Setting it straight: Human factors, technology, and pipe alignment in shipbuilding

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SUMMARY

Pipe alignment is a critical task in shipbuilding, requiring high precision. Accurate measurement can be assisted by digital technology, with potential benefits for operators and business. This paper summarises a trial comparing a manual and technology-assisted pipe alignment task in shipbuilding.

KEYWORDS

Pipe alignment, shipbuilding, motion capture technology

Introduction

Like the circulatory system in the human body, piping transports energy and wastes throughout ships ensuring their safe and efficient operation. Pipework fabrication is a major process in shipbuilding due to its high volume and complexity. The integrity of pipes is critical so all pipe sections must be aligned and welded compliant with stringent specifications. Alignment is a skilful task requiring hand-eye coordination and manual dexterity. Digital technology may assist in reducing task demands while improving quality and efficiency. Human factors trials aim to assess user acceptance and the impacts of technology on tradespersons' performance and operations. This paper reports on a trial of motion capture technology to support alignment of pipes to flanges.

Methods

This study involved a total of 25 male participants with general experience in pipe alignment and welding work. Participants took part in either a live trial (n=7, mean age 40.6 years, range 30-59) in which they performed two alignment tasks (manual versus technology/smart-assisted), or a virtual videoconferencing trial (n=18, mean age 41.9 years, range 21-64) involving viewing each task. Virtual trials became necessary to comply with COVID-19 restrictions. Live trial participants rated workload on the National Aeronautics and Space Administration Task Load Index (NASA-TLX) scale and provided feedback on a survey following each task. Virtual participants took part in an interview of between 30-60 minutes, evaluating perceived usability and operational impacts.

Equipment

Key equipment included four infra-red cameras mounted on each corner of a frame above a Demmeler workbench, Optitrack motion capture software viewed through a large screen, a FitRite pipe fitting jig, digital spirit level (rigid bodies that can be tracked by the Optitrack software in x, y, z directions), pipe clamps, Class 150 flange, and DN80 carbon steel pipe. See Figure 1 and Table 1 for layout of key items of equipment.

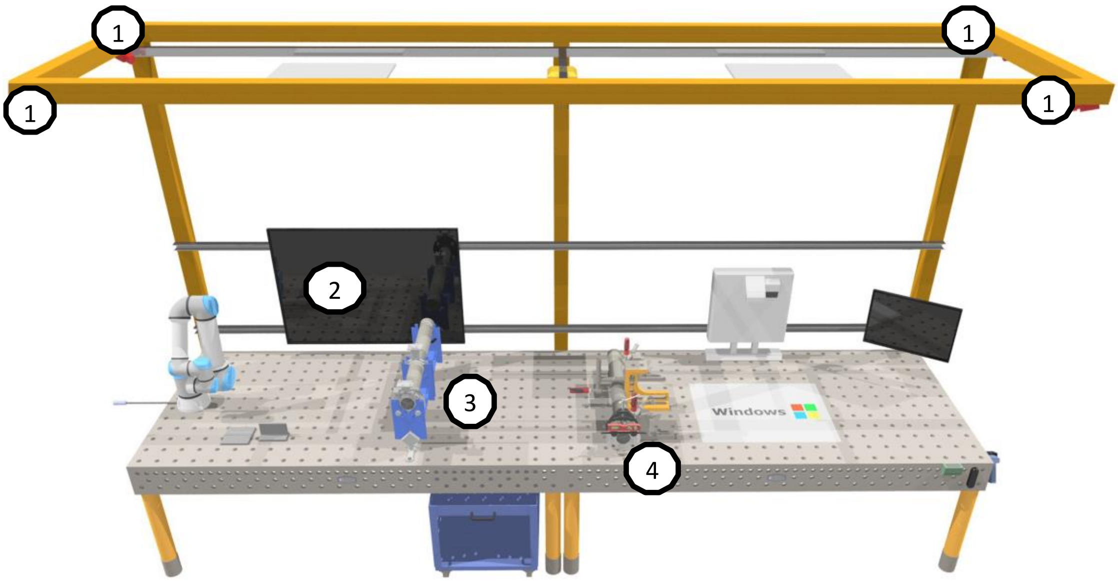

Figure 1: Smart production cell showing configuration of key equipment

Table 1: Legend describing equipment as depicted in Figure 1

Equipment number	Equipment
1	IR cameras which detect reflections from markers on digital spirit level
2	Large screen to display dimensional control graphic user interface
3	FitRite pipe fitting jig
4	Manual pipe fitting jig

Results

Due to small numbers in the live trial, differences in workload demands and performance times between the tasks were inconclusive. Feedback indicated that task demands were lower overall using the smart-assisted version due to its accuracy and ease of use, with the manual version being described as awkward and time-consuming. All live participants preferred the smart-assisted version due to its precision, fewer variables to consider, and lower physical demands. Thematic analysis of virtual participants' comments revealed five broad themes: impact on skills, reliability, speed and accuracy, impact on work design and workload, cost benefit, and technology acceptance.

Implications

Due to small sample sizes, performance findings require further evaluation. Preliminary results suggest the smart-assisted technique combining the FitRite jig and Optitrack motion tracking system may have quality and performance benefits. Perceptions of impact on skill acquisition from using the smart-assisted technique were mixed. Virtual participants were more likely to consider the system would diminish skills for experienced workers but fast track skill acquisition in newer workers. Workflow and layout were likely to change, with the smart version deemed more suited to workshop fabrication, than the high-mix, low volume production found in shipbuilding.

Conclusion

Technology adoption requires careful attention to change management practices to promote user acceptance, develop strategies for job redesign, and ensure sustainability in uptake.