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EARLY STAGE ERGONOMICS STUDY TO ENSURE SAFER MANUFACTURING WORK PLACE IN AUTOMOTIVE INDUSTRY- A CASE STUDY

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***Abstract*— Workplace ergonomics plays an important role in an automotive industry as quantum of work is done manually. Good ergonomically designed processes are key to employee's safety, good product quality and productivity. Organizations are working continuously to improve their processes in order to improve the workplace ergonomics. Acquiescent the importance and benefits that can be reaped from good ergonomically designed processes and for healthy and motivated workforce organizations are working proactively to identify the potential improvement areas. For automotive OEM's having large number of processes, it is difficult to identify ergonomics issues at early stages of new process design during launch of new products. Therefore, systematic approach along with effective management of study data is required for result oriented ergonomics improvement on large scale. An apt ergonomics study of processes will help to identify key ergonomics issues and also to sort them for prioritizing actions based on key studied parameter values. This paper presents methodology of early stage ergonomic study to ensure safer work place. This methodology is combination of existing ergonomics study methods which are integrated with process engineering software tool and uses 3D simulation tool for ergonomics posture analysis and improvement plan analysis. This integration is providing numerous benefits such as quick and systematic study, digitally managing information, automated results and reports of study for analysis. This detailed early stage analysis lead to root causes of ergonomic issues which is shown with the help of sample case of an assembly line.**

***Keywords*— Safety, Ergonomics, automotive, DELMIA Process Engineer, DELMIA V5, productivity, musculoskeletal disorders, cognitive ergonomics**

I. INTRODUCTION

Industrial organizations are facing intense competitions from both local and global players. For the industries which wish to have a competitive edge in present scenario, it is necessary to have healthy and motivated workforce for better product quality and excellence. For that, it is very important for organizations to provide ergonomically designed processes to prevent injuries, improve productivity, retain employees, or comply with local, state, regulatory systems requirements. Complexities in the jobs are increasing continuously which are well supported by advanced tools and techniques. But still there are many areas where manual handling of jobs or manual carrying-out of process steps required. Many of them are at awkward positions and that too repetitive in nature. In the absence of Ergonomic study with suitable available study methods, after- effects of the bad postures are reported late with reporting of frequent injuries. Ergonomics management is valuable as a cost reduction, quality improvement, performance improvement and productivity-enhancing process (Marilyn et al., 1995)

Industries today are facing multiple challenges to maintain the health and performance of employees while attempting to integrate new technologies and support a wide range of work styles. It is therefore needed to better understand the employees' demands related to their work area and then to evaluate their work areas and make the changes required for maintaining a healthy workforce (Dr. M Varaprasada Rao et al, 2015).

Major ergonomic risk factors are forces on body, awkward postures, Repetition and lack of recovery time, static work and environmental factors (Health & Safety Authority, Dublin (2019)).

In order to evaluate work areas and working postures, automobile industries are adopting various methods of study available globally. Adoption of these methods to work on a larger scale needs systematic approach and software tools for managing the information and analysis for effective

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improvement findings and implementations. With results from ergonomics studies, industries are actively working to design new processes considering the ergonomics aspects and also working towards improving existing processes continuously.
In this case study some imprints of the ergonomics study methodology of an automotive OEM are carved out and discussed.

II. LITERATURE REVIEW

Musculoskeletal disorders (MSDs) are very common health problems all over world and also a major cause of workplace disability (Punnett and Wegman, 2004). Ghasem khan et al, 2006) reported that the prevalence of MSD was found to be high among automotive assembly line workers. According to Yelin et al.(1999), 90% of disabled older workers had musculoskeletal disorders (MSDs). Jones and Kumar (2004), MSDs accounted for 32% of total claims cost and represents 40% of total time loss—more than any other injury category. Most commonly affected body regions are the low back, neck, shoulder, forearm and hand (Punnett and Wegman, 2004). Most of the work related MSDs are cumulative disorders which result from exposures to high or low intensity repeated loads over a long period of time (Singh et al., 2012). Work related MSDs, low back pain and other health problems result in increased absenteeism and lost working time, adverse effects on labour relations, higher insurance and compensation costs, increased probability of accidents and errors, job transfer and higher turnover of workers, more scrap and decreased production, low-quality work and high administrative and personnel costs (Cardinali, 1998; Miller, 1995; Niu, 2010; Widanarko et al., 2012). Which ultimately reduces productivity and increases cost to company.
In order to identify and evaluate workplace ergonomics issues various ergonomic risk assessment methods were developed over the years which consider multiple physical exposures in an integrated model of risk prediction. There are many popular methods used principally for ergonomics assessment such as RULA, REBA, OWAS, EAWS etc.

RULA is a simple diagnostic tool that allows surveying various tasks involving the upper limbs at workplace with focuses on use of arms, wrists, position of the head and the posture of the upper body. McAtamney and Corlett (1993) introduce RULA, or Rapid Upper Limb Assessment. It is developed to observe the operators who suffered upper limb disorders due to the musculoskeletal loading.
The RULA and REBA both are similar tools to evaluate the musculoskeletal disorders. REBA is an ergonomic assessment tool which uses an orderly process to evaluate whole body postural MSD and risk associated with workplaces. Hignett and McAtamney (2000) introduce REBA and stated that it is used to investigate posture for risk of work related musculoskeletal disorders (WRMSDs). REBA is a better tool for whole body parts (wrist, upper arm, lower arm, neck, trunk and legs,) REBA is user friendly and useful for manual task risk assessment. But here some drawback of REBA is: REBA does not give the combine assessment of biomechanical risk factors.
For REBA a single page worksheet is used to evaluate selected body posture, forceful excretion, type of movement or action, repetition and coupling. The evaluator will assign a score for different body region: Wrist, Forearms, Elbows, Shoulders, Neck, Trunk, Back, Legs and Knees. After data collected and scored. Risk factor variables are derived using these tables.

Ovako Working Posture Analyzing System (OWAS) was developed in conjunction with the finish Institute of Occupational Health. The method allows the analyst to record posture, load and force used according to categories. The procedure takes only a few seconds and may be used in conjunction with random schedule of observations to reflect the magnitude of risk (Li and Buckle, 1999).

European Assembly Worksheet (EAWS) screening tool enables perspective evaluation of individual workstation with respect to their ergonomic design quality. This checklist could be used as an objective and practical method of estimating physical workloads for automobile assembly work [Schaub et al., 2013].

In the last years DHM (Digital Human Modelling) software has been developed, provided with digital biomechanical models, for instance Jack (UGS), Ramsis (TechMat) and Delmia (Dassault Systemes), which allow to simulate human movements by specific tools. By this software's it is possible to create specific virtual environments with CAD data available, in which to insert the manikins; in such way the operator can be simulated during the productive task carrying out in his working place. This approach allows effecting all the necessary analyses before the productive line realization, reducing both design variation costs and execution times (Annarumma et al., 2008).
Evidence has shown that a proactive and systematic ergonomic approach will provide a work environment where people can develop new skill sets, including communication, critical thinking, creative thinking, problem solving, brainstorming, technical and influencing skills. These skills are very important in managing ergonomic risk effectively but can also be applied to other aspects of the business (Health & Safety Authority, Dublin (2019)).

III. ERGONOMICS STUDY METHODOLOGY, MANAGEMENT AND ANALYSIS IN AN AUTOMOTIVE INDUSTRY – CASE STUDY

A. Organization Under Study

This case study was conducted at an Indian automotive plant manufacturing Commercial Vehicles. Total Employee

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Strength was estimated at about 5000 and Number of different processes in the plant was about 3500.

B. Ergonomics Study Methodology

With the aim to provide safer working environment, focus was on to define and further improve processes ergonomically safe. Ergonomics Study was done by the organization with the aim to identify the processes having ergonomic issues from large number of processes and then plan actions to make them safe. Processes were to be prioritized so that process with high intensity of problems are resolved first then others. It was complex to carry-out study of large number of processes which are associated with different assembly lines, different vehicle models and having huge variant matrix. Therefore, it was required that ergonomics study should be done in structured manner for quick and effective results. Study cover workplace assessment of posture and force analysis, complexity, regulations and environment factors for each process.

For posture assessments there are various tools available in the market using Digital Human modeling and simulation of postures in the virtual environment which can be used to study each process, but study of large number of processes require huge efforts and time which was not viable. Therefore, to shortlist the critical processes, the study was first done using the Questionnaire based method. Questionnaire covers questions on postures, complexity, regulation & Environment areas. These questionnaires were prepared after study of various global standards such as NIOSH.

C. Questionnaire

The Questionnaire was divided into different segments for postures & force analysis, complexity, regulation & Environment areas

Posture and Force analysis questionnaire mainly covers back posture, arm posture, shoulder/arm movement, wrist posture, neck posture and lower limb posture values. This questionnaire captures extend of bending and frequency of movement, duration of total time spent on task, weight handled during the task and visual demand of work.

Complexity Questionnaire covers cognitive aspects at workplace. It covers factors like handling multiple tools, time variability in task completion, difficult access for positioning, precision important for positioning, Diversity of parts for positioning, risk of part scratching, high speed work etc. Figure 1 shows picture of Complexity Questionnaire from the in-house developed software tool.

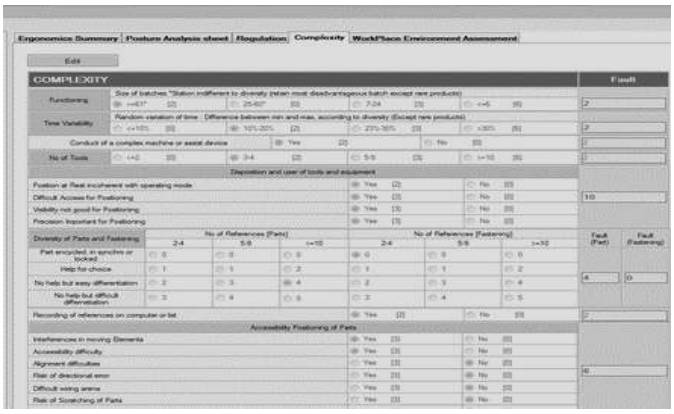


Fig. 1. Complexity Questionnaire in in-house developed software tool

Regulation Questionnaire covers overcrowding of workplace, variability of task, difficult packing, difficult removal of adhesive protection, work alignment, wearing of individual protection equipment which conforms but hinders in activity etc.

Key environment factors for study were vibrating tools, improper ambient light, unfavorable temperature, unfavorable noise levels, presence of smoke, dust, aerosol etc.

These questionnaires were filled for each process after directly interviewing the workforce working on the processes.

Results of questionnaire were analyzed and used for shortlisting of processes for further study using various available methods which include Digital Human Modeling using DELMIA.

For shortlisted processes RULA analysis (using DELMIA) was done and analyzed. Based on the outcome for improvement, changes in the processes were identified for ergonomic improvement of the process. DELMIA tool was also used to conceptualize the process in virtual environment and ergonomics studied before going for implementation.

D. Management of Ergonomics Study

For effective and efficient study, all the data captured from the questionnaire was required to be managed for further results and analysis with their change management. There was platform available for managing this customized study data. Organization was using DELMIA Process Engineer tool for process planning of large number of processes. Therefore, seamless integration of ergonomics study methodology & data with existing process information was a good idea for efficient and managed ergonomics study and analysis of processes. But it was a challenge to integrate in the absence of any ready-made solution.

As mentioned, this organization was using DELMIA Process Engineer for managing all the process information. Figure-2 shows process information in DELMIA Process Engineer software tool. This provides single source of truth to all users with all updated information's. Therefore, it was decided to

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find ways for ergonomics study and analysis on top of processes available in DELMIA Process Engineer.

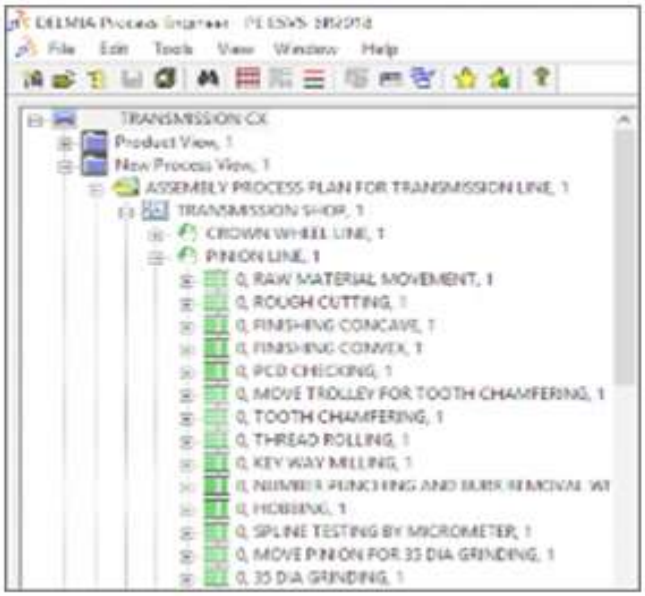


Fig. 2. Process Information in DELMIA Process Engineer

As a solution an in-house software application tool was designed & developed after deliberations which works in tight integration with DELMIA Process Engineer.

This in-house developed ergonomic study tool when launched presents the same process list from DELMIA Process Engineer for the selected vehicle program. For each process in the program, options were developed to do one or multiple ergonomic studies depending upon requirement based on sub-processes and complexity. These options were called as ergo cards which can be created as per need for each process. Larger and complex processes more ergo card whereas small and simple process can be studied using single ergo cards.
Each ergo card study comprises of questionnaire of all types discussed above. Information's gathered through interview of work-force is fed through this in-house software tool and saved in DELMIA Process Engineer. The seamless integration was the key for quick and effective study methodology which was otherwise complex & difficult. Complete flow-chart of ergonomics study is shown in Figure 3.
This integration also takes care of change management of processes using in-built features of DELMIA Process Engineer. This tool also provided the inbuilt capability to filter the data assembly line wise or product wise, therefore assisting to carry-out study and analysis in much easier manner.

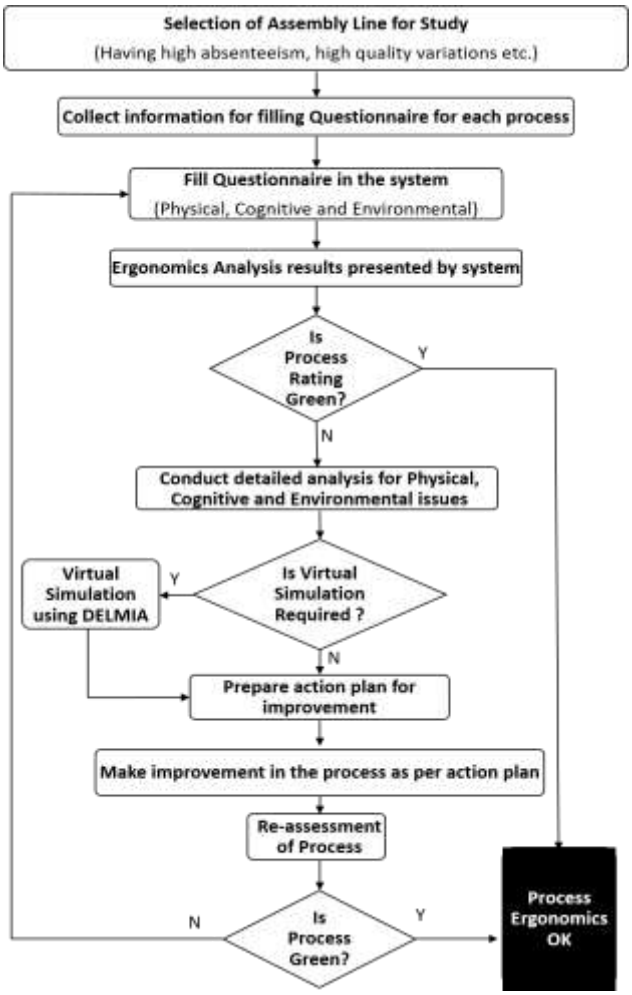


Fig. 3. Flowchart of Ergonomics study

E. Analysis and result representation of Ergonomics Study data

This in-house developed ergonomics tool automatically does the calculations based on standard methods and present the summary results, thus saving the time of doing calculations using excel sheets. There were many different kinds of results and analysis presented from the tool for the user. This tool presents quick dashboard information's like assembly –line wise ergonomics study completion status, assembly line wise-ergonomics study major parameter values. Results summary in the tabular form and graphical form for posture, complexity regulation etc. Similarly results summary was also presented for each process like results of posture analysis after calculations, which contains physical rating for exposures on different body areas. Calculated results are presented on the scales of Low, moderate, High and Very High. Posture Analysis Results are finally presented as percentage which is further divided into three zones Green, Yellow and Red. Similarly, results are presented for Cognitive analysis.

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Based on the rating given to the process in each of cognitive or posture analysis, the rating of the process is determined as the worst rating achieved in either case. For example, if a process comes out to be Green in posture assessment and Red in cognitive assessment, then the overall rating assigned to the process would be Red.

Along with the cognitive and posture analysis, workplace environment analysis was also carried out, due to the fact that some parameters are not accounted for in the posture or cognitive study. The parameters included in the workplace environment assessment deals with the environmental factors such as light, noise level, temperature etc.

Reports provided deep insights of the processes and underlying ergonomic issues which were not so much possible with study in isolated manner.

The in-house developed tool simplified all the exercises and results were presented directly after the questionnaire responses were fed into the system.

F. Actions Planning

After the analysis, shortlisted processes are analyzed for further actions. Some of the processes may require further analysis using simulation in virtual environment with the help of DELMIA Software as shown in Figure 4. Actions are planned based on the kind of improvement required, other department teams are also involved for finalizing actions for improvement.

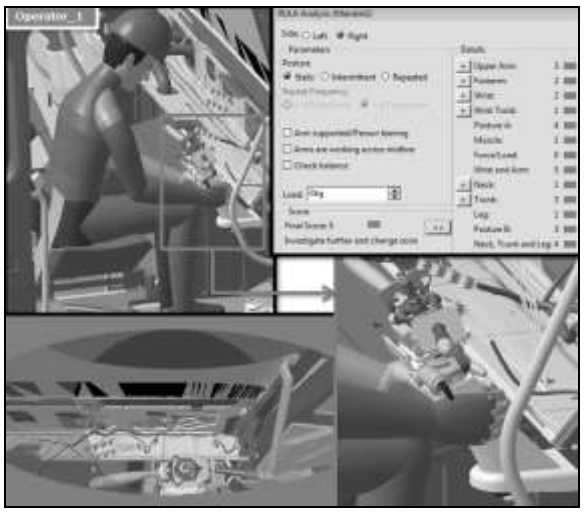


Fig. 4. Ergonomics Analysis using DELMIA Software

F. Re-assessment

Once the actions are implemented, re-assessment of the process was done to find out if the issue pertaining to the process has been resolved and accordingly status of process is updated in system.

G. Performance Indicators

Total number of red processes post study and total number of red process post reassessment are calculated which is further calculated in percentage as reduction in red processes after reassessment.

The % reduction in the number of areas is calculated as

[(Total Number of Red Processes post Study) – (Total Number of Red Processes post Re-assessment)]* 100 / (Total Number of Red Processes post Study)

H. Sample case

In order to establish the results, we have taken one assembly line comprising of 142 processes. During first time study it was found that 30 processes were in red category (high risk), 34 were in Yellow Category (moderate risk) and rest were in Green (no risk). High risk processes were further analyzed and it was found that there were 12 cases which needed Human Simulation for RULA Analysis for detail understanding of current problem and to validate suggested solutions.

With the help of system based approach, various analysis reports were readily available on few clicks of mouse which helped to drill down the problem causes quickly. Some of the common causes of ergonomic issues were identified as in-appropriate height to reach the assembly points. Obstruction due to other parts, difficult postures for underbody positions, difficult adjustments due to moving conveyor, blind work with difficulty in alignment. long duration for difficult postures etc.

Various solutions were adopted to resolve these ergonomic issues such as providing raised long platform, changes made in process sequence, work-station change for processes, manipulators were provided to assist load movement, existing tools were modified for better ergonomics, newly designed tools and jigs were provided for better reachability and alignment. In order to reduce complexity visual and color markings were done.

Solutions were prioritized and implemented one by one based on both criticalities of requirement and ease of deployment. After six months' same line was again studied with the same methodology as number of improvements were made on the line. Due to integrated approach having in-build feature of change management, changes made in processes were readily available for ergonomic study. This integrated approach helped to automatically filter only those processes which are affected and thus study was done in very quick time.

It was observed that after second study number of red status processes reduced to 3, number of yellow status processes was now 40 and rest were green processes. Therefore, about 90% of red processes were moved to either yellow or green category. Line stoppage data was also analyzed and it was observed that stoppages related to man factors has shown drop

of about 16% which was attributed to ergonomics related improvements made on assembly line.

It was also identified that this system based and integrated approach was very useful in reducing the study and analysis time which was reduced by about 55 percent due to automatic result generation and analysis report on clicks of button otherwise it was difficult to work with various excel sheets. Integrated approach was also helpful to provide process list and their details upfront without hassles of collecting from various sources.

IV. RESULT AND DISCUSSION

For ergonomically safe processes, ergonomics study and improvement are necessary for automotive manufacturing plants where lot of work is done manually. For large manufacturing units it is very difficult to manage ergonomics study data and to drive the improvements efficiently. Therefore, it is necessary that these studies must be done in a systematic manner with the help of some software tools designed to meet the purpose. In this case study, in-house developed software tool was very effective as it works in a seamless manner and integrates itself with the existing process engineering tool. It is difficult to perform RULA analysis for all processes using DELMIA Manikin for analyzing postures due to long time required to study large number of processes. Therefore, Questionnaire based approach was used & was found very useful to filter critical processes from ergonomic point of view.

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