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Pre-Eliminary Design Adjustable Workstation for Piston Assembly Line Considering Anthropometric for Indonesian People

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***Abstract*—**Manufacturing process has been considered as one of the most important activity in business process. It correlates with productivity and quality of the product so industries could fulfill customer's demand. With the increasing demand from customer, industries must improve their manufacturing ability such as shorten lead-time and reduce wastes on their process. Lean manufacturing has been considered as one of the tools to waste elimination in manufacturing or service industry. Workforce development is one practice in lean manufacturing that can reduce waste generated from operator such as waste of unnecessary motion. Anthropometric approach is proposed to determine the recommended measurement in operator's work area. The method will get some dimensions from Indonesia people that related to piston workstation. The result from this research can be obtained new design for the work area considering ergonomic aspect.

***Keywords*—**Adjustable, anthropometric, ergonomic, waste.

I. Introduction

NOWADAYS, modern manufacturing systems led industries to meet market demand in order to be able to compete. Decent production is decisively required to be able to respond quickly what is desired by the market. As one of the main components in the production, workers have a significant impact on the productivity of the manufacturing process.

According to [1], there are four factors affect workers in an organization, namely: Task, Physical Environment, Workspace, and Organization and procedures. These four factors are strongly influenced by psychological factors and physical labor. It is then studied further in a science called ergonomics. The science of ergonomics applied to the manufacturing industry to increase worker productivity significantly.

Work station as a key component in the manufacturing process, should be ergonomically designed to support the best capabilities that operators thus making the operator, machine and the environment are interconnected and interacting that will lead to an increase in the efficiency of work, safety, and comfort that leads to increased productivity. However, the science of ergonomics are applied in various industries around the world differ from one another depends on the physical condition or the human (indigenous people) where the industry is located. These measures resulted in a standard measure based on the posture of the natives in certain areas, which meet the threshold optimal posture and safe in doing a particular job called anthropometry.

Working position at the workstation often caused by incorrect use of the appliance is not in accordance with anthropometric operators working thus affecting the performance of the operator. If the working position is wrong then it will result in the disposal of excessive force so tired, discomfort work thus affecting the outcome or the productivity.

Past research has tended to take into account the re-configuration is devoted to the production line without too much attention to psychological and physical factors and not the operator there is a special attention to posture for workers to Indonesian people so that the health and safety of the operator was likely to be ignored. Whereas health and safety factors may indirectly increase the motivation of operators to increase productivity.

With get increase productivity, indirectly the expected output will increase also thus company's profit. Actually, it is not easy to obtain the increasing of productivity. There are lots of findings or problems related to productivity such as a lot of waste in each manufacturing process. Therefore, these findings must be further analyzed to improve and eliminate waste in each manufacturing process. Some of methods to improve are measure and redesign workstation on manufacturing process with qualitative method and quantitative method.

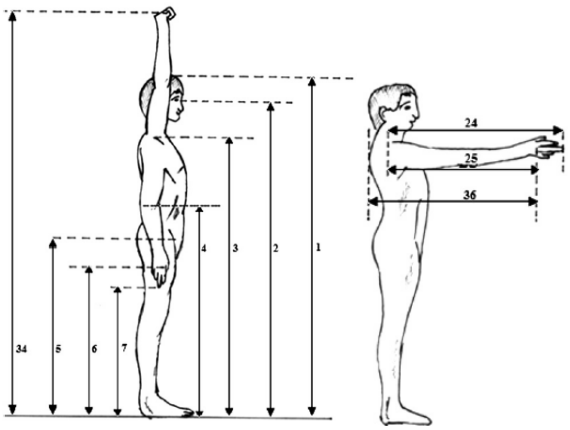

Fig. 1 Size posture with anthropometric Indonesian people in assembly lines

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This research was carried out on piston assembly lines on Lean Production System Laboratory belonging to Manufacturing Systems Laboratory at Department of Industrial Engineering University of Indonesia, when it was discovered similar problems where there is fatigue of assembly-line workers such as lab with time inconsistent. This is because the work table operator who does not comply with anthropometry workers. This causes a cycle time takes longer and decreased worker productivity. Therefore, this study will focus on factors workspace where the need for design and simulation results increased productivity on assembly line car pistons with regard to human factors or side ergonomic work desk operator with reference anthropometric Indonesian people. Additionally, it will at this research will be examined also from other disciplines are health and safety risks related to occupational safety and health operators resulting from improper work desk posture.

This research can be expected to be the basic for future research in designing workstation so from this research can be improve and measurement related some aspects to increase productivity. This research is also intended to benefit to all academic world in applying existing laboratory so it can apply the factor's ergonomics and practitioners can make this study as a reference in implementing ergonomic factors working in a larger scale again.

II. Literature Review

A. Ergonomics Definition

Ergonomics is derived from the Greek meaning ergos work and nomos, which means the study. Ergonomics can be translated as the study of employment or employment system, including the workers, work equipment, and workplaces of workers [2].

Ergonomics uses information about human behavior, posture, movement, displacement, and other characteristics for the design of tools, machines, and the work environment in order to improve productivity, safety, comfort, and affectivity [3].

Good working environment in manufacturing and services industries rarely gives a chance to work that exceeds the ability of the workers. However, there are some specific workload exceeds the ability of workers that cannot be sustained in the long term. By applying ergonomic principles in designing a work will improve the performance of workers without feeling fatigue in the muscles.

B. Risk Factors in Ergonomics

Risk Factors in ergonomics are elements of workplace-related discomfort experienced by employees at work, and if neglected, long may increase the damage to the worker's body cause the accident. The most important risk factors of neglect of ergonomic factors in the workplace are MSDs (musculoskeletal disorders).

Musculoskeletal disorder is a disorder caused by a buildup of injury or damage to small musculoskeletal system due to repetitive trauma that not every event can be cured completely so that the form of damage is large enough to cause pain [4].

Risk factors contained in the related activities MSDs can be classified into risk factors associated with job characteristics (work postures, frequency, and duration), object characteristic (shape and weight of materials /objects), work environment, and individual factors (subjectivity).

C. Anthropometric

Anthropometry is the study of human body measurement dimensions (size, weight, volume, etc.) and the specific characteristics of the body such as space. Anthropometric data are used for various purposes, such as the design of workstations, working facilities, and the design of products in order to obtain the appropriate sizes and dimensions worthy of the human limbs that will use it. Anthropometric database is very important to use to get a good design based Human Centered Design to be able to increase work productivity.

Anthropometric data is different according to each region on the physical condition of the majority of the region or country. For Indonesia, anthropometric data are similar to those Singaporean [5].

D. Production Systems

Production in simple terms is the overall process and the operations performed for products or services. The production system is a collection of sub-systems that interact with the aim of transforming inputs into outputs of production. These inputs can be raw materials, machinery, labor, capital and information. Other side inputs in the system such as sewage, information will act as supporting process to produce the expected product.

The production system generates the maximum added value factors - factors involved in the production process must be managed or regulated so that ongoing production systems effectively and efficiently [6].

E. Occupational Health and Safety

Safety refers to the protection of physical well-being with the aim of preventing the occurrence of accidents or injuries related to the job [7]. Occupational accident is any act or condition that can lead to an accident survived. Factors companies do to prevent accidents [8] one of which is to conduct good ergonomic (adjustment to the shape of the tools and materials available). Occupational health is a state free from physical disorders, mental, or emotional pain caused by the working environment [9].

F. Lean Production System

The main idea of Lean is to maximize customer value and eliminate waste on production system. In the end, lean organization give the ‘perfect value’ to customer through ’zero waste’ process.

There are five lean principles, which described as following:

1. Value

- Customer defines the product value in lean supply chain.

- Value-adding activity is to process raw material into the product that customer's wanted.
- The activity, which is not giving the benefit, is waste.

2. Value Stream

- It is identifying the whole process sequence from raw material to customer.
- Value stream mapping is the integral aspect of lean.
- Value stream can be a complete supply chain

3. Flow

- Using one-piece flow to connect all activity and process into the most efficient combination to maximize benefit and eliminate wastes.
- Waiting time between activities is eliminated, to accelerate adding value.

4. Pull

- Only produce the product/service that is needed by customer.
- There are not production activities until there is a demand based on supply chain view from end to end.

5. Perfection

- Continuous improvement activity.
- Only produce the product/service, which is wanted by customer.
- Perfection is an inspiration and anything that can be improved.

Lean or TPS refer to its philosophy, eliminated waste and respect to worker. Taiichi Ohno said that there are seven wastes, which must be eliminated in lean production. There are:

- Overproduction
- Waiting time
- Transport
- Process
- Inventory
- Motion
- Defective goods

III. Experimental Method

Fig. 2 Methodology Flow Chart

Fig. 3 has shown the anthropometric data for Indonesian people. From this table we can get percentile allowance ranged from 5th percentile to 95th percentile to propose the design for adjustable workstation. In this research, we get 10 dimensions that related to the workplace from Fig. 3 which are dimension number 1, 2, 3, 4, 20, 22, 28, 32, 33.

After selecting anthropometric dimension that required for the design, the dimension measurement will be used for basic requirement for get design adjustable workstation based on the anthropometric.

A. Anthropometric Data

Dimension	Male citizens			
	5th	50th	95th	SD
1. Stature	162	172	183	6.23
2. Eye height	151	160	172	6.3
3. Shoulder height	134	143	155	6.41
4. Elbow height	99	107	114	5.12
5. Hip height	83	95	105	6.76
6. Knuckel height	68	75	82	4.75
7. Fingertip height	58	64	71	4.82
8. Sitting height	80	89	96	5.24
9. Sitting eye height	69	76	84	4.58
10. Sitting shoulder height	52	59	67	6.27
11. Sitting elbow height	19	24	30	4.74
12. Thigh thickness	12	16	22	3.59
13. Buttock-knee length	48	56	64	4.89
14. Buttock-popliteal length	40	46	54	4.82
15. Knee height	46	54	62	5.21
16. Popliteal height	38	44	49	3.78
17. Shoulder breadth (bideltoid)	36	45	52	4.66
18. Shoulder breadth (biacromial)	31	37	43	3.61
19. Hip breadth	28	35	43	4.41
20. Chest (bust) depth	16	21	27	3.5
21. Abdominal depth	15	21	29	4.46
22. Shoulder-elbow length	NA	NA	NA	NA
23. Elbow-fingertip length	42	47	56	4.55
24. Upper limb length	68	76	84	6.39
25. Shoulder-grip length	56	65	73	6.29
26. Head length	17	20	24	2.21
27. Head breadth	15	18	22	2.06
28. Hand length	17	19	22	1.64
29. Hand breadth	7	9	11	1.09
30. Foot length	22	25	29	2.58
31. Foot breadth	8	10	12	3.96
32. Span	158	172	186	8.5
33. Elbow span	78	86	96	5.97
34. Vertical grip reach (standing)	192	206	221	10.54
35. Vertical grip reach (sitting)	112	122	136	7.9
36. Forward grip reach	64	73	81	5.89
37. Body weight (kg)	50	63	89.25	13.19

Fig. 3 Anthropometric Dimension for Indonesian

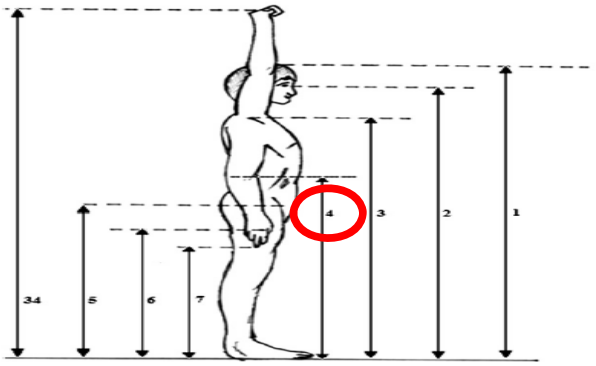

Fig. 4 Elbow height dimension

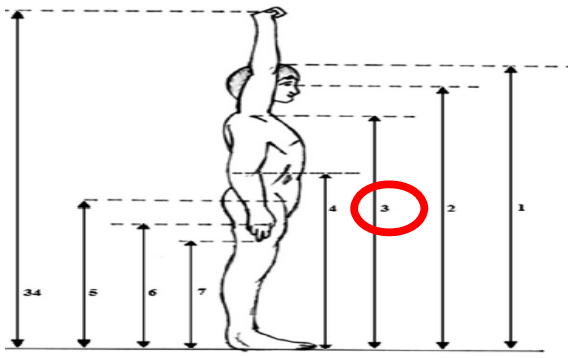

Fig. 5 Shoulder height dimension

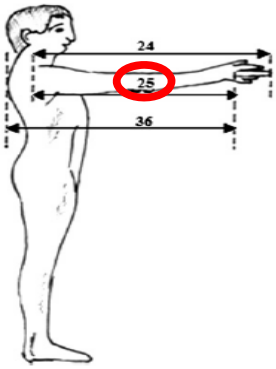

Fig. 6 Shoulder grip length dimension

IV. Result and Discussion

A. Piston Workstation

Piston workstation in LPS laboratory is consisted from Workstation 1 to workstation 4 that have different activity on each workstation. The layout for the current piston workstation is shown on Fig. 7.

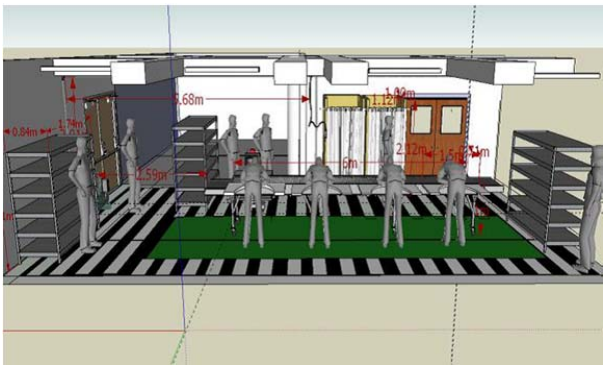

Fig. 7 LPS Layout in System Manufacturing Laboratory, Department of Industrial Engineering Universitas Indonesia

During the practicum, pallet container is used as porters are run manually on the tracks / conveyor. In the practicum is divided into several divisions, among others:

1. Work Station 1 (WS1)

WS1 serves to attach the connecting rod bolts, preparing piston crown, piston pin and connecting rod bolts installed, onto pallets, which are then given to WS2. In this division, used drill the mounting bolts are useful for installing the connecting rod bolts.

2. Work Station 2 (WS2)

In WS2 was installed of piston pin and snap ring to connect the piston crown and its connecting rod is then given to WS3. Installer is used to install the piston pin and piston pin snap ring pliers are used to clamp and install snap ring.

3. Work Station 3 (WS3)

WS3 is working to install oil ring, N1, and N2 on the piston, which is then given to WS4. In WS, the mounting ring oil, N1, and N2 are used to attach each ring.

4. Work Station 4 (WS4)

In WS4, inspections performed to check whether the installation of the piston is correct or not before being given to the finished goods warehouse. Once the piston is given to GBJ, the palette placed on the bottom palette rail to be returned to WS1. This division does not require special tools to do the job.

B. Current Problem on Piston Workstation

There are several *wastes* that can be found on production process which are:

- Overproduction
- Waiting Time
- Transportation
- Process
- Inventory
- Motion
- Defective Goods

Whereas all the *waste* is occured on the current piston workstation, these *waste* is caused from the current design of piston workstation that did not required some ergonomic aspects. Bad designs will caused operator to make some unnecessary motion thus work load for operator will increase.

Based on observation from the piston workstation, some findings caused operator to make unnecessary motion along piston making activity. Some of these findings are such as bad neck posture, bad upper arm posture, and bad wrist posture.

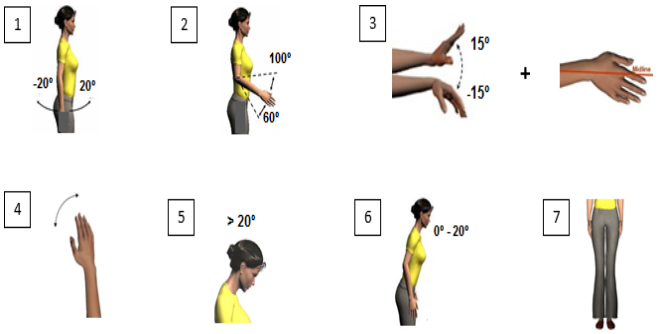

Fig. 8 Observed Problems on Piston Workstation

After that, this research can be proposed new workplace design for piston workstation to get ergonomic design based on Indonesian people's anthropometric measurement and improve operator's posture.

The first step to redesign the current workplace is to make the workplace adjustable for different dimension operators thus eliminate the unnecessary motion from before.

Height dimension from the piston workstation can be change with the new height dimension based on anthropometric dimension measurement shown on Fig. 3.

After the new height dimension is applied to the piston workplace, the improved layout can be proposed to piston workstation.

The new piston workstation layout can be expected to improve the piston workstation before to increase productivity

by eliminate operator's unnecessary motion. This research is still based on qualitative method so quantitative method is recommended for future research. One of the quantitative methods that can be proposed is anthropometric measurement with statistical testing such as normality testing, homogeneity testing, and adequate testing. Ergonomic aspects can be improved with RULA for analyze the operator's motion and posture and Jack Simulation to get movement simulation operator during the piston making activity.

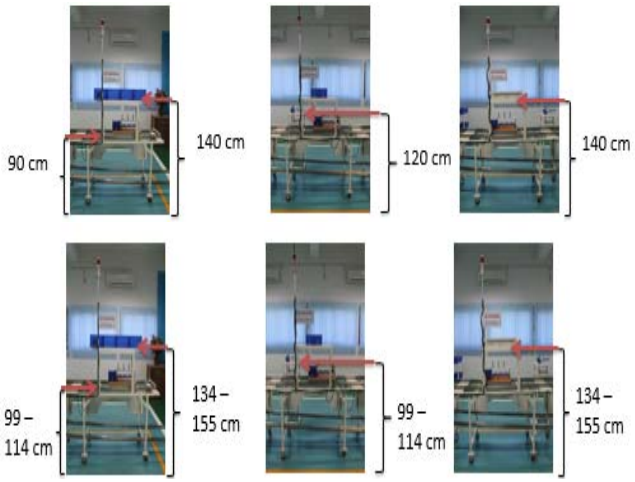

Fig. 9 (a) Work area dimension before improvement (b) Work area dimension after improvement

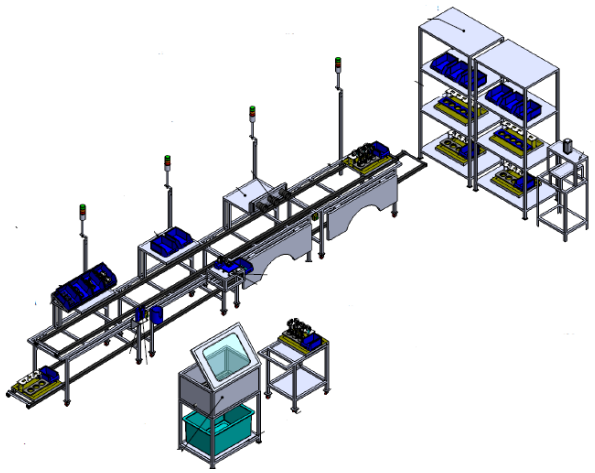

Fig. 10 New piston workstation layout

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