Human-centered Design of a Mooring Winch Control Panel

DNV GL & IST
Mooring winch Control Panels

A high variety of designs can be found on merchant vessels through the whole shipping industry – are these and other designs human-centered?
Motivation

- Mooring is a typical daily operation
- Mooring procedures and equipment are similar on most types of ships
- Since last decades very few changes were implemented on mooring equipment
- Many accidents happen during mooring operations, some of them caused by poor design or poor arrangement of mooring equipment on deck
Goal

- Understand mooring context by observing mooring operation on-board of ship

- Analyse the shortcomings of existing equipment, identify hazards

- Propose a design update with main focus on user-centeredness

- Evaluate the proposal
Approach

- Familiarisation with mooring equipment and procedures (literature, web)
- Analysis of mooring accidents (accident databases, MAIB, BSU etc.)
- Review of existing rules, regulations and guidance (IMO, Class Societies, maritime associations etc.)
- Identification of users and environment (on board visit, interviews)
- Identification of operator tasks (on board visit, observation, interviews)
- Evaluation of existing winch control panels
- Design of new control panels (fixed and portable versions)
- Evaluation (users, manufacturer, rule-based)
Typical mooring equipment arrangement on forecastle deck

1. Storage part of the mooring drum
2. Pulling section of the drum (working part)
3. Brake band
4. Gear box
5. Electro-motor
6. Spurling pipe
7. Chain in the gypsy wheel
8. Dog clutch
9. Guide roller
10. Warping drum
11. Hatch to chain locker
12. Guide roller, guide pulleys
13. Panama chock
14. Chain stopper, hawse pipe below
15. Bollard (double)

Source: van Dokkum, 2003
Analysis of mooring accidents

- Mooring operations are accident-prone
- Injuries by mooring accidents are severe and often fatal
- Human factor plays a major role
- The majority of serious incidents involve parting lines
- Poor arrangement and design of equipment are contributing factors

Source: UK P&I Club “Understanding mooring incidents, 2009"
Review of existing rules, regulations and guidance

- Looking for human-centered design guidance for mooring equipment
  
  ➢ ABS Guidance Notes contains guidance on ergonomics for marine systems for *controls, displays, alarms, valves, labelling, stairs, material handling etc.*
  
  ➢ US Defence Department Military standard contains general information on ergonomics for engineering systems
  
  ➢ Maritime and Coastguard Agency Guidance Notes on safe installation and operation of mooring, towing or hauling equipment on all vessels
  
  ➢ IMO Code on Alerts and Indicators
  
  ➢ UK P&I Club Risk Focus: Mooring
Users

- Users of mooring equipment are officers and able seamen, all trained in mooring operations
  - Different levels of experience
  - Different physical conditions (body dimensions, physical strength, ...)
  - Communication sometimes difficult due to limited language skills
  - Concentration of involved crew may be reduced due to lack of sleep (fatigue)

- Additionally involved:
  - Bridge team (leading the manoeuvre, in contact with mooring team leaders via VHF)
  - Shore team
  - Tug crew (occasionally)
The mooring deck is exposed to challenging environmental conditions:

- Rain or snow can lead to slippery surfaces and limited visibility
- Cold temperatures require wearing of adequate clothes and gloves
- Mooring operations happen in darkness or bright sunlight, inter alia a challenge for the readability of displays
- Communication is hampered by high noise
The mooring team on the container feeder consists of forecastle deck mooring team (Bosun and able seaman, AB) and after deck mooring team (second officer and three AB).

Hierarchical task analysis is done for identification of what is required for the main task to be carried out.

Afterwards, the error influencing factors for each sub-task are identified.
Case study

- Mooring equipment on 100 m container feeder

- Complains on mooring equipment, in particular on location of mooring winch control panel

- Users (crew) highly interested in improvements
Case study

- Snap-back zone on after deck of visited container ship:
  - Operators work in a snap-back zone
  - No space rather for steel protective guards around the panel
  - Need for conceptual improvement
  - Human error: putting too high tension on mooring lines and staying in the snap-back zone
Existing winch control panel

[A] – Master switch  
[B] – Emergency stop  
[C] – Pulling force control switch  
[D] – Pulling force indicator  
[E] – “Fault” indicator  
[F] – “Automatic” indicator  
[G] – “Ready for service” indicator
Existing design: evaluation

Identified main shortcomings:

- Control panel is located in snap back area
- *Emergency stop*[B] placed unfavourable
  - Inadvertent activation by operators' legs possible
  - In case of emergency not easily accessible
  - Need for better identification
- *Control switch*[C] placed unfavourable
  - It is covered by operator’s legs during operation
  - Need for better identification
- Display elements [D, E, F, G] placed outside normal line of sight
- Size of *indicators*[E, F, G] and their labels too small
- *Pulling force indicator* scale [D]:
  - Does not provide caution for dangerous upper operating limits (large pulling force)
  - Readability not sufficient under all possible lightning conditions
- No glare protection available
Way to new design

New design specifications were proposed based on

- Identified shortcomings of existing design
- Field work observation
  - Design of a portable panel to:
    - Avoid working in snap back zones
    - Allow choosing a working position with good overview
- Interviews with users and manufacturers
  - User requirements on the portable control panel:
    - Light panel, not small but not too large either; having stable platform to perform the winch control at all kinds of sea conditions
    - Attached to the operator with belts at his waist or/ and shoulders in order to support the equipment in a comfortable way
    - Panel and lever size large enough for operation with gloves
- Application of guidelines
  - ABS (American Bureau of Shipping) guidance notes on the application of ergonomics to marine systems
  - IMO Code on Alerts and Indicators
New design – fixed control panel

New design of fixed mooring winch control panel

- Pull force indicator
- Control switch
- Emergency stop
- Slack
- Heave

300

160
New design – fixed control panel

**Emergency stop** located on top of the panel:
- easy to reach
- improved identification
- better protected against unintended activation
New design – fixed control panel

Different sizes of indicators:
- better identification
- better perception
- clear and readable labelling

Pull force indicator
Control switch
EMERGENCY STOP
SLACK
HEAVE

WINCH CONTROL STATION
New design – fixed control panel

Vertical grouping of pull force indicator and control switch:
- better identification
- easy to reach
- improved identification of functionality of pull force indicator and control switch
New design – portable control panel

Design of portable mooring winch control panel

- Remote control via radio with option for cable control;
- Provides user freedom to work in safety zone;
- Allows user to maintain a line of sight for the mooring outside the ship.
New design – portable control panel

Selector switch:
✓ used to select between portside and starboard winch
New design – portable control panel

READY *indicator* vertically grouped with the *selector switch*:
- provides better functionality relation
For the presented case study the evaluation process includes:

- Feedback from ship crew (users)
- Comments from a reputable manufacturer
- Check of compliance with Human-centered design guidance
# Evaluation by crew

## Fixed design

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Concerns &amp; issues</th>
</tr>
</thead>
<tbody>
<tr>
<td>✓ Better location of <em>emergency stop</em> button</td>
<td>➢ Concern is a robustness of the control panel on different weather and operating conditions</td>
</tr>
<tr>
<td>✓ Better location of the <em>control switch</em></td>
<td>➢ Need for <em>takeover button</em> with protection against unintended activation</td>
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<tr>
<td>✓ All controls &amp; display elements are now accessible from any position of</td>
<td></td>
</tr>
<tr>
<td>the operator</td>
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## Portable design

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Concerns &amp; issues</th>
</tr>
</thead>
<tbody>
<tr>
<td>✓ Using one <em>master switch</em> to control two winches (portside and starboard)</td>
<td>➢ Need for <em>takeover button</em> with protection against unintended activation</td>
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<td></td>
<td>➢ Need for strong top cover protection and handles</td>
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<td></td>
<td>➢ Lack of <em>charge indicator</em> and <em>low battery alarm</em></td>
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Manufacturer’s feedback on fixed panel (1)

➢ **Display (pulling force indicator)**
  - Increase size (one standard size is 72x72 mm)
  - Increase scale range (>150%) because 100% will sometimes be exceeded during operation and the crew should be aware of that

➢ **Control switch:**
  - The 0% position is misleading as it corresponds to the “manual mode” and should be labelled accordingly
  - The % sign is missing for 25, 50, 75 and 100 values
  - The selected type of switch should provide sufficient watertightness

➢ **Automatic mode indicator:**
  - blue colour is used for automatic mode by the manufacturer (also on other equipment)
Manufacturer’s feedback on fixed panel (2)

- **Emergency stop**
  - Yellow area around the button is missing
  - Protection guards around *emergency stop* are preferred (also for safe transportation)

- **Takeover button**
  - Need for *takeover button* for winch operation from different control panels

- **Labelling:**
  - All letters should be capital letters.
  - Use of additional symbols (e.g. for heaving and slacking) is recommended
Manufacturer’s feedback on portable panel

- **Takeover button**
  - Need for *takeover button* for winch operation from different control panels

- **Selector switch control**
  - Safety issue regarding the proposed *selector switch* (option to select portside or starboard winch): operator can unintentionally switch for the wrong mooring winch:
    - Proposal made for *push lightning buttons* (lightning should better provide identification of the selected winch)

- **Master switch**
  - Based on a manufacturer experience, the control panel should provide control for several winches simultaneously, i.e. the number of *master switches* should match the number of winches to be controlled
**Rule-based evaluation**

- **Formal evaluation based on the following guidance and standards:**
  - The ABS Guidance notes on the application of ergonomics to marine systems (ABS, 2013);
  - The US Department of defense design criteria standard on human engineering, MIL-STD-1472G (MIL, 2012);
  - The IMO Code on Alerts and Indicators (IMO, 2009).

- **Extensive and structured evaluation of controls, display, alarms, integration and arrangement and labelling covered check of 97 items with the following results:**
  - 60 items comply with used recommendations
  - 25 items could not be evaluated as no information was provided
  - 12 items did not comply with used guidance and standards
## Rule-based evaluation: excerpt (1)

### Emergency stop
- The Emergency stop button should be protected against unintended activation
  - Provide control resistance to avoid unintentional movements (ABS, Section 2, 2.7)
  - Surround the control by physical barriers, cover or guard the control (MIL 2012, 5.1.1.8)

### Visual alarms
- Visual alarms should flash at onset; flash rates should be three to five flashes per second with approximately equal on and off time (ABS, Section 4, 3.2)

### Display (pulling force indicator)
- Saturation coding shall be used to indicate relative intensity and is best done in grayscale, except when showcasing more dangerous to less dangerous (where red intensity is used for dangerous areas while the background is grayscale) (MIL, 5.2.2.3.2)
Display hood missing (for fixed panel)
- when dark adaptation is required or high ambient light conditions are specified, all displays shall have an upper 1/3 hood with rounded corners (MIL, 5.2.1.6.5)

Master switch
- Hazardous operations: where practical, the critical position of a control that initiates hazardous operations (e.g. master switch) shall activate visible and audible warning signals in the affected work area (MIL, 5.1.1.10)
Summary & Conclusion

- The main purpose was to develop methodology for considering human element during the design phase of equipment and to apply it to case study.

- Human-centered design, even of simple equipment, is complex
  - Human-centered design process requires team work
  - User requirements’ identification was more difficult than expected (it was hard for the crew to formulate their needs)
  - Guidance and rules for user-centered design are available but not always easy to find and to apply
  - The implementation of user’s requirements might induce new risks (e.g. by use of portable controls)
  - Hence only selected design items were considered in this case study

- The case study demonstrated
  - That even established equipment is worth to be updated with regards to human-centredness
  - The selected approach is feasible and may be applicable to other equipment.