Digital Human Modelling and Biomechanics Analysis for Ergonomic Postural Assessment

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Abstract - **Many manufacturing industries nowadays largely depend upon the human intervened activities for overall growth and sustainability of their product in the competitive market. It is evident; therefore, that humans will be necessarily an essential and intact part of manufacturing for a long time to come. Hence humans need comfortable work environment which feels safe for them to work. The human factor is much more necessary and successful when completely integrated into the work environment. Ergonomic study suggests some important guidelines regarding human work activities in the manufacturing department. Ergonomics has become a major concern for industrial organization, which are cared about their employers towards safe and comfortable work environment as well as producing high quality products to customers. At the same time stressing on continuous improvement in productivity and producing user-friendly products. The main objective of this study is to minimize the discomfort level among the workers working in a pump manufacturing industry using ergonomic assessment tools like RULA (Rapid Upper Limb Assessment), Comfort, Vision and Reach analysis in Drilling machine and CNC to reduce Work related Muso-Skeletal Disorder (WMSD)'s symptoms related to occupational health, safety and suggesting ergonomic guidelines for better working postures.**

keywords - **Bio-mechanical, work force analysis, Ergonomics, Posture assessment, Musculo Skeletal Disorder**

I.INTRODUCTION

Rapid Upper Limb Assessment (RULA)

There are a number of ergonomic assessment tools that attempt to evaluate the ergonomic risk of a job or task. For example, the Rapid Upper Limb Assessment (RULA), the Rapid Entire Body Assessment (REBA) and Quick Exposure Check (QEC) are more holistic ergonomic risk assessment tools that measure the ergonomic risks of both upper and lower parts of the musculoskeletal system. Evaluations of several ergonomic observational methods revealed that these methods were applicable under various workplace conditions. Each method has its own posture classification procedure, which is different from other methods and therefore may lead to assign different postural scores for a given posture, depending on particular methods used. Rapid Upper Limb Assessment (RULA) index is one of the most cited and commonly used tools for evaluating ergonomic risk of work-related MSDs Meksaw et.al 2012. RULA is a subjective observation method for posture analysis that focuses on the upper part of the body with the particular attention to the neck, trunk and upper limbs. It is a coding system used to generate an action list which indicates the level of intervention required to reduce the risks of injury due to physical loading on the operator.

Comfort Analysis

Industrial workers are easier to be exposed to discomfort and pain at work. The occupational risk factors are the biggest factors to these health problems and it can be found in any industries (Halim, et al. 2005). Work-related Musculoskeletal Disorders are pathologies of great impact in the working population. The main risk factor in the onset of these diseases are the postures adopted and held by the workers or, in other words, the critical joint angles adopted by them during significant time periods. Large exposure periods usually occur in the workplace. In order to achieve correct ergonomic design and comfort it is necessary to work with joint angles in DHM which have to be deduced from scientific studies in literature.

Reach Analysis

Workspace is defined as the area within which all the points can be reached by a reference point of the mechanism, for example, the center of the fore arm. Workspace properties can represent an important criterion in evaluation programming, design of mechanisms, robots and similar devices, and human-centric design. Workspace comes from the robotics field and significant efforts have been made in this area. Due to rising physical disorders with respect to ergonomic design, human reach envelope has attained great attention. Human reach envelope is one of the tools to eliminate the risk of injury.

Vision Analysis

Ergonomic evaluation of visual demands becomes necessary for dynamically changing operation which requires quick decision-making skills. Vision analysis tools like view cones, eye view windows, blind spot area, obscuration zone, reflection zone etc. were employed in industries during evaluation of visual fields. Visual analysis is a prerequisite for any workstation design. Visual field can be defined as the view information from the environment when both eyes and head are held still. Human visual field can be divided into three areas: (i) distinct vision - viewing angle 1 foveal area, (ii) middle field - viewing angle from 2 to 40 and (iii) outer field – viewing angle > 40 to 70. Tools from the vision analysis in DHM and simulation software are now being used by ergonomists and design engineers for analysis of vision of the operators in virtual workstation environment to evaluate their location as per one's visual field according to priority of task.

I. WORKSPACE MODEL

CAD modeling for two machines are made for ergonomic analysis in CATIA V5 R17. The dimensions are measured from the Rotary Machinery Division by using appropriate measuring instruments and reproduced in CAD modeling. The model is then projected for its top view, front view and side view using CREO 3.0. CAD modeling for two machines are shown in figure1and 2.

CAD model of drilling machine.

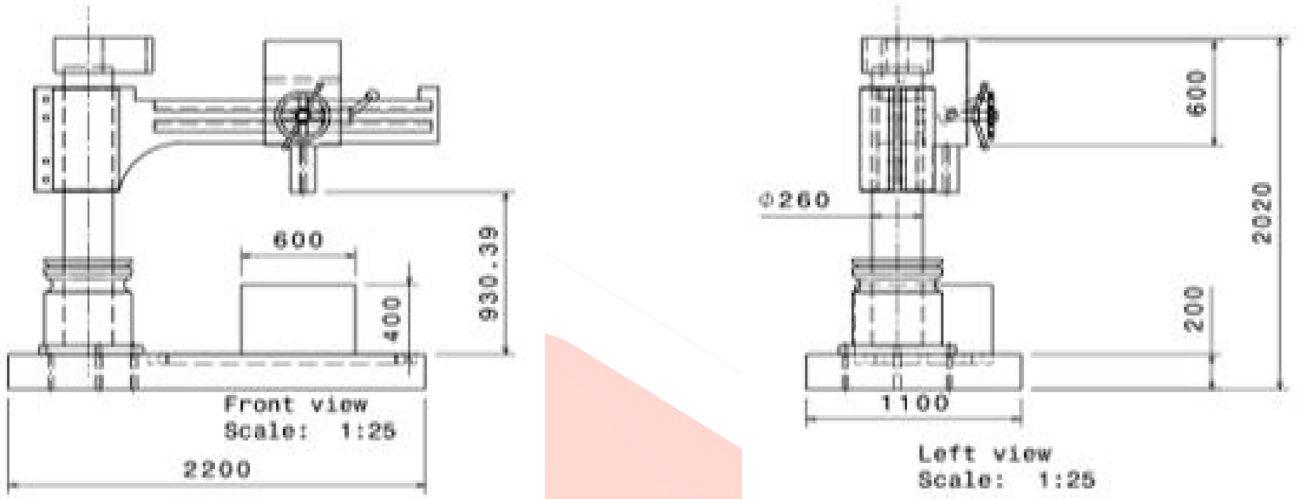

Fig 1: CAD model for radial drilling machining

The workspace model for existing Radial drilling machine as shown in Fig. 1 is created using CATIA V5 for ergonomic analysis

CAD model of CNC machine

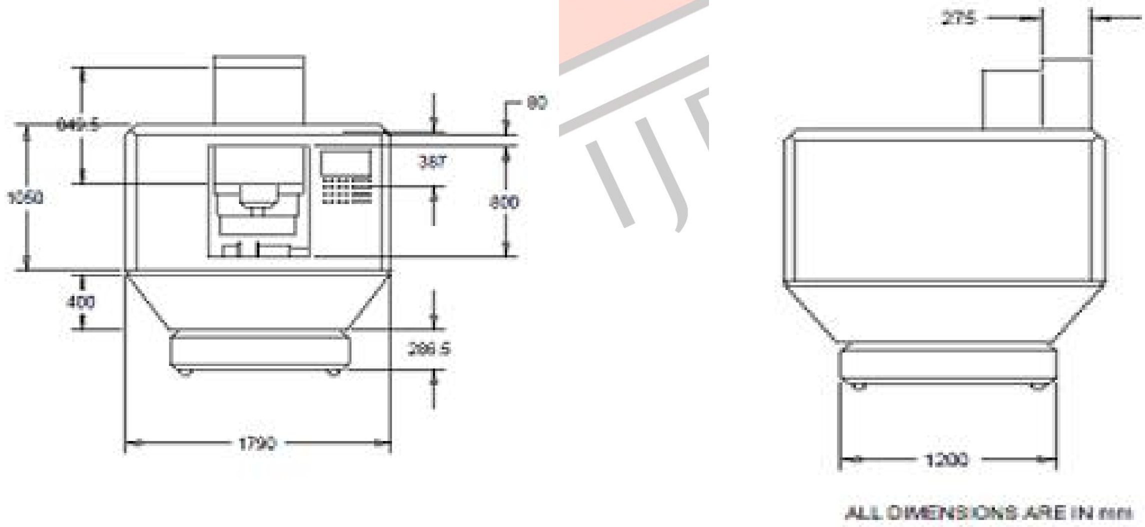

Fig. 2 CAD model for CNC machine

The workspace model for existing CNC machine is as shown in Fig. 2 is created using CREO parametric and is imported to CATIA V5 for ergonomic analysis.

II. RULA FOR WORKING POSTURES

A. RULA for working postures

The RULA assessment tool was developed to evaluate the exposure of individual workers to ergonomic risk factors associated with upper extremity musculoskeletal disorder. The RULA ergonomic assessment tool considers biomechanical and postural load requirements of job tasks/demands on the neck, trunk and upper extremities. The postural data of the worker is the input for RULA.

B. RULA for CNC machine

RULA score for CNC operation is found and it is found to be 3 out of 7 which shows that it has to be considered anthropometric analysis for change in posture for later application even though it does not cause any immediate disorders.

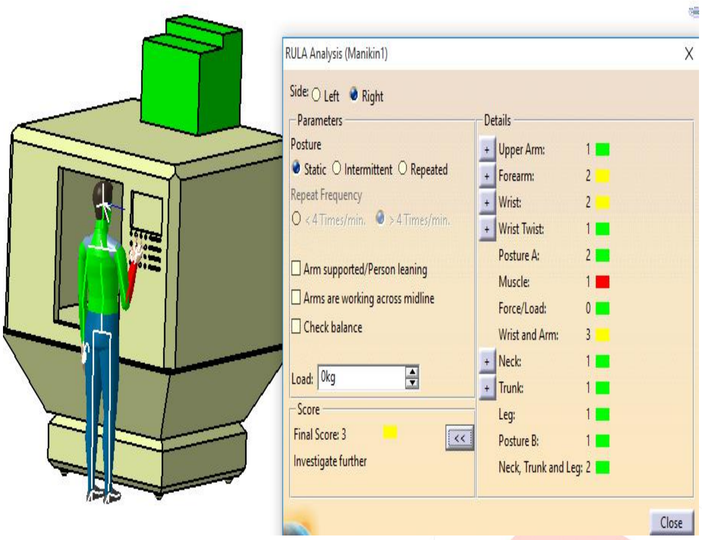

Figure 3a

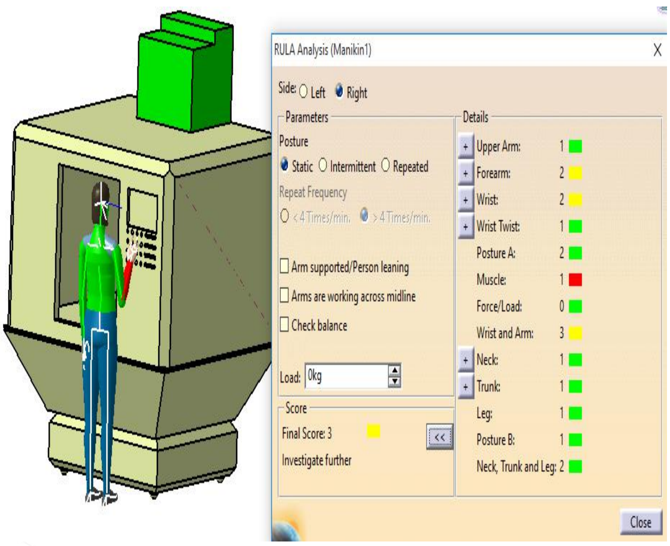

Figure 3b

RULA score for CNC machine operation

C. RULA for Drilling Machine

RULA analysis for drilling machine with operations like drilling, loading, hole change and Unloading as shown in fig 7.2.1 to 7.2.4 respectively. The analysis results show's that immediate change is needed to reduce muscular-skeletal disorder. The input for RULA was the postural data which was recorded by the camera and segregated into several frames by image processing software.

III. COMFORT ANALYSIS

A. Preferred Angles for Human Posture

The comfort range for each degree of freedom is given as input to the Manikin of all percentile in CATIA V5. The posture analysis is carried out for various operating postures of the mankind.

Table 1. Degree of Comfort

SEGMENT	DEGREES OF FREEDOM	COMFORT RANGE (in deg)
Arm	Flexion/Extension	-15 to 35
	Abduction/Adduction	0 to 30
	Medial/Lateral Rotation	-27.758 to 45
Clavicular	Flexion/ Extension	-3 to 5
Forearm	Flexion/ Extension	15 to 100
Lumbar	Flexion/ Extension	-10 to 25
Thoracic	Flexion/ Extension	-10 to 25
Thigh	Flexion/ Extension	-10 to 25
	Abduction/Adduction	-15 to 15
Leg	Flexion/ Extension	0 to 15
	Medial/ Lateral Rotation	-5 to 5
Foot	Dorsiflexion/ Planar Flexion	0 to -25
Hand	Flexion/ Extension	-25 to 45
	Radial/Ulnar Deviation	-10 to 0
Head	Flexion/ Extension	-5 to 20
	Lateral left/ Right	-20 to 20

Source: Macleod, D. (1999), The office Ergonomics Kit, CRC Press Publishers. Henry Dreyfuss Associated (2002), The Measure of Man and Woman, Human factors in design, Wiley and sons, New York.

B. Comfort analysis for CNC machining operation

The comfort analysis for the working posture of 95 percentile manikin (male and female) operating CNC machine are shown in the figure 4a and 4b.

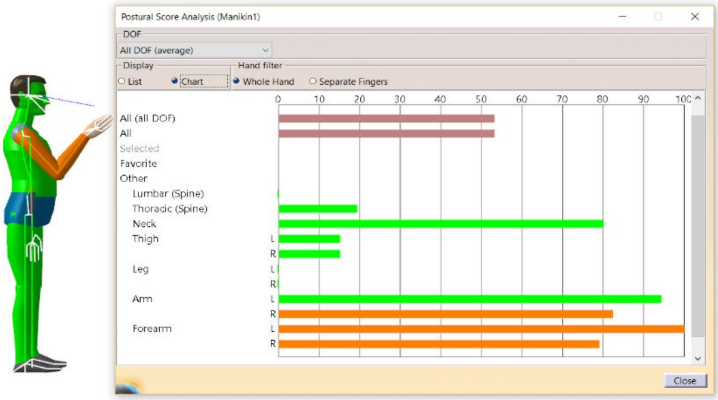

Figure 4a

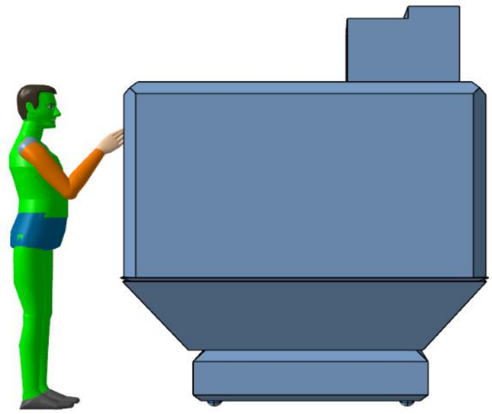

Figure 4b.

C. Comfort analysis for Radial Drilling operation

The comfort analysis for the working posture of 95 percentile manikin (male) operating radial machine lifting the part for loading it to the machine is shown in Fig 5a, 5b.

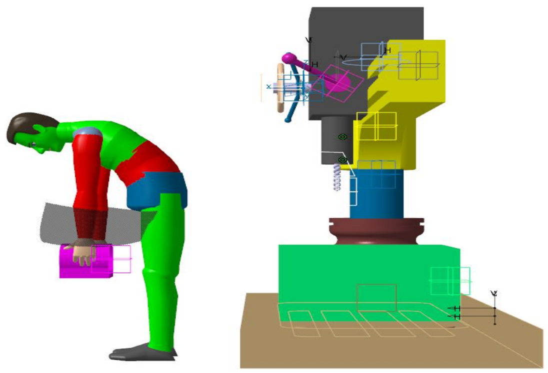

Figure 5a

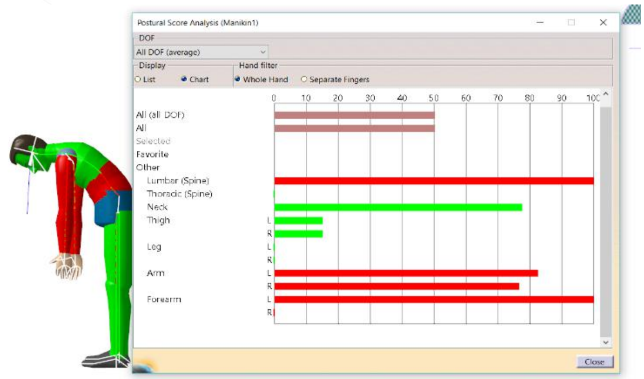

Figure 5b.

Comfort Analysis for loading part in Radial Drilling machine

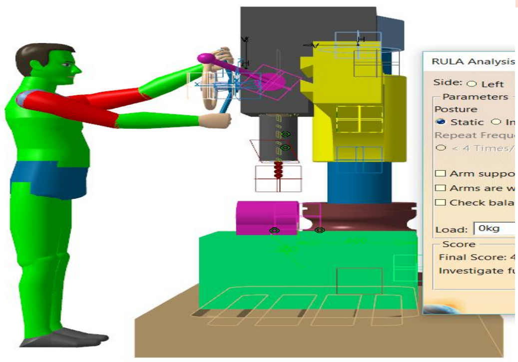

Figure 6a

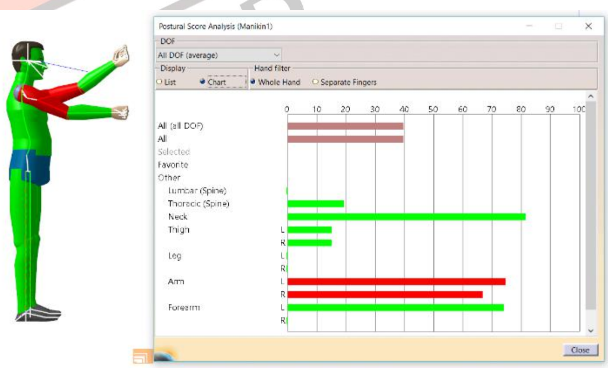

Figure 6b.

Comfort analysis for 95 percentile manikin (male) operating Radial Drilling machine.

From the chart the overall degree of freedom is 50% and Lumbar spine, both the arms and forearms fall out of the comfort zone. The comfort analysis for the working posture of 95 percentile manikin(male) performing drilling operation in radial machine is shown in Fig 6a, 6b. From the chart the overall degree of freedom is 40 and both the arms fall out of the comfort zone. The comfort analysis for the working posture of 95 percentile manikin (male) moving the column to change the position of drill bit to the next hole is shown in Fig 7a, 7b.

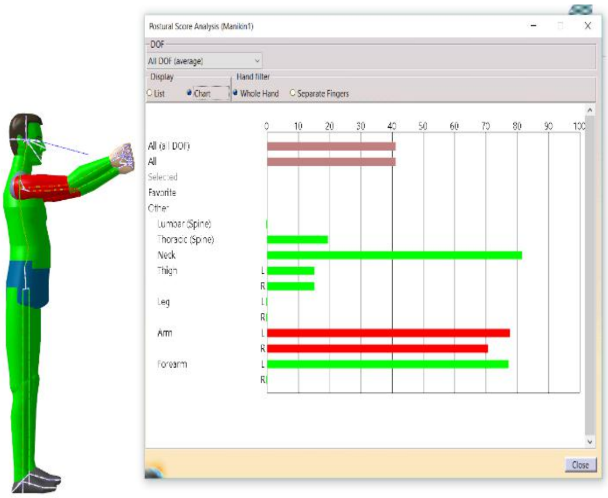

Figure 7a

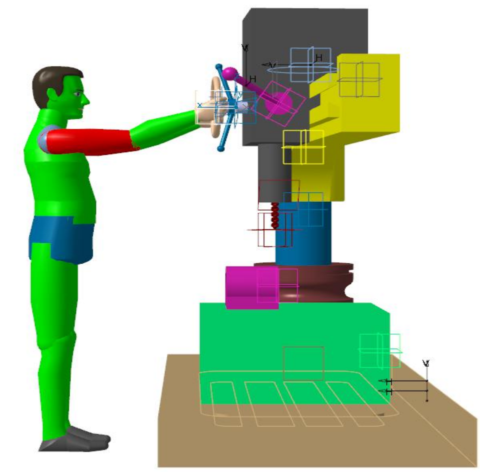

Figure 7b

Comfort analysis for working posture of 95 percentile manikin (male) operating drilling machine

The comfort analysis for the working posture of 95 percentile manikin(male) unloading the part from the machine is shown in Fig 8a ,8b.

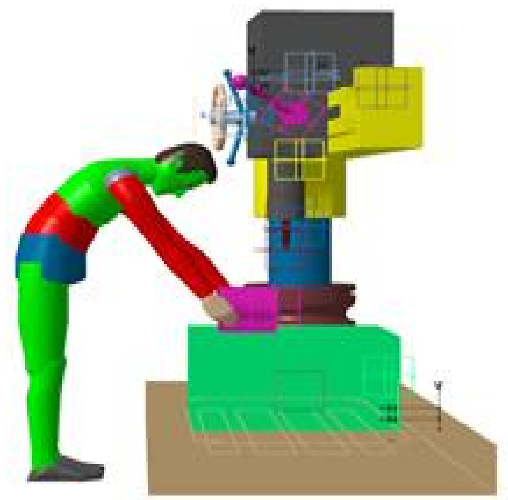

Figure 8a

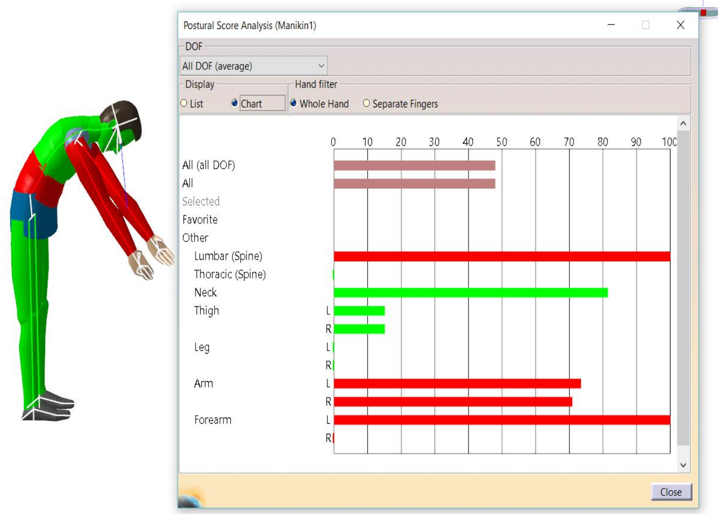

Figure 8b

Comfort analysis for 95 percentile manikin (male) unloading part from Radial Drilling machine

From the chart the overall degree of freedom is 49% and lumbar spine, both the forearm and arm fall out of the comfort zone

IV. VISION ANALYSIS

A. Investing Vision analysis

The vision analysis has been performed for the 50th percentile manikin for radial drilling machine, CNC, winding machine and lathe. The digital manikins were stationed in front of machines at olecranon-styli on length. This distance was selected as works normally tend to stand near about same distance while beginning to perform any activity involving interfacing with the machines. In the vision analysis the view cone and vision window has been used as shown in fig 9 a, b and c

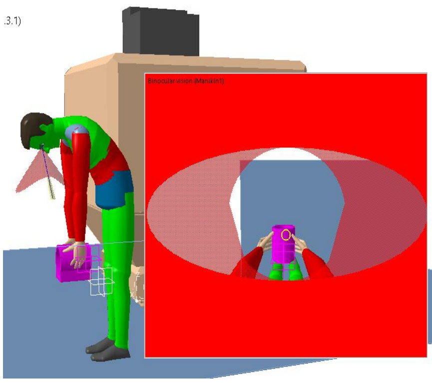

Figure 9a

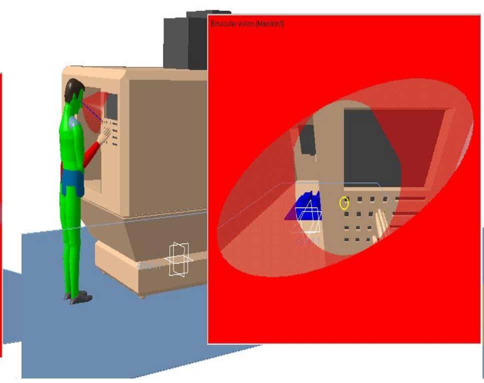

Figure 9b

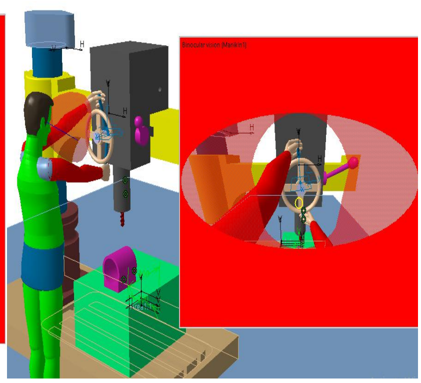

Figure 9c

Vision analysis for Radial drilling machine and CNC machine

VI. BIOMECHANICAL FORCE ANALYSIS

Manual Material Handling is the most common cause of occupational fatigue and low back pain. Thus, biomechanical force analysis is addressed by taking into account of force of the object that workers lift during their process acting in their hand or trunk plus the self-weight of the worker then this L4-L5 compression lumbar spine data is compared with the NIOSH (National Institute for Occupational Safety and Health) safe limit for lumbar spine compression data

A. L4-L5 Compression Data for Radial Drilling Machine

Bio-mechanical force analysis is used to find the compression force and moment acting on the worker when he performs any activity during the course of the work

Table 3.1 L4-L5 compression data

Sl. No	POSTURE	L4-L5 compression (N)		
		5th percentile	50th percentile	95th percentile
1	Loading	2131	2958	3895
2	Drilling process	851	1031	1049
3	Hole changing process	712	975	1094
	Unloading	2588	3232	4249

Table3.2: L4-L5 Moment Data

Sl. No	POSTURE	L4-L5 moment (Nm)		
		5th percentile	50th percentile	95th percentile
1	Loading	-116	-162	204
2	Drilling process	-27	-33	-30
3	Hole changing process	26	-35	-32
4	Unloading	141	-173	-222

Biomechanical force analysis is addressed by taking into account of force of the object that workers lift during their process acting in their hand or trunk plus the self-weight of the worker. During loading, all the percentile manikin experience about 2800 – 3100 N L4-L5 compression. During drilling process, 95th percentile manikin experiences maximum compression load. During hole change process, the manikin experiences 700-975 N compression load. During unloading posture, the 5th percentile manikin experiences less compression load of 1397 N compared to others.

B. L4-L5 Compression Data for CNC Machine

In CATIA, Human activity analysis work bench, the biomechanics single action analysis is generally used to calculate the maximum force and moment in the lumbar spine region where commonly L4-L5 lumbar spine region is taken into account.

Table 2.1. L4-L5 Compression Data

Sl No	POSTURE	L4-L5 compression (N)		
		5th percentile	50th percentile	95th percentile
1	Loading	281	280	341
2	Operation panel	592	203	203
3	Unloading	2146	2980	2977

Table 2.2 L4-L5 Moment Data

Sl. No	POSTURE	L4-L5 moment (Nm)		
		5th percentile	50th percentile	95th percentile
1	Loading	1	2	3
2	Operation panel	-75	-49	-49
3	Unloading	37	52	52

VII. RESULTS AND DISCUSSION

A. Modification of Radial Drilling machine workstation

The RULA scores for the existing workstations require changes to be made to reduce the stresses faced by the workers. The modification made is a multipurpose trolley which can be used as table and for material handling. The dimension of trolley is such that it suits the worker of 5th percentile comfortably as described in Fig 11 a This setup automatically suits best for workers of 50th and 95th percentile. The conceptual improved design is shown in fig 11b.

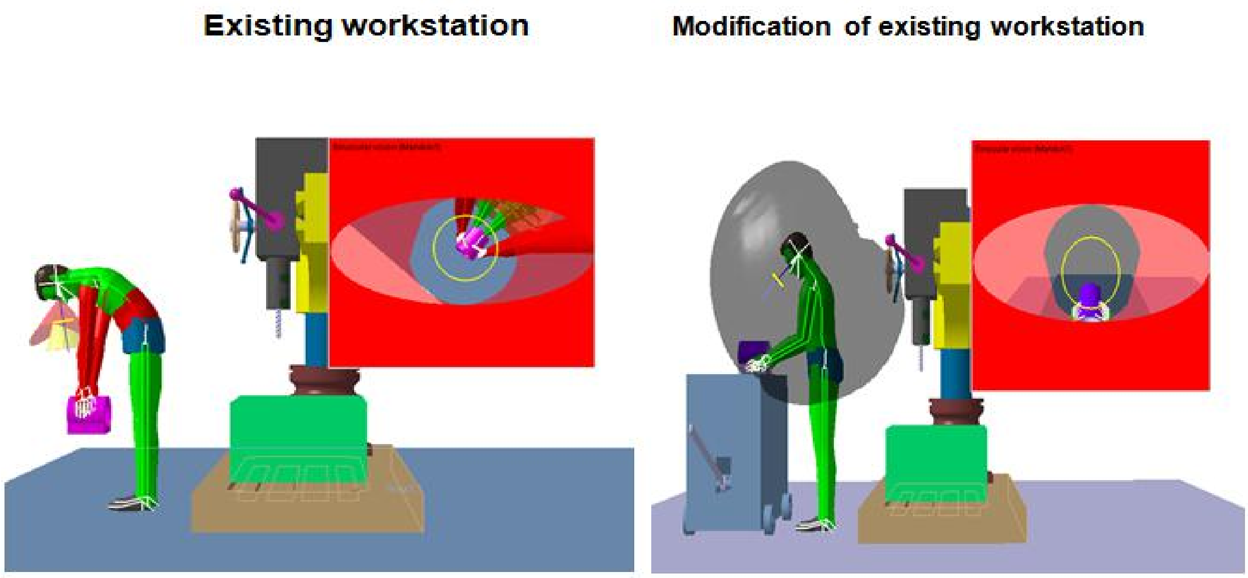

Figure 11a. Figure 11b.

Fig 11a, 11b Existing and modified workstations

Table 3.1 RULA score for existing and modified Radial drilling machine workstations

Segment no		Score range	Color associated to scores					
			11	22	33	44	55	66
Upper arm	Before	3						
	After	2						
Forearm	Before	2						
	After	2						
Wrist	Before	2						
	After	2						
Wrist twist	Before	1						
	After	1						
Neck	Before	1						
	After	2						
Trunk	Before	3						
	After	2						
Final score	Before	5						
	After	3						

B. Modification of CNC Machine Workstation

The modification made is a table of dimension that suits the worker of 5^{th} percentile comfortably as described in Fig 12 a and 12 b. This setup automatically suits best for workers of 50^{th} and 95^{th} percentile

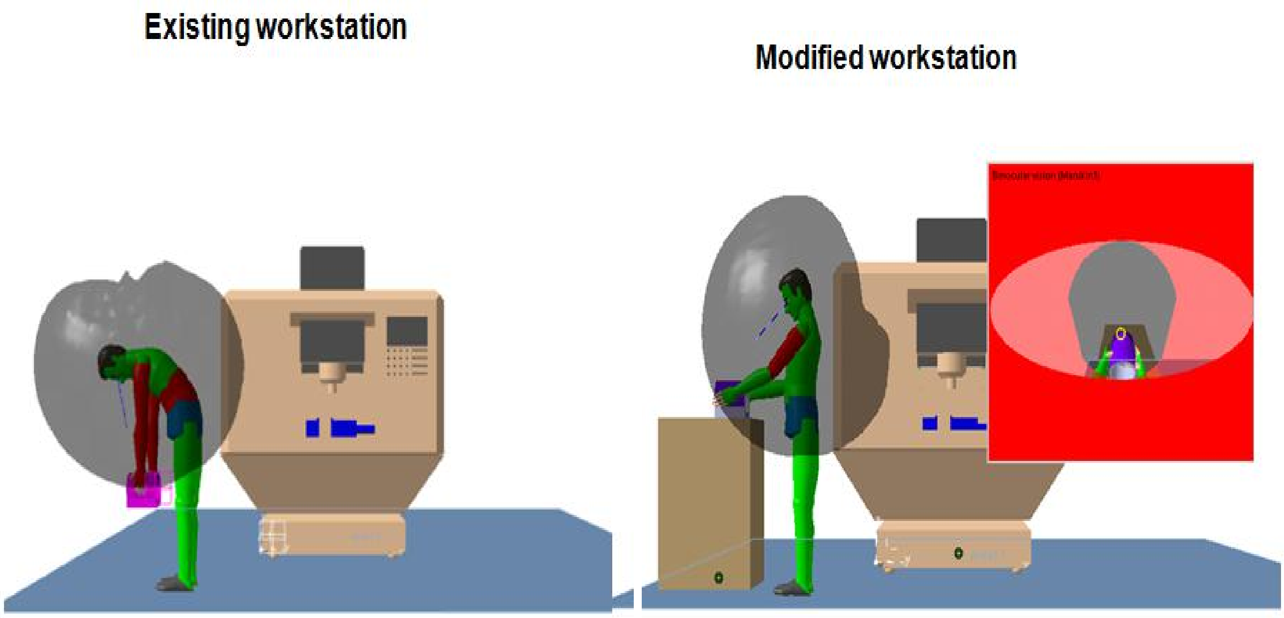

Figure 12a. Figure 12b.

Fig 12 a, 12 b Existing and modified CNC workstations

Table 3.2 RULA score for existing and modified CNC workstations

Segment		Score range	Color associated to scores					
			1	2	3	4	5	6
Upper arm	Before	4						
	After	2						
Forearm	Before	2						
	After	2						
Wrist	Before	2						
	After	2						
Wrist twist	Before	1						
	After	1						
Neck	Before	1						
	After	2						
Trunk	Before	3						
	After	1						
Final score	Before	5						
	After	3						

CONCLUSION

The Posture assessment has been performed on the employees working in a stator assembly shop and the result has been compared using CATIA and Bio-mechanics analysis. A biomechanics analysis and RULA score indicated ‘at risk’ jobs have been performed on work activities in occupation groups. The model provides the severity of the posture towards MSDs, through the investigation of risk factors and recommendations for reducing risk have been provided with a vision to demonstrate compliance with the requirements of existing ergonomic legislation directed at improving working posture. Significant insights have been gained through using a methodology that combines assessment techniques to derive risk of musculoskeletal injury and respective proposal is made in a pump manufacturing industry.

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