"Ergonomic analysis of an assembly workstation to identify time consuming and fatigue causing factors using application of motion study"

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Abstract— **Ergonomics plays an important role in workers' productivity. Workstation layout and work design are two major factors of ergonomics of worker's efficiency. Now, manufacturers found that instead of investing 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. Ergonomic study of this assembly workstation was done by using motion study. Observations were made by studying each element of motion film recorded by video recorder. Results from this study reveal that there is need to modify workstation layout according to ergonomic principles.**

Keywords: Ergonomics, Motion film, Fatigue factors, Productivity, Workplace Layout

I. INTRODUCTION

For productivity improvement in manufacturing industries, efficiency of worker plays an important role .Productivity of worker greatly depends upon ergonomic design of workstation. Efficient ergonomics in workstation design shows better interaction between man-machine systems. Lot of research has been done on analysing and improving ergonomics of workstation, facility layout and tool design. Study regarding operator performance and comfort in repetitive assembly task has been done (Shikdar *et al*, 2009).Workstation may function with less efficiency, if anthropometry data mismatches with workstation design (Deros *et al*, 2009). Methodology has been proposed to analyse and classify assembly workplace layout configuration in relation to both technological and environmental parameters (Battini *et al*, 2011). Effect of workstation design, assembly design, jig design and working postures on assembly line shows jig design have most significant effect on assembly line (Saptari *et al*, 2011).Study of discomfort experienced by operators during process has been studied and analysis of working postures has been done in WinOWAS software to find out awkward postures (Ismail *et al*, 2009). Analysis of work stress during process among Indian workers has been carried in manufacturing industries of India (Kumar *et al*, 2011).Ergonomic study on manual component insertion line in printed circuit board assembly has been done using method of questionnaire, direct interview and archived data (Yeow *et al* and Sen *et al*,2006).

This study is conducted on a metal part assembly workstation which has high cycle time. Objective of this study includes performance evaluation of workers during assembly process. In primary phase study regarding workstation layout, process design and product specification has been carried out. Further motion study is done for ergonomic study by capturing motion film of assembly process using high definition video recorder. Motion film is analysed for each motion element of worker's body postures and movement of other body members. Results of motion study revealed various fatigue causing and time consuming factors related to worker and workstation layout.

II. METHODOLOGY

This study was conducted on assembly workstation in a welding shop. Four different metal parts from press shop are assembled by manual welding process. Assembly process consists of metal parts of different size and weights; they are kept in different bins around workplace. Two operators are working on this workstation. Their anthropometric measurements are carried out by direct interview with both operators. The main focus of this study is to find out complex task of assembly which leads to more time consumption and fatigue causing.

Hence ergonomic study is carried out using application of motion study by video recorder. Handy cam is used to record whole process in .MPEGV video format which is easy to use and transfer from device to computer.

A. Workstation Design and Workplace Layout:

Fig.no.1 (a) and (b) shows present workplace layout and design in side and top view respectively. Workstation consists of two operators working on LH side and RH side. The task consists of assembly of metal parts using manual welding process. The process consists of repetitive tasks which seem to be because of poor ergonomics. The assembly process includes picking and loading of parts from bins to workstation, handling welding gun for spotting, unloading and part transfer to next station. Operators are Indian male and average age of the workers is 25, average weight of workers is 72 kgs., Average height is 175 cms. Workplace consists of four bins for storage of four different metal parts. Dimension of bins are as shown in fig.1. (a) and (b).Though heights of all bins are 80 cms. Workstation layout dimensions are 275x200x90 cms. From these figures it is concluded that workplace layout is improper and needs to modify it. During assembly process various motions like rotation, more walk, bending, lifting etc. have been observed and these tasks highly repetitive if shift working hours are considered. Operators are not able to maintain standard body postures and movement because of poor workplace layout. Hence lead to fatigue like shoulder stress, back pain, neck pain etc. which reduces working efficiency.Fig.1. (b) Shows distance (in meters) covered by workers from original position to bins and control button.

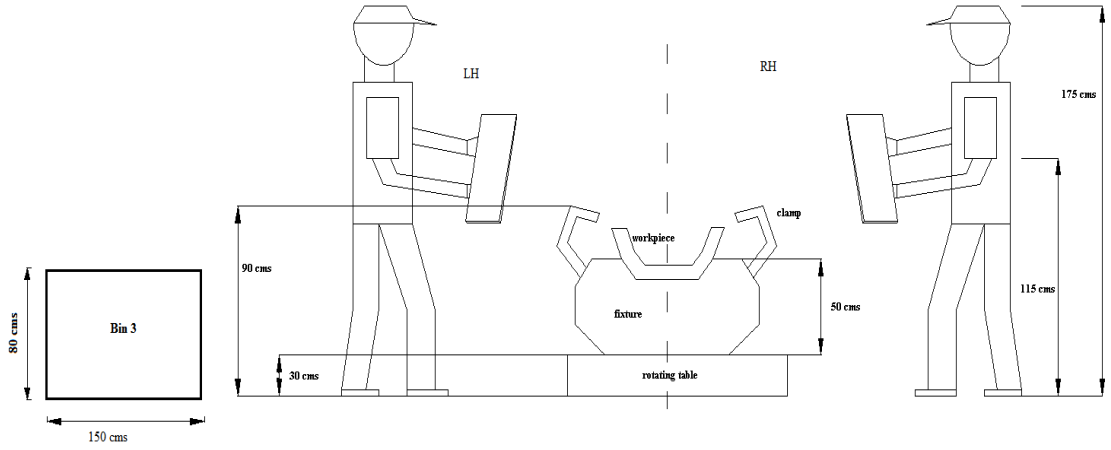


Fig.1.a). Side view of workplace layout and design

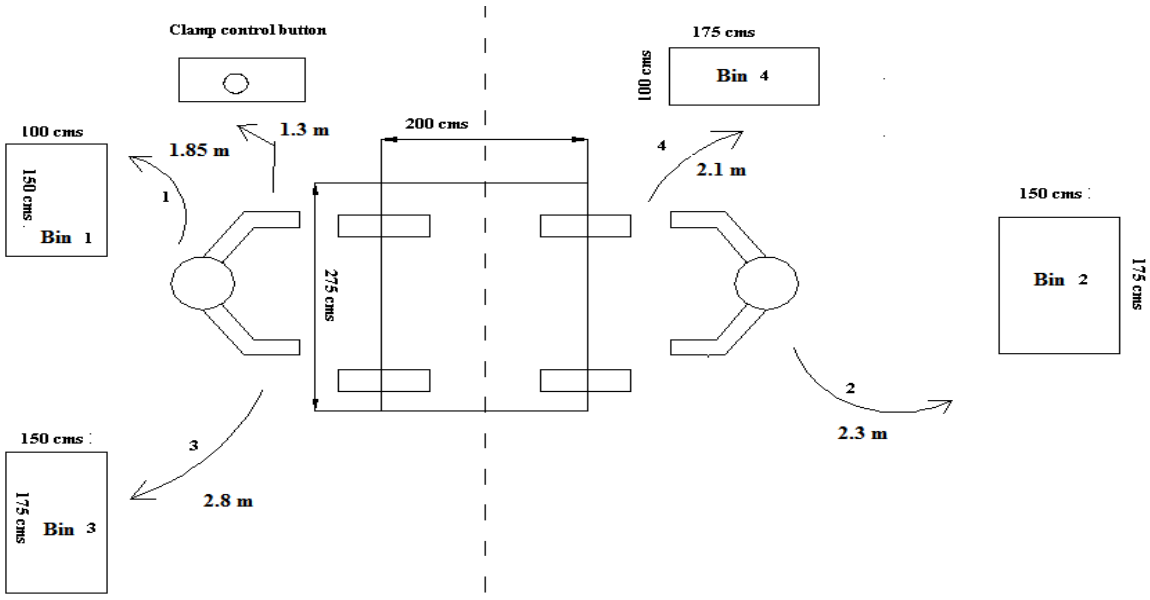


Fig.1.b). Top view of workplace layout and design

B. Flowchart of assembly process :

Following flowchart shows assembly process of metal parts on workstation,

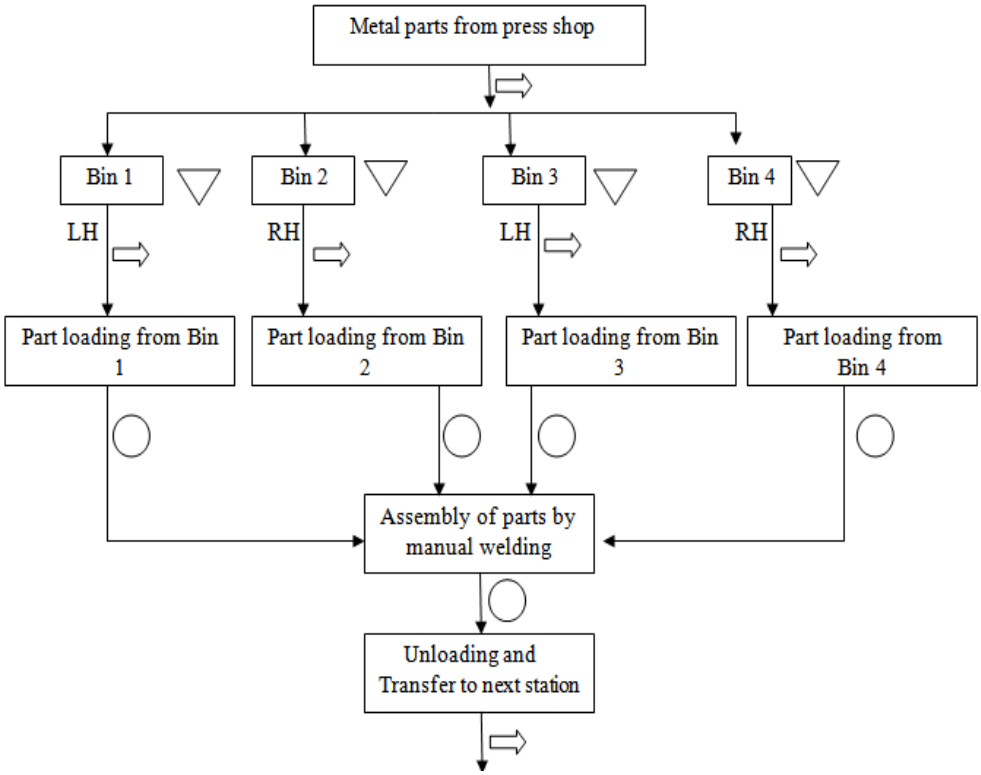


Fig.2.Process flow of assembly operation

TABLE 1
Frequency of activities during assembly process

Symbol	Transport ⇨	Process ○	Storage ▽	Delay D
Frequency(LH)	2	2	-	-
Frequency(RH)	2	2	-	-
Frequency(Both)	1	1	-	-
Other	1	-	4	-

Table no.1 shows frequency of various activities involved in assembly process by LH worker and RH worker. Workloads have seen to be equally distributed amongst both workers. Assembly process does not contain
delay operations as shown by above table.

C. Product Design:

Fig.3.a. shows design of input metal parts, though thickness of all parts is constant i.e.0.3 cm while fig.3.b. shows final assembled single product. Following table shows specifications of input parts and final product. Part 2 and part 4 are heavier than other parts. Hence more effort is required while handling these parts. The total weight of final product is 15.214 kgs which needs more efforts while transferring finished product to next station. For example, this paragraph begins with a level-3 heading.

TABLE 2
Specifications of input parts and final product

Part No	Dimensions (l x b x h) cms	Weight (in kgs)	Material
1	135 x 30 x 0.3	1.675	EN 10
2	155 x 52 x 0.3	7.538	EN 10
3	135 x 43 x 0.3	1.632	EN 10
4	135 x 35 x 0.3	4.356	EN 10
Final	155 x 100 x 0.3	15.214	EN 10

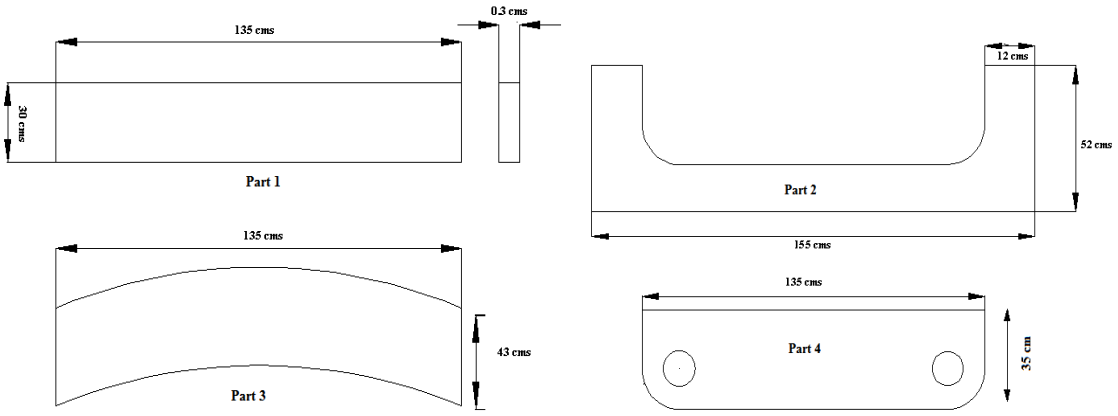


Fig.3.a) Design of input parts

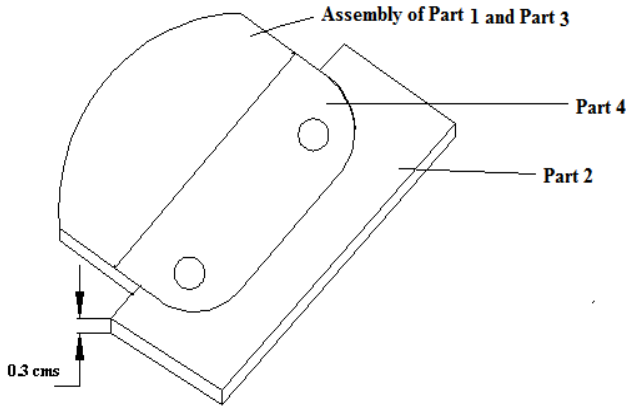


Fig.3. b) Design of final product

D. Motion Study:

Critical analysis of workstation is done by using motion study. Every task performed by man or machine involves body members and their respective movements. The efficiency of these movements can be accurately determined by distance moved, control actions, co-ordination of different body members with each other and working conditions. The purpose of such motion study is to identify and understand motion bottlenecks related to human effort and system. In order to achieve required objective there is need to go into details of body and hand movements and thus best possible and most economical pattern of movements can be developed to perform efficient work or activity. This type of study involves making motion film of an operation to analyse frame by frame and result of each frame element like bending; lifting, twisting etc is noted.

Following procedure is used for motion study analysis in this work,

- Recording of motion film is done by using high definition handy-cam in the .MPEG file format.
- Motion films in .MPEG format are analysed by using Windows Movie Maker, the inbuilt video editing software from Microsoft in windows operating system at 0.125X running speed.
- At this low speed it is easy to examine and analyse body motions while working at the workstations.

Fig.no.4. shows motion study of workstation done in windows movie maker .The left hand side shows running film at speed of 0.125X and the right side shows film breakdown in small elements for each body motion. These elements are nothing but frames which shows particular activity done by worker e.g. frame 1 shows loading of part 1 i.e. left end of frame is the start of picking part and right end is the end of frame means loading part to station. These activities belong to therbligs “grasp (G)” and “transport loaded (TL)”.

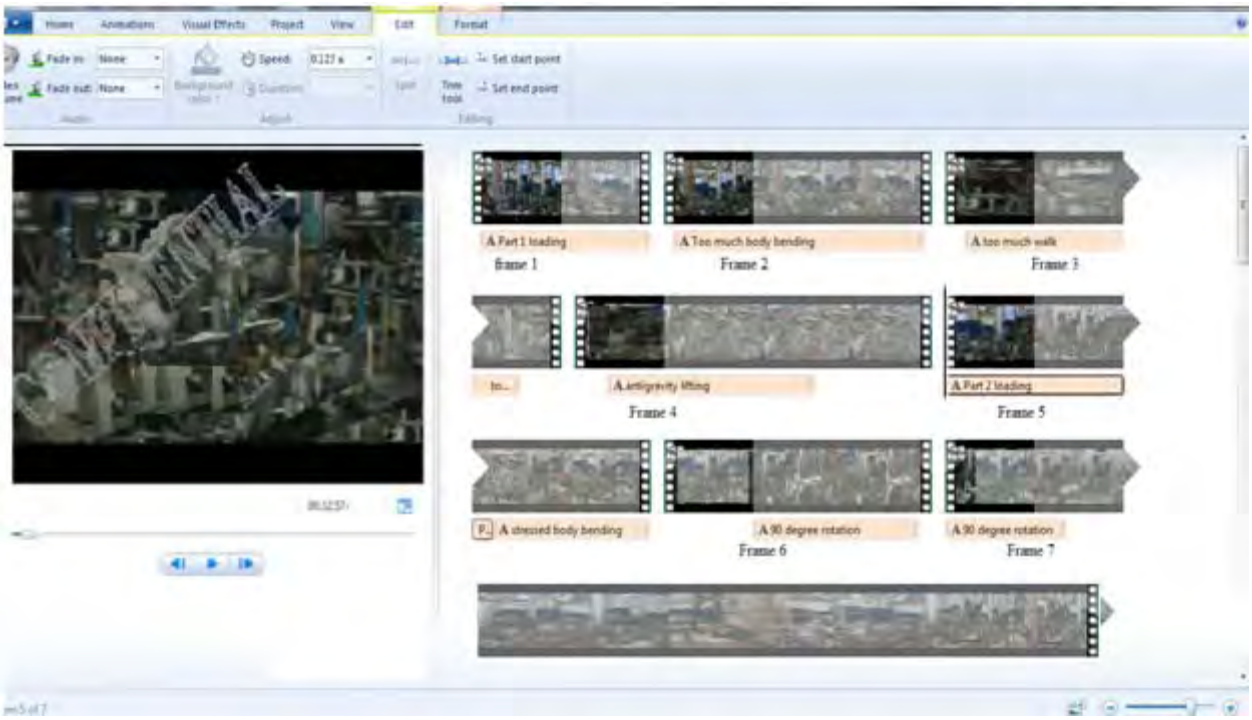


Fig.no.4.Motion film of assembly process in windows movie maker.

III.RESULTS

A. Cycle time:

Table no. 3. Shows result of each assembly task in seconds observed from motion study .From table total task time is calculated for assembly of product and it is found to be 132 seconds. Tasks are considered for both LH and RH worker and time required to each task by each worker is measured.

TABLE 3
Elemental break up of assembly process

Task No	LH Worker	RH worker	Time per task(Secs)	Clock time (Hr: Mins: Secs.)
1	Pick up and load part 1	-	8 secs	10:00:00 AM
2	-	Pick up and load part 2	10 secs	10:00:08 AM
2	Pick up and load part 3	-	7 secs	10:00:18 AM
3	Rotate and walk to clamp button	-	6 secs	10:00:25 AM
3	-	Pick up and load part 4	8 secs	10:00:25 AM
4	Pick up gun	-	5 secs	10:00:33 AM
4	-	Pick up gun	5 secs	10:00:38 AM
5	Spotting	-	68 secs	10:00:38 AM
5	-	Spotting	78 secs	10:01:46 AM
6	Remove gun and wait at clamp button until RH worker finishes task	-	12 secs	10:01:56 AM
6	-	Remove gun	6 secs	10:01:58 AM
7	Unload and transfer		8 secs	10:02:04 AM
8	End of task			10:02:12 AM

Cycle time calculation:

End time: 10:02:12 AM

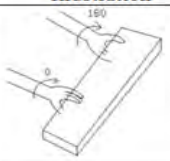
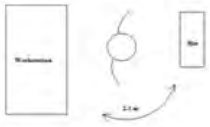
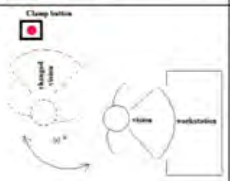
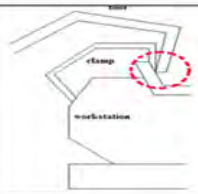
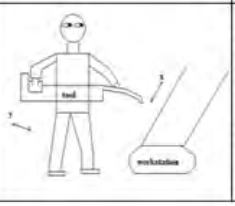
— Start time: 10:00:00 AM

Cycle time: 00:02:12=132 seconds

B. Ergonomic Analysis:

When operators are interviewed for getting information regarding awkward postures and complex task, various illnesses are informed by these workers including neck pain, back pain, shoulder pain etc. lead to reduced efficiency of workers and in severe cases long duration pains. Motion study revels reasons of these illnesses. Analysis of these factors is done by motion film and root causes of these things are found out. Table no.4. Shows ergonomic analysis of workstation obtained from motion study.

TABLE 4
Bottleneck factors analysed by motion study

Factor	Illustration	Description	Reasons
1.Wrong gripping and grasping of objects Effect on: Wrist and hand		Left hand fingers are over the surface and thumb is underneath while vice-a-versa for right hand which is wrong activity as per ergonomics	Part design not suitable for grasp and hold, Lack of awareness to hold parts
2.Bending Effect on: Back and neck		Too much body bending for loading to station and picking parts from bin(≈ 70°)	Height of workstation is less
3.Frequent and long walk for material handling Effect on: Leg and foot		Distance between workstation and destination like tool, bin, button etc. is more	Poor facility layout
4.Antigravity lifts Effect on: Shoulders and Hands		Lifting originally not allowed in workplace design as it is antigravity task takes more time, fatigue causing even in this study lifting task seen above chest which is even more severe.	Size, weight of parts are not suitable to handle it manually , no assistance for material handling
5.Stressed body Postures Effect on: Various body parts depending on posture		Improper loading of parts since workstation design causes complex and stressed body movements.	Poor workplace design and less awareness of body postures
6.Eye Movements Effect on: Eye and Pupil		Eye movements are frequently changed for picking parts, pressing button etc.	Poor workplace layout and less awareness of movements.
7.Critical area Working Effect on: whole body		Working in critical area of parts and resistance due to workstation design causes complex task hence time consumption is more.	Tool geometry and workstation design
8.Improper position of worker Effect on: Eye, Hand, Leg and Shoulder		Worker is not parallel with workstation though it is recommended to stand parallel with station so as to get good eye-hand co-ordination(see for eye direction)	Improper tool geometry and workplace layout

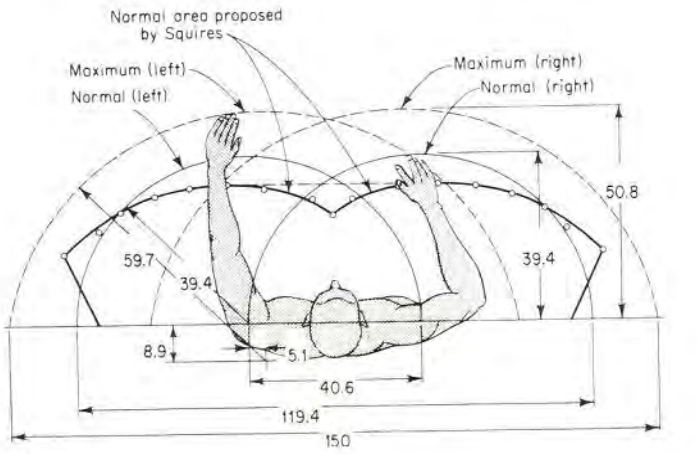


Fig.no.5. Recommended distance for arms (in cms) (Sanders and McCormick, 1993)

IV. CONCLUSIONS

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. Here attempt has been made to identify fatigue causing factors which leads to reduced efficiency of workers hence less productivity of workstations. To study and analyse factors causing less efficiency, motion study technique is used. The other source of data is interview with workers, managers, archived documents etc. Ergonomically improved workplace layout helps in reduced stress on workers, elimination of repetitive tasks, cycle time reduction and hence increased productivity.

Fig.no.5 shows recommended working area for human left and right hand, the dimensions are shown in centimetres (Sanders and McCormick, 1993). Normal area can be easily reachable by swiping forearm while maximum area refers to be reached by spreading arm from shoulder.

Following conclusions are made from this study:

1. Natural motions of workers are constrained by poor workstation design and layout. Material handling, tool handling, control system operation have seen significant effect on worker efficiency.
2. Workers are seen to be unaware of ergonomic principles as body postures and movements are seen to be not following standard work procedure.
3. Frequent body postures like bending ,twisting, eye movements, lifting have seen in single product assembly though company works for 8 hrs , hence health issues are observed like back pain, shoulder pain , wrist pain , neck pain etc. lead to less efficiency of workers.
4. Tool design and part design have significant effect on worker efficiency as tool is seen to be heavy to handle, geometry of tool are not supportive towards smooth operation.
5. Workers are seen to be having discomfort while handling parts as sharp edges and large size of metal parts may lead to fear of injury. Also tool and parts are not supportive for gripping.

Following recommendation are suggested in order to overcome above problems:

1. Workers must be trained to aware and follow standard work procedure including standard body postures, motion sequences. Training should be given in order to follow standard procedure for tool and material handling.
2. Modify the workstation layout and design so as to suitable for good body postures and good tool-work piece contact.
3. Use of low cost mechanical automation assistance can reduce complex tasks and hence reduces fatigue.
4. Some work must be assigned for foot usage like foot pedal so to avoid muscular stress and cramp to muscles.
5. Increase comfort situation by implementing healthy environment like air supply system, good lightning system etc.

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