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ERGONOMIC ANALYSIS AND WORKSTATION DESIGN FOR AUTOMATION IN STEEL INDUSTRY

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Abstract: This paper discusses the ergonomic analysis and workstation design for sheet-metal disc teeth cutting operation on a power press. Presently the operation under consideration is manual. The worker manually picks the disc from the input bin and places it onto a press bed for teeth cutting and after completion, removes the disc and places it into an output bin. Because of such repetitive task, the worker is prone to various musculoskeletal disorders (MSDs) and cumulative trauma disorders (CTDs). If the cycle time is further reduced, there will be gain in production quantitatively, but the efficiency of the worker will further reduce and there will be chances of fatal injuries. For studying the ergonomic conditions of the worker, a detailed RULA and REBA analysis of the worker is carried out. The analysis significantly proves that the present working conditions are not suitable for the worker and further reduction in cycle time will be harmful physically to the worker. Therefore, an alternative to the manual operation, a more sophisticated automated loading and unloading system is designed. A conceptual CAD model is developed for this purpose. The simulation of the CAD model is done, which verifies its workability. The design of the CAD model is done. The software used for RULA analysis and CAD model development and simulation is CATIA V5R19. For REBA analysis REBA assessment worksheet is used.

Keywords: RULA, REBA, Modeling, Ergonomic, Simulation, Automation

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INTRODUCTION

Material handling is a necessary, but wasteful and expensive activity in manufacturing and distributing. Insufficient material handling accounts for additional costs in two main ways: idle time and cost of labour. Effective material handling solutions can reduce a production or distribution facility's cost by significant amounts. The aim of the work described in this paper was to ergonomically analyze the working condition of the worker for a sheet-metal disc handling tasks, specifically for picking, transferring and placing, which have been identified as the most frequently encountered tasks in a number of industrial sectors and are currently performed manually. Their analysis and providing the alternative would greatly improve the productivity and cost effectiveness of these industries.

In the context of industrial jobs, manually transferring an object from one point to another (pick-and-place or hand transfer tasks) occurs frequently in the retail trades, manufacturing, and production assembly and is a common component for many machine-paced tasks. The time available to do one transfer (pick then place) will be referred to as cycle time (CT). There are certain effects and physical demands of speeding up the demands of the job by reducing the CT [5]. It results in mainly workers, muscle pain and tenderness of the neck and shoulder areas, and forearm extensors. Neck and shoulder complaints are also common in repetitive tasks, if the CT is reduced.

An MIDC, Hingna based steel industry named Bajaj steel Pvt. Ltd. is the leading manufacturer of the cotton ginning and pressing machinery in India. The sub-part of that machinery is an Impact Cleaner Machine which is used for cleaning the raw cotton. In that machine saw blades in the form of teathed disc are required for freeing the raw cotton. The teeth cutting on the disc is done on the power press. The pick-transfer-and-place operation of the disc on power press is presently being done manually by the worker. This paper suggests on the basis of an ergonomic analysis that an automated material handling system for that operation will perform efficiently and productivity gain can be obtained.

The present system is shown in the figure below:

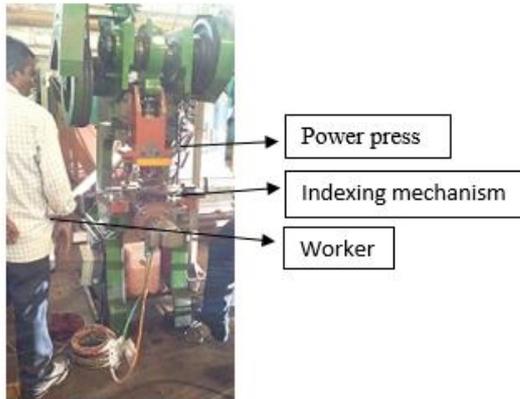


Figure 1 Present system

LITERATURE REVIEW

For carrying out the ergonomic analysis a detailed literature survey has been carried out. It shows effects of bad postural working conditions on human body. The bad postures and anthropometric data mismatch had contributed to musculoskeletal disorder problems. For designing the workstation it is necessary to obtain the relevant information or data on task performance, equipment, working posture and environment. In developing an industrial workstation, the designer should take into account workstation height. When the workstation is too high results in cramp in shoulder of worker whereas when the workstation is too low this may result in backache. Also as the operator is a highly paid skilled worker and machine time is very expensive the reduction in performance has far-reaching economical consequences for the user organisations. Material handling system and ergonomics go hand by hand. There is a link between ergonomics and material handling work which underlines the necessity to analyze and classify the manufacturing system layout configuration in relation to both technological and environmental parameters. The prevalence and incidence of work-related musculo-skeletal disorders (WMSDs) among industrial workers have been well recognized[5]. There have been documented work-related problems in the manufacturing industries such as electronics assembly, materials picking and assembly tasks, parts assembly, cashiering, laminate industry, and garment sewing and printing. Many of these jobs involve grasping and moving objects. The US Bureau of Labor Statistics reported that repetitive placing, grasping, and moving objects accounted for 31% of non-fatal occupational injuries in private industry workplaces that were associated with repetitive movement. Of these cases, 65% affected the fingers, hands, and the wrists and 11% make up shoulder-related complaints. Thus safe environment for workers is needed at the workplace.



Figure 2 Disc

III. RESEARCH METHODOLOGY

1. Subject

The object to be handled is a sheet-metal disc having:

Outer Dia. 40.64cm

Inner Dia. 18cm

No. of teeth 330

Thickness 1mm appr.

Material Spring Steel

2. RULA Analysis

RULA stands for *Rapid Upper Limb*

Assessment which is used for rapid assessment on neck and upper limb loading in mainly sedentary tasks (repetitive tasks). It was developed to investigate the exposure of individual workers to risks associated with work-related upper limb disorders. The RULA analysis examines the following risk factors: number of movements, static muscle work, force, working posture, and time worked without a break. All these factors combine to provide a final score that ranges from 1(Good) to 7(Worse).

2.1 Parameters Used for RULA Analysis

- 1) Posture: Intermittent
- 2) Repeat Frequency: Fewer than 4 times per minute

3) Worker's posture:

A) Arms are working across midline

B) Check balance

4) Load: 750 gm. Divided to 375 gm. on each arm.

5) Manikin: Japanese (Asian, closely resembling to Indian (Not listed in software)), male, weight 65 kg and height 170 cm approximately.

According to above parameters, a manikin is built under human builder module in CATIA as shown in figure 2. The load of the disc is shown by downward green arrows. The posture of the manikin is equivalent to the worker.

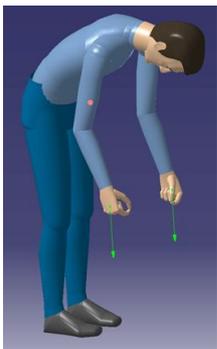
Figure 3. Manikin

2.2 Scores obtained

The RULA analysis is carried out for each posture of the worker for generating its individual score. The scores obtained from these analysis are then compared with that of REBA analysis scores. There postures are:

1. Disc pick-up from input bin

3. Disc placing on indexing machine



3. Finished disc placing in output bin.

2.2.1 Disc pick-up from stack ISC placing on indexing machine

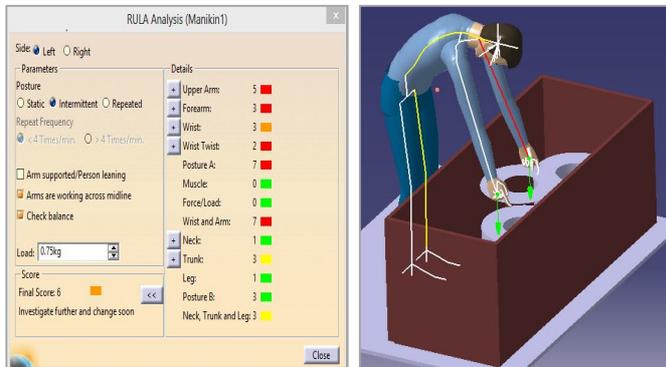


Figure 4(a) LHS Score

4(b) Tube view

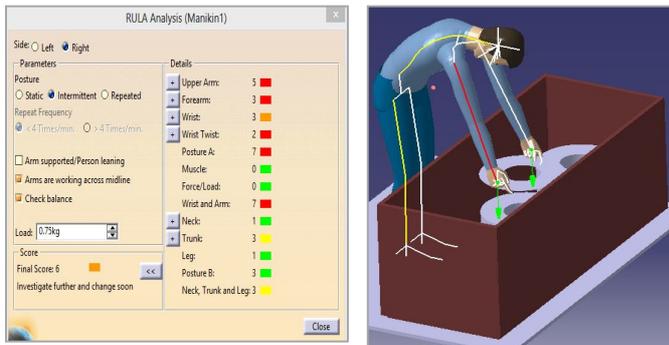


Figure 5(a) RHS Score

5(b) Tube view

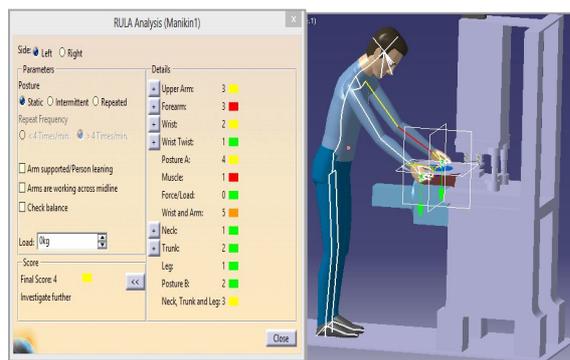


Figure 7(a) LHS Score

7(b) Tube view

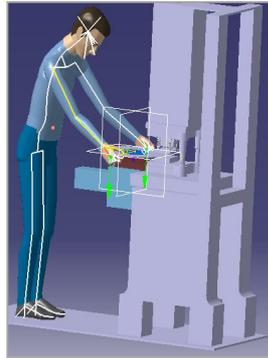
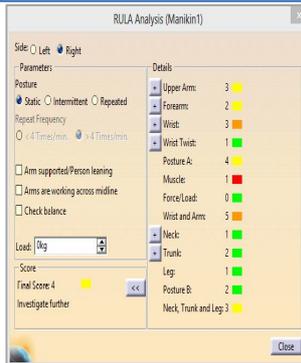


Figure 8(a) RHS Score

8(b) Tube view

2.2.3. Finished disc placing in output bin



Figure 9(a) LHS Score

9(b) Tube view

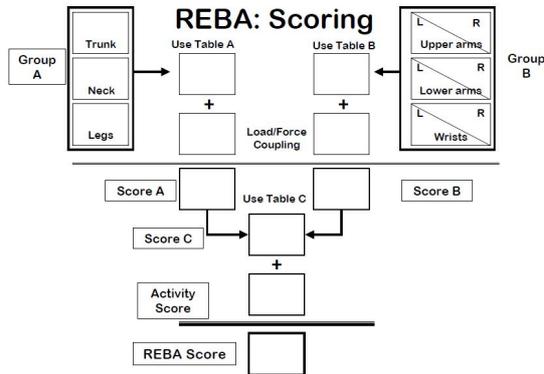


Figure 10(a) RHS Score

10(b) Tube view

load/force, coupling, activity level. Body regions considered are trunk, neck, legs, knees, upper and lower arms, wrists. Inter-observer reliability was found to be 62-85% for 14 users of REBA Analysis. (S. Hignett and L.McAtamney)

REBA scoring is carried out as shown in figure



3.1. Scores obtained:

A detailed REBA Analysis is carried out on the worker postures. The scores of each body region are calculated and are assembled with load, coupling and activity scores. The final scores are obtained for comparing with RULA scores.

3.1.1 Disc pick-up from input bin

The image shows two examples of the REBA Employee Assessment Worksheet. The first worksheet is for the task 'Disc pick-up from input bin' and shows scores for Neck (2), Trunk (3), Legs (1), Upper arms (2), Lower arms (2), and Wrists (1), resulting in a Total REBA Score of 11. The second worksheet is for the task 'Finished disc placing in output bin' and shows scores for Neck (2), Trunk (3), Legs (1), Upper arms (2), Lower arms (2), and Wrists (1), resulting in a Total REBA Score of 11.

3.1.3 Finished disc placing in output bin

The image shows a screenshot of the REBA Employee Assessment Worksheet for the task 'Finished disc placing in output bin'. It shows scores for Neck (2), Trunk (3), Legs (1), Upper arms (2), Lower arms (2), and Wrists (1), resulting in a Total REBA Score of 11.

IV. RESULTS

Method	Scores			Remarks
	Activity 1	Activity 2	Activity 3	
RULA	6	4	6	Investigate further & change soon
REBA	6	5	8	Medium risk, further investigate, implement change

As these scores suggests that there is a need of change in the present manual material handling system, a conceptual automated material handling system is suggested.

V. CONCEPTUAL CAD MODEL

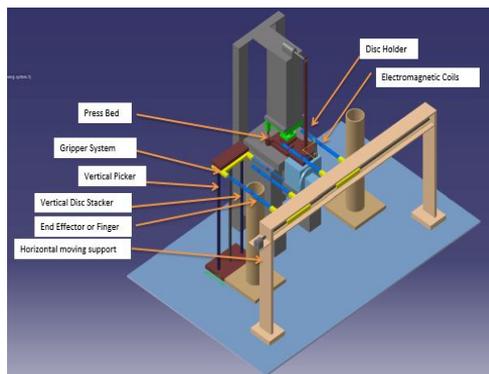


Figure 12. Conceptual CAD Model

Working of model is as follows:

The conceptual model in figure 12 depict the material handling system proposed for disc handling operation. There is a vertical picker equipped with gripper system to which end effectors in the form of two bars are attached. The end effectors have slots one on each bar for mounting the electromagnetic coil. There will be a proximity and tactile sensor attached to the end effector which will calculate the distance of the end effector from the disc in the stack and for the touch detection respectively. Vertical stacker is placed concentrically with the two bars of end effector. Vertical stacker has a key slot in which the discs with key will be stacked so as to maintain their orientation with respect to indexing machine key slot.

The horizontal support will be consists of two gripper systems having two bars each and the bars can be moved vertically when required. On each bar two electromagnetic coils will be mounted [4]. The vertical and horizontal movements to the gripper systems will be transferred by electric motors with the help of lead screw. A disc holder is attached to the press body which carries a thick metal disc and can be placed over the sheet-metal disc when clamping of the disc is required. The thick metal disc can be moved vertically with the help of a mechanism attached to a motor. There is another stacker serving as output bin in which the finished teathed disc will be placed. The vertical gripper system will be placed slightly above the horizontal gripper system.

The operation will be carried out as follows:

1) The vertical gripper system will move downwards, the sensor will sense the distance of the end effector from the disc in the stack and the motion will be transmitted from motor to the lead screw and ultimately to the end effector. As the end effector touches the disc in the stack the tactile sensor sense the touch and the current to the electromagnetic coil is passed which will create electromagnetism in the coil and the disc will be picked from the stack. The current to the electromagnetic coil will be sent as per the magnetic strength required to lift one disc at a time.

2) The vertical gripper carrying the disc will travel to its original top position.

While going to top position the horizontal gripper proximity sensor will sense the vertical gripper movement and when the vertical gripper will be crossing the horizontal gripper the electromagnetic colis in the horizontal gripper will be energized also at the same time current polarity in electromagnetic coils of vertical gripper will be reversed so as to loose its electromagnetism. Thus the horizontal gripper will be carrying the disc at this time.

3) Now the horizontal gripper will travel to its right with the disc attached to the end effector. The motion to the gripper will be transferred from motor to the lead screw and lead screw to the end effector. When the gripper will be above the indexing machine the end effector will travel downwards and will place the disc on the indexing machine.

4) The disc holder will now travel downwards and hold the sheet-metal disc in its place till the teeth are cut onto it. During this time the leftmost gripper will travel to its original position and will grab another disc from the vertical gripper.

5) When the teeth cutting will be completed onto the disc, the disc holder will move upwards. The rightmost horizontal gripper's end effector will travel downward and pick the teathed disc

from the indexing machine. It will carry the disc to the output vertical stacker, during which the leftmost horizontal gripper will place another disc onto the indexing machine. This cycle will go on and on until the discs in the stack are finished.

VI. CONCLUSIONS

The phase (1) of the project is done successfully. The RULA & REBA analysis are carried out on the present worker conditions and their results have shown the need of change in the present material handling system which is manual. Thus the development of automated material handling system is justified. The conceptual model developed has several advantages over the manual system. It can work continuously without much downtime. Significant productivity gain can be obtained as labour costs will be optimized. Now, phase (2) of the project will be carried out which constitutes FEM analysis of the model under loading conditions and development of working prototype of the model.

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