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APPLIED ERGONOMICS: AN INVESTIGATION OF THE IMPACT OF ERGONOMIC DESIGN ON JOB SATISFACTION, EMPLOYEE HEALTH AND OVERALL PRODUCTIVITENESS

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ABSTRACT

Performing repetitive tasks periodically on automobile assembly line is challenging. Ergonomic design of the shop floor can affect not only operator health but his/her job satisfaction and overall productiveness. Current study takes a sample size of 95 employees working in Vehicle Chassis Frame Assembly shop at Tata Motors Ltd. and explores the impact of ergonomics on all of these factors. The shop was selected based upon the health related issues reported at the medical center inside the manufacturing facility. First, the as is condition of the shop floor processes concerning ergonomics was examined using a method developed in-house based upon the RULA & REBA methodologies. Based upon the results, numerous improvements were undertaken in the processes spanning the entire assembly line. Then a re-assessment was carried out to gauge the ergonomic improvements after a period of 6 months. Subsequently, improvements in overall health were observed using the medical data over a time period of about three years from Jan-14 to Dec-16. Finally, a focused group discussions were carried out with the employees to understand their perception about ergonomic shop design and its impact on their health, wellness and productiveness. The study found that adopting ergonomics design on the shop floor significantly benefits employee health and productiveness. Moreover, it instills a sense of wellness and trust amongst the employees who take pride in the improvements implemented with their direct involvement.

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INTRODUCTION

Work related injuries in manufacturing industry are most commonly associated with safety accidents such as due to heavy machinery and falling objects. However, another major source of disorders is the repetitive motions in assembly plants. Exposure to these quick and repetitive motions periodically over a long period of time puts operators to the risk of injuries of the human body movement systems commonly known as Musculoskeletal Disorders (MSD) affecting muscles, tendons, ligaments, discs, etc. Ergonomics is the practice of designing products and processes taking into account human interaction with them. (IEA Council, 2000)

Its application is crucial where jobs are repeated periodically such as on an automobile assembly line. Most frequently hurt body parts are back, shoulder, arm, wrist, neck and lower limb (Michael Spallek Email *et al*., 2015; Punnett *et al*., 1998; John *et al*., 1984). Repetitive motions such as in assembling fasteners, handling heavy parts and holding a posture for long period such as working while bent below waist height are high risk exposures. The most common MSDs include carpal tunnel syndrome, tendonitis, trigger finger, and aggravation of pre-existing conditions, such as arthritis. (Van Tulder *et al*., 2007; Yassi, 1997) Poorly designed workplace leads to fatigued, frustrated and hurt operators. Consequently, it influences operators' health and morale and incur the company losses in form of costly injuries, loss of productiveness and poor product quality. (Ann-Christine Falck *et al*., 2009; Mohsen Zare *et al*., 2015; Burton *et al*., 1999; James *et al*., 2005 Goetzel *et al*., 2004)

MATERIALS AND METHODS

Selecting the labor pool

The pool of employees for the current study was selected based upon the two years' (2014-15) history of medical complaints registered at the clinic inside the manufacturing facility. The data collected is shown in the table below;

Table.1. Shop-wise record of medical complaints from the clinic. 'Author's work'

Shop	Average Work force	Medical Complaints			
		2014 H1	2014 H2	2015 H1	2015 H2
Vehicle Assembly Lines	813	274	270	242	222
Trim Shops	334	116	102	72	68
Frame Fabrication Shop	95	42	39	36	33
Weld Shop	299	118	94	102	90
Paint Shop	179	75	70	82	64
Gear Shop	64	18	22	22	14
Driveline shop	178	50	66	58	54

The average number of complaints half yearly per Ten employees was taken as indicator for selecting the shop for current study.

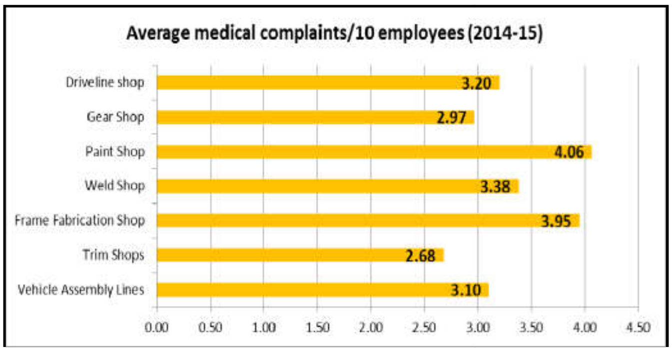

Fig. 1. Average number of complaints plotted against the employee count. 'Author's work'

Two shops rank high on the chosen indicator – Paint shop and Frame fabrication. But the later was selected owing to smaller size of the work force which would help in completing the study quickly.

Identifying high risk areas

Ergonomic assessment was done using a survey form developed in-house incorporating questionnaire to assess the shop floor ergonomics on the basis of two key factors affecting the operator – Cognitive stress and Physical stress. Cognitive stress is associated with complexities arising from large model mix, different varieties of parts and fasteners, incompatible working modes (like part assembly and computer entries) and repetitive decision making. It increases mental stress. Physical stress is a direct result of high load on body parts due to intense work or bad postures. The questionnaire design was based upon RULA & REBA methodologies.

Improving ergonomics

Identifying high risk operations based upon the assessment, improvement projects were undertaken to eliminate or minimise distressing factors which affect major body parts such as neck, wrists, back, lower limb, etc.

Measurement of the impact

i. Re-assessment was carried out to gauge the ergonomic benefits of the improvements.
ii. Analysis of the data from the medical facility dated after the improvements was used to investigate impacts the on employee health.
iii. An employee feedback was recorded with the help of focused group discussions.

Shop Floor Set up

The Frame Shop assembly line fabricates ladder frames for Medium & Heavy Commercial Vehicles from long members and cross members. Major operations performed include punching, riveting, tightening and inspection activities. The assembly line has 95 operators with an average age of 45 years. It has a designed capacity of producing 50 frames per shift of 8 hours. The assembly line is divided into 19 stations manned by 95 operators to perform 21 operations at a Takt Time of 8.80 minutes. Length of each station is 18 meters with a raised platform to provide a working height of 1.2 meters. The line conveyor speed is 2m/s. All the operations are categorised as either Left Hand (LH) or Right Hand (RH) and assigned to operators separately, thus, eliminating any need to cross the conveyor.

Initial Ergonomics Assessment

Employee awareness and survey

Initial survey was conducted to capture the awareness amongst the operators about their occupational health and ergonomics. The survey had 5 questions to be rated on a scale of one to five. The survey covered awareness regarding workplace injuries, health concerns and ergonomics concepts. Twenty participants gave overall rating of 1.98 (out of 5). (*Annexure II*)

Work related complaints

The medical data collected from the plant's medical facility for the Jan-2014 to Dec-2015 shows the number of instances of work related injuries or illness reported by the operators.

Table 2. Category-wise record of medical complaints from the Frame shop employees, 'Author's work'

	Injury/Time	Medical Complaints			
		2014 H1	2014 H2	2015 H1	2015 H2
1	Neck	4	3	4	2
2	Shoulder/Arm	6	4	5	4
3	Wrist/Hand	3	1	1	2
4	Back - Upper	3	4	2	2
5	Back - Lower	14	14	13	11
6	Lower Limbs	12	13	11	12
	Total	**42**	**39**	**36**	**33**

Major and recurring factors found were

1. Back pain
2. Muscle fatigue
3. Shoulder strain
4. Leg joint pain

GEMBA analysis

1. Man
   1.1. Overcrowding
   1.2. Uneven work load distribution.
2. Machine
   2.1. Lack of space due to fixture position.
   2.2. Improper bed length.
3. Method
   3.1. High bending while riveting.
   3.2. High dependency amongst operators.
4. Material handling
   4.1. Weights of parts worked upon in the shop floor are close to one ton.
   4.2. Punching templates lack handles for ease of use.
   4.3. Sharp edges and burrs on long members.

Ergonomics risk assessment

The approach followed to assess the ergonomics risk status was;

a) Observing the operation on the shop floor
b) Filing out the survey form based upon the observations and inputs from the operators.
c) Computing the results (Red/Yellow/Green) as per the scales defined.

An in-house questionnaire was developed (*Annexure III*) based upon the RULA & REBA methodologies. The survey covers the ergonomics effects of the shop floor environment factors such as lux level, noise, dust & smoke concentration, etc., the cognitive stress caused by complexities of the tasks performed and the physical stresses on back, shoulder/arm, wrist/hand, neck and lower limb. The effects of long time exposure to driving and vibrating tools are also included. Section I determines any complexities arising in the processes due to model mixes, difficult packaging, accessibility, etc. Section II of the survey questionnaire records positions of major body parts for majority of the work time. Then combinations of these records are used to assign stress ratings to affected body parts on scales with ranges within two to twelve. These ratings are used to calculate the risk exposure percentage and arrive at the overall Red/Yellow/Green risk status.

The results from the preliminary assessment are as follows;

Table 3. Ergonomic risk exposure status for all 21 fitments in the shop. 'Author's work'

	Risk Status →	Red	Yellow	Green
Jan 2016	Cognitive stress	4	9	9
	Physical stress	2	14	5

The operations with Red status were;

i. Long Member transfer to Heft station and reaming station
ii. Cross member fitment
iii. Long member punching

Further detailed analysis suggests highest risk exposure to shoulder/arm and wrist/hand due to handling of heavy loads for longer durations. Unnecessary decisions making and inter-dependency amongst operators contributed to high complexities.

Ergonomics Improvement

Based upon the results of the initial assessment, improvement projects were carried out on the shop floor. Few of the projects implemented are illustrated below;

Problem A: Low accessibility to the station.

Fig. 2. Congested work space with limited access to the work piece. 'Author's work'

Initially, the flow of the work piece was in a zig-zag motion with high probability of hitting the operator. The crowded shop floor also hindered operator movement with low accessibility in performing certain operations like reaming and tightening.

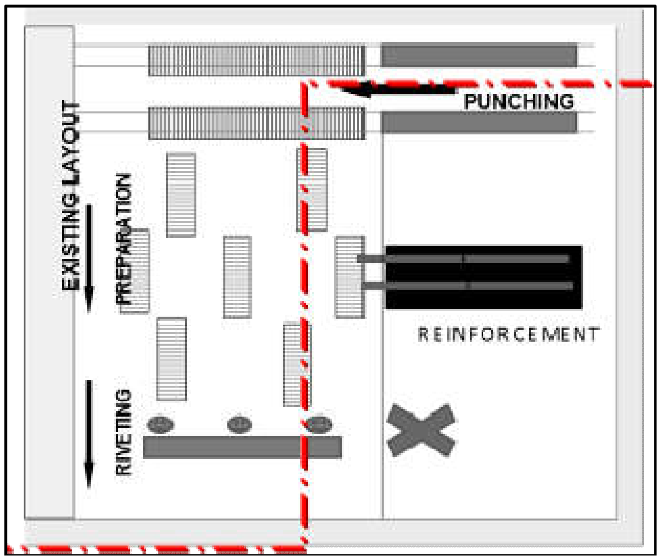

Fig. 3. Old shop layout with zig-zag flow path for the work piece. 'Author's work'

As can been seen in the above figure, the work piece flowed across the space occupied by operators at the riveting station, giving rise to chances of hitting them while in movement. Improvement A: Layout of the shop was improved to find the best fit between the work and the operator. The re lay-outing ensured single piece flow and eliminated any chances of contact with the operators. Improved layout and work piece flow –

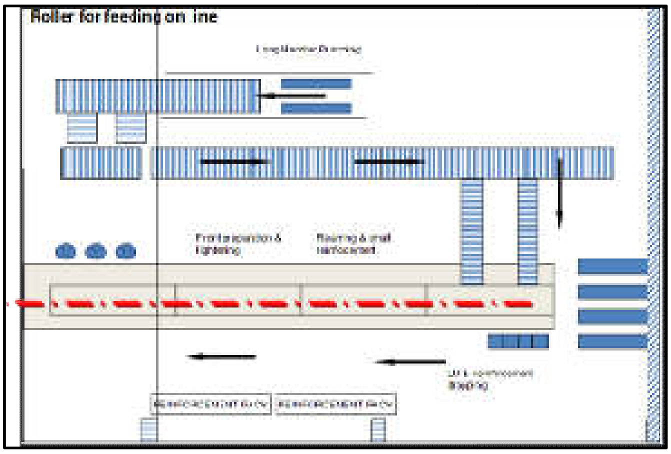

Fig. 4. Improved shop layout for streamlined single piece flow. 'Author's work'

Fig. 5. Actual implemented project. 'Author's work'

Problem B: High ergonomics risk exposure to hands & back in lifting templates without any handles.

Fig. 6. Template without any handle. 'Author's work'

Improvement B: Handles were provided on all the templates for ease of handling.

Fig. 7. Welded handle for ease of lifting. 'Author's work'

Problem C: Huge risk of falling of long member as they slip due to hammering of the brackets by the operators. The root cause was the use of external pin which may come out on impact.

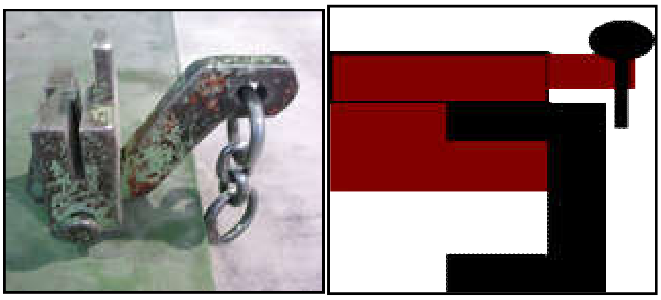

Fig.8. Bracket with loose pin susceptible to falling. 'Author's work'

Improvement C: Bracket design was modified to eliminate slips resulting in improved cognitive ergonomics and employee safety.

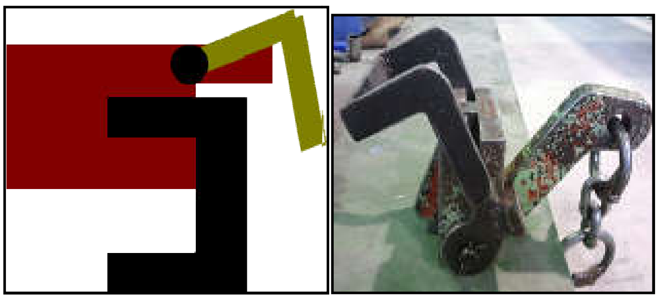

Fig. 9. Bracket fitted with latch to eliminate any chances of falling. 'Author's work'

Problem D: Operator had to sit and crouch for tightening the cable around the Long Member stack.

Improvement D: Stand for stacking up the Long Members was fabricated to eliminate bending.

Fig. 10. Long member stacking with and without stands. 'Author's work'

Likewise, several other projects were implemented to address the high risk factors such as –

i. Cuts & bruises on hand
ii. Accessibility of parts
iii. Overcrowding
iv. Overhead working

Measurement of Impact

Re Assessment of ergonomics status

Post the projects' implementations, ergonomic status of all the stations was re-assessed. Results of the assessment are as follows;

Table 4. Ergonomic risk status for the 21 fitments after improvement projects compared to 6 months earlier. 'Author's work'

	Risk Status →	Red	Yellow	Green
Jan 2016	Cognitive stress	4	9	9
	Physical stress	2	14	5
Jul 2016	Cognitive stress	0	9	12
	Physical stress	0	11	10

Thus, all the operations in Red zone exposed to high ergonomic risk were improved to reduce their exposure to either Yellow or Green zones.

Work related injuries

Medical data was re-examined for FY 16-17.

Table 5. Category-wise record of medical complaints from the Frame shop employees. 'Author's work'

	Injury/Time	Medical Complaints					
		2014 H1	2014 H2	2015 H1	2015 H2	2016 H1	2016 H2
1	Neck	4	3	4	2	2	0
2	Shoulder/Arm	6	4	5	4	2	2
3	Wrist/Hand	3	1	1	2	0	0
4	Back - Upper	3	4	2	2	1	1
5	Back - Lower	14	14	13	11	11	6
6	Lower Limbs	12	13	11	12	10	8
	Total	**42**	**39**	**36**	**33**	**26**	**17**

The data clearly showed a decline in work-related injuries.

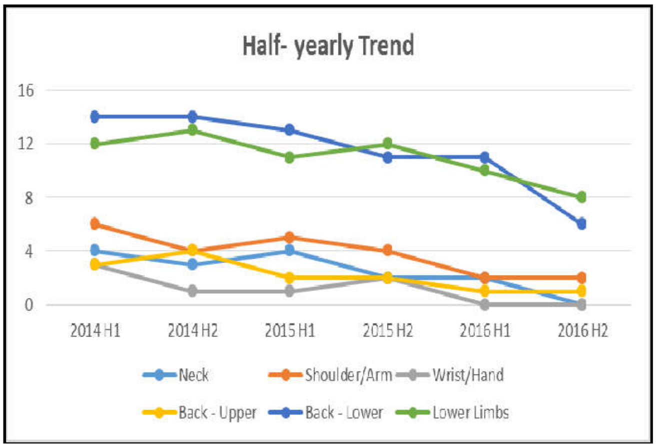

Fig. 11. Declining medical complaints in last one year. 'Author's work'

Impact of ergonomics improvement on employee morale and overall productiveness

A focused group discussion with select employees was carried out to capture their perspective on the application of ergonomic design. The employees selected were team leads and union representatives working in the shop.

The conclusive opinions shared were as follows –

1. The study of ergonomics achieved dual goals of eliminating immediate shop floor injury concerns as well as educating employees about concepts of ergonomic design for long-term benefits.
2. Participative approach for improvement projects has instilled feeling of pride and confidence amongst the employees.
3. Declining health issues validated by the medical data has contributed to overall wellness and boosted the productiveness of the employees.

Another brief post-project survey about the perception towards employing ergonomic shop floor design amongst the employees averaged a score of 2.80. (*Annexure II*)

Conclusion

Several conclusions can be drawn about the ergonomics in the frame fabrication processes used by operators in the shop. In each case, it was found that the current material handling processes presented a high risk of musculoskeletal injury resulting from:

1. Heavy loads/excessive forces
2. Awkward postures: largely due to space constraint and heavy loads.
3. High inter-dependency: between the operators
4. Continuous decision making: due to large variety of models

Losses associated with ergonomic injuries include direct costs, such as medical costs, fines, and lost wages, and indirect costs, which can include reduced production, long term physical restrictions of employees work activities, increased insurance costs, the total amount of time lost, etc. Conclusively, application of Ergonomics and its results have two aspects associated with them –

Evident benefits in measurable parameters

1. Ergonomics reduces costs - by methodically reducing ergonomic risks, which prevents costly MSDs and resulting compensation costs. The compensation costs tend to be several times the preventions costs.
2. Ergonomics improves productiveness - by designing a job to allow for good posture with less exertion and fewer motions, the employee becomes more efficient and absenteeism falls.
3. Ergonomics improves quality - poor ergonomics leads to fatigue which impedes the best output from the employees, hampering product quality.

Intangible benefits of immeasurable characteristics

1. Sense of wellness amongst the employees – employees feel dynamic about their job and confident about their workplace safety, which improves employee job satisfaction, morale and involvement.
2. Empowerment and pride – owing to participatory approach with employees for solving ergonomic problems.
3. Ergonomics improves employee engagement –Employees acknowledge employer's commitment towards their safety and health as a core value.
4. Ergonomics creates a better safety culture – with complementing contributions from both employer and more importantly the employees.

Recommendations

From the results of this study, several recommendations can be made in an effort to reduce or eliminate the risk of ergonomic injuries. These include,

1. Awareness on embracing workplace ergonomics application at the strategic level –
   Management is recommended to absorb principles of ergonomics in the core values of planning and executing production processes.
2. Management's support in implementation of workplace ergonomics –
   Process tools to progressively assess and correct shop floor ergonomics should be put in place to encourage and facilitate participatory approach for ensuring continuous and long-term benefits.

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