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Design of Working Facilities Based on Posture Risk Assessment and Anthropometry

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Abstract – **The operators on assembly lines are complaining about pain in their muscle and joints when carrying out work. This study aimed to assess posture risk on assembly line with manual work, and propose appropriate design for work station facilities. The research was conducted to operators in the n transformer assembly lines. The method used to evaluate the working posture effort and risk was the combined Nordic Body Map and Rapid Upper Limb Assessment (RULA). Based on the RULA method, the operator's body position is at high risk with a score of seven (7), so immediate working corrections are needed. The current faulty design of work stations that are not in accordance with ergonomic principles causes work musculoskeletal disorder in wound core assembly line operators. Based on the lengthy analysis of the faulty operator postures in the wound core assembly, a new table and chair design was proposed.**

Keywords *– Anthropometry, Ergonomics, Manual Work, Posture, Risk Assessment.*

INTRODUCTION

The Small Medium Enterprise's (SMEs) in the manufacturing industries in Indonesia generally employs many operator manual activities. This is due to the fact many manufacturing companies with SMEs still use a lot of manual labor in the production process. Repetitive activities and unnatural or awkward work position are closely related to poor workstation design. The appropriate design of a work station must apply ergonomic principles so that operators can work comfortably and safely. Working with repetitive activities and non ergonomic work station design results in excessive exertion and incorrect postures such as bending and twisting, which is a risk factor for pain complaints in the skeletal muscles of operators commonly known as musculoskeletal disorders (MSD).

Work-related musculoskeletal disorders (WMSD) is one of the main occupational health problems. The best strategy to prevent this lies in ergonomic interventions. The variety of industrial processes and environments, however, makes it difficult to define an all-purpose framework to guide these ergonomic interventions. This undefinition is exacerbated by the recurrent introduction of new technologies e.g., collaborative robots [1].

The development of WMSD is mainly attributed to three factors, (1) occupational risk, (2) individual characteristics, and (3) social factors [2]. Occupational risk factors include awkward postures, repetitive tasks, frequent and/or excessive tasks involving the handling of heavy loads and thermal discomfort. The individual characteristics are related to individual limitations or health problems. Finally, social factors such as family and economic problems may interfere with motivation and attention during work [3].

The RULA technique evaluates required body postures, forces and repetitions for each performed task. Scores are based on deviation from neutral body positions. Separate scores are combined to find the overall arm and wrist score and neck, trunk, and leg score. A final RULA scoring ranging from 1 to 7 is calculated based on these two sub-scores. Scores ranging from 1 to 2 are classified as acceptable, 3–4 require further investigation with change may

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needed, 5–6 require further investigation with changes needed soon, and a score of 7 meaning investigate and implement changes immediately [3].

PT X is a small enterprise, this company that manufactures transformers for general purposes. The production process goes through various stages and requires various types of components to be assembled. One important component is the wound core as an electrical core component. Wound core assembly is done manually on a table and the operator sits in an unnatural working posture. Operators have experienced complaints of pain in body parts such as pain in the neck, shoulders, back, waist, hands, knees and feet.

The main objective of this study was to assess the physical workload related to musculoskeletal disorder. The operator posture when working in static conditions and work done repeatedly.Based on the risk and finding of the study, it is proposed to improve the comfort and ergonomics of work facilities for workers in wound core work station. The research focused on its main subject which is production line of transformator at PT X as manufacturing company that located in Jati Uwung, Tangerang, Indonesia. The production line has a small target group, which is 15 regular workers, this study considered the whole population as its participants. The focus of this study will extend to the evaluation of work related musculoskeletal disorder the utilization of the knowledge and performance in actual problem solving which is dealing with wound core of transformator.

METHODS

This study used a *descriptive method* as it provides subjective information and determining and assessing the necessary data in achieving the objectives of this study. The data was gathered systematically through observation and following the descriptive method using Nordic Body Map Questionnaire, for better understanding the possible risk index of the action are use RULA (Rapid Upper Limb Assessment). Based on measurement risk of MSD are proposed facilities design using anthropometry of operator.

Collecting data directly through observation and interviews asked for the permission of the operator and the supervisors to conduct this study. They quitioner of Nordic Body Map are used by conducted interviews and observations for assessment. The data were collected through interview and survey questionnaire using Nordic Body Map Questionnaire and observation using documentation of photo-taking for work posture. To design more ergonomic work facilities, anthropometric data is used. The use of anthropometric data can be done with individual measurements or group measurement data [4].

Designing a workstation for a group is more complicated than for an individual, consideration must be given to both a user's personal space and the shared space between users [5].

RESULTS AND DISCUSSIONS

Musculoskeletal complaint

Based on the data gathered, the following are the job performance requirements for operator dealing with wound core workstation. The number of operators working on the wound core production line of PT. X is 15 people and have complaints of pain in the limbs. The Standard Nordic Questionnaire data was used to evaluate 28 type of pains of body part. The percentage of complaints from body parts of operators is shown in table 1. There are 4 levels of sick complaints: not sick (score 0), rather sick (score 1), sick (score 2) and very sick (score 3).

Work-related musculoskeletal disorders (WMSDs) are defined as a group of injuries to the muscles, tendons, cartilage, ligaments, bone and nerves caused by fixed or constrained body positions, repetitive movements, the concentration of forces on the body or due to a work pace that does not allow for sufficient recovery.

Table 1. Percentage Complaint in Wound Core Line

No	Complaint	Percentage (%)			
		0	1	2	3
0	Upper neck	0	0	46.67	53.33
1	Lower neck	0	0	40.00	60.00
2	Left shoulder	0	0	40.00	60.00
3	Right shoulder	0	0	26.67	73.33
4	Left upper arm	0	0	73.33	26.67
5	Back	0	0	20.00	80.00
6	Right upper arm	0	0	73.33	26.67
7	Waist	0	0	26.67	73.33
8	Buttock	0	0	20.00	80.00
9	Bottom	0	0	26.67	73.33
10	Left elbow	20	13.3	20.00	46.67
11	Right elbow	0	20	26.67	53.33
12	Left low arm	0	46.7	26.67	26.67
13	Right low arm	0	6.67	53.33	40.00

No	Complaint	Percentage (%)			
		0	1	2	3
14	Left wrist	0	33.3	26.67	40.00
15	Right wrist	0	6.67	46.67	46.67
16	Left hand	0	6.67	60.00	33.33
17	Right hand	0	6.67	46.67	46.67
18	Left thigh	40	53.3	6.67	0.00
19	Right thigh	53.33	26.7	20.00	0.00

Using the Nordic Body Map, almost every operator experiences complaints in all limbs after work. Complaints in the form of pain are felt in the limbs of the neck, thighs, shoulders and upper limbs such as the upper arms, forearms, elbows, wrists and hands. Complaints in the form of severe pain are felt in the back (80%) waist and lower back (hips) and buttocks because of the facilities available in the PT. X in wound core production line is still not in accordance with the principles of anthropometry.

Posture Analysis

Multiple studies have selected RULA as their method of evaluating manual labor types of work. Research also pointed to RULA as being a more sensitive system for assessing risk for WMSDs over the Ovako Working Posture Analysis System [6]. To assess the posture of operator which are working in the wound core assembling, the tools RULA were used. The selection of operators who work normally is carried out based on observations to assess their work postures. The observed work postures of operators are the working postures of preparing wound cores for work elements assembling silicon steel manually. The work elements of assembling are divided into three movements including taking silicon steel, compiling silicon steel and hammering silicon steel. The activities of compiling cores manually can be seen in the figure 1.

Figure 1. Operator Posture for Taking, Arranging and Hammering Silicon Steel

Figure 1 shows that the operator carried out the activity of taking silicon steel from the pushing table to the core preparation table in a sitting position with bent body posture and bent leg position. The height of the push table is 55 cm and the chair height is 60 cm. After taking the silicon steel, the operator then arranges the silicon steel on the assembling table. The operator activity stacks silicon steel with a bent posture and twists back from the pushing table to the core preparation table. This happened because the position of the pushing table with the core preparation table was not parallel. After doing the core arrangement, the next element of activity is hammering silicon steel using a mechanical hammer with the aim of tightening the core arrangement. Operators carry out work activities repeatedly with high frequency during long working hours. The operator must work in some positions of rotating and awkward postures.

Work posture was analyzed using RULA, recapitulation of the results of the calculation of the working posture for the preparation of the RULA wound core method in table 2 shows that the score of the three elements of the core making activity (taking silicon steel, assembling silicon steel sheets and hammering silicon steel) obtained a final score of 7 with a high level of risk and action is needed now. The level of MSD Risk of three activities are very high risk and should implement change now as shown at table 2.

Table 2. Level of MSD Risk Working Posture on Wound Core Assembling

No	Element of Activity	Score	Level of risk	Investigation and changes required
1	Taking *Steel*	7	High	Immediately
2	Arranging *Silicon Steel*	7	High	Immediately
3	Hammering *Silicon Steel*	7	High	Immediately

Proposed of Working Facilities

The facilities that support the manual wound core assembly activities consist of an assembly table (workbench table), a push table and one chair . The work table and push table for manual wound core preparation consist of an iron table and chairs consist of wooden chairs. The facilities used for manual core preparation can be seen in figure 2 and dimension of them are shown in table 3.

Figure 2. Working Facilities

Table 3. Working Facilities on Assembling Wound Core

Working facilities	Length (cm)	height (Cm)	Width (cm)
Assembling Table	300	65	180
Push Table	150	55	150
Chair (*diameter)	25 *	47	

The size of the wound core assembly work facility in table 3 shows the size of the facility that is not in accordance with ergonomic principles. It is proposed to design work facilities consisting of desks and chairs using anthropometric data based on sitting work positions. For the dimensions of the chair, the principle of measuring anthropometric data is used following the type of data in the following figure.

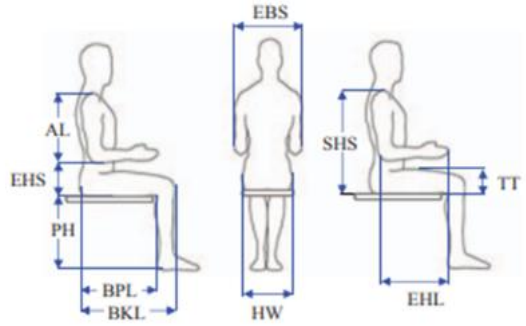

Figure 3. Relevant Anthropometric Dimensions Chairs Design.

The selection of anthropometric data should consider product user interaction and capabilities. If a database is available that contains investigations based on user surveys, an inclusive design will result [7]. According to figure 3, the relevant anthropometric dimensions for side-mounted desktop chairs design are Popliteal height (PH); Elbow height sitting (EHS); Buttock popliteal length (BPL); Butock-knee length (BKL); Hip width (HW); Shoulder height sitting (SHS); Elbow breadth sitting (EBS); Thigh thickness (TT); Arm length (AL); Elbow-hand length (EHL).

Design of work facilities refers to some principles. Context-of-use refers to the relationship between the use-activity-situation during people's interaction with products [8].

The purpose of designing new of chairs and tables aims to enable operators to work with normal postures and to reduce the risk of MSD. Anthropometric data is needed considering the dimensions of workbench, the height needs to be classified so that it can accommodate all groups of users with different size ranges. Anthropometric calculation recapitulation results for table and chair are shown at table 4.

Table 4. Anthropometry Data for The Proposed Work Facility

No	Dimen-sion	Size (X) (cm	Standard deviation	Persentil	Size	Tolerance	Design Size
Anthropometry data for *table* design							
1	Elbow height	107.32	11.06	50	107.32	2.68	110
2	Hand reach forward	76.72	4.73	50	76.72	3.28	80
3	Foot lenght	19.4	8.78	95	33.89	1.11	35
4	Hand Range	168.72	9.03	50	168.72	1.28	170
Anthropometry data for chair design							
1	Popliteal height	50.08	3.33	5	44.60	-0.60	44
2	Knees height	49.66	2.59	95	53.92	1.08	55
3	Hip width	24.92	5.22	95	33.51	1.49	35
4	Shoulder weight sitting	35.08	6.03	95	45.00	0.00	45
5	Buttock to popliteal	45.68	6.87	50	45.68	-0.68	45

Wound core assembly operators are suggested to work in a sitting-standing position. This allows the operator to change working positions to reduce muscle fatigue due to forced stances for long hours in one working position. The proposed picture of working facilities are shown in figure 4.

Figure 4. Design of Working Facilities on Wound Core Assembling

Assembly using facilities that have been designed will reduce unergonomic working postures. This will reduce the risk of MSD for operators are working in wound core assembling.

CONCLUSION

The most important process in transformer assembly is the wound core assembly stage. Operators experienced pain complaints in almost all parts of the body when identified with the NBM questionnaire, especially on the waist. Occupational risks in the form of MSD are identified by using RULA. The measurement results on three important activities in the form of taking, arranging and hammering are manual work which are done repeatedly. The level of MSD Risk of those three activities are very high risk, therefore correction should be implemented immediately. For this purpose we proposed the redesign of tables and chairs taking into account the anthropometric data of the workers.

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