

Ergonomic Analysis of an Assembly Workstation to Identify Time Consuming And Fatigue Causing Factors to Improve The Productivity

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ABSTRACT- The industrial success greatly depends on the quality and delivery time. In order to achieve this industry should implement new techniques which will increase the quality, productivity and decrease worker fatigue. One such technique is ergonomics. This paper addresses the application of ergonomics in improving the quality of work life, reducing musculoskeletal disorders and increasing productivity. The existing workstation was studied and suggestion was given to improve the method for productivity by reducing shoulder and wrist injury and fatigue. A good ergonomic work station design showed a better interaction between man-machine systems. The new approach of studying the operations by Ergonomics assessment Work sheet includes Rula assessment, Work-place assessment and Composite Scoring system, by considering these factors, problems regarding the MSDs is reduced. It is observed that the newly designed workstation improved working posture and resulted in reduced postural stress on operator's bodies and consequently reduced prevalence of MSDs symptoms.

KEYWORDS- Ergonomics Evaluation, Musculoskeletal Disorders, RULA assessment, Work place assessment

I. INTRODUCTION

The word Ergonomics comes from two Greek words: ERGO: meaning work, NOMOS: meaning law, Ergonomics can be defined simply as the study of work. More specifically, ergonomics is the science of designing the job to fit the worker, rather than physically forcing the worker's body to fit the job. Adapting tasks, work stations, tools, and equipment to fit the worker can help reduce physical stress on a worker's body and eliminate many potentially serious, disabling work related musculoskeletal disorders (MSDs). Ergonomics covers all aspects of a job, from the physical stresses it places on joints, muscles, nerves, tendons, bones and the like, to environmental factors which can affect hearing, vision, and general comfort and health, when there is a mismatch between the physical requirements of the job and the physical capacity of the worker, work-related musculoskeletal disorders (WMSDs) can result. Physical stresses include repetitive motions such as those caused by typing or continual use of a manual screwdriver. Other physical stresses could be tasks involving vibration such as using a jackhammer, or tasks which involve using excessive force, such as lifting boxes of heavy books. Types of work which pose ergonomic hazards are Manual handling, Manufacturing and production, Heavy lifting,

Twisting movements, and Long hours of working in awkward positions. **Baba MdDeros et al.**, [1] studied that assembly workstation at Company a need to be redesign to eliminate awkward postures and anthropometric mismatches to lower MSDs problem and improve productivity among assembly workers.

Ravikumar Kamble et al., [2] studied the cycle time and existing method of different work stations and suggesting improved method for the same so as to reduce the cycle time

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and to improve productivity. The importance of the work study is directly related to the reduction of the inefficient time and increasing the productivity. He also Suggested a proper sequence of operations which reduces the cycle time of the work stations.

Sandip B. Wanave et al., evaluated the work station to improve the productivity by reducing the back pain, shoulder injury, fatigue etc. Productivity is an important indicator of economic growth and social health. High performance and productivity require the right sitting posture. So for considering this factor operator needs proper seating arrangement such that their problems regarding the MSDs. It is revealed that the suggested workstation improved working posture and results in reduced postural stress on operators' bodies and consequently reduced prevalence of MSDs symptoms. Analysis and implementation of ergonomic chair give a great difference in the readings taken for different factors. Capability and concentration of workers increases due to less fatigue observed [3]

II. ERGONOMIC DESIGN

'Ergonomic design' is a way of considering design options to ensure that people's capabilities and limitations are taken into account. This helps to ensure that the product is fit for use by the target users. The principles of ergonomic design can be applied to everyday objects and work spaces. Mass production of products does not take into account that humans come in various shapes and sizes.

2.1 Ergonomic Assessment

A detailed workplace ergonomics assessment used risk analysis tools like:

- RULA - Rapid Upper Limb assessment
- Workplace assessment
- REBA - Rapid Entire Body assessment
- MAC - Manual Handling Assessment Charts
- ART - Assessment of Repetitive upper limb Tasks

2.2 Systematic Approach for Ergonomics Assessment

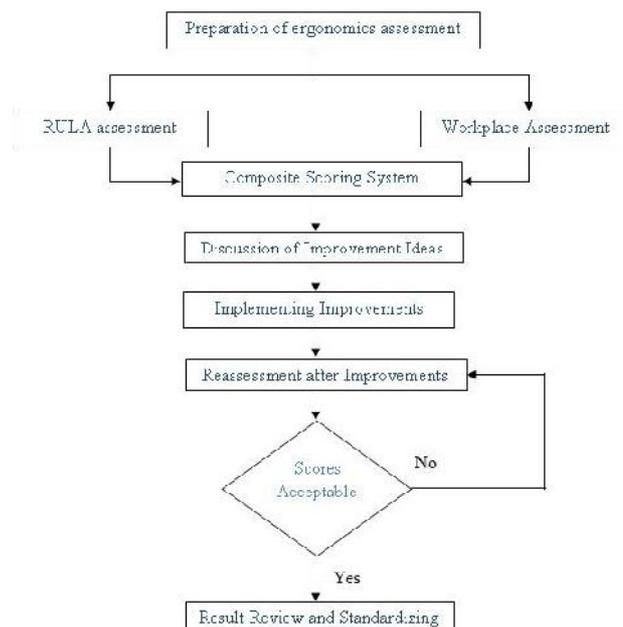


Fig 1. Approach for ergonomic assesment

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2.2.1 Rapid Upper Limb Assessment (RULA)

Rapid Upper Limb Assessment (RULA) RULA was developed to evaluate the exposure of individual workers to ergonomic risk factors associated with upper extremity MSD. The RULA ergonomic assessment tool considers biomechanical and postural load requirements of job tasks demands on the neck, trunk and upper extremities. A single page worksheet is used to evaluate required body posture, force, and repetition. Based on the evaluations, scores are entered for each body region in section A for the arm and wrist, and section B for the neck and trunk.

2.2.2 Ergonomic Workplace Assessment:-

Poor working postures, repetitive tasks and heavy workloads can lead to increased risk of workplace injuries. An Ergonomic assessment can identify these risk factors by using a variety of data capture and risk assessment tools. By performing an Ergonomic assessment, business can benefit from: Prevent costly litigation, comply with health and safety citations, decrease injury risk, error rates and lost working days, increase efficiency and productivity. It covers the major areas like Controls and displays, lightings, material Handling, surrounding Environment.

2.3 COMPOSITE SCORING SYSTEM

Table 1: RULA score and Recommendations

RULA Score	Recommendation by authors
1 or 2	Acceptable
3 or 4	Investigate Further and change may be required
5 or 6	Investigate Further and change soon
7 or more	Change immediately

Table 2: Workplace score and recommendation

Workplace Score	Recommendation by authors
1	Good
5	Can Improve
10	Poor

Ergonomic Score = RULA Score * Workplace Score

Table 3: Ergonomic score and its remarks

Ergonomic Score	Color	Remarks
1-5	Green	Comfort zone
6-7	Blue	Acceptable zone
Greater than 8	Red	Alert Zone

- Alert zone is one where the working conditions are unfavorable to the operator with stress and strain.
- Acceptable zone is one where the working conditions are favorable but still scope for betterment of working condition.
- Comfortable zone is one where the operator produces to the minimum quantity without stress and strain on operator's physical and mental health.

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III. CASE STUDY

Ergonomics improvement –During the initially conduction of the study of ergonomics at Idler and Relay assembly workstation of an steering gear company, the critical areas having the maximum ergonomic score which means having a unfavorable working postures which comes under alert zone which needs immediate attention, are suggested them to reduce the ergonomic score by implementing the Pneumatic torque wrenches with Spring balancer concept which lowers the ergonomics score from alert zone to acceptable zone/ Comfortable zone.

Assembly station: In the Assembly work-station operations of the Idler and Relay is carried out like Pre-assembly, Greasing, Final-assembly, Drop-arm Torque, Pre-delivery inspection and Pre-delivery continuity fixture after these operation it send it to the NALT Assembly station and to the customer.

Table 4: Ergonomic score Assessment and Zone Disposition

Sl no	cell	Operation	RULA score			Work Place Score	Ergo Score	Zone disposition
			Ar m scor e	Neck, trunk, and leg score	Final RULA score			
1	N A L T	Pre Assembly	3	2	3	1.9	5.7	Acceptable zone
2		Greasing	3	2	3	1.2	3.6	Comfort zone
3		Final Assembly	3	2	3	1.9	5.7	Acceptable zone
4		Drop-arm Torquing	5	3	5	2.3	11.5	Alert zone
5		PD-Inspection	3	2	3	1.2	3.6	Comfort zone
6		PDI-Continuity Fixture	3	2	3	1.2	3.6	Comfort zone
7		Boot-Capping	3	2	3	1.2	3.6	Comfort zone

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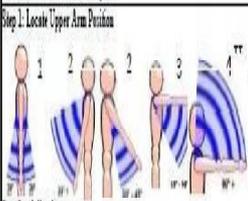
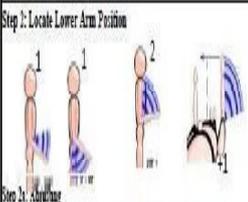
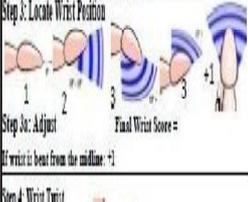
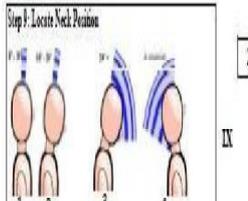
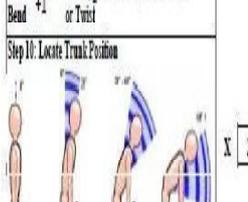
Module: NALT		Date:		Operation: Drop-arm torque			
Station: Assembly		Operator:		Operator:			
RULA ASSESSMENT SHEET		Score	Observation	Score	Observation		
Arm & Wrist Analysis							
Step 1: Locate Upper Arm Position 		RIGHT	LEFT	3	2		
Step 2a: Adjusting If shoulder is raised: +1 If upper arm is abducted: +1 If arm is supported or person is leaning: -1 Final Upper Arm Score =		These are the values influencing and making RULA score					
Step 2: Locate Lower Arm Position 						2	2
Step 2a: Adjusting If arm outside of body: +1 If arm is working across midline of the body: +1 Final Upper Arm Score =						(2) (1)	
Step 3: Locate Wrist Position 							
Step 3a: Adjust If wrist is bent from the midline: +1 Final Wrist Score =		1	1				
Step 4: Wrist Twist 		1	1				
STEP 5: Look up Posture score in TABLE A Use values I, II, III & IV		V					
Table A Score Choose the maximum score as arm score		4	3				
STEP 6: Add Muscle use score Static (i.e. held longer than 1 min) or: Repeated more than 5 times in a minute = +1		VI	1				
STEP 8: Find row in TABLE C FINAL WRIST & ARM SCORE		VII	=				
		5					
Step 8: Locate Neck Position 				2	IX		
Step 9a: Adjust Bend: +1 or Twist: +1 Final Neck Score = with neck position score							
Step 10: Locate Trunk Position 						X	2
Step 10a: Adjust If Trunk is twisted: +1; if Trunk is side-bending: +1 Final Trunk Score =							
Step 11: Leg Score 						XI	1
Balanced Unbalanced Final Leg Score =							
STEP 12: Look-up Posturer score in TABLE B						XII	2
STEP 13: Add Muscle use score Static (i.e. held longer than 1 min) or: Repeated more than 5 times in a minute = +1		XIII	1	+			
STEP 16: Find column in TABLE C Neck, Trunk and Leg score		XIV	3	=			
Final RULA score				5			
Overall Suggestions 5 = 2.0 = 11.5 Alert Zone							

Fig 2. RULA Employee assessment worksheet (Before implementation)

Area	S.No	EVALUATION CRITERIA	Quantification & Parameters			OBSERVATION SCORE			Observation
			Poor	Can improve	Good	Poor (0)	Can improve (1)	Good (2)	
Controls and Displays	1	Labeling of Controls	Not available	available - not legible	available and legible			<input checked="" type="checkbox"/>	
	2	Accessibility of Controls including emergency controls & Logical arrangement of controls and displays	>5.0 feet <- 1.5 feet Distancing	2.5 feet to 3.5 feet	4.5 feet= 0.5 feet			<input checked="" type="checkbox"/>	
	3	Color Coding for Gauge Meters (RVC)	Not available	Partially Available	available and legible			<input checked="" type="checkbox"/>	
	4	Position of Displays and controls >2.3 feet	No visibility from stand position	Function with in one meter movement	All controls visible from one stand point			<input checked="" type="checkbox"/>	
Noise and Vibration	5	Responsibility of controls when operator has gloves	Control operate	Clear and operability and ready in gloves	Can operate			<input checked="" type="checkbox"/>	
	6	Material flow through gravity	Manual carrying material within cell	Automated load and unload	Gravity chutes connecting work stations	<input checked="" type="checkbox"/>			
	7	Prevalence of Back Twisting w.r.t operator	trunk bend > 90° for placing/picking material	trunk bend 30°- 90° for placing/picking material	trunk bend < 20° for placing/picking material			<input checked="" type="checkbox"/>	These are the values influencing and making workplace score is more
	8	Redirection of Job w.r.t Operator	Changing Position	Using Handing	Not Change in orientation			<input checked="" type="checkbox"/>	
Ergonomics	9	Access to reach without any obstruction (especially for heavy objects)	Obstruction from other persons	Walking to approach	No obstruction			<input checked="" type="checkbox"/>	
	10	Slip condition	Maximum slip can happen	No maximum slip can happen	No slip will occur			<input checked="" type="checkbox"/>	
	11	Access to machine	Standing in steps & bending to access machine	standing in steps and not bending to access machine	Standing in flow			<input checked="" type="checkbox"/>	
	12	Weight per lift	Load more than 15 kg in 10 minutes	Load between 10-15 kg in 10 minutes	Less than 10 kg in 10 minutes	<input checked="" type="checkbox"/>			
Environmental Parameters & Lighting	13	Workplace design location	< 5.0 feet	3.5 - 5.0 feet	3.0 - 4.5 feet			<input checked="" type="checkbox"/>	
	14	Sound level	< 90 dBA	70 - 90 dBA	< 70 dBA			<input checked="" type="checkbox"/>	
	15	Frequency of high peak noise	Exposed in every cycle	Once in a hour	Once in a day			<input checked="" type="checkbox"/>	
	16	Temperature	> 32°	Between 20-32°	< 20°			<input checked="" type="checkbox"/>	
Ergonomics	17	Relative humidity	Less than 30% or More than 75%	between 40-50%	Between 55-75%			<input checked="" type="checkbox"/>	
	18	Air circulation	Over air circulation, No openings for fresh air flow	Moderate air circulation with few openings for fresh air flow	Fresh air circulation			<input checked="" type="checkbox"/>	
	19	Intensity of lighting for workplace & displays without glare	Less than 100 to 300	Less than 100 to 200	Between 200 to 300			<input checked="" type="checkbox"/>	
	20	Control in highlighting safety critical areas	Not available	available - not legible	Available and visible			<input checked="" type="checkbox"/>	
Total						28	10	18	
Grand Total						46			(Addition of all total scores)
Work Place Score						2.3			(Grand Total/18)
Initiated By:						Signature:			

Fig 3. Workplace Employee assessment worksheet (Before implementation)

3.1 Analysis of the alert zone area

In the Assembly Workstation of the Idler and Relay component Drop-arm Torquing operation is Carrying out manually through the Click type torque wrenches and these leads to more lead time of the operation and causes fatigue to the operator in the wrist, upper-arm and lower-arm position and also it leads to the decrease in productivity.

3.2 Problem identified: More lead time of the operation, working in Awkward positions, decrease in productivity and Drop-arm torque operation in the alert zone

3.3 Scope of the project: Reduce cycle time of the operations; improve productivity, operator safety, ergonomic postures and environment of the workstations and improve alert zone to comfort zone.

3.4 List of ideas / Measures:

List of ideas to improve drop-arm torque operation

3.4.1 Click Torque Wrenches:

One of the most common types of torque wrench is the “click” style. It’s so named for the audible “click” that is generated when the wrench reaches its set torque value. When the desired torque is reached, a clutch releases inside of the wrench, creating a clicking sound and allowing the wrench to briefly swing free. This positive tactile and audible feedback assures the user that the proper torque value has been reached.

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3.4.2 Digital torque wrenches:

are quickly gaining popularity in many shops and garages. Though slightly more expensive than click type wrenches, their ease of use and high accuracy have made them a popular choice. As opposed to an internal clutch, these wrenches use a strain gauge to measure tension. When the correct torque is reached, an electronic signal is sent to the control, which can provide several methods of alerting the user.

3.4.3 Hydraulic torque wrench:

is a tool designed to exert torque on a fastener to achieve proper tightening or loosening of a connection through the use of hydraulics. A torque wrench is applied to the nut either directly or in conjunction with an impact socket. Hydraulic torque wrenches apply a predetermined, controlled amount of torque to a properly lubricated fastener.

3.4.4 Pneumatic torque wrench:

is a planetary torque multiplier or a gearbox that is mated to a pneumatic air motor. At the end of the gearbox is a reaction device that is used to absorb the torque and allows the tool operator to use it with very little effort. The torque output is adjusted by controlling the air pressure. These planetary torque multiplier gearboxes have multiplication ratios up to 4000:1 and are primarily used anywhere accurate torque is required on a nut and bolt, or where a stubborn nut needs to be removed.

Pneumatic torque wrenches is selected for drop-arm torque operation to improve the ergonomic working posture and productivity.

3.4.5 Torque and Air-Pressure Calculation:-

Pressure described as a Force which is exerted over a surface area, in regards to Compression springs, the pressure exerted as the result of Specific deflection can be more described as "Force over a Flat Surface with Circular Perimeter

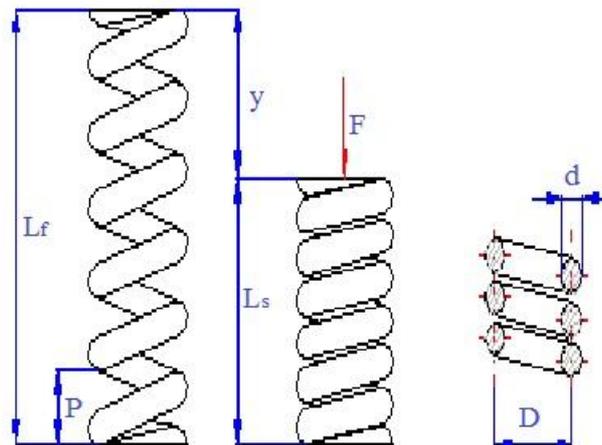


Fig4. Helical Cylindrical Compression Spring

D_o = Outer diameter = 24mm
 D_i = inner diameter = 14mm
 d = Wire diameter = 5mm
 D = Mean diameter = $D_o - d = 19$ mm
 N = no of Coils = 3

L_f = free length = 17.4 mm
 L_s = Solid length = 14.7 mm.
 K = Constant pounds of Load per inch of deflection

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G= Modulus of Rigidity of Spring Material, pounds per square inch

Formula for „K“

$$K = (G d^4) / (8nD^3)$$

$$K = (79 * 109 * 54) / (8 * 3 * 193 * 106)$$

$$K = 299.94$$

$$F = K (L_f - L_s)$$

$$F = 299.94 (17.4 - 14.7)$$

$$F = 809.839N$$

Note:- Factor of safety for spring material is 2.

$$F = F * FOS$$

$$F = 809.839 * 2 = 1619.67 N$$

$$F = 1619.67 / 9.81 = 165.10 kg$$

Torque required:-

$$T = F * R$$

$$T = 1619.67 * 9.5$$

$$T = 15.386 N-m .$$

According to standard catalogues of pneumatic torque wrenches for to achieve a torque of 15.386 N-m, 4bar inletair pressure is selected.

Brief Operational Sequence pneumatic torque

Wrench Principle:

Connect the inlet air source to FRL Unit if required adjust the lubricant flow rate on FRL. Set the required pressure as per the requirement, on the FRL while trigger pressed in torquing direction. Fix the required socket and reaction arm on to the tool. Place the tool along with socket on the fastener; operate the trigger for giving torque.

Concept of Spring Balancers: are specially designed to free the operator from the weight of hand tools. The tool balancers can be pulled down with least pressure, without any strain or fatigue. Handling of the tool balancers is very easy as the load balancers and pressure required for operation is counter balanced in the mechanism of Spring Balancers / Tool Balancers itself. The operation is free of gravitational force.

Designed for rugged work environments

- Easy spring adjustment
- Cable travel ranging from 5 to 9 ft
- Safety locking device in case of spring breakage on medium, intermediate, heavy, and super duty models.

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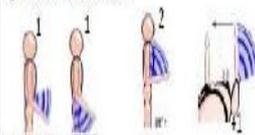
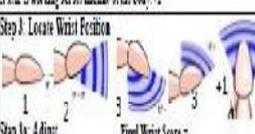
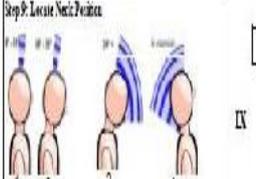
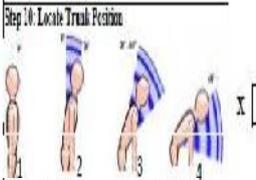
Module: NALT		Date:		RULA ASSESSMENT SHEET		Operation: Drop-arm torque	
Station: Assembly						Operator:	
Area of Work Analysis		Scores		Observation		Scores	
		RIGHT		LEFT			
Step 1: Locate Upper Arm Position 		I		2 1			
Step 1a: Adjusting If shoulder is raised = -1 If upper arm is abducted = -1 If arm is supported or person is leaning = +1 Final Upper Arm Score =							
Step 2: Locate Lower Arm Position 		II		2 1			
Step 2a: Adjusting If arm outside of body = +1 If arm is working across midline of the body = +1 Final Lower Arm Score =							
Step 3: Locate Wrist Position 		III		2 1			
Step 3a: Adjusting If wrist is bent from the midline = -1 Final Wrist Score =							
Step 4: Wrist Twist 		IV		1 1			
Final Wrist Score =							
STEP 5: Look up Posture score in TABLE A Use values I, II, III & IV Table A Score Choose the maximum score as arm score		V		3 3			
STEP 6: Add Muscle use score Static (ie held longer than 1 min) or Repeated more than 5 times in a minute = +1		VI		-			
STEP 8: Find row in TABLE C FINAL WRIST & ARM SCORE		VII		=			
				3			
Step 9: Locate Neck Position 		IX		2			
Final Neck Score = with neck position score Final = -1 or +1							
Step 10: Locate Trunk Position 		X		2			
Step 10a: Adjusting If Trunk is rotated = -1; if Trunk is side-bending = +1 Final Trunk Score =							
Step 11: Leg Score 		XI		1			
Final Leg Score = Balanced Unbalanced							
STEP 12: Look-up Posture score in TABLE B		XII		2			
STEP 13: Add Muscle use score Static (ie held longer than 1 min) or Repeated more than 5 times in a minute = +1		XIII		+			
STEP 15: Find column in TABLE C Neck, Trunk and Leg score		XIV		2			
Final RULA score				3			
Overall Suggestions 3*1.95 = 4.95 Comfort zone							

Fig5. RULA Employee assessment worksheet (After implementation)

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Zone (Index) / Lot		Date / Shift	ERGONOMICS Assessment - Work place audit sheet			Module - NALT	Operation - Drop-arm
S/N		EVALUATION CRITERIA	Quantification of Parameters			OBSERVATION SCORE	
			Poor	Can improve	Good	Poor (0)	Good (1)
Controls and Display	1	Availability of Controls	Not available	available - acceptable	available and legible		✓
	2	Accessibility of Controls (including emergency controls) & Logical arrangement of controls and Displays	<math> < 1.5 \text{ feet}</math> <math> < 1.25 \text{ feet}</math>	2.5 feet to 3.5 feet	4.5 feet to 6.5 feet		✓
	3	Colour Coding for Gauge Displays (GVG)	Not available	Partially available	available and legible		✓
	4	Position of Display and controls w.r.t eye level	No visibility from stand position	Conform with the sector movement	All controls visible from the stand point		✓
	5	Operability of controls when operator has gloves	Cannot operate	Clear and operable (not too heavy in gloves)	Can operate		✓
Material Handling	6	Material flow through gantry	Hand carrying material within cell	Combined hand and chains	Gravity chutes connecting work stations		✓
	7	Proximity of Rack/Trolley w.r.t operator	crank bend - 60° for picking/packing material	crank bend 30-60° for picking/packing material	crank bend - 30° for picking/packing material		✓
	8	Orientation of Jib w.r.t Operation	Changing Position	Filling / Rotating	Not Change in orientation		✓
	9	Access to rack without any obstruction (especially for heavy objects)	Not required from other person	Walking to approach	No obstruction		✓
	10	Floor condition	Maximum slip can happen	Moderate slip can happen	No slip will occur		✓
	11	Access to machine	Straddling in steps & bending to access machine	standing in steps and not bending to access machine	standing in flow		✓
	12	Weight per lift	Load more than 10 kg & 10 times / minute	Load between 10 to 15 kg & 10 times / minute	Less than 10 kg & Maximum 10 times / minute		✓
	13	Trolley handle design location	<math> < 1.50 \text{ feet}</math>	1.5 to 1.50 feet	1.5 to 1.50 feet		✓
	14	ambient noise	<math> < 90 \text{ dBA}</math>	70 - 90 Dba	<math> < 70 \text{ dBA}</math>		✓
	15	Frequency of high peak noise	Exposed in every cycle	Once in a hour	Once in a day	✓	
16	Temperature	<math> < 32^{\circ}</math>	Between 30-32°	30°		✓	
17	Relative humidity	Less than 60% & More than 70%	between 40-50%	Between 45-50%		✓	
18	Air circulation	Flow air circulation, No opening for fresh air stream	Moderate air circulation with fresh opening for fresh air stream	Fresh air circulation		✓	
19	Adequacy of lighting for workplace if displays without glare	Lux level - 100 to - 300	Lux level 100 to 200	Between 200 to 300		✓	
20	Contrast in highlighting safety critical areas	Not available	Available - not legible	available and legible		✓	

Total: 18 5 18
Grand total: 33 Addition of all tick scores
Work Place Score: 1.85 Grand Total 18
Assessed By: _____ Signature: _____

Fig 6. Workplace Employee assessment worksheet (After implementation)

3.5 Location of the Alert zone area

Idler & Relay Assembly station: Drop-arm torque Operation Before



Fig 7. Manual torque before implementation Problem

RULA: Rotation of arm and Wrist with High Human Pressure causing poor working posture

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Work place audit: Manual Torquing

After



Fig 8. Pneumatic torquing After implementation Action Taken

RULA: Posture brought acceptable by modified work

Setup

Work place

RESULT

RULA score: improved from 5 to 3

Work place score: improved from 2.3 to 1.65

Composite zone: improved from

Alert zone to **Comfort zone**

IV. CONCLUSIONS

Ergonomic study carried out at Idler and Relay workstation of the Assembly cell, the changes made were based on the interview with the operators and observations. After the study, best possible suggestion was Pneumatic torque wrenches with spring balancer has proven to be remarkable with the drastic changes in its working postures and also in production. The idea of Pneumatic torque wrenches with spring balancer has been successfully implemented. After the implementation the ergonomic posture is improved with reduced Musculoskeletal Disorders and fatigue, the processing time reduced from 100 secs to 65 secs where the difference of 35 secs is converted as the productive time. The method has proved to be economical and effective. Without high investment by the company the problem has been solved.



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