

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

1. 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 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 workstation to improve the productivity by reducing the back pain, shoulder

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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

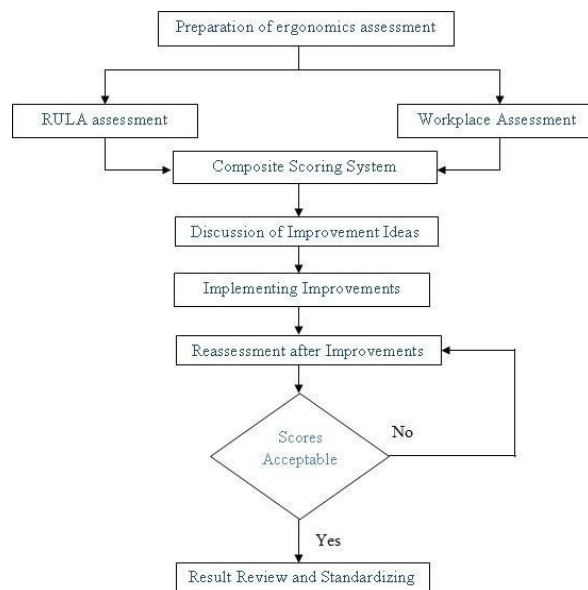


Fig 1. Approach for ergonomic assessment

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

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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
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.

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- Comfortable zone is one where the operator produces to the minimum quantity without stress and strain on operator’s physical and mental health.

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 score	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	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	Torquing	3	1.2	3.6	Comfort zone
7		Boot-Capping	3	2	3	1.2	3.6	Comfort zone

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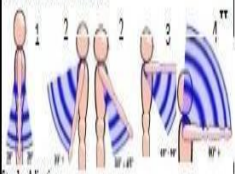
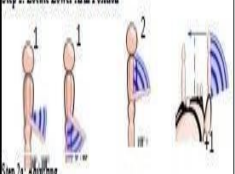
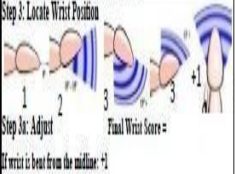

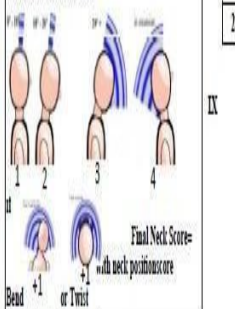
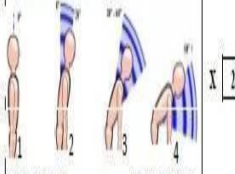
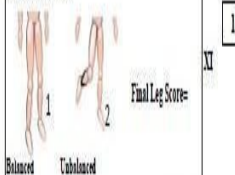
Module: NALT		Date:	RULA ASSESSMENT SHEET		Operation: Drop-arm torque
Station: Assembly					Operator:
		Score	Observation	Score	Observation
Arm & Wrist Analysis					
Step 1: Locate Upper Arm Position 		RIGHT	LEFT	I	3 2
Step 2: Adjusting If shoulder is raised +1 If upper arm is abducted +1 If arm is supported or person is leaning +1 Final Upper Arm Score =					
Step 3: Locate Lower Arm Position 		II	2	2	
Step 3a: Adjusting If arm outside of body +1 If arm is working across midline of the body +1 Final Upper Arm Score =					
Step 3: Locate Wrist Position 		III	2	1	
Step 3a: Adjust 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		V	4	3	
Table A Score Choose the maximum score as arm score		4			
STEP 6: Add Muscle use score Static (ie held longer than 1 min) or; Repeated more than 5 times in a minute = +1		VI	1	1	
STEP 8: Find row in TABLE C FINAL WRIST & ARM SCORE		VII	5	4	
		VIII	5	4	
Step 9: Locate Neck Position 		IX	2	2	
Final Neck Score = with neck position score Head +1 or Twist					
Step 10: Locate Trunk Position 		X	2	2	
Step 10a: Adjust If Trunk is twisted +1; if Trunk is side-bending +1 Final Trunk Score =					
Step 11: Leg Score 		XI	1	1	
Final Leg Score = Balanced Unbalanced					
STEP 12: Look-up Posturer score in TABLE B		XII	2	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	1	1	
STEP 15: Find column in TABLE C Neck, Trunk and Leg score		XIV	3	3	
Final RULA score		XV	5	5	
Overall Suggestions 5 * 2.3 = 11.5 Alert Zone					

Fig 2. RULA Employee assessment worksheet (Before implementation)

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Area	SLNo	EVALUATION CRITERIA	Quantification & Parameters			OBSERVATION SCORE		Observation
			Poor	Can improve	Good	Poor (0)	Good (1)	
Controls and Displays	1	Labeling of Controls	Not available	available - not legible	available and legible		✓	
	2	Accessibility of Controls including emergency controls & Logical arrangement of controls and Displays	≥ 5 ft - 1.5 feet Stretching	1.5 feet to 2.5 feet	4.5 feet ± 0.5 feet		✓	
	3	Colour Coding for Gauges Displays (RVC)	Not available	Partially Available	available and legible		✓	
	4	Position of Displays and controls w.r.t eye level	No visibility from stand position	Can view with in one meter movement	All controls visible from one stand point		✓	
Material Handling	5	Operability of controls when operator has gloves	Cannot operate	Clear and operate (only and heavy in gloves)	Can operate		✓	
	6	Material flow through priority	Hand carrying material within cell	Combined hand and chutes	Gravity chutes connecting work zones		✓	
	7	Proximity of Rack/Trolley w.r.t operator	reach bend - 60° for placing/picking material	reach bend 10°-60° for placing/picking material	reach bend - 10° for placing/picking material		✓	These are the values influencing and affecting workplace score is more
	8	Orientation of Job w.r.t Operation	Changing Position	Tilting / 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	Standing in step & bending to access machine	standing in steps and not bending to access machine	Standing in floor		✓	
	12	Weight per lift	Load more than 25 kg at time	Load between 10 - 25 kg at time	Less than 10 kg at Maximum time		✓	
	13	Trolley Handle design location	≤ 5.0 feet	3.5 - 5.0 feet	3.0-4.5 feet		✓	
	14	Ambient Noise	≥ 90 dBA	70 - 90 DBa	≤ 70 dBA		✓	
Workplace Safety & Hygiene	15	Frequency of high pick noise	Repeated in every cycle	Once in a hour	Once in a day		✓	
	16	Temperature	≥ 32°	Between 20-32°	≤ 30°		✓	
	17	Relative humidity	Less than 30% & More than 75%	between 40-55%	Between 55-75%		✓	
	18	Air circulation	Poor air circulation, No opening for fresh air flow	Moderate air circulation with free opening for fresh air flow	Fresh air circulation		✓	
	19	Adequacy of lighting for workplace & Displays without glare	Less level - 100 ft - 300	Less level 100 to 200	Between 200 to 300		✓	
20	Contrast in highlighting safety critical areas	Not available	available - not legible	available and legible		✓		
Total						20	10	10
Grand total						46		(addition of all total scores)
Work Place Score						2.3		(Grand Total/10)
Author 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

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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.

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

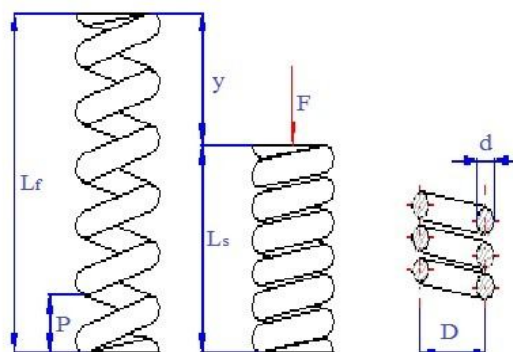


Fig4. Helical Cylindrical Compression Spring

Do = Outer diameter = 24mm

Di = inner diameter = 14mm d = Wire diameter = 5mm

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D = Mean diameter = $D_o - d = 19\text{mm}$
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
G= Modulus of Rigidity of Spring Material, pounds per square inch

Formula for „K“

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

$$K = (79 * 10^9 * 5^4) / (8 * 3 * 19^3 * 10^6) \quad K = 299.94$$

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

$$F = 299.94 (17.4 - 14.7) \quad F = 809.839\text{N}$$

Note:- Factor of safety for spring material is 2. $F = F * \text{FOS}$

$$F = 809.839 * 2 = 1619.67 \text{ N}$$

$$F = 1619.67 / 9.81 = 165.10 \text{ kg}$$

Torque required:- $T = F * R$

$$T = 1619.67 * 9.5$$

$$T = 15.386 \text{ N-m.}$$

According to standard catalogues of pneumatic torque wrenches for to achieve a torque of 15.386 N-m, 4bar inlet air 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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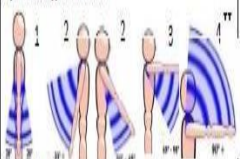
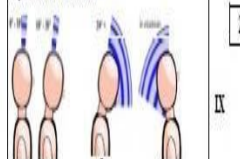

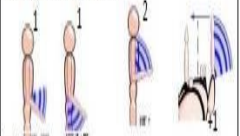
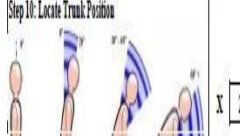



Module: NALT		Date:	RULA ASSESSMENT SHEET		Operation: Drop-arm torque
Station: Assembly				Operator:	
Arm & Wrist Analysis		Score:	Observation	Score:	Observation
		RIGHT	LEFT		
Step 1: Locate Upper Arm Position 		2	2	2	
Step 1a: Adjusting If shoulder is raised: +1 If upper arm is abducted: +1 If arm is supported or person is leaning: +1 Final Upper Arm Score =	Step 9: Locate Neck Position 				IX
Step 2: Locate Lower Arm Position 	Step 10: Locate Trunk Position 	2	2		X
Step 2a: Adjusting If arm outside of body: +1 If arm is working across midline of the body: +1 Final Upper Arm Score =	Step 10a: Adjust If Trunk is twisted: +1; if Trunk is side-bending: +1 Final Trunk Score =				
Step 3: Locate Wrist Position 	Step 11: Leg Score 	2	1		XI
Step 3a: Adjust If wrist is bent from the midline: +1 Final Wrist Score =	STEP 12: Look-up Posturer score in TABLE B 				XII
Step 4: Wrist Twist 	STEP 13: Add Muscle use score Static (i.e. held longer than 1 min) or; Repeated more than 5 times in a minute = +1 	1	1		XIII
Final Wrist Score =	STEP 14: Find column in TABLE C Neck, Trunk and Leg score 				XIV
STEP 5: Look up Posture score in TABLE A Use values I, II, III & IV 	Final RULA score	3	3	3	
Table A Score Choose the maximum score as arm score 	Overall Suggestions 3+1.98 = 4.98 Comfort zone	3	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 					
STEP 8: Find row in TABLE C FINAL WRIST & ARM SCORE					

Fig5. RULA Employee assessment worksheet (After implementation)

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Form (Address) / Lat		Date		ERGONOMIC Assessment - Work place audit sheet			Module : NALT		Operation : Drop-arm	
							Station: Assembly		Operator:	
Area	SLNo	EVALUATION CRITERIA	Quantification & Parameters			OBSERVATION SCORE			Observation	
			Poor	Can improve	Good	Poor (0)	Can Improve (5)	Good (1)		
Controls and Displays	1	Labeling of Controls	Not available	available - not legible	available and legible			✓		
	2	Accessibility of Controls including emergency controls & logical arrangement of controls and Displays	>5.0 feet >1.5 feet Swinging	2.5 feet to 3.5 feet	4.5 feet ± 1.5 feet			✓		
	3	Colour Coding for Gauge Displays (W/G)	Not available	Partially available	available and legible			✓		
	4	Position of Displays and controls w.r.t eye level	No visibility from stand position	Can view with in one meter movement	All controls visible from one stand point			✓		
	5	Operability of controls when operator has gloves	Cannot operate	Can and operate (only and Dexterity in gloves)	Can operate			✓		
Material Handling	6	Material flow through gravity	Hand carrying material within cell	Combined hand and dials	Gravity chutes connecting work stations			✓		
	7	Proximity of Rack/Trolley w.r.t operator	trunk bend < 60° for placing/picking material	trunk bend 20°-60° for placing/picking material	trunk bend < 20° for placing/picking material			✓		
	8	Orientation of Job w.r.t Operation	Changing Posture	Flipping / Rotating	No Change in orientation			✓		
	9	Access to rack without any obstruction (especially for heavy objects)	Exposed 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	Standing in step & bending to access machine	standing in step and not bending to access machine	Standing in line			✓		
	12	Weight per lift	Load more than __ kg & __ time/minute	Load between __ to __ kg & __ times/minute	Less than __ kg & Maximum __ time/minute			✓		
	13	Trolley Handle design location	> 5.0 feet	3.5 - 5.0 feet	3.0 - 4.5 feet			✓		
	Environment & Lighting	14	Ambient Noise	< 90 dBA	70 - 90 Dba	< 70 dBA			✓	
		15	Frequency of high pitch noise	Repeated in every cycle	Once in a hour	Once in a day			✓	
16		Temperature	> 32°	Between 20-25°	< 30°			✓		
17		Relative humidity	Less than 20% & More than 75%	between 40-60%	Between 55-70%			✓		
18		Air circulation	Poor air circulation, No opening for fresh air flow	Moderate air circulation with free opening for fresh air flow	Fresh air circulation			✓		
19		Adequacy of lighting for workplace & displays without glare	Less than 100 & > 300	Less than 100 to 300	Between 200 to 300			✓		
20		Contrast in highlighting safety critical areas	Not available	Available - not legible	Available and legible			✓		
Total						10	5	18		
Grand total						33			(Addition of all total scores)	
Work Place Score						1.65			(Grand Total/18)	
Authored by:									Signature:	

Manual Torquing with human pressure

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

After



Fig 8. Pneumatic torquing After implementation

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IV. 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**



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V. 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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