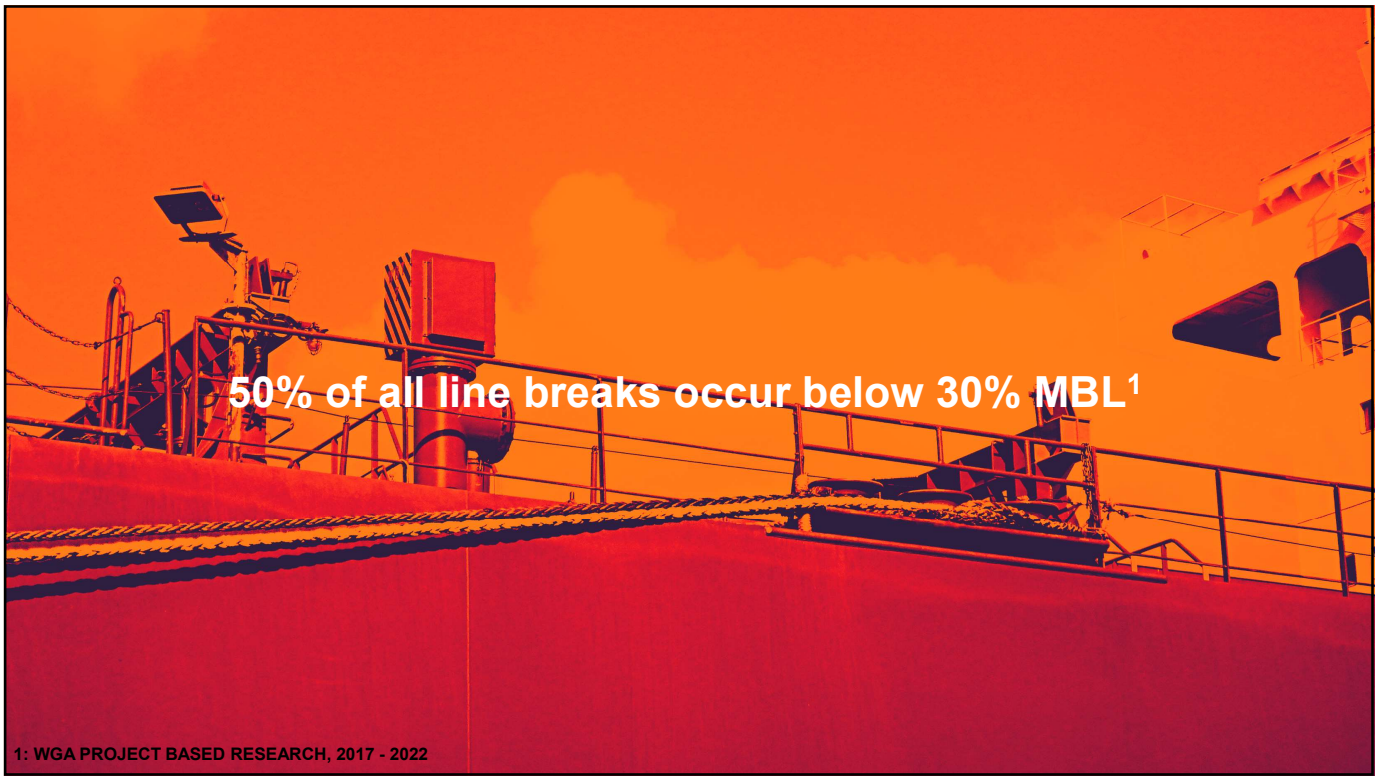

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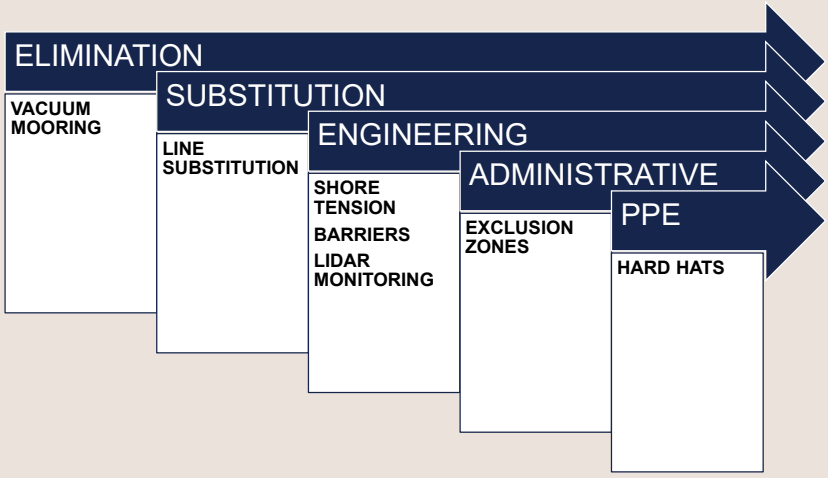
CURRENT STATE OF THE ART

What is being done to keep people safe?



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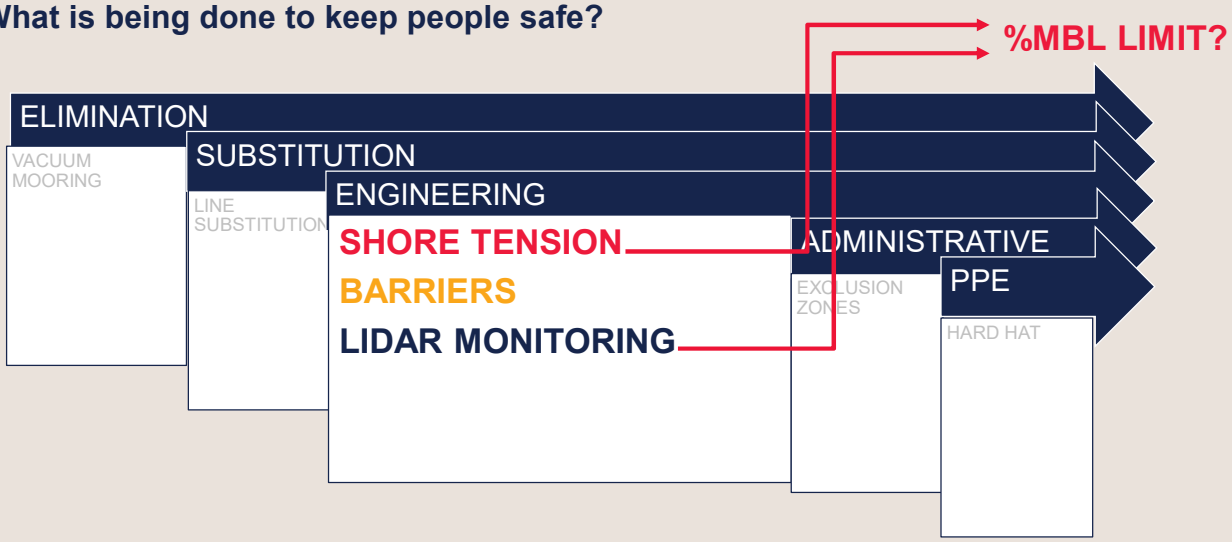

CURRENT BARRIER DESIGN PHILOSOPHIES
What are we designing for?

Current Design Philosophies:

1. **Point loading (i.e. 50 kN)**
2. **Energy absorption (i.e. Linear elastic force-deflection methods)**
3. **Nuclear bomb proof***
4. **Protect defined "snapback cone regions"**

***Maybe**

CURRENT BARRIER DESIGN PHILOSOPHIES
What are we designing for?

Questions Arising:

1. **How much energy is in a parted line?**
2. **What is the path of a parted line?**
3. **How much force is produced at the point of impact?**
4. **Do force-deflection methods adequately describe the dynamics?**

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SPLITTING THE PROBLEM

Let's define things in terms of Action and Resistance

ACTION MODEL

- **Describes the kinematics of a line in motion**
- **Computes the energy, velocity, and momentum within a line**

RESISTANCE MODEL

- **Describes the dynamics of a structure when struck**
- **Computes the local effects of momentum transfer, modal behaviour, and forces**

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ACTION MODEL

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ACTION MODEL
CURRENT STATE OF THE ART

CURRENT INDUSTRY APPROACH:

1. Calculate the stored energy within the line	Lines do not behave as linear springs
2. Assume a lossless conversion from potential energy to kinetic energy	Losses during parting can be significant
3. Calculate the system velocity through the mass of the line	Tip velocities vastly exceed system velocity
4. Assign an impact length of line	Length along the line is just as important as length itself
5. Calculate the energy in this length of line based on the system velocity	Incorrect assumptions lead to an incorrect outcome

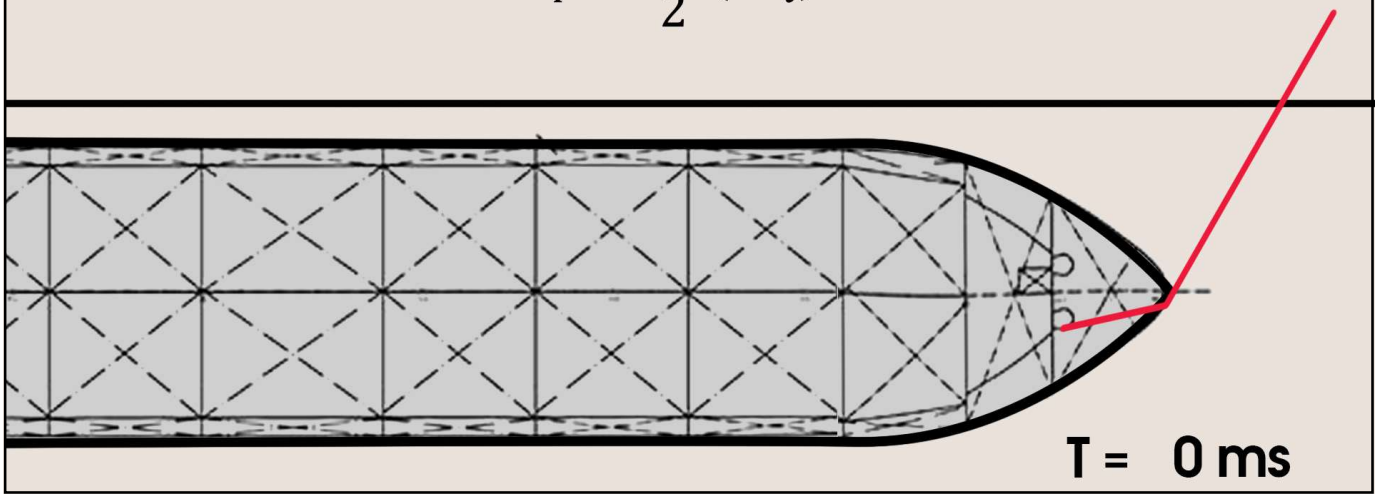
THE WGA METHODOLOGY
ACTION MODEL

HOW FAST IS DOES A PARTED MOORING LINE MOVE?

1. They just drop harmlessly into the ocean (<5 m/s) ?
2. As fast as a vehicle on a freeway (28 m/s) ?
3. As fast as cyclonic wind (80 m/s) ?
4. Faster than the speed of sound (>340 m/s) ?

line is in tension and in static equilibrium.

$$E_P = \frac{k_s}{2}(\varepsilon L_i)^2$$



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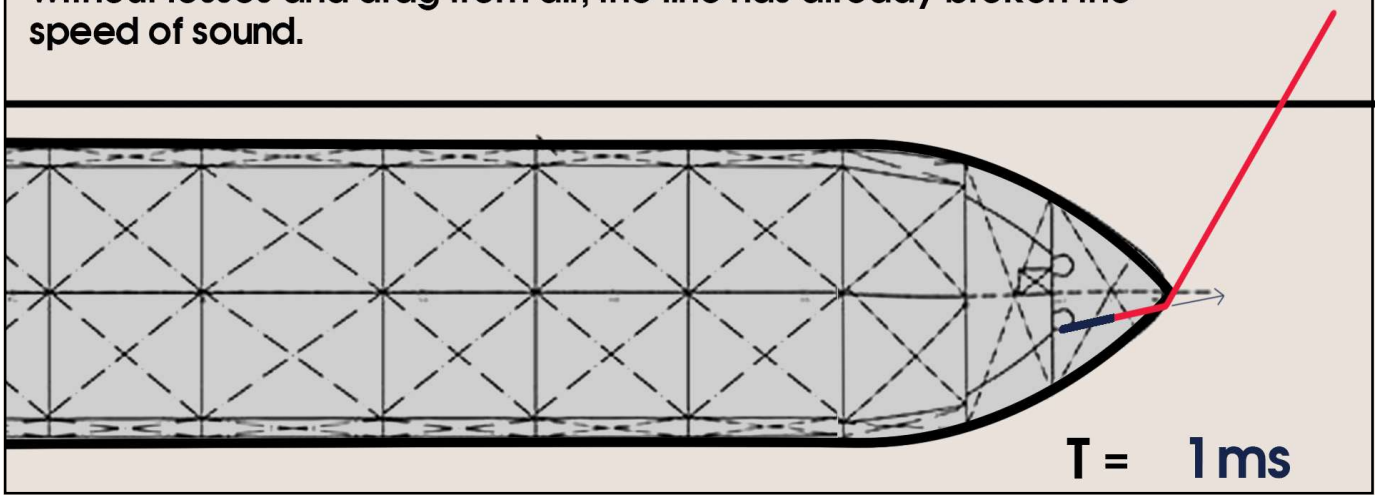
Line parts - free end is no longer in equilibrium.

Approximately 2.5 m of line is being accelerated by the breaking load of the line, translating to roughly 45,000 g's.

Without losses and drag from air, the line has already broken the speed of sound.



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Locally the difference in acceleration causes a compression in the line, which in turn creates a sinusoidal buckling.

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ACTION MODEL
KINEMATICS

1. **After 20 – 40 ms (depending on line length and material) the entire line is in motion**
2. **Due to a linear decrease in acceleration over time and a linear increase in mass in motion, the tip velocity is significantly greater than the rest of the line**
3. **After some time (depending on geometry) the tip pulls the line back into tension, generating a transfer of momentum**

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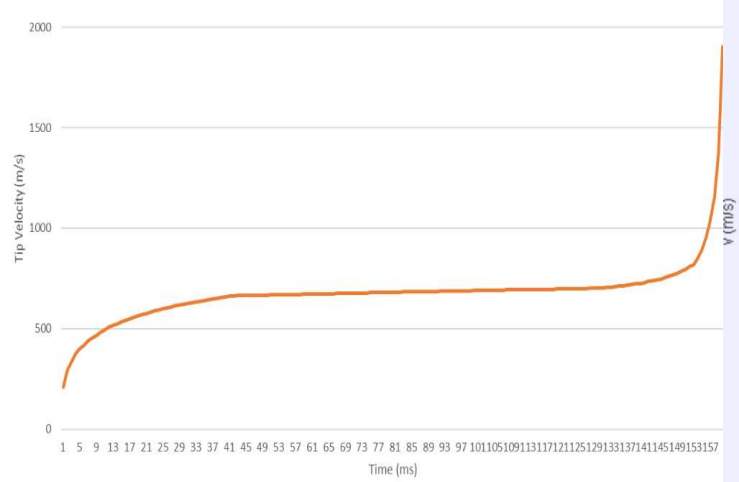
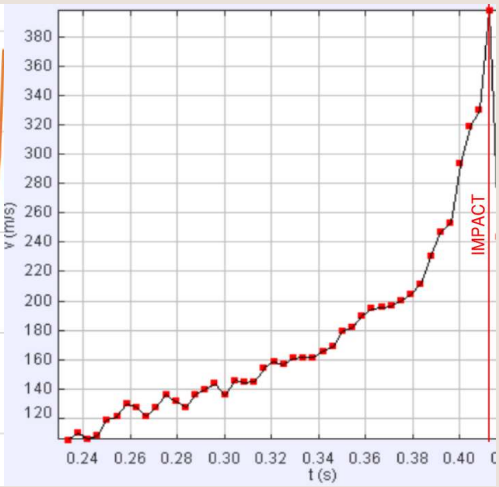
ACTION MODEL
WGA THEORETICAL MODEL



HOLMES PHYSICAL TESTING



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ACTION MODEL
KINEMATICS

The WGA Action Model predicts a secondary acceleration due to momentum transfer that is also observed in the physical testing.

The consequences of these accelerations produce large concentrations of energy at the tip of the parted line.

Percentage increments of the line from the free tip	%E_k
1	13.81%
2	9.00%
3	6.98%
4	5.77%
5	4.95%
6	4.33%
7	3.85%
8	3.46%
9	3.13%
10	2.86%

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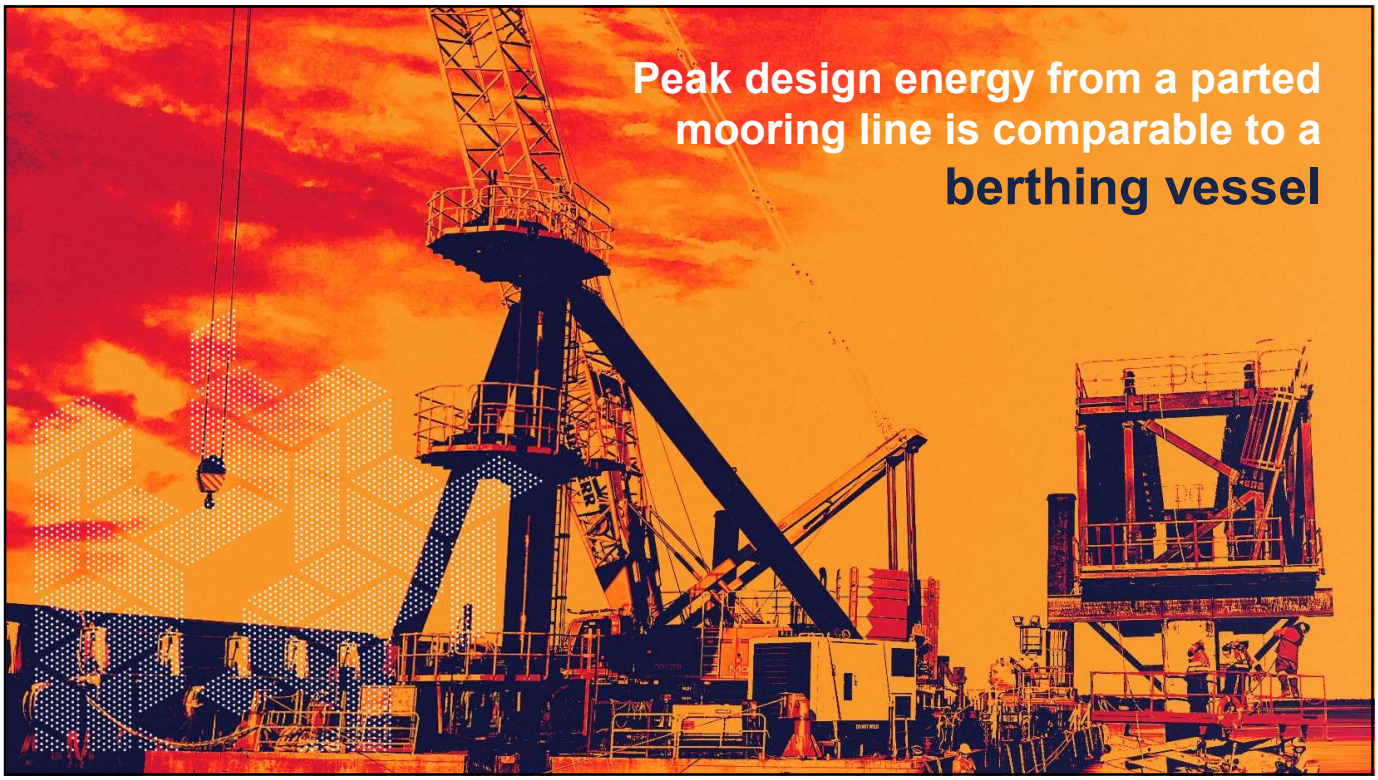

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FOR CONTEXT

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RESISTANCE MODEL
CURRENT STATE OF THE ART

1. **Protect snapback zones** — **Path is unknown/assumes linear behaviour**
2. **Absorb energy through force deflection** — **Load is transient/deflections do not occur**
3. **Make structures robust** — **Decreases time domain/might be worse!**

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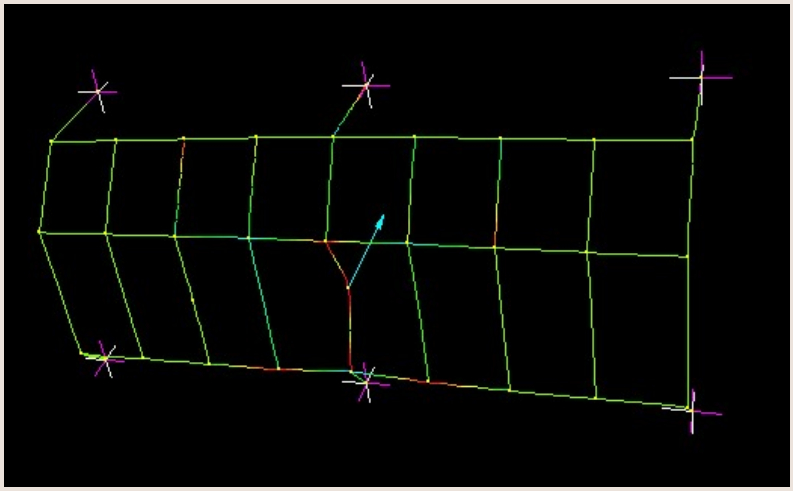
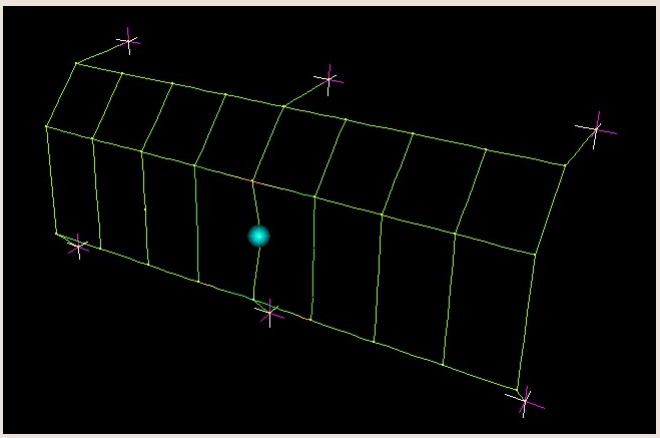
RESISTANCE MODEL
WHAT HAPPENS WHEN WE USE THE CLASSICAL MODELS?

1. **Failure is somewhat localised but distributes through the frame.**
2. **Momentum transfer is reasonable due to high mass/ high deflection of the structure.**

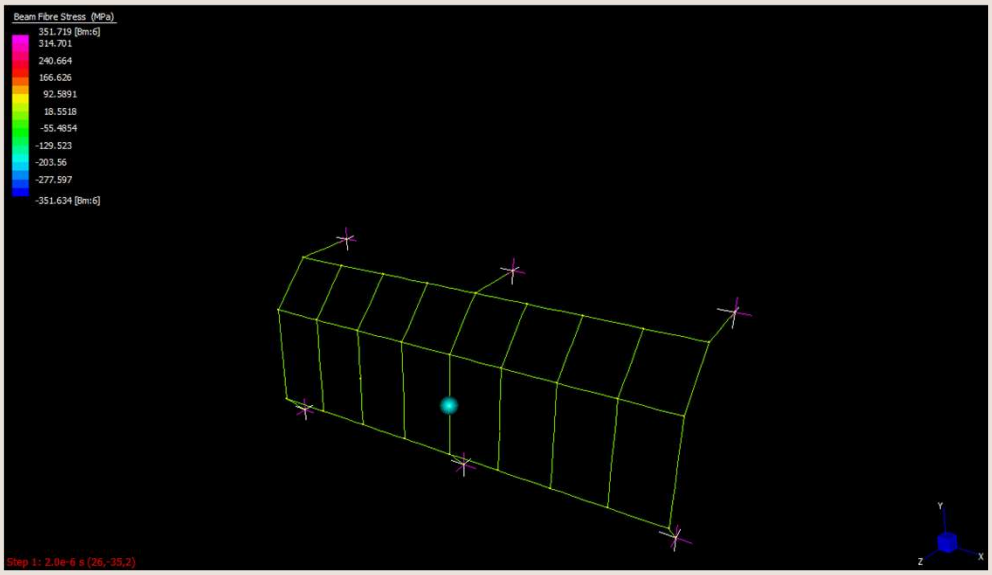


RESISTANCE MODEL
WHAT HAPPENS WHEN WE USE A TIME DOMAIN MODEL?

1. **Local failure occurs within milliseconds**
2. **High modal behaviour/shockwaves move through the structure for seconds after the line has already penetrated the structure.**
3. **Full linear force-deflection is never realised.**



TIME DOMAIN IMPACT MODEL



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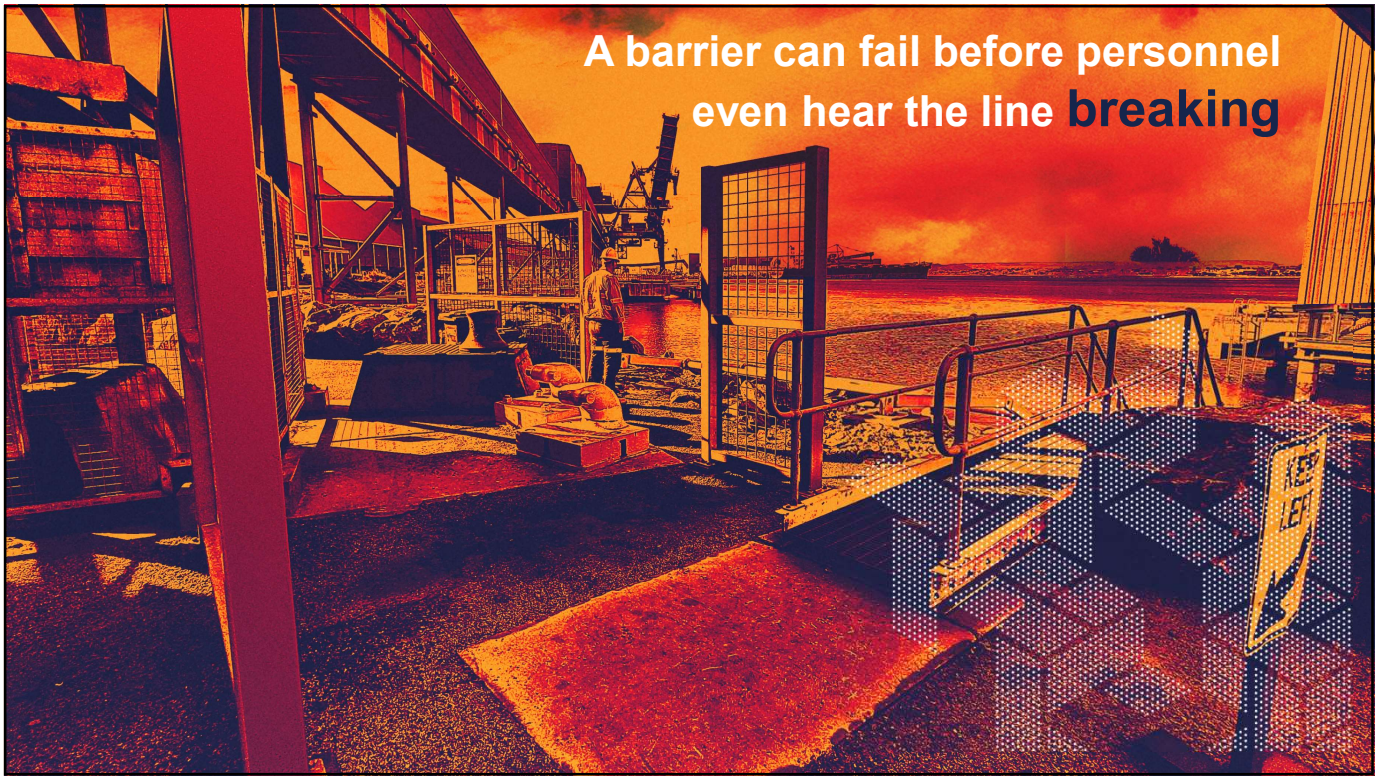

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RESISTANCE MODEL
WHAT HAVE WE LEARNT?

HIGHLY FLEXIBLE STRUCTURES REDUCE OVERALL LOADING AND IMPROVE DISTRIBUTION OF LOADING

HIGH MASS STRUCTURES DECREASE RESULTANT VELOCITY THROUGH TRANSFER OF MOMENTUM

SOLUTION:

HIGH MASS HIGH FLEXIBILITY STRUCTURE THAT IS ALSO RESISTANT TO LOCAL FAILURE?

SYNONYM: MAJOR DESIGN CHALLENGE

THE PATHWAY FORWARD
What we need to do from here

ACTION MODELLING

- Quantify the statistical risk of a design event
- Quantify the magnitude of a design event
- Quantify the probabilistic control volume in which a design event will occur

RESISTANCE MODELLING

- Investigate different structural models with time domain impact analyses
- Inform design based on the ULS exceedance defined by the action model
- Test and validate

INDUSTRY

- Share our research with one another
- Develop design standards for snapback safety
- Holistically consider measures for reducing the risk of snapback events

PLEASE JOIN US FOR PART II, PRESENTED BY MY COLLEAGUE

NICK DEUSSEN

WGA

WGA are currently undertaking detailed design and testing of Snapback Barriers to improve mooring line safety world wide.

AUS | NZ

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