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Design of Multilevel Height Adjusting Industrial Trolley: Using Ergonomic Approach

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Abstract—*Often ergonomics and worker's safety is neglected when Quality and quantity of products are given priority in the industries. The paper aims to design a trolley with multi adjustment facility, so as to improve quality and quantity of the product manufactured as well as keeps the workers safe and healthy. In a large scale industry observations were taken for various operations and posture analysis was done for two different workstations which were using the same material handling device. The ergonomic assessment score for legs, neck and trunk came out to be 8. Such score is an indicator towards high risk of Work Related Musculoskeletal Disorders (WMSDs) in the operators. The operators were bound to use such postures because of the use of standard trolleys for all the workstations. The workstations under observation were on platforms of different heights depending upon the machine used for the respective operations. In order to maintain the quality of the finished product from one operation, it is required to place the product neatly in the trolley which has to be taken further to next workstation. The design aims to fulfill mainly three objectives, first is safety of the operator by providing better posture, second is to hold and transport the products without compromising on the quality and to be able to adjust the dimensions so as to fit in with different workstations. The design has two different adjustments, one is the coarse adjustment which is to facilitate with variable heights for workstations on different platforms and second is a self adjusting type spring loaded platform which pushes down the datum plane depending upon the weight of the products being placed on it. The new design was based on optimizing the ergonomic assessment score of about 3 using human manikin with anthropometric dimensions for 50th percentile.*

1. INTRODUCTION

Material handling equipments in an industry are one of the most important equipments which play role at every step of manufacturing, assembly and packaging. But material handling devices such as a trolley is mostly neglected in an industry as everyone is habitual to use it daily and only improve manufacturing systems, automatic machines, high precision and quantity. The material handling equipments like trolleys and conveyors also play a vital role in maintaining the quality and precision of products manufactured by the state of the art machines.

In this paper observations in a large scale industry has been taken with the trolley used for material handling at various workstations and its movement has been tracked. The trolley is used to carry a sheet metal component to various workstations located in the industry for various operations. All the workstations are designed as per the machine which is performing the operation; also the worker is standing on platforms on different heights. The trolley used is of a constant fixed dimension which has no flexibility to accommodate the variability in the heights of the platforms where the worker has to work.

Due to such problems the workers have to bend at extreme angles to reach the trolley base in order to keep the finished or machined product safely without damaging it. Workers have reported severe back and neck pains on frequent basis. In this paper a new trolley has been designed in order to reduce the risk of Work Related Musculoskeletal Disorders (WMSDs) in operators of the industry.

2. METHODOLOGY

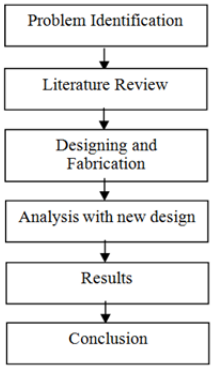

Fig. 1. Flow diagram of adopted methodology

The material handling trolley is a conventional trolley which cannot fulfill the requirements of variable dimensions of all workstations. Due to this inflexibility the workers and operators are bound to opt for the body postures which increase the risk of MSDs to develop in them. The need of a new flexible design of trolley has to be created in order to reduce the risk of injury and to improve the level of comfort and safety to the workers.

3. LITERATURE REVIEW

The need of a well flexible material handling trolley is not only for the operator's and worker's safety, but also for to maintain the quality and precision of the products manufactured. The ill postures which are opted by the workers effects their health in long term, as well as it reduces the output in terms of quantity of products produced per unit time. As the worker is stressed and tired due to pain and bad body posture, his/her speed of working will reduce which in turn will increase the machine idle time. Bad body posture is related to health, quality and quantity.

Segment	Score Range	Color associated to the score					
		1	2	3	4	5	6
Upper arm	1 to 6						
Forearm	1 to 3						
Wrist	1 to 4						
Wrist twist	1 to 2						
Neck	1 to 6						
Trunk	1 to 6						

Fig. 2. Body Segment-wise range of score and color coding [5]

Ghazali et al. [11] in the research work have shown the significance and working of ergonomic assessment tools. The application of tools like Rapid Entire Body Assessment (REBA) and Rapid Upper Limb Assessment (RULA) has been discussed. In order to do the assessment, photographs and video of the workers while performing the tasks and operations has to be taken as observations. These photograph are then analyzed to calculate the RULA or REBA scores on the basis of tables and charts. Depending upon the body postures and the angles between the limbs and other joints, the severity of the risk in that particular posture is judged. Larger the score value, more is the risk of injury and pains. Table 1 shows the relation of action to be taken with the score of ergonomic assessment.

Table 1: Relation between the assessment scores and the urgency of actions to be taken.

Action Level	REBA score	Risk level	Action (Including further assessment)
0	1	Negligible	None necessary
1	2 to 3	Low	May be necessary
2	4 to 7	Medium	Necessary
3	8 to 10	High	Necessary soon
4	11 to 15	Very High	Necessary NOW

Yadhu et al. [9] in the research has taken photographs of workers working in a food packaging industry. The workers using the conventional material handling devices were analyzed by their body postures. On the basis of the REBA score the risk and its severity was identified. The authors redesigned the material handling equipment and made a 3d model in CAD software. The CAD model was then analyzed in simulation software CATIA V5 to compare the assessment scores of old conventional method to the new method using a well designed equipment. The validation was done by reducing the REBA score with the help of better body posture and well designed equipment.

4. PROBLEM IDENTIFICATION AND OBJECTIVES

The industry makes several components which are supplied to parent companies, these parts are made by performing various operations on the metallic and non metallic components. The material handling device which was observed for this research paper is being used in the manufacturing of a sheet metal component. The metal component is processed and operated upon at multiple stages, and all the operations are done on automatic machines. These machines are high precision machines with high quality outputs, and are located as per the layout in the industry plant. Machines are of various sizes as per the operations they perform, and as per the size the platform and surroundings are constructed so as to facilitate the worker or operator to feed the machine and also to take out finished components from it.

The material handling equipment is required to work with all the workstations and to feed the machines and also to carry the finished products. The products which are manufactured at a high precision grade, are also required to be carried with a lot of care so that they are not damaged and the quality is maintained.

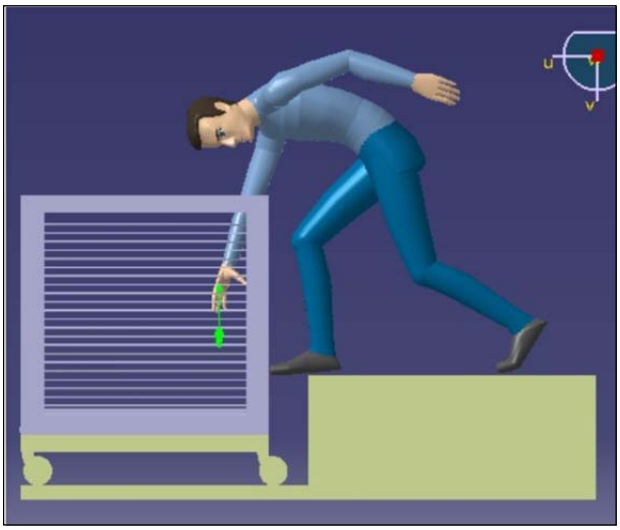

Fig. 3. Posture opted by the worker at one of the platforms.

In Fig. 3 the posture is opted by the operator in order to keep the finished product in to the trolley. As the product has to be taken care of regarding surface finish and precision in dimensions, it has to be kept on the datum of the trolley and not just thrown into it. In order to fulfill the requirements as per the product the worker has to opt for such extreme posture with a weight of about 500 grams per product, and the posture is repeated as many times as the number of products produced per day.

The posture has been built in the software using a manikin and by manually feeding the angles to it. The manikin available with the software was not according to the Indian anthropometric data so the dimensions have also been fed to the software, as per the following measurements, shown in Table 2.

Table 2: Measurements for the human builder as per Indian Anthropometric data.

Measurement	In millimeters
Stature	1648
Axilla Height	1265.5
Chest Height, standing	1180
Waist Height, omphalion	970
Crotch Height, standing	765
Acromion-radiale length	312
Radiale-stylion length	243

The above mentioned measurements are based on Indian anthropometric data for 50^{th} percentile of the population, so as to make such design of the trolley that fits for almost all the workers.

The manikin which is built as per the desired measurements has been used for the posture analysis and to calculate an ergonomic assessment score of "8" for legs, trunk and neck of the manikin. This score was analyzed on the basis of bent neck, bent trunk repeated load of 0.5kg. A score of "8" indicates that the risk of MSD is high onto the worker and an immediate action should be taken in order to improve the assessment score.

The objective is to design a material handling device such as a trolley which can fulfill the need of adjusting its datum according to the height of the operator or platform on which he/she is working. It is not possible to make elevated platforms for trolley as well at every machine, thus there is a need to re-design the conventional trolley to make it capable of flexible datum height.

5. TROLLEY DESIGN

The re-designing of the trolley has been done keeping in mind the objective of making the body posture of the operator better and to handle the products with maximum care. The design should be such that the ergonomic assessment score should be reduced.

The criteria are as follows:

- Improve the posture and ergonomic assessment score should be reduced.
- Live height adjustment when the products are placed into the trolley or they are taken out.
- Height adjustment according to the platform where the operators are standing.
- Handle the finished products with maximum care in order to prevent from damage to surface finish or dimensions.

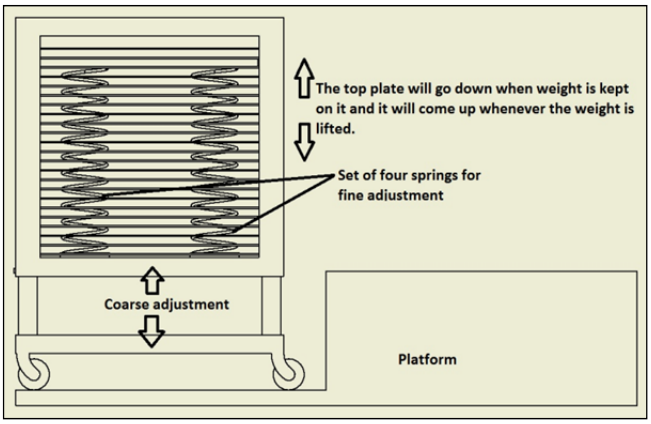

Fig. 4. Significant features of the trolley.

Fig. 4 shows significant features of the redesigned trolley. The trolley has four springs which facilitate as a dispenser with height adjustment according to the weight kept on it. The height adjustment is live, if the weight is kept on the top plate it will go down and if the weight is lifted from the top plate it will come up. This helps in keeping the top plate at a constant height which is suitable to the operator or the worker. The details of the spring specifications are as follows, which have been calculated as per the weight of the product kept on it and the deflection of the spring required.

Minimum load: 2.5 N

Maximum load: 600 N

Working load: 5 N

Wire diameter: 9mm

Outside Diameter: 150mm

Loose spring length: 650mm

No. of active coils: 13

Material: Steel

Stiffness: 1.7N/mm

Apart from the live adjustment, the trolley will be able to adjust its spring base which has been termed as coarse adjustment. This adjustment is provided so as to meet the requirement of varied height of the platforms. Fig. 5 shows a 3D view of the trolley.

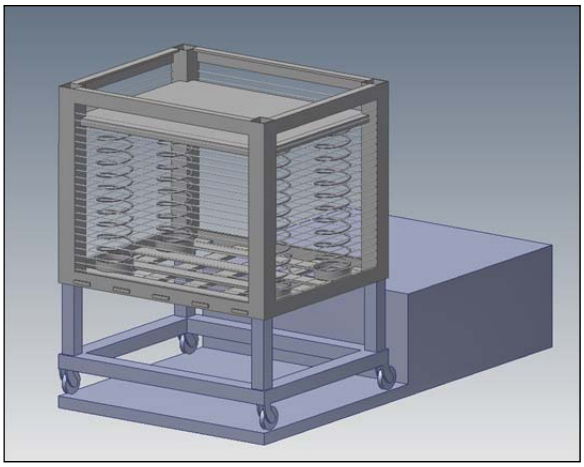

Fig. 5. Three dimensional view of the trolley

6. RESULTS

The new design of the trolley has been made using a 3D modeling tool and the dimensions are taken as per the 50th percentile of the population and referred to the Indian Anthropometric data. The 3D model was then assembled using the same tool and the mechanism was tested. The springs calculations were done and then it was exported into a simulation software which was used to evaluate the ergonomic assessment score. Fig. 6 shows the model in simulation software environment.

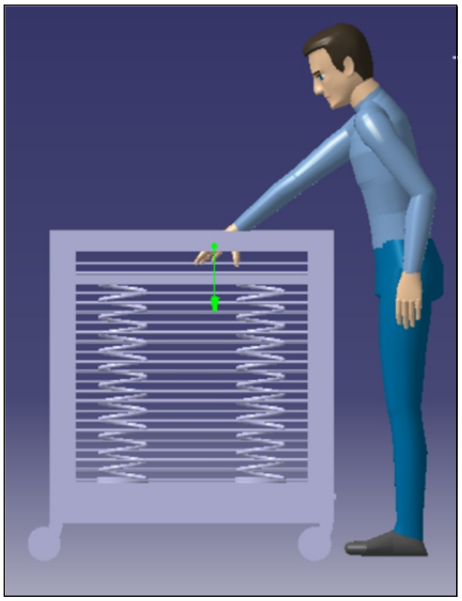

Fig. 6. Manikin and trolley in simulation software environment.

The new analysis report gave ergonomic assessment score as "3" for the posture of worker with the new trolley. This score is based upon no neck bending, no trunk bending and no legs bending. The arms working across the mid line and repeated load of 0.5kg is applied. The new assessment score showed improvement in the posture and thus reducing the risk of injury in workers. The comparison of scores is shown in the Table 3 below.

Table 3. Comparisons of ergonomic assessment scores.

Body segment	Old design		New Design	
	Posture A	Posture B	Posture A	Posture B
Neck	4	8	1	3
Trunk	4	8	2	3
Legs	1	8	1	3

7. CONCLUSION

The new design of trolley which is capable of coarse and fine adjustment is able to show significant improvements in the body posture. Also the features of the new design will help to maintain the quality of finished products as they are manufactured.

The improved body posture will help the operators to perform with much higher efficiency and will effectively reduce the machine idle time as well. The new trolley once manufactured and used in the industry will improve health of workers, quality and quantity of the products. The new design of material handling will improve the overall performance of the industry and in the long run increase the profits as well.

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