ISSN (Online) : 2319 - 8753
ISSN (Print) : 2347 - 6710

International Journal of Innovative Research in Science, Engineering and Technology

An ISO 3297: 2007 Certified Organization, *Volume 2, Special Issue 1, December 2013*

Proceedings of International Conference on Energy and Environment-2013 (ICEE 2013)

On 12th to 14th December Organized by

Department of Civil Engineering and Mechanical Engineering of Rajiv Gandhi Institute of Technology, Kottayam, Kerala, India

ERGONOMIC REDESIGN OF A MATERIAL HANDLING WORKSYSTEM IN A MANUFACTURING PLANT

Raghunathan Rajesh, Rakesh V Babu, Saran Ramachandran

Associate Professor, Rajiv Gandhi Institute of Technology, Kottayam, Kerala - 686501, India

B.Tech (Mech Engg), Rajiv Gandhi Institute of Technology, Kottayam, Kerala - 686501,India

B.Tech (Mech Engg), Rajiv Gandhi Institute of Technology, Kottayam, Kerala - 686501, India

ABSTRACT

Manual material handling is one of the most physically demanding operations where workers are exposed to repetitive movements, awkward postures, contact stresses, and forceful exertions. The study presents a case of ergonomic intervention in a manufacturing plant towards reducing the physical strain for workers undertaking material handling in a worksystem. Digital human model in CATIA was used for biomechanical analysis and for redesign of material handling worksystem where higher levels of physical exertions are observed. The ergonomic solutions for the material handling worksystem are presented.

Relevance to Industry: The design solution shall help the Industrial Engineers of the plant towards its implementation, and therefore enable reduction in the physical stress encountered by the workers in the specific worksystem studied.

1INTRODUCTION

Manual material handling (MMH) tasks are amoung the major contributors to musculoskeletal disorders (MSD) [1]. Mechanization has brought a change in the way material handling is accomplished [2-3]. Tasks previously undertaken by lifting-lowering or carrying alone are now undertaken by combinations of MMH tasks such as lifting-carrying-lowering, lifting-carrying-pushing or lowering-pushing-lifting. This has brought about a change in health effects on workers engaged in material handling.

MMH consists of differing task contents and durations producing different MSD related effects because of complex interactions amongst the components of the worksystem. As a result physical exposure quantification and response measurement have been a challenging issue. The effort undertaken by developed countries towards mitigating manual material handling is more pronounced than the efforts undertaken by developing countries. There is now some effort directed by Indian researchers and Industry stakeholders towards physical exposure measurement and devising ergonomic interventions for reducing the physical stress of material handling workers [4-11]. It is imperative that ergonomic solutions are highlighted amoung the Industry stakeholders for positive intervention efforts.

The objective of the paper is to highlight on ergonomic intervention of a material handling worksystem in an Indian manufacturing plant.

2. METHOD

Firstly, a work-sampling based field study spanning more than a month was used to identify hazardous locations in the plant. During the field study details of material handling tasks and postures adopted for the material handling activity were recorded [12]. Secondly, through on-field trials hand forces were measured for the MMH tasks representative of those observed in the first step. In this step the pushing and pulling activities were covered, as the force estimates for lifting, lowering and carrying can be obtained directly from the weights of the materials. The real-time push-pull forces were recorded using a force-gauge (LUTRON make) into a laptop at 1 Hz. Thirdly, biomechanical assessment of the MMH tasks were undertaken. For this digital human model was built in CATIA V5 for current worksystem. For the digital human model anthropometric data [13] of 75th percentile Indian population was used. Finally, the hazardous worksystem i.e. location-3 (L3) was redesigned ergonomically. The biomechanical analysis for current worksystem and redesigned worksystem was undertaken.

The layout of L3 with fifteen mid-sized racks is shown in Figure 1. At L3 boxes weighing 25-31 kg are stored and later moved to machine centers based on daily production schedules. The loading task involves moving 15-20 boxes from truck unloading point to L3 (task-1) and storing those boxes there (task-2). Based on daily production schedule the boxes from L3 are loaded onto pallet truck (task-3) and moved onto other location (task-4). Figure 1 shows the storage task at L3 and Figure 2 shows the task involving material movement from L3.

FIGURE 1. MATERIAL STORAGE AT L3

FIGURE 2. MATERIAL MOVEMENT FROM L3

3. RESULTS & DISCUSSION

MMH Task Analysis

Figure 1 shows the layout of L3, and the issues encountered by the material handling workers. For task-1 and task-4 (pushing-pulling) the causes for higher physical exertion include poor floor-surface, and damaged pallets. This causes high shoulder, elbow and hand forces. For task-1 and task-4 the peak and sustained pushing-pulling force was 11 kgf mean (sd=2) and 27.8 kgf mean (sd=6.7) respectively [14]. The sustained force is below the maximum acceptable sustained force limit of 15 kgf, while the peak hand force while pushing-pulling is above the maximum acceptable peak force limit of 23 kgf [15]. It is recommended that damaged pallets be replaced, irregular floor-surface and dirty floor-surface be cleared to avoid generation of higher peak forces [9].

For task-2 and task-3 (lifting-lowering-carrying) the causes for high physical exertion include low aisle width, high box weight, unfavorable origin-destination heights during lifting-lowering, poor coupling for heavy material, and carrying heavy boxes. This causes high compressive and shear forces on lower back. The results from biomechanical analysis in CATIA software is shown in Table 1. Figure 3 shows the digital human model for various postures adopted during task-2. It can be seen that material handling at L3 causes high physical exertion on lower back and exceeds the NIOSH recommended limit of 3400 N [16].

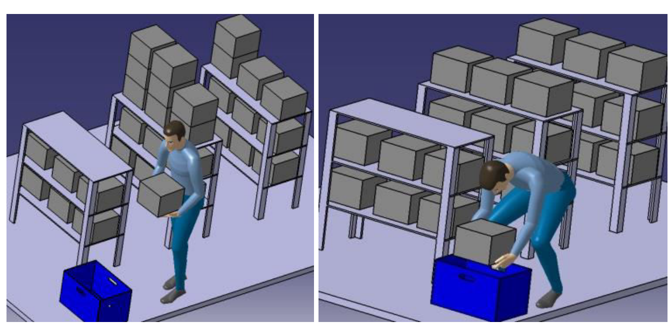

FIGURE 3. POSTURE ADOPTED DURING TASK-2&3 AT L3

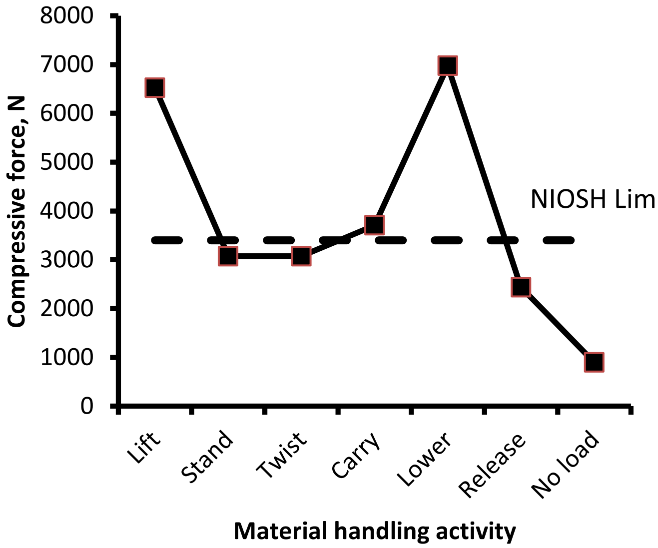

FIGURE 4. COMPRESSIVE FORCE ON LOWER-BACK

TABLE 1. BIOMECHANICAL FORCES ON LOWER-BACK

Task	Compressive forces, N	Cumulative compressive forces
Current worksystem (L3)		
Task-2	6521	727 KNs
Task-3	6521	582 KNs
Modified worksystem (ML3) with 31 kg box		
Task-2	4958	113 KNs
Task-3	4958	91 KNs
Modified worksystem (ML3) with 25 kg box		
Task-2	4278	106 KNs
Task-3	4278	85 KNs

Note: L3 indicates location '3' and ML3 indicates redesigned location '3'.

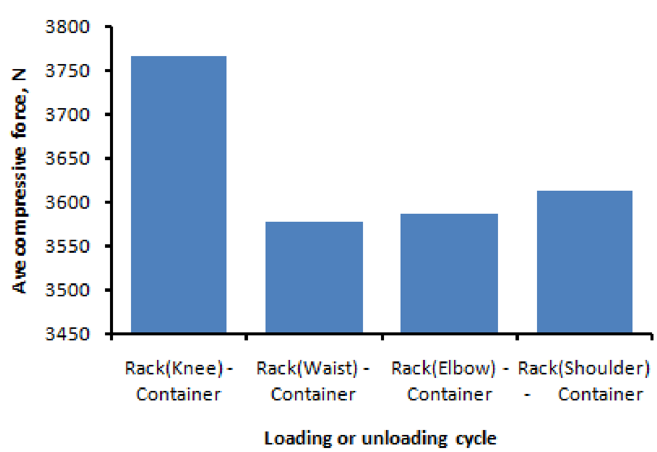

FIGURE 5. AVERAGE COMPRESSIVE FORCE OVER DIFFERENT MMH TASKS

The cumulative spine load was calculated based on 'component' method followed by Callaghan et al. [17]. The work of Chang and Wang [18] and Waters et al. [19] provided useful insight into ergonomic evaluation through digital human model simulation. Figure 4 shows the compressive force during significant postures while undertaking the MMH activity i.e. lifting 31 kg box from knee height of rack , carry the box at waist height over a distance of 2-5 m, and lower onto blue container at knee level. The cycle time for the MMH activity is 8-10 seconds. The average cumulative load on lower-back is 3636 N for a loading or unloading cycle per second. For each unloading/loading cycle between rack and container the cumulative compressive force on lower-back was in the range 3578 to 3766 N. In the current worksystem both the instantaneous compressive force and sustained spine loading (i.e. cumulative forces) are higher than the NIOSH limit of 3400 N. Therefore an intervention at L3 is imperative.

Ergonomic redesign

The ergonomic solutions provided to the company studied are from analysis through biomechanical assessment. The redesign changes suggested at L3 include: aisle width to be increased from 47 to 90 cm, rack shelf at 20 cm height to be removed, height adjustable pallet truck with weight indicator to be introduced, reduce the weight of the box and redesign the box for hand slot.

The redesigned worksystem brings about a significant change in postural activity during manual material handling (Figure 6). Silva et al. [18] provided useful insight into box design.

After redesign the posture adopted is largely standing. Figure 7 shows the redesigned L3. The peak biomechanical forces observed at the existing location-3 were 6521 N compressive force on L4-L5. The corresponding biomechanical forces for the redesigned worksystem (Figure 3) is 4958 N for material handling of 31 kg boxes. Since 31 kg is above the psychophysically determined maximum acceptable weight limit it is recommended that the box weight be reduced to 25 kg. The peak compressive force on lower back has been further reduced to 4278 N for material handling of 25 kg boxes. The average compressive force in current worksystem has been reduced from 3562 N to 2126 N in the modified worksystem. In addition, the cumulative compressive force on lower back has reduced from 456-570 KNs to 85-106 KNs for the modified worksystem. The redesign of the current worksystem brings about a 39% reduction in peak forces and 85% reduction in cumulative forces.

The modified design now has addressed the issues indentified earlier i.e. low aisle width, high box weight, unfavorable origin-destination heights during lifting-lowering, poor coupling for heavy material, and carrying heavy boxes. An added advantage apart from the reduction in physical strain is the reduction in loading and unloading time in the modified L3.

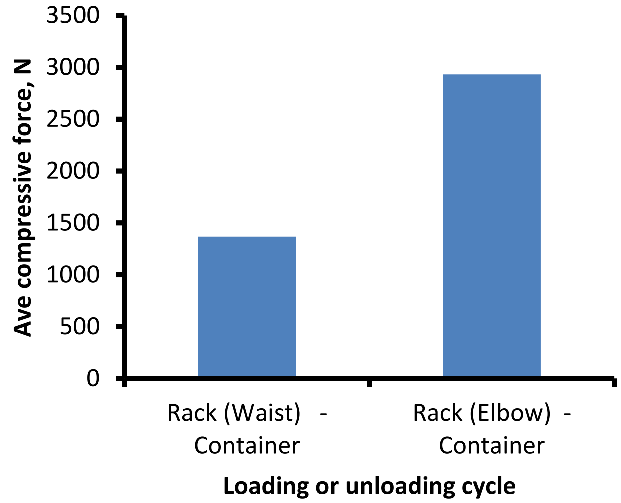

FIGURE 6. AVERAGE COMPRESSIVE FORCE IN MODIFIED WORKSYSTEM

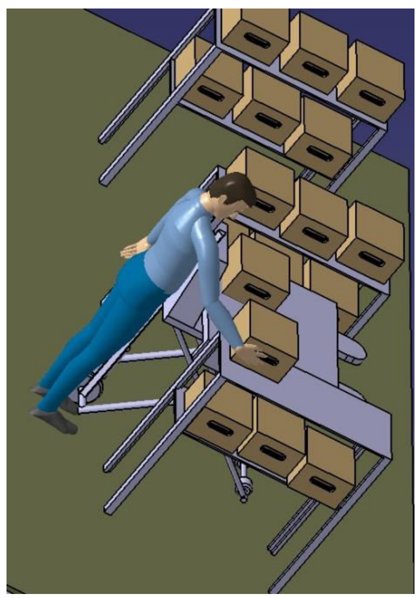

FIGURE 7. Redesigned L3

4. CONCLUSION

The causes of ergonomic stressors at a hazardous location in a manufacturing plant were identified. The ergonomic redesign of manual material worksystem was done. The design solution provides a significant reduction in stress on lower back.

The design solution shall help the Industrial Engineers of the plant towards its implementation, and thereby enable reduction in the physical stress during material handling activities at L3. This case study also provides useful information for pallet truck designers and suppliers.

There is scope for further study to explore the impact of ergonomic interventions on productivity.

ACKNOWLEDGMENT

The authors gratefully acknowledge the support and cooperation provided by the management of the manufacturing plant.

REFERENCES

[1] Dempsey, P. G., and Hashemi, L., 1999. "Analysis of workers' compensation claims associated with manual materials handling". *Ergonomics, 42*(1), pp. 183-195.

[2] Ciriello, V. M., and Snook, S. H., 1999. "Survey of manual handling tasks". *International Journal of Industrial Ergonomics, 23*(3), pp. 149-156.

[3] Garg, A., Waters, T., Kapellusch, J., and Karwowski, W., 2012. Psychophysical basis for maximum pushing and pulling forces: A review and recommendations. *International Journal of Industrial Ergonomics*, In press.

[4] Sen, R.N., and Sahu, S., 1996. "Ergonomic evaluation of a multipurpose shovel-cum-hoe for manual material handling". *International Journal of Industrial Ergonomics*, 17, pp. 53-58.

[5] Maiti, R., 2008. "Workload assessment in building construction related activities in India". *Applied Ergonomics*, 39(6), pp. 754-765.

[6] Batish, A., and Singh, T. P., 2008. "MHAC - an assessment tool for analysing manual material handling tasks". *International Journal of Occupational Safety and Ergonomics*, 14(2), pp. 223-235.

[7] Parida, R., and Ray, P.K., 2011. "Comprehensive framework for physical evaluation of manual material handling tasks". *International Journal of Manufacturing Technology and Management*, 24(1), pp. 153-166.

[8] Batish, A., Bhattacharya, A., and Singh, B., 2011. Multi-Response Optimization and Empirical Modeling of Cardiopulmonary Responses during Manual Lifting Tasks. *Human Factors and Ergonomics in Manufacturing & Service Industries*, 21 (1), pp. 29–43.

[9] Rajesh, J., and Maiti, J., 2011. "Implication of container clearance on materials handling by pallet truck". *International Ergonomics Conference HWWE 2011*.

[10] Rohit, S., and Singh, R., 2012. Determination of Safe Carrying Load Limit for Women Carrying Water. Journal of Ergonomics, 2(2), pp. 1-7.

[11] Singh, J., Kalra, P., and Walia, R.S., 2012. "Study of Maximum Acceptable Weight of Lift for Indian Male Industrial Workers". *International Journal of Engineering Research & Technology*, 1(9).

[12] Genaidy, A. M., Al-Shedi, A. A., and Karwowski, W., 1994. "Postural stress analysis in industry". *Applied Ergonomics*, 25(2), pp. 77-87.

[13] Debkumar, C., 1997. Indian Anthropometric Dimensions. *National Institute of Design, Ahmedabad, India*.

[14] Rajesh, J., and Maiti, J., 2013. "Application of Cube model for MMH tasks in a manufacturing plant in India". *IIE Transactions on Occupational Ergonomics and Human Factors*, Under review.

[15] Snook, S. H., and Ciriello, V. M., 1991. The design of manual handling tasks: Revised tables of maximum acceptable weights and forces. *Ergonomics*, 34(9), pp. 1197-1213.

[16] Waters, T.R., Putz-Anderson, V., Garg, A., and Fine, L.J., 1993. "Revised NIOSH equation for the design and evaluation of manual lifting tasks". *Ergonomics*, 36(7), pp. 749-776.

[17] Callaghan, J. P., Salewytsch, A. J., and Andrews, D. M., 2001. "An evaluation of predictive methods 367 for estimating cumulative spinal loading. Ergonomics". 44(9), pp. 825-837.

[18] Chang, S.W., and Wang, M.J.J., 2007. "Digital human modeling and workplace evaluation: Using an automobile assembly task as an example". *Human Factors and Ergonomics in Manufacturing* 17(5), pp. 445-455.

[19] Silva, L. C. C. B., de Oliveira, A. B., Silva, D. C., Paschoarelli, L. C., and Coury, H. J. C. G., 2013. "Evaluation of reusable cardboard box designs: Biomechanical and perceptual aspects". *International Journal of Industrial Ergonomics*, 43(2), pp. 154-160.