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Analysis of Ergonomics for Making Precision Work In Indian Manufacturing Industry that Consider for Productivity

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Abstract

Manufacturers are determining for automated equipment to accelerate and improve their productivity, but implement an ergonomically designed environment, further increases the productivity. In this context small scale manufacturers are lagging behind due to neglecting the ergonomics consideration. It is essential to consider ergonomics and production when designing workplace for manual material handling tasks. Process quality, costs and productivity highly influenced on the human postures (e.g. Mental and Physical work load, comfort, personal satisfaction etc.). In this study, we consider carrying the Multi-pin crankshaft in the container to load for CNC lathe machine. Present study made an endeavour to assess and improve the lifting height with respect to constant mass of the component in the digital environment using DHM (digital human models) for the prevention of work-related musculoskeletal disorders (MSD). The different postural score of body part obtained from an eminent validated posture analysis tools called rapid upper limb assessment (RULA) and Lower Back Analysis (LBA) are used for ergonomic design improvement for 50th and 95th percentile male workers.

Keywords; *Ergonomics, Lifting height, Lower back, RULA, Simulation*

I. INTRODUCTION

A suitable ergonomic design is vital to prevent repetitious strain injuries and further work-related musculoskeletal disorders (WMSDs), which can lead to long term disability and over time. WMSDs are described to happen as a result of jobs that lay muscles under moderate physical demand [1].Virtual environment (VE) methodology approach to the Human-centred product design through digital human modelling system (DHM) is helpful for development of product. VE is computer generated 3D graphics environment used for numerous types of simulation and modelling actions [2]. Better performance and efficiency can be attained without conceding safety of the workers, thus it is necessary to give importance to workplace environment, considering proper tool design and equipment's for the prospective of anthropometric data for the industry workers [3]. Ergonomic factor of industrial workstations is very crucial for reducing the musculoskeletal disorders which helps to the productivity. DHM helps to evaluate the performance of human operator for the material handling with respect the workplace design. There are various methods to analyse the ergonomics such as RULA, NIOSH, OWAS, [5] static strength prediction, Fatigue recovery, predetermined motion time. Each method indicates the disorders in Human performance with respect to height, mass of the object, motion with the object etc. [4]. RULA help us to evaluate the exposure of operators to the risk

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of upper limb disorders based on posture, weight of the load and frequency and time of the task. Hence to optimize the disorders we should give attention towards the new design for the ergonomics modification. RULA report records the scores credited to muscle use, load weight and posture (discrete scores for the upper arm, wrist, lower arm, neck, trunk and legs). The scale of these separate scores can help recognize the phases of a task that are in the utmost need for the modification [6, 7]. Automotive industries developed new designs for various factors to minimizes or optimize the MSD [8, 9] such as biomechanical analysis using CAD software's helps to find optimum force required, degree of bending positions, limiting mass with respect to time and human factors (height and Weight). Fatigue recovery during the process due to lifting the components in automotive industries is predicted using Tecnomatix Jack software, by using this we can compute the time required to recovery for a job. If it is not enough it accommodate recovery time for the operators or workers to eliminate the fatigue risk. To obtain ergonomic and joint angles analyses, for different postures is predicted from lab-based physical tasks. There is significant in predicted and real postures has seen for joints and angles [10]. We can estimate spinal force using lower back analysis on a virtual human modal for different loading conditions and postures. Shear force, torque moments and muscle strain acting on the L4/L5 joints can be identifying for different interval of time. To Predict manual work operations [11] proposed a framework to identify risk and asses ergonomic related tasks. However, currently the system used for Industrial practice, there are some limitations for assessment of ergonomics: there is a gap between ergonomic assessment tool and industries to analysis for virtual manufacturing systems. Some tools are difficult to simulate for the virtual manufacturing system related to the digital human. No provision for dynamic investigation via simultaneous recording and ergonomic examination. This leads to obstruct efficient evaluation of ergonomic.

II. METHOD

A. Build the model for lifting task

Developed a process to find out best workplace design for different heights for lifting a object. Virtual Environment was created which consists of crankshaft storage container with a digital human model. To execute the simulation process we used Tecnomatix JACK^{TM} software 8.4 version. Initially we determine the workplace parameters and calculated cycle time to complete the process i.e. lifting the component form storage container and walk towards lathe machine to load the component. We used Rapid Upper Limb Assessment (RULA) and Lower Back Analysis (LBA) tools to find optimal solutions for different percentile male workers. Flow of ergonomics simulation is illustrated in Fig 1.

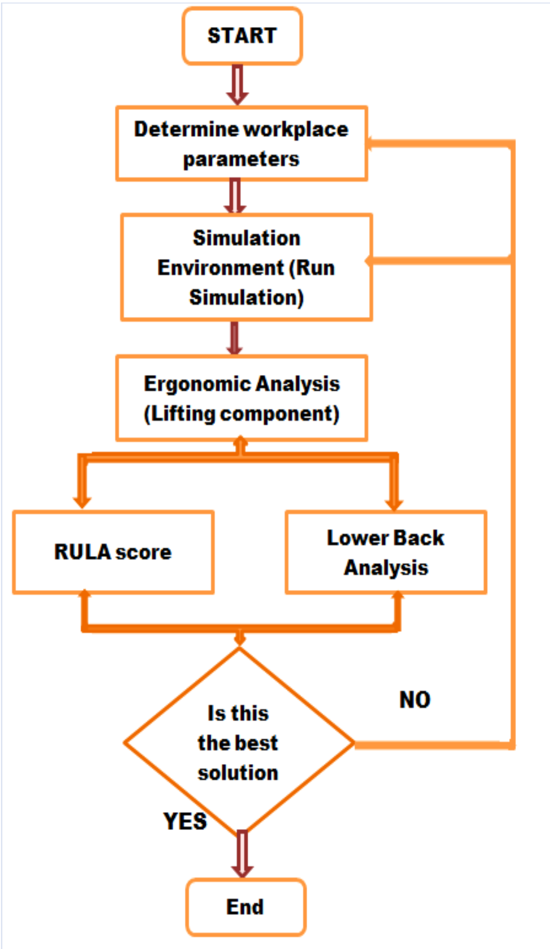

Fig 1: Flow of Ergonomics simulation

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B. Case study

In this case study we demonstrate and asses our approach for identifying optimizes work situation handled by the worker during process. In this section we concentrate on lifting the crankshaft from the storage container which is 70 x 70 x 60 (length x breadth x height) common in precision manufacturing Industry. The process has following tasks: (i) Lifting a crankshaft form a container, (ii) carrying the crankshaft towards lathe (iii) Loading the crankshaft to the Lathe machine. The virtual environment (VE), i.e. workplace design and digital human as shown in the Fig 2 and Fig 3. The CAD modal for the process simulation was design using SOLIDWORKS 2017 version (Crankshaft, storage container, Lathe machine). In this study we selected anthropometric data for ASIAN_INDIAN male database i.e. 50^{th} percentile (height 164.8cm and weight 54kg) and 95^{th} percentile (height 178cm and weight 76kg). The cycle time of the task is 45sec. The worker had to lift the crankshaft form the container with the weighing 18kg.

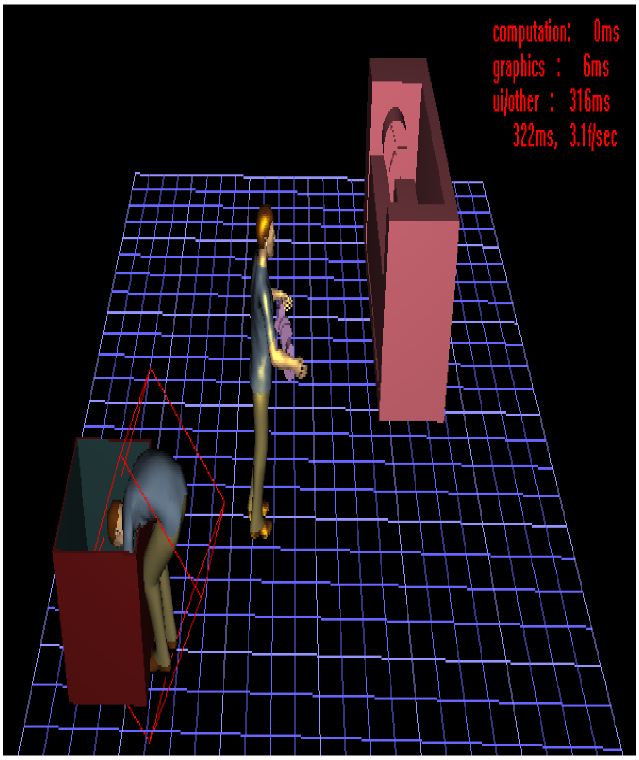

Fig 2: Workplace designed in JACK software

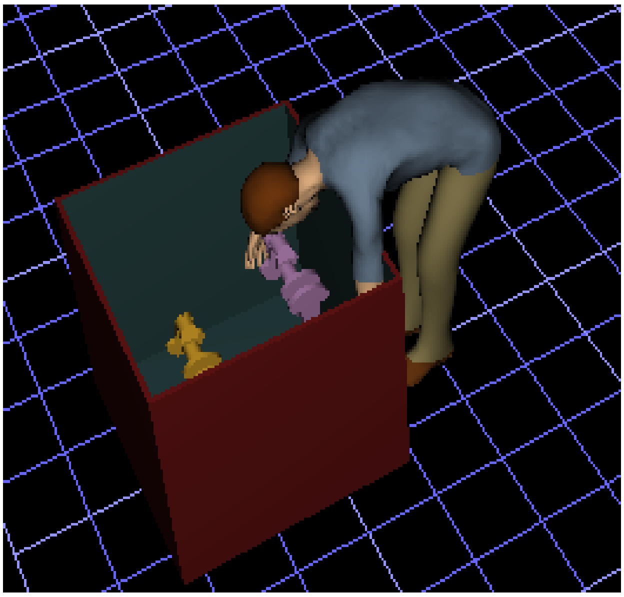

Fig 3: Lifting Crankshaft posture of operator

III. ERGONOMICS ANALYSIS

A. Problem description

In small scale Industries lot of problems in production line i.e. resources manage, most of the work is manual. To introduce new automated system cost is major issue. Shape of the production layout is also one of the major problems to handle manual work. In this case the operator has to lift the component from the storage buffer and carry the component to load for the lathe machine. Due to the weight of the component it is difficult to manage for complete working hours every day which leads to create fatigue for operators.

B. Biomechanical Analysis

Consider a workplace design involving various heights to handle components, which is directly impact on the cycle time of the process. As we know any weighted object for long time carry or handle leads to pain or destruct the work, hence cycle time is important for a manual material handling processes. The simulation study consists of lifting, walking and carrying with component. Therefore, to find total cycle time (CT) of work process as follows:

$$CT= t_b + t_r + t_l + t_c + t_o + t_r + t_w \tag{1}$$

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Where t_b, t_r, t_l, t_c, t_o, t_r and t_w are the times to bend, reach, lift, carry, load, release and walk. For bend, reach, release there is no mass consideration, whereas lift carry and walk mass has considered [11].

To determine lifting time for this process with respect to mass as follows:

$$t_l = t_b + t_r + t_l \quad (2)$$

Where t_b, t_r, &t_l are the times to bend, reach, lift, of the component.

To find bending time with respect to mass as follows:

$$t_b = \frac{\Delta_{if}}{T_v(k)} \quad (3)$$

Where Δ_{if} is change in trunk angle, T_v is change in angular velocity and K is the allowance (1.13).

To find carrying time with respect to mass as follows:

$$t_c = \frac{d}{v} \quad (4)$$

Where d is the distance carrying with mass and v is the carrying velocity.

C. Posture Analysis

Posture analysis is subjected to RULA and LBA methods. RULA focused on the individual parts of the body major attention on upper limb, trunk and neck. The grand score varied between 1-7 based on the risk due to MSD loading. The LBA evaluate the stress level pressure on the lower back disk. This pressure level is expressed in three stages. The risk score of RULA and LBA force level is summarize in the Table 1.

Table 1: Risks score and force level according to posture

RULA		LBA	
Score	**Action**	**Force level**	**Action**
1-2	Acceptable	≥ 3400N	Low risk
3-4	Investigate further		
5-6	Investigate & change soon	3400-6400N	Moderate risk
7 & above	Investigate & change immediately	Above 6400N	High risk

IV. RESULTS AND DISCUSSION

A. Results

The existing process doing by the worker has selected for analysis of posture with male gender. The parameters which are relevant to this process analysis are height to pick the component with respect to time for the operators. It was observed that height of the lifting component from the container was the most significant factor to worker and operators comfort. Hence the posture selected was simulating with different percentile. Results are analysing for RULA and LBA methods. These methods are recorded for different scores, according to the scores risk factor is identify. The RULA score and LBA force level required action are as shown in Table1. The results of the process simulation as shown in below figures.

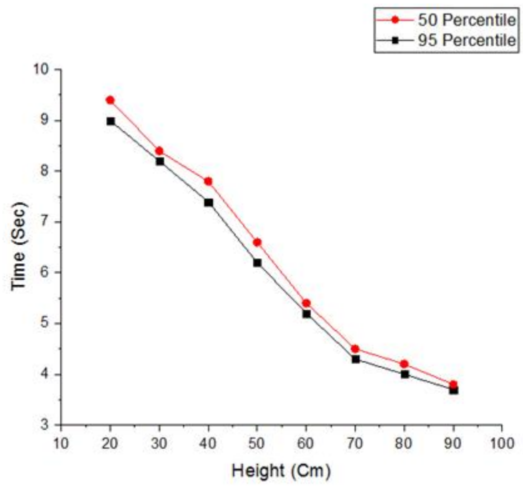

Fig 4: Lifting duration as a function of the crankshaft weight for different percentile

The relation between the height and time was not linear, because the movement of the worker changes as a function of the height to lift the component. Though the process movement was same the time taken to complete the task has varied. The time taken by 95th percentile worker has less compare to 50th percentile. It also point out increase in lifting height lowering the durations as shown in Fig 4. Decreases the component handle duration less risk

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on the body and also improve the work posture of the operator hence reduce the physical work stress.

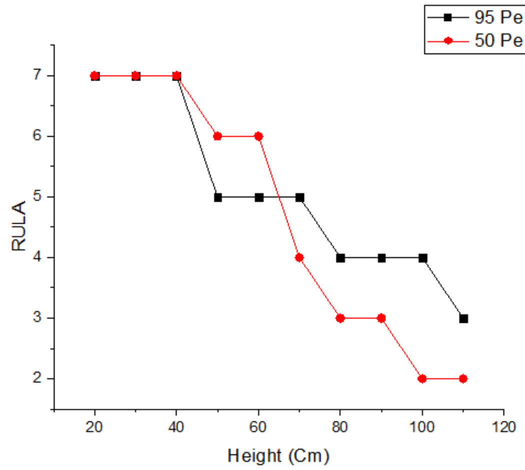

Fig 5: RULA scores as a function of the lifting height

The effect of crankshaft lifting height on the RULA score for different percentile was examined. For a constant mass of the component (18kg) lifting from the storage container was significantly impact on the upper portion of the worker body. The effect score decreased with increases height of the lifting position. RULA score shows high risk at 20 & 40 cm height for both 50^{th}& 95^{th} percentile. For 50^{th} percentile moderate risk for the height 70cm, whereas for 95^{th} percentile it has for 50cm. RULA safe score shows for 100cm lifting height for 50^{th} percentile but for 95^{th} percentile it was small amount of risk for continuous work in the process. We also observed there was dramatic improvement in the score with respect to height in 50^{th} percentile, whereas in the 95^{th} percentile continuous improvement with respect to lifting height. The RULA score for different body parts of worker shown in table 2.

Table 2: RULA score for various body parts of worker

	20cm		30cm		40cm		50cm		60cm		70cm		80cm		90cm		100cm	
Body part	**50^{th}**	**95^{th}**	**50^{th}**	**95^{th}**	**50^{th}**	**95^{th}**	**50^{th}**	**95^{th}**	**50^{th}**	**95^{th}**	**50^{th}**	**95^{th}**	**50^{th}**	**95^{th}**	**50^{th}**	**95^{th}**	**50^{th}**	**95^{th}**
Upper arm	5	5	5	5	5	5	5	5	5	5	5	4	3	4	3	3	2	3
Fore arm	3	3	3	3	3	3	3	3	3	3	2	2	2	2	3	2	2	2
Wrist	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3	2	3	2
Wrist & arm	6	6	6	6	6	6	5	6	4	6	5	4	3	3	3	2	3	2
Neck	4	4	4	4	4	4	4	4	4	3	3	3	3	3	2	2	1	2
Trunk	4	4	4	4	4	4	4	4	4	3	3	3	3	3	2	2	1	2
RULA Grand Score	**7**	**7**	**7**	**7**	**7**	**7**	**6**	**5**	**6**	**5**	**5**	**4**	**3**	**4**	**3**	**4**	**2**	**4**

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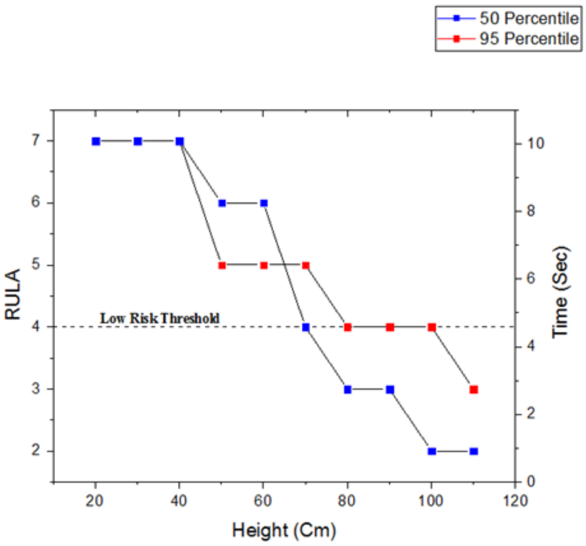

Fig 6: RULA values as a function of lifting height with respect to time

The optimal solution for the lifting component was examined in fig 6. The safe score for the process is 2 and below, the low risk has considered for 4 and below due to less injury for the worker. The lifting height from 20 to 40cm the time required for both 50th and 95th percentile was same i.e. about 10 sec. As per low risk and injury for the worker, we consider the low risk threshold for 4, which was about 4.2 sec. That indicates for safe work, the worker must complete the lifting task within 4.2 sec. The optimize solution for 50th percentile worker (height 164.8cm and weight 54kg) was at 70cm. For 95th percentile worker (height 178cm and weight 76kg) the optimize solution was at 80cm.

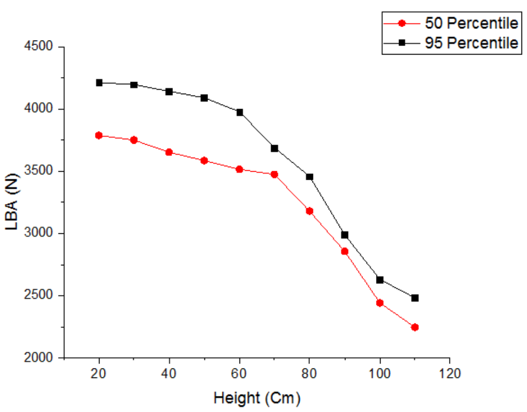

Fig 7: Lower back value as a function of the lifting height

We observed the biomechanical compression force acting on the lower back portion of the body. During task bending and reaching the component was not effective on the body due to no load on the body, but during lift the component the load acting on the body will generate compressive force on the lower back. It's clearly indicated that increased in the lifting height, force acting on the body was decrease. Though there was similar kind of behaviour in 50th and 95th percentile, significant changes occurs during improvement in lifting height of the component. The maximum force at 95th percentile worker due to height, which makes difficult in bending and lifting the component as compare to 50th percentile worker (Fig 7). The safe threshold of 3400N according to NIOSH was obtained at 80cm height for 50th percentile worker and interestingly same (80cm) for 95th percentile worker.

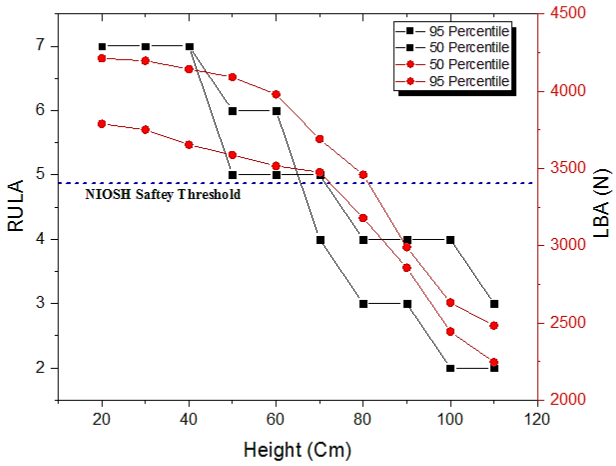

Fig 8: RULA and Lower back values as a function of the lifting height for a crankshaft mass of 18kg.

The effect of the lifting height on the worker was examined with the relationship between RULA and LBA. According to maximum permissible NIOSH (National Institute for Occupational Safety and Health) limit was 3400N. The safe threshold value for 50th and 95th percentile was observed for 80cm respectively. It's also shows the RULA score is below 5 i.e. acceptable or low risks for the worker for both percentile workers. The optimal solution for

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50^{th} and 95^{th} percentile to lift the crankshaft to be 80cm, which reduce the risk for worker, works for long duration

B. Discussion

The variations among different percentile workers of industrial environment indicated that ergonomics design unsuitability for movement of the worker with load on the body. The mismatch between the tool and workers leads to is comfort hence lower output in the productivity. In recent years, the objective of precision manufacturing companies to deliver high quality with low costs of production. Virtual simulation between man machine relations will give the user to qualitative and quantitative analysis for all working posture of production. From analysis, comparison between 50^{th} and 95^{th} percentile suggest the best way to work with less effort in manufacturing of precision components. The use different RULA scores and LBA level indicates the problem area and the risk factors, which aids to development of better working posture. The recognition of possible areas of improvement minimizes discomfited stances, stress and risk among workers. We observed RULA score decreasing with increasing height of lifting, which indicates that the component lifting height is smaller, further recommends increasing in height. Existing design recommends immediate changes in design for both 50^{th} and 95^{th} percentile. The optimal solution for combination of height and handling time for lifting component posture resulted in an LBA value of 3220N. Though it is below NIOSH threshold value, may still increase the risk for keep on working process.

V. CONCLUSION

It is possible to merge the CAD tools with virtual reality software's. This work insists a new method to incorporate ergonomics requirement fulfilment for production planning and time management. By simulating human posture in a virtual environment, it is possible to avoid major errors in the manufacturing of crankshaft. The results of the study based on ergonomics analysis and optimization process were as follows:

It was found that, increase in height distance for lifting components will significantly impact on the component handle time in both 50^{th} and 95^{th} percentile male workers.

The postural analysis for 50^{th} and 95^{th} percentile was performed for male group database. It was found, the RULA score decreases with increasing lifting height. The optimal score for 50^{th} and 95^{th} percentile was found at 70 and 80cm respectively. But for safe work condition it should be 100 and 110cm respectively.

For LBA, it was found, increase in height of lifting component decrease the risk level. The optimal solution was found in above 70 and 80cm for 50^{th} and 95^{th} percentile respectively.

Therefore the present study recommends that optimal height for 50^{th} and 95^{th} percentile was 70 and 80cm, but for safe work condition it should be 90 to 110cm, which would reduce risk and discomfort for male anthropometric database.

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