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Design of Material Handling System Based On Anthropometric Data and its Ergonomic Evaluation

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Abstract: A study for ergonomics was carried out in a stone polishing plant in Solapur, Maharashtra to understand the current material handling methods in the said plant. It was found that the major way of material handling in the plants is manual and is done by bare hands by the workers. Rapid Upper Limb Assessment was used to ascertain the level of comfort and safety of postures of these workers. The assessment gave a result of 7 for every step in the material handling activity. Anthropometric data was collected from various plants and statistical survey was carried out. Later a material handling system was designed using design and modeling softwares. At the end ergonomic analysis was carried out on the newly designed material handling system to assess the improvement in comfort and safety.

KEYWORDS: RULA, Anthropometry, Design

I. INTRODUCTION

Ergonomics (or its synonym human factors) is “the scientific discipline concerned with the understanding of the 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 wellbeing and overall system performance”, and it considers both a social goal (human wellbeing) and an economic goal (overall system performance), these two goals are corresponding to dimensions of sustainability. (mmh niosh 2007)

Anthropometry is derived from greek word “anthropos” meaning human and “metron” meaning to measure, refers to measurement of human individual. An early tool of physical anthropology, it has been used for identification, for the purpose of understanding human physical variation. It involves the systematic measurement of the physical properties of the human body, primarily dimensional descriptors of body size and shape. (bridger 1995). The RULA (Rapid Upper Limb Assessment) system was developed at the University of Nottingham's Institute for Occupational Ergonomics (Reference: Lynn McAtamney and E. Nigel Corlett, RULA: A Survey Method for the Investigation of Work-related Upper Limb Disorders). It was developed to investigate the exposure of individual workers to risks associated with work-related upper limb disorders.

II. LITERATURE SURVEY

as stated by quaid khan Et al. (2015) Marble industry is a major industry that affects the Gross Domestic Product of any country. Unsafe working environment is causing the workers to be exposed to health problems at alarming levels. Protection of labor reduces the social costs associated with safety. A systematic approach needs to be utilised to check working environment.

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Tarwinder Singh, (July 2014) et. al. surveyed Three electronic industries in an around Chandigarh. It was observed that the manual lifting tasks were the most critical task, resulted in MSDs amongst workers. These tasks were analyzed by using RULA and REBA techniques. They suggested successful improvements.

Raghunathan Rajesh, et. al (December 2013) identified The causes of ergonomic stressors at a hazardous location in a manufacturing plant. The ergonomic redesign of manual material worksystem was done. The design solution provides a significant reduction in stress on lower back. It was identified that there is scope for further study to explore the impact of ergonomic interventions on productivity.

Dohyung Kee et. al. (2007) Carried out a study aimed to compare 3 observational techniques for assessing postural load, namely, OWAS, RULA, and REBA. The inter-method reliability for postural load category between OWAS and RULA was just 29.2%, and the reliability between RULA and REBA was 48.2%. This was helping in deciding RULA as a method for ergonomic evaluation.

III. METHODOLOGY

First an anthropometric survey was carried out with help of ISO 7250 using an anthropometer and then these values were used to design a material handling system. The material handling system was modeled in CATIA and the 2D drawings were obtained in SolidWorks. CATIA was used to carry out the ergonomic analysis.

IV. SELECTION OF ANTHROPOMETRIC PARAMETERS

Five anthropometric measurements were chosen as the basis to design, they were:

Shoulder height is chosen so that the worker will always work staying upright.

Length of elbow is chosen as a parameter so that the handle stays close to the workers body so that he doesn't have to bend or stoop.

Span is chosen as a parameter so that the pillars are no far placed so that they are within capacity of the worker.

Grip reach is chosen so that the worker is not placed too far away from the pillars.

Maximum grip breadth and grip inside diameter are chosen to design the handle and the hand wheel so that these can be handled optimally.

V. SELECTION OF SUBJECTS

The subjects chosen were workers working at various marble industries in solapur. There are 10 workers in siddeshwar marble industries. 50 workers were chosen, who came from different backgrounds. They speak languages like Marathi, Kannada, Hindi and Telugu. They are of age groups between 18 to 52.

VI. STATISTICAL ANALYSIS AND PRESENTATION OF DATA

An anthropometer was used to carry out measurements of workers at various stone polishing plants in solapur. Measurement were taken and noted. The workers were made to stand erect on horizontal surface and without any footwear. Series of measurements were then taken. Following are the various measurements that were taken. Following tables hold the data that was gathered by travelling around various stone processing units in and around Solapur. The data was taken from different places so that it is random and to avoid repetition.

Table 1: anthropometric measurements

Six major measurements were chosen which affected the design ergonomically and the check for normality and other statistical analysis were carried out using IBM SPSS 16 software. The mean, median and standard deviation were found and maximum and minimum of each measurement were found out. The data was first analysed to get the

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test of normality. The sigma values were found to be within range and hence this data was further utilised to get the maximum and minimum values. The fifth and 95th percentiles were also found out.

The results are as follows

Fig 1: frequency statistics tool in SPSS

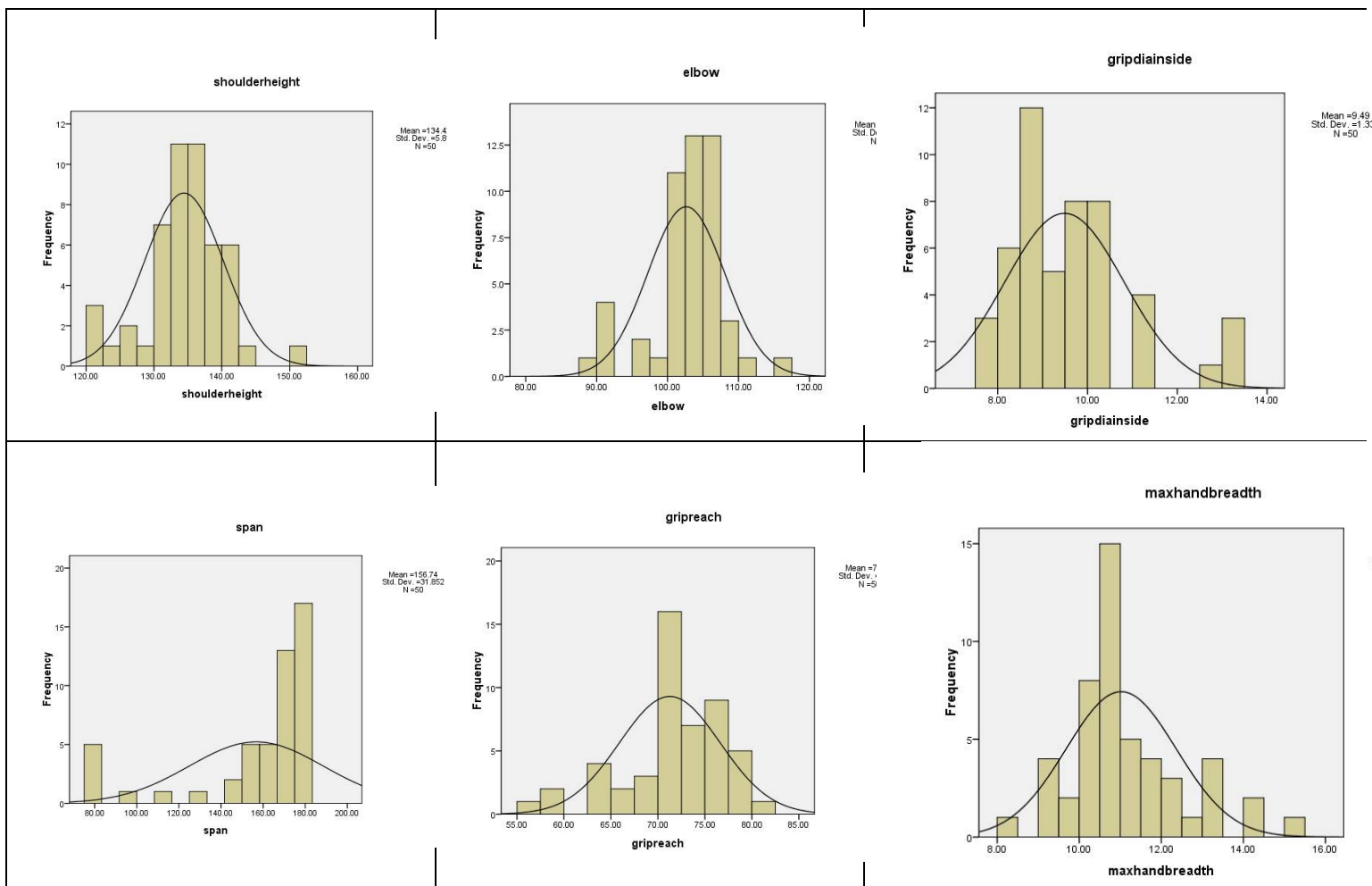


Fig 3: histogram of selected measurements

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	Shoulderheight	elbow	Span	gripreach	maxhandbreadth	gripdiainside	
N	Valid	50	50	50	50	50	
	Missing	0	0	0	0	0	
	Mean	134.4220	1.0263E2	1.5674E2	71.2600	11.0220	9.4860
	Median	134.5000	1.0400E2	1.7100E2	72.0000	10.7000	9.2000
	Mode	134.00	102.00a	178.00	75.00	10.50	10.00
	Std. Deviation	5.81537	5.43973	3.18522E1	5.36226	1.34184	1.33172
	Variance	33.818	29.591	1.015E3	28.754	1.801	1.773
	Skewness	-.321	-.821	-1.793	-.939	.893	1.215
	Std. Error of Skewness	.337	.337	.337	.337	.337	.337
	Kurtosis	.860	1.376	1.988	.875	.931	1.319
	Std. Error of Kurtosis	.662	.662	.662	.662	.662	.662
	Minimum	121.00	89.00	75.00	56.00	8.40	7.80
	Maximum	150.00	116.00	182.00	80.00	15.00	13.00

Multiple modes exist. The smallest value is shown

Table2: results of stastical analysis

For designing the following values were choden:

Shoulder height – 5th percentile 117cm

Elbow length - 5th percentile 94.32cm

Span - 5th percentile 88.65cm

Grip reach- 5th percentile 61.2cm

Maximum hand breadth- 95th percentile 13.36cm

Grip diameter - 95th percentile 11.879cm

These values were used to decide the basic dimensions of the material handling system. The distance of the worker stands 612mm away from the cart because of his maximum grip reach, the handwheel has to be placed at 943.2mm because of the elbow height. The vertical columns have to be higher than 1170mm because of the shoulder height. The handle of the handwheel has to be larger than 133.6mm because of the maximum hand breadth and its diameter has to be more than 11.879mm

VII. DESIGN

The material handling system works as shown in the figure. A moving platform is placed on two columns that's moves up and down with the help of a screw jack. The worker slides the slab on to the platform and clamps it. He then lowers the platform by rotating the handwheel and then pushes the trolley to the storage area. He then unclamps the slab and then pushes the slab into the storage area.

The design began with frame on which the other components had to be placed. Tata structura rectangular pipes of various were used for this purpose. A higher factor of safety was assumed while designed. A proper balance was tried to be obtained between safety and economy.

Later the actuator mechanism was chosen for the lifting of slabs. Among various options that included hydraulic jack and rack and pinion mechanism a screw jack was chosen. The load was already

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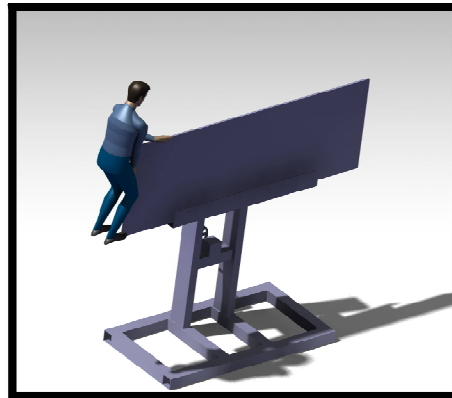


Fig 4: working of the material handling system

chosen based on the torque a human hand can generate. Appropriate calculations based on the literature available were carried out and it was found that the said screw jack is safe in all respects.

Finally for the ease of movement urethane on steel castor wheels with brakes were chosen. Four such wheels were chosen with one at each respective corner. \

The components of the design are:

1. Vertical column
2. Base
3. Handwheel
4. Lifting platform
5. Screw jack
6. Clamp
7. Castor Whee

The material handling equipment is basically a trolley with a lifting platform. This platform is lifted using a screw jack. The screw jack is operated manually with a hand wheel. The trolley is provided with four castor wheels one on each corner.

Component	Specifications
Frame	of vertical members= $60 \times 40 \times 3.60\text{mm}$
	Design of horizontal member- $100 \times 100 \times 6\text{mm}$
	Smaller horizontal member- $100 \times 100 \times 6\text{mm}$ Total dimension= $1900 \times 2113.50 \times 1000\text{mm}$
gear box	Root diameter of worm, $=40.63\text{mm}$ Axial module = 8mm Pitch diameter of worm= 50mm Lead angle, $\gamma = 9.09^\circ$

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	<p>$\alpha = 20^\circ$ full depth involute Face width $L_1 = 113.6\text{mm}$ Depth of tooth $h_1 = 17.24\text{mm}$ Addendum $ha_1 = 8\text{mm}$ Outside diameter of worm $= 66\text{mm}$</p> <p>diametric quotient, $q = 6.25\text{mm}$ Axial module, $m = 8\text{mm}$ Normal module $= 7.799\text{mm}$ Dedendum, $hf_1 = 9.37\text{mm}$ Root diameter of worm $= 40.63\text{mm}$</p> <p>PCD of worm wheel, $d_2 = 40\text{mm}$ Face width of worm wheel, $b = 37.5$ addendum, $ha_2 = 7.799\text{mm}$ Outside diameter of worm wheel= 55.598mm</p> <p>bolts: Material – plain carbon steel 45C8 $d_c = 9.67\text{mm}, d = 12\text{mm}$ The standard size of bolt is M12.</p>
Castor wheels	<p>Weight on each wheel = $636.89\text{ lbs} = 288.88\text{kg}$ Series 30 medium load capacity Dia- 5" = 127mm Width- 2" = 50.8mm Capacity- 900 lbs = 408.233kg Bolts 30C8 plane carbon steel $d_c = 10\text{mm}$ $d \approx 12\text{mm}$ Hence the required bolts are M12.</p>
Screw jack	<p>Nominal diameter = 26mm Pitch = 6.35mm Mean diameter = 22.825mm Starting torque, $T = 27.067\text{ N-mm}$ $d_c = 19.65\text{mm}$</p> <p>material – mild steel 30C8</p>

Table 3: results of design calculations

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VIII. ECONOMIC IMPACT

wage of the worker per day = Rs 300

no. of workers required to handle one slab=5

time required to lower one slab= 60 seconds

cost of newly designed material handling system = Rs 29,631

no. of slabs handled by new material handling system at one time = 5

no. of tiles= $\frac{\text{total weight in truck}}{\text{weight of one tile}} = \frac{26000}{147} = 177$ tiles

total time required to manually unload the truck= $177 \times 60 = 10620 = 3$ hours

cost of one complete manual unloading of slabs= wage per worker \times no. of workers
= $300 \times 5 = 1500$ Rs

But, no. of workers required to lower the slab = 3

Cost of one complete unloading of slabs = $3 \times 300 = 900$ Rs

Total time required to recover total cost of the new material handling system = $\frac{29631}{1500} = 20$ unloading operations.

IX. ERGONOMIC ANALYSIS OF THE NEW MATERIAL HANDLING SYSTEM FOR UNLOADING RAW MATERIALS

The new design was tested to do the operation of handling raw materials and RULA analysis was conducted over it. So that its results could be compared with the results of earlier operations. As done before the manikin was modelled in catia and the RULA analysis was done. In this operation the slabs need to be lowered from the truck and placed on the trolley. A worker pushes the trolley near the truck and and raises the platform. A worker standing on truck slides the slab on the platform and clamps it. The worker on the ground then lowers the platform. The worker then pushes the trolley towards the storage area. He then applies brakes on the castor wheel. He then removes the clamp and then pushes the slab into a stack.

Step1-moving the trolley to the required spot

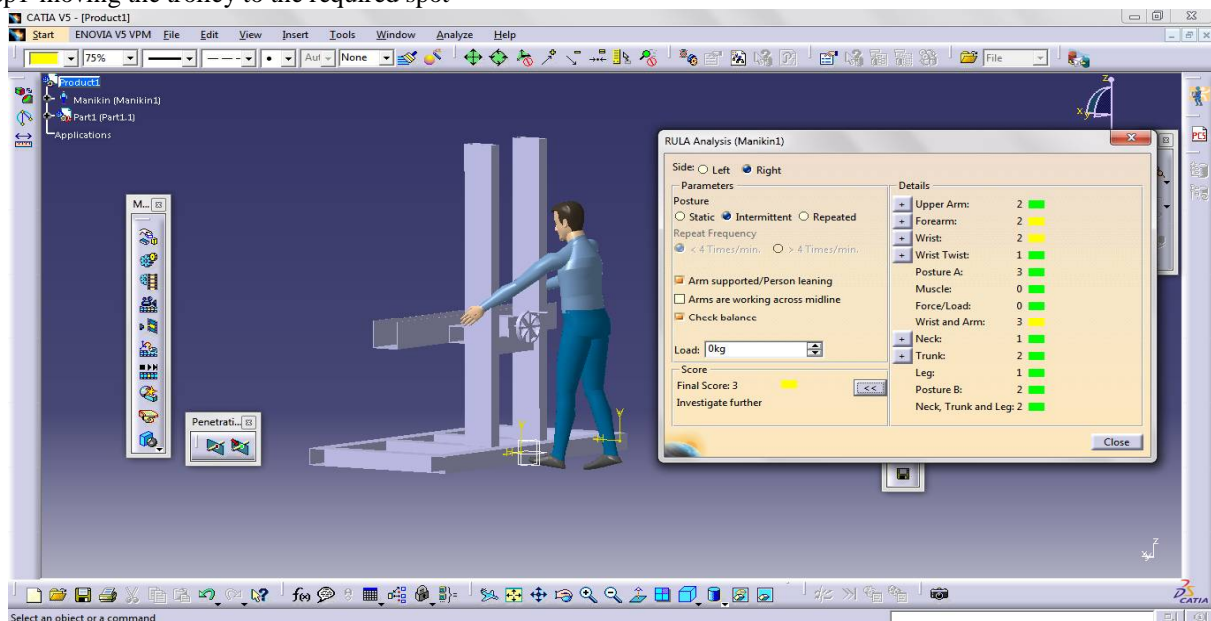


Fig 5: result of RULA for step1

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The worker here first pushes the empty cart towards the truck. He pushes the truck by the two columns. The final RULA score obtained is 3, earlier for the same activity the score was 7 hence we can say the comfort has increased.

Step 2- lifting the rack by rotating the handwheel

The worker is rotating the handwheel here. The worker rotates the handwheel to lift the platform until it reaches the height same as that of the truck. This activity was not present earlier so it cannot be directly compared. But it forms a part of the activity of carrying the slab whose score was earlier 7 but now it has reduced to 4. Hence we can say that the comfort has increased.

Step 3- placing the slab on the rack

The worker is now transferring the slabs on the trolley from the truck. The worker pushes the slab on the platform and clamps it, The RULA score for this was 7 earlier now it has reduced. Hence we can say there is increase in comfort level.

Step 4- lowering the rack by rotating the handwheel

The worker here is lowering the slab. four persons were required earlier for this activity. Now only 2 are required. The RULA score earlier was 7 now it has reduced to 4 hence we can say comfort has increased. Here wrist score is slightly high while turning the handle.

Step 5- pushing the cart to the storage area

The worker now pushes the cart to the storage area . The score of wrist is 2 and posture is 3 which is considerably low than the earlier method and within limit.

Step 6- removing the slab from the trolley

In this activity the worker pushes the slabs from the platform into the stack. Due to the rollers on the platform the force required to push is reduced considerably. The RULA score for this activity is 3 which was earlier 7. Hence we can say that the activity is comfortable. Three people were required to carry out this task now only 1 is required.

Table of results:

s. no.	Step 1	Step 2	Step 3a	Step 3b	Step 3c	Step 4a	Step 4b	Step 4c	Step 5a	Step 5b	Step 5c	Step 6
RULA of earlier activity	7	7	7	7	7	7	7	7	7	7	7	7
RULA of changed activity	4	4	4	4	4	4	3	3	3	4	4	4

Table 5: comparison of RULA results of earlier and newly designed material handling system

When compared with the results of activity carried out earlier the RULA analysis shows that the activity being carried out now is more comfortable and hence safe.

X. CONCLUSION

The anthropometric survey gave a range of measurements required for the design to be suitable for a range of people. The design was done on CATIA which enabled faster drafting and 3D modeling. Ergonomic analysis helped to determine the level of comfort obtained by using the new design. The RULA score obtained was 3 which is within limit

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of comfort. The cost of device was found to be Rs 29631 and it was found that the total cost of machine can be recovered if the material handling system was used 20 times.

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