International Journal of Mechanical Engineering and Robotics Research

ISSN 2278 – 0149 www.ijmerr.com
Vol. 2, No. 2, April 2013

Research Paper

MODELING AND OPTIMIZATION OF ASSEMBLY OF TRANSMISSION SYSTEM THROUGH ERGONOMIC CONSIDERATION: AN OVERVIEW

Jayant P Giri[1]*, Kaustubh N Kalaspurkar[1] and Prasad A Hatwalne[2]

Corresponding Author: **Jayant P Giri, ✉ jayantpgiri@gmail.com*

Increased competition in the market, ever increasing demands of products and delivery of the quality product within committed dates forcing the manufacturers to involve newer and more optimized techniques in their production scheduling. This technique either involves costly Automation and Flexible Manufacturing System (FMS) or the techniques forcing on elimination of unnecessary and unproductive operation (i.e., motion) during the production. In this paper, a case study at one of leading tractor manufacturing company in India for one of its production operation, i.e., assembly of Rear Axle Carrier (Transmission System) of tractor is presented using the technique of time and motion study. For this technique such as Predetermined Motion Time Study (PMTS), Method Time Measurement (MTM), various process charts are used for analysis and optimize their present methodology of assembling Rear Axle Carrier.

Keywords: Automation, Time study and motion study, Workstation design, Ergonomics, Productivity, Assembly tasks, Rear axle carrier, Stop watch

INTRODUCTION

For the improved productivity to satisfy the market demand the efficiency of man, machine and methodology plays a vital role. The efficiency of man, i.e., operator is highly depending on how well the workstation is designed ergonomically, where as the efficiency of machine is more if its utilization is more and proper. But efficiency of both, i.e., man and machine is highly affected by methodology adopted in the manufacturing system as unnecessary and unproductive movements and operation will cause the fatigue to operator as well as improper machine utilization. Here proper production scheduling is very important. To analyses the task in the manufacturing.

[1] Department of Mechanical Engineering, Yeshwantrao Chavan College of Engineering, Nagpur, India.

[2] Department of Mechanical Engineering, Jawaaharlal Darda Institute of Engineering and Technology, Yavatmal.

Time study and motion study is widely used. Time study is defined as ‘ time study is a work measurement technique for recording the times and rates of working for the elements of a specified job carried out under specified conditions, and for analyzing the data so as to determine the time necessary for carrying out the job at a defined level of performance. Motion study is defined as ‘motion study is the systematic recording and critical examination of existing and proposed ways of doing work, as a means of developing and applying easier and more effective methods and reducing costs.’

In the present paper, assembly task at one of the leading tractor manufacturing company in India at Nagpur is studied for the objective of performance evaluation of the productivity. In the primary phase the study regarding the workplace layout, no of components involved, movement of workers, available tools and their location, etc., were analyzed.

The motion study was carried out for analyzing the material component flow and workers movement for the flow process charts were developed and critically examined. The stop watch technique of time study was used to determine the time required for each of the operation involved in the assembly task. The study related that assembly task was characterized by various time consuming factors as result of unproductive workers movement, which ultimately results in workers fatigues and high cycle time hence there was a scope for reducing the total time required for assembly.

LITERATURE REVIEW

Gurunath and Jadhav (2012a) conducted ‘Ergonomic analysis of an assembly workstation to identify time consuming and fatigue causing factors using application of motion study’ and investigate lots of money on man, machine, material, method (4m), improving ergonomics of workplaces is cost saving. Ergonomics found great need when market demand is high and manufacturers need more output within short period. This study was conducted on assembly workstation of welding shop. This work was conducted on an assembly station in welding shop. The shop was facing problem of less efficiency of workers due to poor ergonomics and in some severe cases hazardous health issues are found. This work was conducted on an assembly station in welding shop. The shop was facing problem of less efficiency of workers due to poor ergonomics and in some severe cases hazardous health issues are found.

Baba Md Deros *et al.* (2011), conducted ‘An ergonomics study on assembly line workstation design’ and suggested the concept of high demand for products in the manufacturing industry had driven the human workers to work faster and adapt to their un-ergonomically designed workstation. This study was conducted at an automotive component manufacturer and shows current 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.

Gurunath and Jadhav (2012b) conducted ‘A computer based novel approach of ergonomic study and analysis of a workstation in a manual process’ and identify complex tasks which lead to less efficiency of worker. Various approaches had been develop including direct observations, questionnaires, interview, etc., for ergonomic evaluation of workstation. This technique of ergonomic analysis is very useful to identify complex tasks and root cause of each complex task which is useful in simplifying it and hence to reduce stress on various workers movements.

Ibrahim (2001), conducted 'An experimental study on assembly workstation considering ergonomically issues' and investigate the effects of assembly of a product on operator performance. Workstations for assembly tasks should be designed so that any operator can adjust to his/her comfort to relieve stress and improve performance. The main contribution of this work has how to measure the production rate of manual assembly lines based on design ergonomically assembly workstation.

Yeowa and Sen (2006) conducted 'Productivity and quality improvements, revenue increment, and rejection cost reduction in the manual component insertion lines through the application of ergonomics' and improving productivity and quality, increasing revenue and reducing rejection cost of the Manual Component Insertion (MCI) lines in a Printed Circuit Assembly (PCA) factory. Live experiments were conducted on production lines. Eleven problems were identified, i.e., long search for materials from the stores, unproductive manual component counting, obstructions during insertions, component fall-off while the PCA board was traveling on a U-shaped conveyor, etc., increasing profit for the company owners, providing price reductions to the customers, and giving large bonus and annual increment to their employees.

Shikdar and Al-Hadhrami (2007), conducted 'Smart workstation design: an ergonomics and methods engineering approach' and this research was to design and develop a smart workstation for performing industrial assembly tasks. A fully adjustable ergonomically designed workstation was developed.

Santos and Sarriegi (2007), conducted 'Using ergonomic software in non-repetitive manufacturing processes: a case study'. This paper uncovers, by means of a case study based on a real process, the advantages and the practical barriers involved in the implementation of 3D simulation tools in SMEs. The chosen case study is based on a non-repetitive manufacturing process.

Battini and Faccio (2011) conducted 'New methodological framework to improve productivity and ergonomics in assembly system design'. This work analyse how ergonomics and assembly system design techniques are intimately related. It also develops a new theoretical framework to assess a concurrent engineering approach to assembly systems design problems, in conjunction with an ergonomics optimization of the workplace. This work provides an extremely valuable methodological framework to companies who recognize the link between assembly and ergonomics.

Adi *et al.* (2011) conducted 'Jig design, assembly line design and work station design and their effect to productivity'. The most productive assembly line design which achieved the lowest assembly time is the combination of one operator, with rectangular jig and work station design sitting. This assembly station determines the sequences of operations to manufacture of components as well as the final product.

Francesco *et al.* (2006), conducted 'Effective design of an assembly line using modeling and simulation' invented work regarding the effective design of an assembly line for heaters production. The effective design of assembly line workstations by means of integration between ergonomic analyses and modeling and simulation. Modeling and simulation in combination with ergonomic analyses is a powerful tool for analyzing assembly line and providing effective design and optimal ergonomic solutions.

METHODOLOGY ADOPTED

This study was conducted at a workstation for the assembly of Rear Axle Carrier. This assembly operation involves 27 components. The entire component was assembled by manual process. The total assembly process was carried out on three different process stations. The assembly of the component of each were presented in the following tables.

Total part for station 1, 2 and 3: (6 + 13 + 8) = 27.

Table 1: Total Parts for Station 1

S. No.	Name of Part	No. of Parts
1.	Retainer	1
2.	Oil Seal	2
3.	Gasket	1
4.	Axle	1
5.	Ball Bearing (Axle)	1
Total Part for Station 1		**6**

Table 2: Total Parts for Station 2

S. No.	Name of Part	No. of Parts
6.	Circlip (Rear Axle)	1
7.	Pr. Bearing (Carrier)	1
8.	Spacer (Carrier)	1
9.	Carrier	1
10.	Collar	1
11.	Bolts	4
12.	Washer	4
Total Part for Station 2		**13**

Table 3: Total Parts for Station 3

S. No.	Name of Part	No. of Parts
13.	Long D – Headed Wheel Bolt	8
Total Part for Station 3		**8**

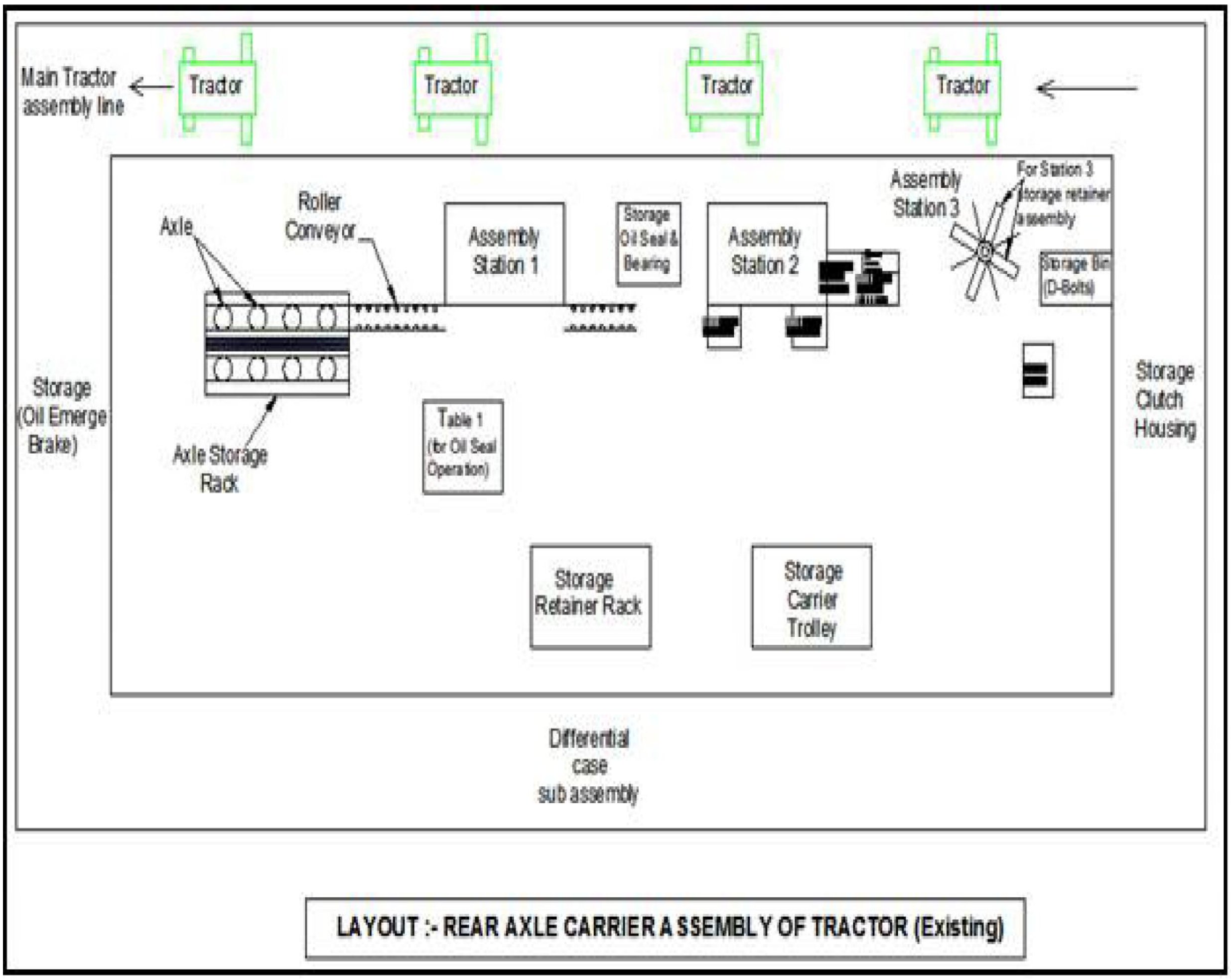
Assembly process consist of parts of different sizes and weight kept in different bins around the workplace four operators, one on workstation 1, two on workstation 2 and one workstation 3 are working. The main focus of the study is to find out the task of assembly which leads to high cycle time. Hence each operation involved in the assembly where analyzed critically using time study and motion study. Stop watch technique was used to determine the time for each activity.

Analysis of Work Place Layout

The existing layout for the assembly of Rear Axle Carrier (RAC) is as shown in Figure 1.

As shown in Figure 1 it consist of three in line assembly workstation namely station 1, 2 and 3. Material flow was successive from station 1 to station 2 then from station 2 to station 3. To assist the operator for the material flow roller conveyor (manually operated), and cranes are used.

Figure 1: Rear Axle Carrier Assembly of Tractor (Existing)



Assembly operation at station 1 involves the assembly of 6 components as shown in Table 1 out of which retainers are stores in the retainer rack which was located just behind the operator as shown in Figure 1. Also the oil seal, gasket, bearing and the axle are located surrounding the workplace as shown in Figure 1. During each assembly operator has to move at each of these location and collects the parts for the assembly. Similarly the components required assembly station 2 and 3 is to be connected by the operator from the various storage locations surrounding the workplace as shown in the Figure 1.

Flow Process Charts

From the above workplace layout and the nature of assembly involved requires several activity at each station 1, 2 and 3. For example at assembly station 1 total 51 activities of the time 6.029 min are involved. At assembly station 2 total 38 activities of the time 5.379 min and 23 activities of the 4.052 min are involves at station 3. Accordingly the flow process chart of the material for each of the assembly station is developed. The sample flow process chart for station 1 is shown in Table 4.

Table 4: Flow Process Chart - Material Type (Station 1)

Flow Process Chart	**Material Type**			
Chart No. **Sheet No.**	**Summary**			
Subject charted Used bus engines	**Activity**	**Present**	**Proposed**	**Saving**
ACTIVITY Stripping cleaning and degreasing prior to inspection METHOD: PRESENT	OPERATION ○ TRANSPORT ⇨ DELAY D INSPECTION □ STORAGE △			
	DISTANCE (m)			
LOCATION: Degreasing Shop	TIME (man-min)	-	-	-
OPERATIVE(S): CLOCK Nos.	COST LABOUR MATERIAL	- - -		
CHARTED BY: APPROVED BY: DATE	TOTAL			

	Description	**Qty**	**Distance (m)**	**Time (sec)**	**Symbol** ○	⇨	D	□	△	**Remarks**
1.	Retainer stored in trolley near assembly station 1			00					o	
2.	Pickup the retainer from retainer rack			5.82	o					
3.	Move to table 1			8.57		o				
4.	Pickup the oil seal from table 1			5.48	o					
5.	Move retainer and oil seal to assembly station 1			7.63		o				
6.	Placed the oil seal on station 1			6.37	o					

Similarly material flow process chart for the assembly station 2 and assembly station 3 is also developed.

Critical Analysis of the Flow Charts

From the above developed flow process chart each of the activity involved at all the 3 station were critically analyzed for the evaluation of the purpose of the each activity. This evaluation is done by finding the answers to the Primary and Secondary questions such as what is achieved through that activity, is that activity is necessary, can it be eliminated, what else might be done, etc., from this critically analysis unnecessary and unproductive activities for the assembly operation at each of the workstation is determined. Accordingly the critical analysis charts for unnecessary and unproductive activities are developed. The sample critical analysis chart for station 1 in Table 5. Similarly critical analysis chart for the assembly station 2 is also developed.

Proposed Improvement in the Workplace Layout

On the critical analysis for assembly station 1 it was found that activity no. 2, 3, 4, 5, 6, 39 and 40 where unnecessary and can be replaced by making certain suitable arrangement in the workplace layout. For example activity no. 2 to 6 involves movement of the worker from the workstation to the storage location for picking and transporting retainers and oil seals to assembly station 1. This activity was consuming the time of 33.87 sec. This amount of the worker can be eliminated by gravity conveyor for the retainer located near the station 1 which will make constant supply of retainer at the assembly station; similarly special storage bin for the oil seal can be located within the reach of the operator near the assembly station 1. This will eliminate the need of movement of worker for each assembly operation and will result in saving of time. Similarly activity 39 and 40 involved movement and pickup of the bearing of the worker which was required in the time of 14.4 sec. This unnecessary movement can be eliminated in similar way by making provision of storage bin of bearing nearer to assembly station 1.

Table 5: Sample Critical Analysis Chart (Station 1)

Subject of Chart – Rear Axle Carrier (RAC) assembly station 1, 2 and 3.

Activity	Primary Questions	Secondary Questions	Remarks
Purpose 2) Pickup the retainer from retainer rack 3) Move to Table 1 4) Pickup the oil seal from Table 1 5) Move retainer and oil seal to assembly station 1 6) Placed the oil seal on station 1	What is achieved? Retainer is pickup by the operator from retainer rack and then move up to table 1 from where he pickup the oil seal and move up to station 1 where he place the oil seal on station 1. Is the activity necessary? Yes, this activity is necessary for performing the operation for a human operator.	What else might be done? The retainer is stored in a bin which is mounted above side of gravity conveyor. This gravity conveyor can be mounting on the left side of assembly station 1 for incoming of retainer on a platform of assembly station 1. Similarly the bin for oil seal can be stored on a right side of assembly station 1 within maximum working area so that operator can pick the incoming retainer with his left hand and oil seal with his right hand simultaneously.	For eliminating the unwanted movement of operator, here we used the gravity conveyor for incoming of retainer and place bin for storing oil seal within maximum area. So we can eliminate the unnecessary motion of the operator and save the production time and can increase productivity.

Similarly for the station 2 and station 3 unnecessary activities were found out and they are eliminated by making required alteration in the workplace. These are tabulated in Table 6.

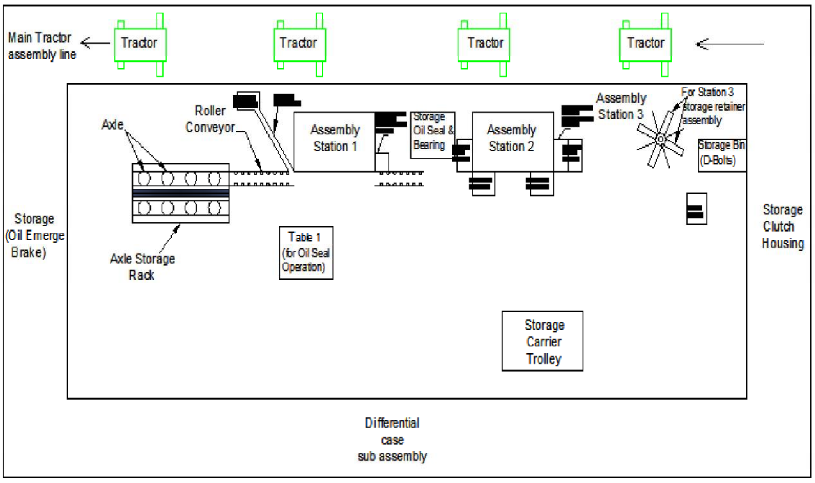
From the above suggested changes the proposed improved workplace layout is as shown in Figure 2.

All these location of the suggested bins are kept within the reach of the operator by

Table 6: Total Time Consume for Station 1 and Station 2

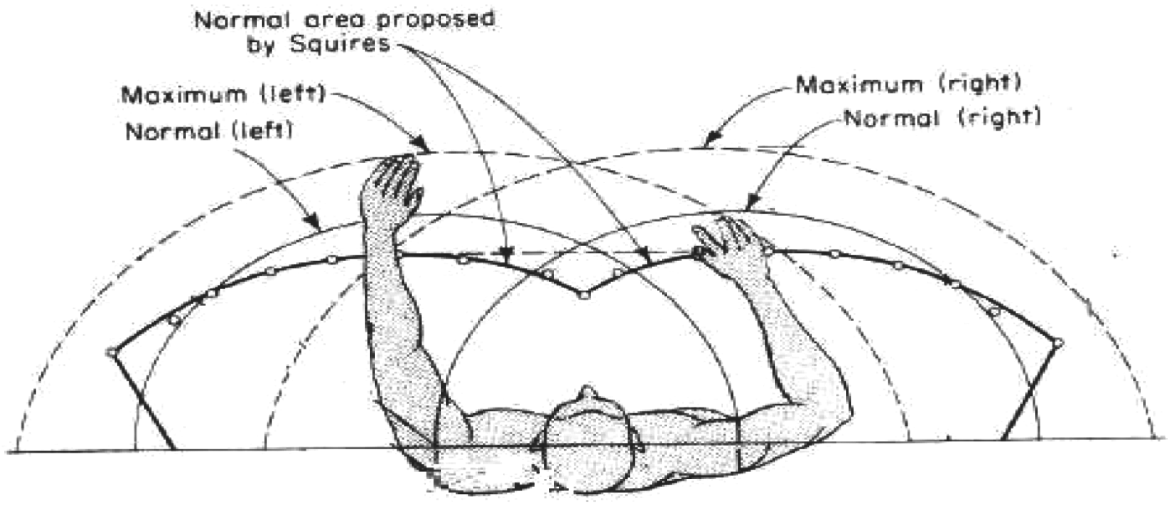
Station	Activity No.	Description	Time Consume	Suggested Improvement
Station 1	Station 2	Pickup the retainer from retainer rack	5.82	Gravity conveyor used near assembly station 1 and oil seal stored near assembly station 1 of used bin arrangement.
	Station 3	Move to Table 1	8.57	
	Station 4	Pickup the oil seal from Table 1	5.48	
	Station 5	Move retainer and oil seal to assembly station 1	7.63	
	Station 6	Placed the oil seal on station 1	6.37	
	Station 39	Pick up the bearing on Table 1	6.71	
	Station 40	Move bearing to station 1	7.69	Bearing stored near assembly station 1 of used bin arrangement.
Station 2	Station 58	Pick up the bearing from storage (labour 2)	7.36	
	Station 59	Move bearing to assembly station 2 (labour 2)	6.73	Bearing stored near assembly station 2 of used bin arrangement.
Total Time Consume			**62.36 min**	

Figure 2: Rear Axle Carrier Assembly of Tractor (Proposed)



LAYOUT :- REAR AXLE CARRIER ASSEMBLY OF TRACTOR (Proposed)

Figure 3: Recommended Working Distance for the Arms



considering the anthropometric dimension of the operator as shown in Figure 3.

CONCLUSION

The workplace layout from the assembly of Rear Axle Carrier (RAC) of one of the leading tractor manufacturing company in India is analysis with object of productivity improvement. The whole assembly process was divided into all the minute activities using the motion study. The time required for each of the activity is determined by using stop watch technique of time study. The complete process is critically analyzed to determine unnecessary, unproductive operation. To eliminate these activities certain modification are proposed in the existing workplace layout for the improved material flow.

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