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Ergonomics Intervention in Steel Panels Handling for Improving Workers' Well-Being Outcomes

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ABSTRACT

The paper emphasizes an ergonomics intervention in a medium-sized manufacturing plant to fit jobs for workers with respect to the handling of steel panels for installation onto central station air handlers. Ergonomic risk factors were identified via qualitative and quantitative data obtained from general survey, participative assessments followed by direct observations. Ergonomics intervention by means of real life experiment was conducted. Post survey incorporating both direct observations and participative assessments was subsequently implemented to gauge its effectiveness. The intervention study comprises the introduction of a trolley designed for placing steel panels horizontally and a mobile rack created for upright placing of those panels. The action-oriented ergonomics study finally produced results which were in conformity with the research aim as anticipated.

Keywords: *Ergonomics intervention, direct observation, participative assessment, occupational safety and health, work-related musculoskeletal defects (WMSDs)*

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Introduction

In an industrial environment, ergonomics is the science of fitting jobs to the workers to bring about industrial improvements. Companies aspiring to remain competitive in the business world do not force their workers to adapt to strenuous tasks, but attempt to pursue 'fitting work to people' to improve performance ratings apart from other means of uplifting human well-being. In the manufacturing sector, for example, various ergonomics studies have been conducted to bring about improvements in this human-machine interactions including (1) Electronics Field (Sen and Yeow [6, 7, 8]; Yeow and Sen [9, 10, 11]), (2) Automotive Sector (Li and Oliver [1, 2]; Alipur, Dashti and Tabibi [3]; Trachtman [4]; Sen and Suribhotla [5]), (3) Air Conditioning Sector (Loo and Yeow [12, 13, 14, 15, 16, 17, 18]), (4) Steel Manufacturing (Abrahamsson [19]). In the research, the authors elected to continue the effort of seeking improvements in the manufacturing field by reducing work-related musculoskeletal disorders (WMSDs) prevalent in the manufacturing of air conditioning equipment. The workers' limitations and capabilities in handling steel panels in an air handler assembling process were investigated. Ergonomics concepts and knowledge were utilised to improve the process of material handling via the utilisation of new devices to ease their tasks. The objective was to uplift work comfort leading to job satisfaction (Grandjean [20]; Konz, [21]; Sanders and McCormik [22]) in the work environment and to advance issues pertaining to occupation health and safety (OHS), workers' well being and their work performance.

The research was conducted in a sub-assembly workstation located in a medium-sized manufacturing plant with the aim of identifying and removing ergonomic risk factors among the workers to reduce WMSDs and enhance OHS. This involved a manager, production supervisors, an engineer and other technical personnel in the workstation. For a clearer understanding of the research study, the panel handling process is briefly described in the following section.

Handling of steel panels in the assembling process

Steel panels comprising an assembly of top Panel, bottom panel and side panels are brought to the sub-assembly workstation by a hand pallet truck from a nearby workstation. They are then manually transferred onto wooden pallets on factory floor. Each steel component (be it top, bottom or side panels) requires to be lifted up by at least two workers (Figure 1) and carried over to the adjacent air handler where installation work is carried out according to manufacturing specifications. After completing panel's installation, the unit is replaced by another (pending the installation of panels) by means of a forklift. The similar panel installation task is then repeated.

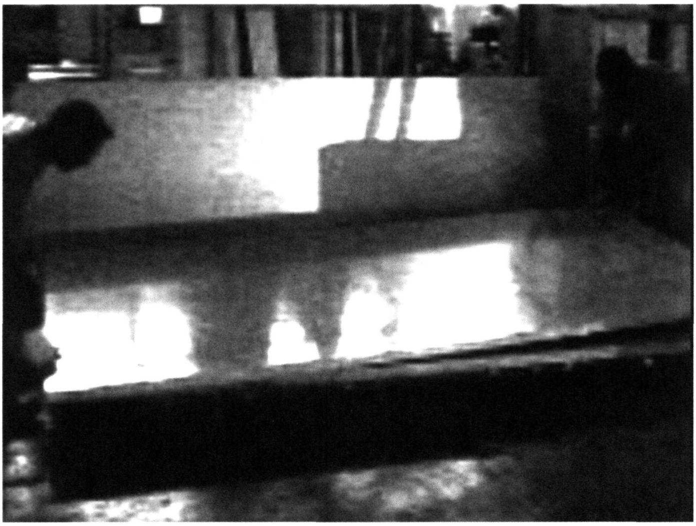


Figure 1: Two workers has to bend their back in the process of lifting up a steel panel

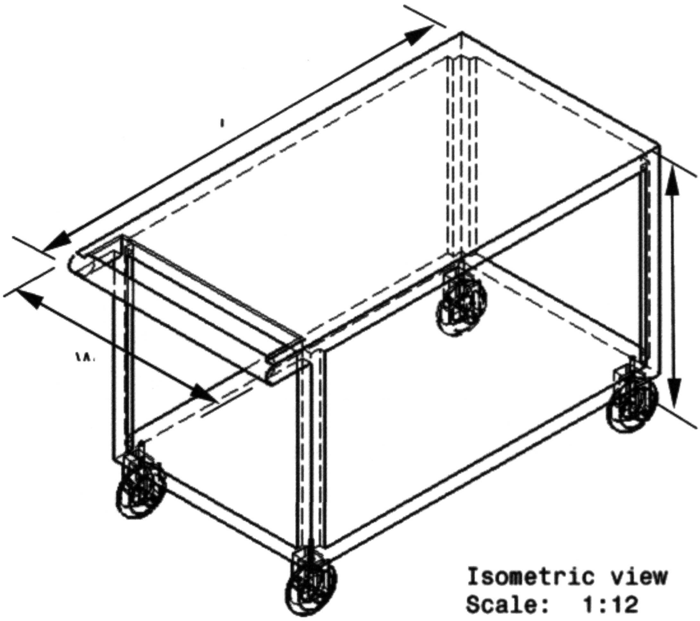
Method

Factory survey

A factory survey was initially carried out in the sub-assembly workstation. An unstructured interview process (Yeow and Loo [23]) was carried out in the presence of eight sub-assembly workers, two supervisors, a production engineer and a production control manager to ascertain major problems in the handling of steel panels. Direct observations (DOs) method (Bisantz and Drury [24]) were utilised to observe and examine the workers' operating postures. These were carried out via scrutinising the video recordings of the workers in action for two shifts at the workstation. Participative assessments (PAs) (Sinclair [25]) via questionnaires were developed and tested upon the workers, one at a time, to confirm the findings of DOs.

Ergonomics intervention

After having obtained a clear picture of the operations, a meeting with the plant management was fixed in order to report the findings. Upon in-depth discussion, the management agreed upon fabricating a low cost steel trolley as well as a mobile steel rack for use in the panel fitting tasks to rectify ergonomic risks. A preliminary design of a trolley was drafted (Figure 2). Upon further discussion with the engineers, a simple structure consisting of both new and scrap steel material was built (Figure 3) for testing use.



Steel trolley dimensions:

- Height, H = 800mm
- Length, L = 660mm
- Width, w = 495mm
- Estimated Max. load = 200kg
- Platform material = Melamine coated panel
- Shelf height, bottom = 220mm
- Shelf height, top = 800mm
- Rolling Wheel = 4 industrial castor

Figure 2: Initial sketch of a steel trolley for placing steel panels horizontally

As for the mobile steel rack to handle those panels, a drafted simple design (Figure 4) was also approved, followed by its construction for upright placing of panels (Figure 5). Ergonomics intervention was then carried out to rectify problems.

After two months, a post survey was conducted. This was carried out via DOs and PAs again on the workers to determine if the intervention was effective in reducing both WMSDs and OHS problems.

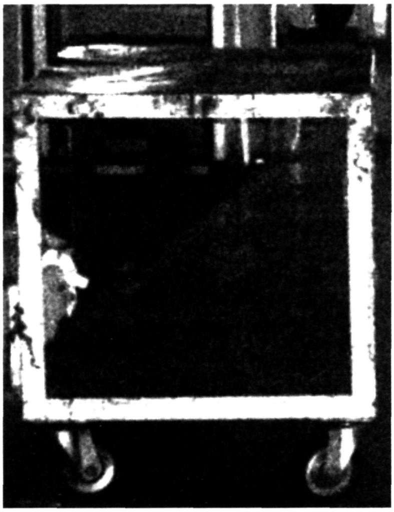


Figure 3: Final steel trolley structure comprising roller wheels for placing panels horizontally

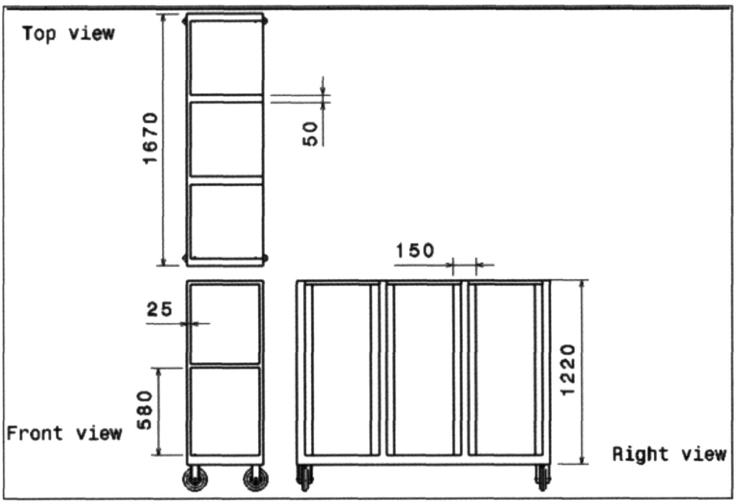


Figure 4: Steel rack (all dimensions are in mm.)

A total of eight experienced male workers (average age of 25.13 ± 5.00) were selected for the case study. Each of them was well informed of the intention and method of testing on steel panels handling for a designated air handler model.

During the installation process, each set of steel panels on wooden pallet on floor from a nearby workstation was transferred onto a trolley located in the sub-assembly workstation by using a forklift. Each panel was then unloaded by hand from the trolley by each team of workers into a mobile rack. This rack was then pushed towards a nearby air handler so as to be parked by its side. A two-member team of workers then removed each panel from the rack for installation onto the air handler according to manufacturing drawing specifications.

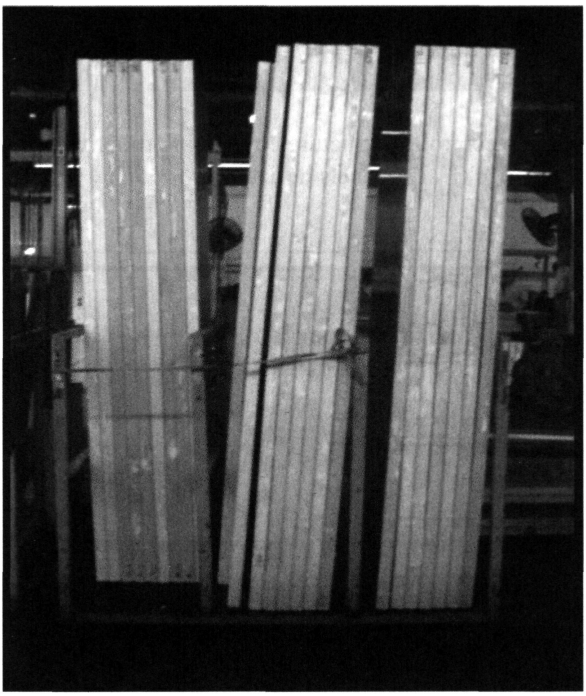


Figure 5: Steel rack structure for upright placing of panels

The rationale underlying the design of trolley and rack

The rationale underlying the use of trolley and rack is to create a set of equipment that allows the workers to adjust their panel handling postures closer to neutral positions. The equipment so designed should minimise awkward positions in the handling of panels, e.g. bending of back, and squatting.

Ergonomic assessment

PA interviews were conducted with one worker at a time to avoid disruption of manufacturing process which might jeopardise the earnings of the factory. After the interview session was completed, each worker was tested on the consistency of certain answers in the Likert scale by rephrasing the question to him. If any of the worker's answer was inconsistent, explanation were given to the worker on the correct way to fill in the Likert scale. The worker was then requested to check all the answers. He was further tested again on the consistency of his answers. The complaints about WMSDs such as low back pain, legs ache and other OHS problems such as dizziness etc. were gathered during the interviews. The interviewer was knowledgeable of the manufacturing process so that he could easily understand the workers' responses and record them in the questionnaire.

DOs were made using video recordings to confirm the findings of the PA and to further examine the problem. A half an hour recording was made on each team of two workers in their panel handling activities. This sum up to a total of 4 hours of video recordings covering eight operators. The recordings were replayed to investigate each worker's problems in detail (e.g. bending of back to reach the panel on floor, etc). The recordings were also played in fast motion to locate the occurrence of a particular problem (e.g. squatting posture to lift a panel from the floor). The workers were also interviewed to confirm all the observations.

Table 1 summarised the reported problems of eight workers and the method used to investigate them at the sub-assembly workstation.

Results and Discussion

Problems identified

From the survey and results of the analysis obtained, it was established that there were four major problems requiring to be addressed. These were low back pain, tiredness, legs ache and dizziness. They are listed as shown in Table 1.

Root-cause of major problems and intervention results

Table 2 summarises the root-cause of problems in the workstation and the intervention results obtained. The data in the 'root-cause' column (in Table 2) was derived from the 'observations' column (in Table 1). The data in the 'results' column (in Table 2) was taken from the ergonomics intervention study and its subsequent assessment as described in earlier sections.

Table 1: Ergonomic methods adopted to investigate four reported problems of eight workers at the sub-assembly workstation

No.	WMSD & OHS Problems	Methods	Observations
1	Low back pain	PA of workers on low back problems	High workers' rating on low back pain (LSR 4.1 ± 0.6).
		DO of workers' postures while handling steel panels	All workers bent their back to reach steel panels placed on floor.
2	Legs ache	PA of workers on leg problems	High workers' rating on leg ache (LSR 4.0 ± 0.5).
		DO of workers on their squatting postures	All operators squatted on floor to lift steel panels.
3	Tiredness	PA of workers on their degree of fatigue	Slightly higher than neutral workers' rating on fatiguing (LSR 3.9 ± 0.6).
		DO of workers on their general activities dealing with panels	All workers showed sign of slowness in their panel lifting activities after 45 minutes to 1 hour of work requiring their bending of back and squatting from time to time. They took rest by sitting on floor occasionally with their back leaning against a pillar, or sitting on carton boxes as makeshift chairs.
4	Dizziness	PA of workers if they experienced dizziness	Higher than neutral workers' rating on dizziness (LSR 3.8 ± 0.5)
		DO of workers' postures that were non-neutral positions	All operators bent their back and squatted on floor when dealing with panels placed on floor.

Note:
PA ≡ Participative Assessment; DO ≡ Direct Observation
x ± y ≡ mean ± standard deviation; LSR ≡ Likert Scale Rating

Table 2: The root causes of problems in the sub-assembly workstation and the intervention results

No.	Problems	Root-Causes***	Intervention Results
1	Low back pain	All workers bent their back to reach steel panels on the floor	Reduction of workers' rating on low back pain to LSR 2.0 ± 0.8** All workers could easily lift up each panel on trolley surface at working height without bending of back, and place it on rack with ease*
2	Legs ache	All workers squatted to lift each panel from floor level	Reduced operators' rating on leg ache to LSR 1.9 ± 0.8** No more squatting to lift up each panel, and mild and momentary squatting incurred when placing it on rack *
3	Tiredness	Squatting on floor and bending of back required from time to time in the process of handling panels	Reduction in operators' rating on tiredness to LSR 1.9 ± 0.8** No bending of back and minimal squatting in handling the installation of panels
4	Dizziness	All workers bent their back to squat on floor to deal with panels placed on floor	Reduced operators' rating on dizziness to LSR 1.9 ± 0.6**

Note:
LSR = Likert Scale Rating
x ± y = mean ± standard deviation
* Data from direct observation of the follow-up study (please see ergonomics intervention and ergonomic assessment sections)
** Data from participative assessment of the follow-up study (please see Sections 2.2 and 2.4)
*** The root-causes were derived from observations in Table 1.

Table 3 below shows the paired samples t-test on LSR of WMSD and other problems of OHS before and after ergonomics intervention.

Occupational health and safety improvements

By comparing DOs and PAs before and after ergonomics intervention, It was found that there were significant improvements in OHS. The adoption of new trolley and rack in the process of handling panels gave a significant impact (see

Table 3: Paired sample t-test on Likert Scale Rating
of work-related problems

No	Problem	LSR Before Intervention (Mean + SD)	LSR After Intervention (Mean + SD)	t-value	p-value	Result
1.	Low back pain	4.1 ± 0.6	2.0 ± 0.8	7.202	< 0.05	significant difference
2.	Legs ache	4.0 ± 0.5	1.9 ± 0.8	7.202	< 0.05	significant difference
3.	Tiredness	3.9 ± 0.6	1.9 ± 0.8	6.110	< 0.05	Significant difference
4.	Dizziness	3.8 ± 0.5	1.9 ± 0.6	8.275	< 0.05	significant difference

LSR = Likert Scale Rating; SD = standard deviation

Table 3), with all the eight workers involved in the study experiencing stress relief. As a result of having ergonomic risk factors removed, there appeared a reduction in WMSDs including backache and legs ache, Other OHS problems such as tiredness and dizziness were also minimised.

Comparison with other ergonomics intervention studies

Andersen, et al. [26] adopted ergonomics concepts and knowledge in their product and workstation design in a manufacturing plant and minimised ergonomic risk factors affecting the assembly process and improved workers' efficiency. Yeow and Loo [23] identified industrial ergonomic risks suffered by the workers in an air handler factory. Ergonomics interventions were conducted to rectify the risks via utilising double nozzle tools for the brazing process along with an efficient brazing method to reduce WMSDs. The authors similarly introduced a trolley, and a mobile rack to remove ergonomic risk factors comprising tiredness and dizziness. Positive improvements were also realised via DOs and PAs.

Conclusions and Recommendation

Ergonomics intervention in the sub-assembly workstation helped to bring numerous improvements in OHS by eliminating ergonomic risk factors. The results are useful in other factories manufacturing air conditioning equipment, especially those in the industrially developing countries having poor awareness of ergonomics. As most of them share similar manufacturing processes, such ergonomic improvement studies can provide solutions to their poor working conditions, not so conducive working environments, and inability to compete effectively globally.

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References

[1] Li, G. and Oliver, S. (2000). The effect of electronic map complexity and orientation on driver response time and error rate for road identification. In D. de Waard, C. Weikert, J. Hoonhout, and J. Ramaekers, (Eds.) *Human-System Interaction: Education, Research and Application in the 21st Century* (pp. 293-302), Shaker Publishing B. V., Maastricht.

[2] Li, G. and Oliver, S. (2000a). Design factors of in-vehicle information display for efficient road recognition. *The Proceedings of the Human Performance, Situation Awareness and Automation: User-Centered Design for the New Millennium*. Savannah, Georgia.

[3] Alipour, A., Dashti, H. and Tabibi, M. (2002). An ergonomic intervention programme in the largest Iranian auto-making industry: methodology and experience. *Proceedings of 3rd CybErg 2002: The Third International Cyberspace Conference in Ergonomics, 2002.* The International Ergonomics, Johannesburg, South Africa.

[4] Trachtman Doris (2002). Passenger-side rear-view mirrors: Driver behaviour and safety. *Proceedings of 3rd CybErg 2002: The Third International Cyberspace Conference on Ergonomics.*

[5] Sen, R. N. and Suribhotla, V. (2003). Ergonomic improvements for the maintenance of the passenger buses through innovative retrieval of the components. In Khalid, H. M., Lim, T. Y. and Lee, N. K. (Eds.). *Proceedings of 7th South East Asian Ergonomics Society and 4th Malaysian Ergonomics Conference (SEAMEC), Kuching, Sarawak, 19-22 May 2003, Kuching, Sarawak.*

[6] Sen. R.N. and Yeow, H.P. (2003). Ergonomic weighted scores to evaluate critical instructions for improvements in a printed circuit assembly factory. *Human Factors and Ergonomics in Manufacturing*, 13, 1-17. US: John Wiley & Sons.

[7] Sen, R. N. and Yeow, P. H. P. (2003a). Ergonomic study on the manual component insertion lines for occupational health and safety improvements. *International Journal of Occupational Safety and Ergonomics* 9, 55-72.

[8] Sen, R. N. and Yeow, P. H. P. (2003b). Cost effectiveness of ergonomic redesign of electronic motherboard. *Applied Ergonomics* 34, 453-463.

[9] Yeow, P. H. P. and Sen, R. N. (2000). Ergonomic improvements for workstations for visual inspection and electrical tests in a multimedia product factory. In *Proceedings of the XIVth Triennial Congress of the International Ergonomics Association and 44th Annual Meeting of the Human Factors and Ergonomics Society, San Diego, California, USA, July 29-August 4, 2000* (Vol. 5, pp. 107-110). Santa Monica, California: Human Factors and Ergonomics Society.

[10] Yeow, P. H. P. and Sen, R. N. (2004). Ergonomic improvements of the visual inspection process of a printed circuit assembly factory. *International Journal of Occupational Safety and Ergonomics*, 10(4), 365-381.

[11] Yeow, P. H. P. and Sen, R. N. (2006). Productivity and quality improvements, revenue increment and rejection cost reduction in the manual component insertion lines through the application of ergonomics. *International Journal of Industrial Ergonomics,* 36, 367-377.

[12] Loo, H. S. and Yeow, P. H. P. (2007). Ergonomics intervention in the manufacturing of air handler coil assembly. *Proceedings of the International Conference on Ergonomics 2007* (pp. 324-328), 3-5th December, 2007, Hotel Istana, Kuala Lumpur, Malaysia.

[13] Loo, H. S. and Yeow, P. H. P. (2008). Ergonomic redesign of air handler coil for effective maintenance. *Invention, Innovation and Design 2008 (IID 2008),* 25-27 March, 2008, UiTM, Shah Alam, Malaysia.

[14] Loo, H. S. and Yeow, P. H. P. (2008a). Ergonomic redesign of cooling coil assembly. *19th International Invention, Innovation & Technology Exhibition (ITEX 2008)*, 9-11 May, 2008, Kuala Lumpur, Malaysia.

[15] Loo, H. S. and Yeow, P. H. P. (2008b). Ergonomics improvements in the brazing of air handler coil assembly. *Proceedings of the 9th Southeast Asian Ergonomics Society Conference (SEAES 2008) (Paper No. A003).* 22-24, October, 2008, Grand Mercule Fortune Bangkok, Thailand.

[16] Loo, H. S. and Yeow, P. H. P. (2008c). Cooling coil assembly redesigned for ergonomic improvements. *57th World Exhibition on Innovation, Research and New Technologies*, 13-15 November 2008, Brussels, Belgium.

[17] Loo, H. S. and Yeow, P. H. P. (2009). Ergonomic redesign options for air handler coil replacement. *Invention, Innovation and Design 2009 (IID 2009).* 13-15 January 2009, UiTM, Shah Alam, Malaysia.

[18] Loo, H. S. and Yeow, P. H. P. (2009a). Options in ergonomic redesign for air handler coil replacement. *Malaysia Technology Expo 2009 (MTE 2009)*, 19-21 February, 2009, Kuala Lumpur, Malaysia.

[19] Abrahamsson, L. (2000). Production economics analysis of investment initiated to improve working environment. *Applied Ergonomics*, 31, 1-7.

[20] Grandjean, E. (1982). *Fitting the task to the man: an ergonomic approach* (4th Ed.). Taylor & Francis, London.

[21] Konz, S. (1983). *Work design industrial ergonomics* (2nd edition). Columbus, OH: Grid.

[22] Sanders, M. S. and McCormick, E. J. (1993). *Human factors in engineering and design* (7th edition). New York: McGraw-Hill.

[23] Yeow, P. H. P. and Loo, H. S. (2009). Ergonomics in the brazing operation of an air handler coil factory. *Proceedings of the 2nd International Conference on Industrial Risk Engineering (CIRI 2009)* (pp. CIRI043). May 13-15th 2009, Reims, France.

[24] Bisantz, A. M. and Drury, C. G. (2005). Applications of archival and observational data. In Wilson, J. R., Corlett, E. N. (Eds.), *Evaluation of Human Work* (3rd ed., pp. 61-82). Taylor & Francis, London.

[25] Sinclair, M. A. (2005). Participative assessment. In Wilson, J. R., Corlett, E. N. (Eds.), *Evaluation of Human Work* (3rd ed., pp. 83-111). Taylor & Francis, London.

[26] Andersen, S., Kent, B., Mui, R. and Wick, J. L. (1998). The effects of applying ergonomics in the design of a product and a manufacturing process. Advances in Occupational Ergonomics and Safety 2, Kumar, S. (Ed.). IOI Press, Amsterdam, pp. 806-809.

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Contributions are invited from various disciplines that are allied to mechanical engineering. The contributions should be based on original research works. All papers submitted to JMechE are subjected to a reviewing process through a worldwide network of specialized and competent referees. To be considered for publication, each paper should have at least two positive referee's assessments.

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ABSTRACT

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[2] H. Coelho and L. M. Pereira, "Automated reasoning in geometry theorem proving with Prolog," J. Automated Reasoning 2 (3), 329-390 (1986).
[3] P. N. Rao, Manufacturing Technology Foundry, Forming and Welding, 2nd ed. (McGraw Hill, Singapore, 2000), pp. 53 – 68.
[4] Hutchinson, F. David and M. Ahmed, U.S. Patent No. 6,912,127 (28 June 2005).