A CASE HISTORY ON THE ERGONOMICS OF A TOWER CRANE CABIN AND ITS EFFECTS ON THE CABIN OPERATOR

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Module: Physical Human Factors in Design
AIMS AND OBJECTIVES

The aim of this case history is to highlight key human factor areas that affect the operator of over-head/tower crane cabins, and how those factors may be ergonomically improved. The themes discussed are as follows:

- Tower Crane Cabin Background
- Seated Postural Comfort
- Visibility
- Whole-Body Vibration
- Controls – Layout
- Ventilation
- Information Display
- Recommendations
- Conclusion
• Wicks Et al (1975) reported that Cabin operators claimed they will terminate their employment because of ill health before their 50th birthday.

• HSE (2006) reported lower back, neck and shoulder affected the most.

• HSE (2006) stated that Operators exposed to whole-body vibration while in an awkward posture are at highest health risks.

• Wang et al (2000) reported that 70% cabin operators surveyed stated poor vision as an issue during operations.

• HSE (2006) stated that Operators exposed to whole-body vibration while in an awkward posture are at highest health risks.

• Work in harsh weather or strong sunlight may cause health problems.

• Research by HSE (2006) indicates Crane drivers are at risk of developing musculoskeletal disorders.

• Shift work, working in isolation & to tight deadlines.

• Large proportion of time spent in one posture,
Seated postures are ideally not the most suitable postures to have, but crane operators spend most of their working time seated, so we need to minimise the stress caused to the spine whilst seated for long hours.

Most discomforts arise in the lower back and the neck-shoulder regions, because of a constant and continuous load while the operator is working.

A 1987 study by Gustafson-Söderman (1987), found that lifts close to the crane resulted in the operator with a bent-forward back and neck with little or no relief without any supports.
SEATED POSTURAL COMFORT

• Whilst seated, the operator needs to be able to view the load and surrounding area.
• Crane operators are likely to be in awkward postures whilst sitting in a seat all day, this can cause discomfort.
• Awkward postures and being seated for long periods can put unwanted pressure on the Lumbar vertebrae region of the back when proper areas are not supported.

• The ISO standard (11226), Ergonomics – Evaluation of Static Working Postures states that the maximum back inclination angle should be $\alpha = 40^\circ$ with a maximum holding time of 2.5 minutes unless adequate support is provided where a significant proportion of the body weight can be transferred to those supports.

[AIST, 2010]
SEATED POSTURAL COMFORT

• Wang et al (2000) conducted a study in which a 158 crane operators out of 198 took part in an anthropometric survey at the Port Le Havre (PAH) in France. The anthropometric dimensions collated, were used to define two extremes where a short (1st percentile) and a tall (99th percentile) operator were represented for the design of crane cabin features.

• Seat design usually relates to a range of particular dimension, there it is convenient to conduct the design in reference to two extremes of a short and tall operator. The chart below shows the 1st, 5th, 50th, 95th and 99th percentiles found for stature of the 158 crane operators who took part in the anthropometric survey.

• Knowing what you are designing and who for determines what percentiles to use. For an ADJUSTABLE operator seat, it would be ideal to use the range of 1st to 99th percentile values.

[Wang et al, 2000]
Discomfort of crane cabin seats can be minimised by:

- Designing cabin seats with armrest supports allowing a proportion weight to be transferred onto supports relieving significant back strain.
- Optional sit-stand and kneeling operation so the cabin operator doesn’t need to remain static in one position for a long duration.
- Minimum size and adjustments must meet the 1st - 99th percentile for males and females in a wide range of body sizes.
- The required height adjustment of the seat should be about 5 inches to fit both a tall 95th percentile male and a 1st percentile female (which is the difference in the lower limb).
- The use of a tilting forward seat would allow the operator to maintain more of an upright posture with minimum a back inclination angle, relieving strain from the neck and shoulders when lifting is close to the crane tower.

[AIST, 2010]
The design of the cabin to a major extent should be driven by the need for optimum field visibility where there is an unrestricted and reliable view of the ground situation and working surroundings.

Barron et al (2005) reports that a clear field of view is a primary factor for the efficient and safe operation of field machines because 90% of the operator's perception is visual.

The repercussions of a poor field of visibility include inadequate utilization of the cabin functions, increased health risks to the operator due to the awkward postures assumed to avoid obstructions to visibility of the task from within the cabin.

An unclear view can also result in possible dangers to the operator himself and the crew working on the ground.

The crane operator in the photograph can clearly be seen in an awkward posture trying to get a better view of the task.

The view however is restricted with protective cabin rails. A better designed cabin would have appropriate sized windows with unrestricted visibility.
Ergonomic guidelines require that a machine operator should have a free view of the operating zone without have to adjust posture (Barron et al., 2005).

The guideline states that the operator should not have to turn their more than 30° to either side and that head should not tilt more than 5° up and 25° down maintain comfort.

Occasional head movements of 50° to the sides and 40° up and 50° down are acceptable.

Seats, windows and cabin features should be designed with these guidelines in perspective.

The operator should inherit a clear view as possible free from large blind areas caused from window frames and obstructions due to the cabin structure such as cabin pillars.
During operation overhead tower cranes experience vibration. This vibration is transmitted to the crane cabin operator as a Whole-Body Vibration (WBV) in axes of 3 translations (x,y,z) at 3 different interfaces with 3 rotations at the hip.

The WBV is distributed to the operator via the closest and largest point of contact that being the Seat and a small amount through the control/joystick and the pedals/footrest within the cabin.

Effect of WBV produces an acceleration which is amplified strongly in seated postures as opposed to standing postures. (Giacomin, 2010).
A study by Bovenzi (2001) of 46 crane operators found that long-term exposure to WBV especially whilst seated and working in awkward postures consequently resulted in the operator developing either lower back pain (LBP), sciatic problems or degenerative changes in the spinal system or any combination of these conditions.

The research also showed that Tower crane operators typically experienced a weighted r.m.s. acceleration around $0.22 - 0.53 \text{ m/s}^2$ which is a vibrational frequency of around $1.25 \text{ Hz} - 5 \text{ Hz}$.

Occasional exposure to these vibrational frequencies is not really harmful, but consistent long-term exposure will certainly cause discomfort and may cause a prevalence to LBP and sciatica.
The principle whole body vibrations experienced are in the 4Hz – 9 Hz range, and the human body is only able to maintain this frequency for short periods of time.

The chart shows the various frequencies that affect parts of the body, but the 4Hz – 9Hz range is where the whole body resonates.

Root Mean Squared (r.m.s.) accelerations experienced by the operator should be minimised as low as possible especially if working for long hours, as shown in the graph by designing seating, hand controls and footrest/pedals with maximum vibration absorption.
• The optimum layout for controls panels in a crane cabin should be ergonomically designed for the working posture of the operator.

• Wang et al (2000) reports in a survey for crane driving discomfort that 85% of the subjects interviewed reported reach of controls as major issue in regards to cabin comfort.

• Some overhead tower cranes have been known to have over 30 control functions. Some primary and some secondary controls.

• The diagram on the bottom right shows an ergonomically challenged layout of controls. To reach the secondary controls adjacent to the side of the seat, require the operator to either twist their body or neck a significant angle making it un-easy to select the correct control element.

• The control panel cabinets in this design are also too close to the armrests thereby blocking the operator’s view.
CONTROLS – LAYOUT

- The formation of the controls layout should depend on the characteristics of the operators feelings and their anthropometry.

- Primary control functions with the highest importance and most frequent use should have an ergonomically better position and be placed within the normal operating range than secondary controls.

- Primary and secondary controls both need to be coherent in adjustability with the seat.

- Shape coding should also be used so that controls for particular functions are instantly recognisable even when they are gripped.

- As a general rule controls with similar functions should be located together.

- Control panels should not block the cabin operator’s field of view required to observe the ground situation.

- The positioning of the controls should not be beyond the best horizon of the operator resulting in a delayed response time.

- Location of Primary controls should be adjustable for 1%tile to 99%tile.

[Wang et al, 2000]
VENTILATION

• Whilst working at a height, the cabin operator is exposed to various environmental conditions such as
  ➢ Blast
  ➢ Heat and cold
  ➢ Radiation
  ➢ Incoming light
  ➢ Dust, gases, pollution – some of these can be hazardous to health and cause lung cancer.

• Hence, the operator needs a supply of fresh air, which means an ergonomically designed cabin with vents and safety glass that opens sufficient enough to let in fresh air, but also safe enough so it present a danger.

• Good general ventilation means rapid fume clearance and a through draught.

• HSE (HSG 194) reports that most of the people in the UK consider 13°C – 30°C as a bearable climate for work conditions.
VENTILATION

- Limited opening of windows, so that fresh air is allowed to circulate around the cabin.

- Vents need to be built into the cabin structure to allow the flow of air into and out of the cabin.

- Air conditioned climate control where the operator is able to adjust the climate from within the cabin for during various weather conditions.

- Ensure air-conditioners do not ‘dump air’ directly onto the operator as that also presents a health hazard.
Information displays let the operator observe the results of the tasks he is controlling and allow him to make correct decisions based on accurate information perceived.

In the image on the right, the display screen is in direct obstruction of the vision needed to observe tasks.

Also, the screen does not appear to be position-adjustable – a key feature required for a good design.
INFORMATION DISPLAYS

- Visual displays relaying feedback to the cabin operator should be within the working visual field, which here is shown as Zone A, according to vertical bending of the neck.
- Zone A would inevitably be determined by the operating height of the cabin, therefore it would be logical for the visual display to be adjustable.
- If illuminated visual displays are used they should be located inside the outer field of vision, defined by Zone B especially when the operator is observing highest and lowest points.

- The dashed lines in the diagram represent where most fixed control panels are placed in relation to the operator.
- Ergonomically optimum control panels should be within the visual range, which from the diagram is 110°.
RECOMMENDATIONS

- Fully height adjustable lockable/swivel seats with adjustable arm, head and back rests for 1st – 99th percentile.
- Arm-rest to allow the operator to transfer most of the strain of weight felt on his back onto the arm rests, thereby causing less long-term damage to the lower spine.
- Use of a tilting forward seat, with the option available to work sit or standing.
- Improvement of shock absorbers within the boom joint, along with comfortable joysticks and a cushioned seat to absorb as much vibration as possible.
- Primary controls should be located within the cabin operator’s visual field without having to twist and turn the torso or neck beyond normal range.
- Closed circuit video system with coloured monitor in the cabin.
- Improve visibility by cleaning windows equipped with wiper blades, washers etc ...
- Sliding windows for ventilation and outside window wipers with washers to clean debris.
CONCLUSIONS

• To conclude, it can be said that the design of a crane cabin should begin from the cabin operator working outwards, where the seat, the controls, the crane structure, and the vibration felt by the operator are all ergonomically designed to fit the operator. After all, it is the operator that spends a significant part of the day carrying out tasks and the safety of the ground crew as well as his own depends on the operator. Therefore it should be any cabin manufacturers concern to keep the cabin operator’s interest’s and ergonomic comfort a priority if the company is to be successful player in the cabin manufacturing market.

• It must also be remembered that the law does not expect the manufacturer to eliminate all risk and discomfort, but the manufacturer is required to make a safe working environment that is ergonomically comfortable with minimised health risks.
BIBLIOGRAPHY


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