Virtual Ergonomics and Time Optimization of a Factory

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Abstract:- This manuscript focuses on designing the virtual factory which has become a subject of paramount importance to all major manufacturing companies. Such virtual solutions enable to verify all conflict situations before real implementation of factories and to optimize the performance, productivity, timing, costs and ergonomics by using simulation and virtual reality technologies. This model sees a real factory as a combination of various sub-systems and includes them. In manufacturing, it creates a virtual simulation exercise that helps in replicating the real life scenario and helps in designing and implementation. Using ergonomics module, distance traveled from end-to-end departments to complete the entire manufacturing process is calculated. Within the virtual factory, assembly planning and manufacturing planning is demonstrated through real-life worker simulation considering the musculoskeletal disorders (MSD). Awkward working postures and improper workstation design leads to MSD. In this paper, virtual representation of a shop floor activity is done by using a digital modeling tool DELMIA V6. The task is performed by the digital human (manikin) and the ergonomic analysis is carried out virtually for the tasks which includes worst working condition. Simulating the manual tasks in virtual environment, the worker postures have been evaluated using the Rapid Upper Limb Assessment (RULA) Analysis, Lift Lower Analysis and Biomechanics Single Action Analysis which are used to provide the level of risk for the musculoskeletal disorders.

Keywords*:- Musculoskeletal disorders (MSDs), DELMIA, Digital Human, Manikin, Rapid Upper Limb Assessment (RULA), Lift Lower Analysis and Biomechanics Single Action Analysis.*

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1. INTRODUCTION

In the present scenario, companies are focusing mainly on producing wide variety of high quality products at large volumes with less production time in order to meet the dynamic demands of customers all over the world in highly competitive market. Many manufacturing firms have started using highly automated equipment for better accuracy and faster production rate without human interventions. However, due to the high cost of installation and operation of automated equipments many manufacturing firm prefers high skill manpower to carry out specific tasks Battini D. (et. al. 2015). This may cause injuries to the workers and may lead to the loss of money and time. The total expenditure of manufacturing is greatly increases due to reduction in quality and productivity due to uncomfortable working condition. Ergonomics is the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data and methods to design in order to optimize human well-being and overall system performance. Ergonomics can be considered as an effective way to reduce human risk factors. Worker capabilities and limitations must be considered while designing the workplace or workstation. International Ergonomics Association (IEA) (2016) defines ergonomics is the scientific study of man and machine interaction at workplace. They also added that, Ergonomics comes from Greek words ergon (work) and nomos (laws), which means science of work.

To provide comfortable work environment, a scientific approach is to be followed to reduce human risk factors which indirectly effects the product quality and productivity. Ergonomic analysis has to be carried out to validate the ergonomic design of every work station. This paper mainly focuses designing the manufacturing shop floor layout and workstations according to the ergonomic principles to ensure safe and comfortable working environment. Mustufa H. Abidi (et. Al 2013) in his study stated, that human factor is drawing more attention in the design, engineering, production, and maintenance of new industrial products especially in automotive industry. Ergonomic quality is becoming a critical criterion for the success of many products. Recently, virtual reality (VR) technique is widely applied during different phases of product development. The use of VR allows designer reducing the production of physical prototypes that are very expensive and requires long production time. Virtual humans are used in the automotive industry especially for ergonomic analysis of a virtual prototype.

As human intervention is involved to perform the task, it is necessary to provide safe and healthy working conditions. Improper worksite design result into musculoskeletal disorders (MSDs) and fatigued and dissatisfied workers.

Damian Grajewski (et. al 2013) in his research describes virtual reality allows to conduct a number of analyses related to designed prototypes, such as: dimensions of devices and possibilities of adjustment to height of the human operator, and arrangement of control and signalling devices according to the rules of ergonomic design. To conduct these analyses, full interaction between user and workplace must be programmed, including collision detection, kinematics of the devices and possibilities of activating their various functions in relation with other objects in the virtual scene. VR techniques allow presenting the virtual prototype of the workplace in its real operation environment, limiting the need for use of real mock-ups. There are many tools and techniques available to identify the musculoskeletal risk related to the manual task, i.e. RULA, REBA, NIOSH lifting equation, OWAS, LUBA and SNOOK table, etc.

McAtamney and Corlett (1993) in his research described rapid upper limb assessment (RULA) worksheet include: angular position of joints and twisting of the arms, wrist, neck, trunk and legs; type of load, load value, and whether activity is static or repeated. RULA assess the working postures and generates a score based on the given information. This score is used to review the MSDs risks, fatigue, and injuries.

The scale for the score is as follows:

- Score 1 - 2: acceptable posture, negligible risk, no actions required.
- Score 3 - 4: low risk, change may be needed.
- Score 5 - 6: medium risk, further investigation, changes required soon.
- Score 7: very high risk, implement change immediately.

From many studies it is concluded that, the workers are exposed to musculoskeletal injuries associated with the working condition which is not designed according to the ergonomics principle. Sonja Pavlovic Veselinovic (et. al. 2016) in his statement described the ergonomics hazards that cause work related musculoskeletal disorders (WRMSDs). He stated that, ergonomic hazards result due to, uncomfortable design of workstations, machineries, and operating procedures. It includes repetitive motions, forceful motions, vibration, temperature extremes (especially cold), and awkward posture.

In Lift Lower Analysis, lifting index (LI) is calculated to provide a relative estimate of the level of physical stress and MSD risk associated with the manual lifting tasks evaluated. This tool is used by occupational health and safety professionals to assess the manual material handling risks associated with lifting and lowering tasks in the workplace. This considers job task variables to determine safe lifting practices and guidelines.

The scale for the score is as follows:

- Score ≤1: acceptable posture, negligible risk, no actions required.
- Score 1<LI≤3: this lift may increase the risk of low back or lifting injury, change may be needed.
- Score >3: This lift may exceed the capabilities of safety performing the lift for nearly all workers. Redesign of the lifting task is recommended.

2. METHODOLOGY

This study is carried out as per a stage vise methodology as represented by Marzano A. (et. al., 2012) paper. In this study a similar procedural flow is followed which is divided into three stages. Stages of methodology are depicted in Fig. 1. Three stages include following tasks:

- Stage I: Real Time Data collection and Virtual Layout creation.
- Stage II: Ergonomic analysis.
- Stage III: Alternate solutions and Optimum solution implementation to modify layout.

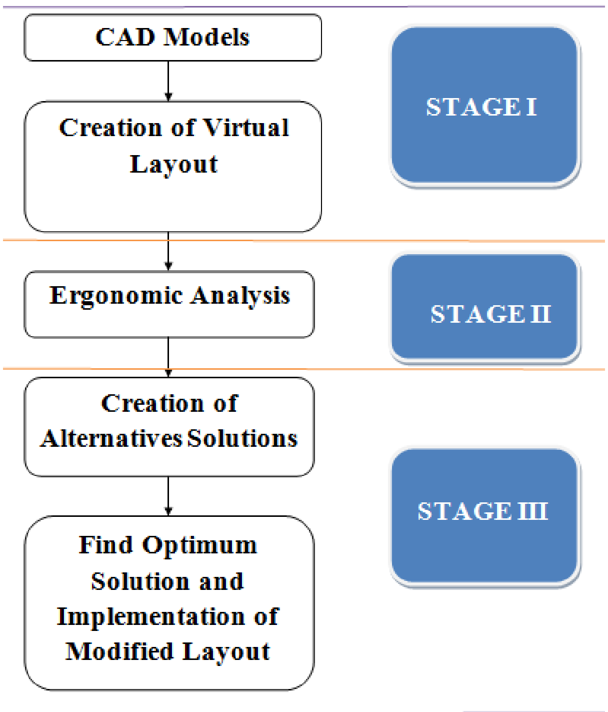

Fig.1 Procedural Flow

3. CASE STUDY

This section discusses about the problem which is considered for ergonomic evaluation. It also shows how the problem is solved following the previously described methodology. Various tasks performed to ergonomically evaluate workstation are explained stage by stage.

STAGE-I: This stage includes real time data collection and virtual layout creation. In this study solar water heater is considered for the ergonomic analysis. In Stage-I, dimensions of the solar water heater have been taken; virtual layout is prepared as per the collected data. In Fig.3 and Fig.4 old layout and modified layout are represented in virtual environment.

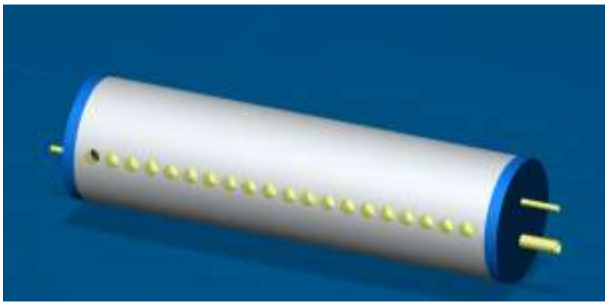

Fig.2 Solar Water Heater

Fig.2 represents solar water heater and Fig.3 represents the old virtual layout of its final assembly with various components of heater. The virtual representation is shown with the manikin/operator to perform virtual ergonomics. The manikin is considered to be an Asian type with 50% of population. The placement of the components is as per the dimensions collected.

STAGE-II: This stage is the main experimental stage, in which all the ergonomic analysis is virtually carried out for the activity. In this paper, the activity which undergoes ergonomic review is: "The operator pick the components from the various bins and place it into the tank holder which is fixed for the assembly."

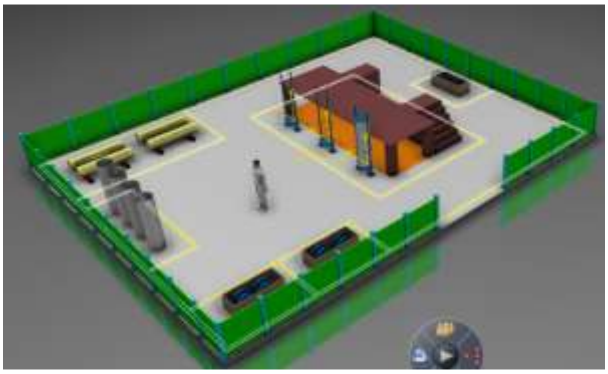

Fig.3 Old Layout

STAGE-III: In this stage the solution for the existing task is designed and virtually represented and ergonomically reviewed. Fig.4 shows the modified layout where bins for components side dish 1, side dish2 and tank holder were replaced with racks; platform for the inner tanks is increased in order to reduce the musculoskeletal disorders that may cause due to lifting of heavy components. From the results it can be seen that all the components are in easy reach of the operator and it can be drawn out that new solution is accepted according to biomechanics single action analysis.

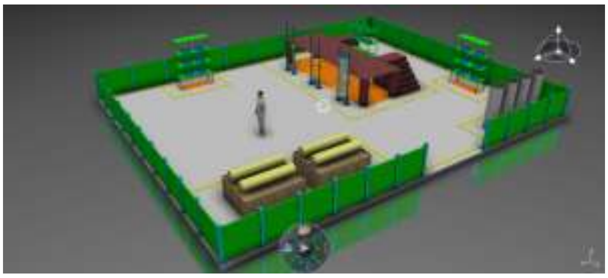

Fig.4 Modified Layout

Fig.5 RULA Analysis

Further analysis of the activity is carried out in LLA. It generally checks the maximum acceptable weight (load) that nearly all healthy employees could lift over the course of an 8 hour shift without increasing the risk of musculoskeletal disorders(MSD) to the lower back.

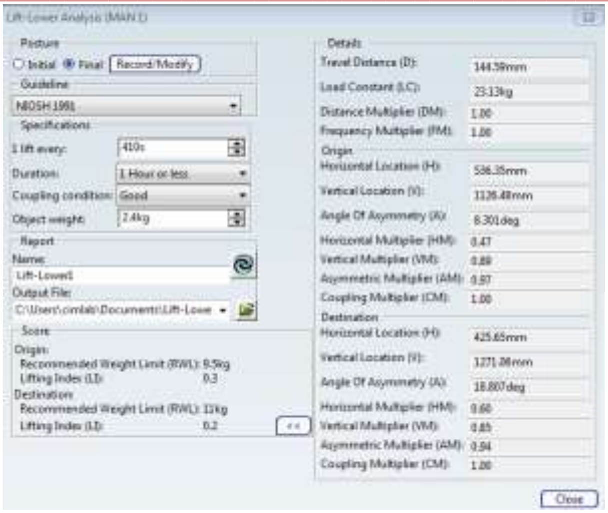

Fig.6 Lift Lower Analysis

Biomechanics single action analysis is an ergonomic tool measures biomechanical data on a worker/manikin in a given pose. From the current manikin posture, the Single Action Analysis tool calculates and outputs information such as the lumbar spinal loads (abdominal force, body movements, abdominal pressure) and the forces and moments on manikin joints.

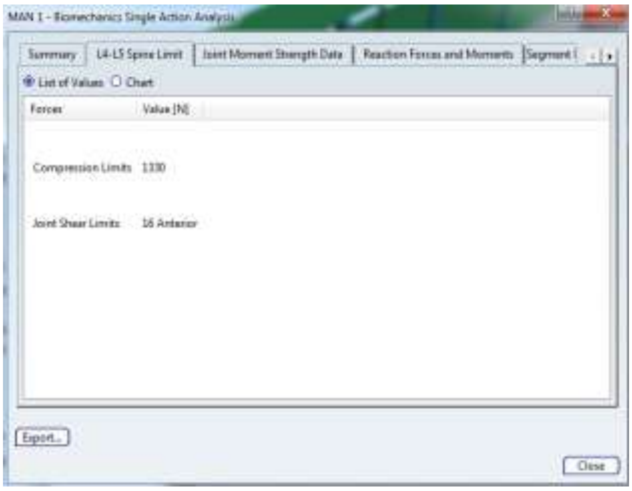

Fig.7 Biomechanics Single Action Analysis

4. RESULTS AND CONCLUSION

Here in Table-1, RULA scores, Table – 2 LLA scores and in Chart -1 BSAA scores (Compression limits (N)) for existing and modified layout are compared.

Component	Old Layout	Modified Layout
Side Dish 1	5	4
Side Dish 2	5	4
Inner Tank	7	6
Outer Tank	4	4
Tank Holder	4	4

Table.1

COMPONENT	LIFTING INDEX	
	OLD LAYOUT	MODIFIED LAYOUT
SIDE DISH 1	0.3	0.3
SIDE DISH 2	0.4	0.3
INNER TANK	1.4	1
OUTER TANK	0.8	0.7
TANK HOLDER	0.5	0.4

Table.2

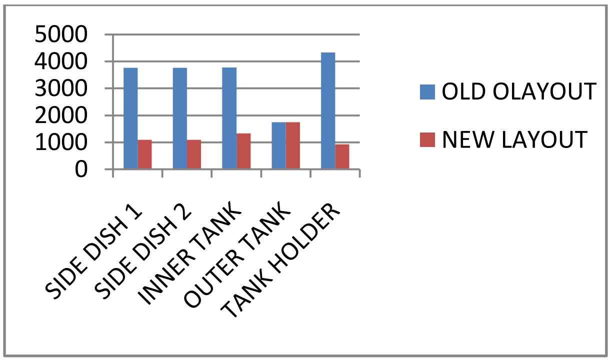

Chart.1

From the comparison of the results it can be concluded that modified layout is ergonomically safe, as it is accepted for all the ergonomic tests. The modified layout is not only ergonomically acceptable but it is optimum considering other aspects such as: the easiness in picking of the object reduces the time required for carrying out the task, which indirectly improves the productivity of the system. The time taken for entire activity is 545sec in old layout where as it is 407sec in modified layout. The MSD risk is reduced by modification in layout, so the activity will be less stressful for the operator and increases the job satisfaction. It is seen that, available space is also properly utilized.

In general from this case study it can be concluded that, the Virtual Ergonomics (VE) approach used in this paper can be implemented in any field to improve the productivity and reduce setup time for individual change in the product in the field of manufacturing, evaluate workplace and product designs with integration of human factors and ergonomics requirements. Detects potential for work-related injuries early in the design process and potential ergonomic issues can be found early in a product or workplace design phase. Designers can avert injuries in the workplace through early identification of potential ergonomics-related problems and analyze more solutions to find out optimum solution of any industrial problem without requiring additional investments and stoppage of production line.

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