Ergonomics Study in Quick Response Manufacturing (QRM) Automotive Workstation Environment to Overcome Employee Complaints

Nelfiyanti, Nik Mohamed, and M. F. F. Ab. Rashid

Abstract The assembly line is an important process in producing a complete car unit before the product is checked and delivered to the consumer. Assembly workers during working hours are affected by work position, workload, placement of components and aids during the process and equipment used in assisting heavy work processes. Work positions with non-ergonomic workloads impact the disability and musculoskeletal complaints (MSD) of workers. The purpose of this study is to identify the ergonomic risks of assembly workers. Analytical methods using the Nordic Body Map (NBM) and QRM principles were used in this study. The results of the analysis of the level of complaints of workers' MSD during the work were obtained for the categories of not sick (NS) 27.94%, slightly sick (SS) 36.76%, sick (S) 29.69% and very sick (VS) 5.6%. The most dominant complaints about S and VS complaints were shoulders, arms, back, waist, buttocks, wrists and hands. MSD complaints that employees feel are in the middle category with an average score of 64 points which means immediate remedial action is needed. Using the time-focused QRM principle, improvements in work procedures and designing ergonomic tools are needed to minimize MSD complaints that impact working hours faster, and there is no overtime.

Keywords Automotive industry · Ergonomics · Musculoskeletal disorder (MSD) · Nordic body map (NBM) · Quick response manufacturing (QRM)

1 Introduction

Development of the manufacturing industry especially in the automotive field is increasing rapidly from year to year. Definition of manufacturing is producing

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product in large quantities in global activity was started during the industrial revolution [1]. Automotive industry is the major contributor sector to the development and growth of the national economy [2]. Today's challenge for automotive industry is on how to improve and sustain the manufacturing process in an unpredictable economic situation, environmental, marketing and policy issues [3]. This is very important as the country's revenue is largely contributed by the automotive industry in driving the industrial growth [4].

Automotive companies from Malaysia and Indonesia, have a high volume of products that will be exported to several countries or imported into countries. Manpower is the main source that influences the running of the automotive industry in these two countries [5]. It uses workers as the main resource especially in the assembly line. Therefore, the assembly processes require skills from workers, and the skills possessed by the workers must be commensurate with the type of work such as checking components, making tools and operating processes [6, 7]. Workers in the assembly line regularly complain about MSD during work and after work [8]. Musculoskeletal disorders are major difficulties faced by workers at automotive assembly line [9]. The impact of these MSD complaints will take longer production time to complete the production target. Hence, the time required by the employees to complete the work in accordance with the company's target exceeds the period that has been standardized by the company.

Ergonomics is a standard approach commonly used in the analysis of the working system of interactions between humans, machines and the environment [10, 11]. Quality and productivity are influenced by work environment and work methods that are part of employee performance assessment by considering ergonomic risk factors [12–14]. There are two methods commonly used in postural risk assessment in the workplace, namely RULA (rapid Upper Limb Assessment) and REBA (Rapid Entire Body Assessment [15]. Many researchers have conducted research on ergonomics in the assembly line using a force-matching approach in determining action in ergonomic evaluation [16]; ergonomic contribution to the use of exoskeleton in the upper-limb work process [17, 18]; the process of making aids using RULA, NIOSH, MITAL guide [14, 19, 20]; and using Most and ERGOALWABP [13, 21] in the identification of problems related to ergonomics. There is no visible QRM method embedded with ergonomic approach in the ergonomic research so far. QRM itself is a strategy used to reduce waiting time from consumers' perspective [22, 23]. QRM responds to the needs of consumers by designing and making products quickly according to needs quality and lower cost [22]. So far QRM is used to complement Lean Manufacturing [24]; QRM Paradigm and Time Based Competition (TBC) in lead-times reduction [25]; become a more effective competitive strategy in targeting market needs [26]; and the application of QRM in reducing lead time to predict material needs budget [27].

Significance of the research is the use of QRM methods embedded with Ergonomic methods in the assembly line of the automotive industry to determine the complaints of MSD felt by workers that have a long impact on working hours. QRM focuses on time studies while ergonomic studies are related to humans. In this research, the object of research is the workers in the assembly section that involves the production

process. QRM implanted with ergonomics studies the relationship between human comfort and the impact of longer production time or compressed production time.

2 Methodology

Figure 1 describes the flow diagram of this research methodology. This diagram consists of the following stages.

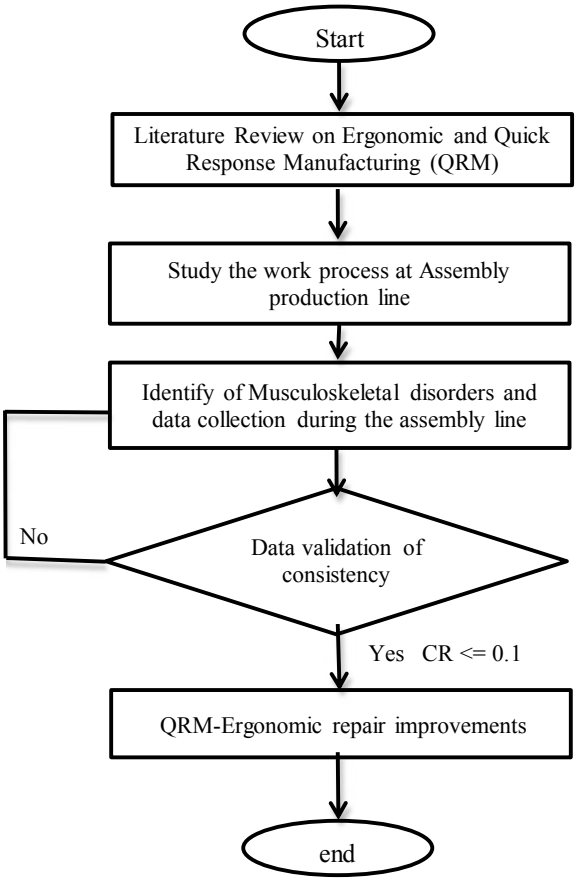

Fig. 1 Flow diagram of research methodology

2.1 Literature Review on Ergonomics and QRM

Research studies related to the topic of ergonomics and QRM are conducted to understand and deepen the application of this method to cases in the industry. Ergonomic methods are used for human-related cases, while QRM is used for processes to minimize time. From the literature review that has been read and understood, no researcher has combined ergonomic methods with QRM.

2.2 Study the Work Process at Assembly Production Line

In order to assemble parts and components, assembly lines for low to medium production are highly dependable on manpower. MSD concerns are high for this form of production set-up due to interruptions faced by workers at almost every workstation along the assembly line [28]. The key source of concerns about MSD is the inappropriate working environment, which affects the effectiveness of employees in carrying out tasks [29].

Since automotive manufacturing is classified as a heavy industry, it is very important to enforce the required ergonomic work environment in the assembly process [30]. Increasing numbers of MSD problems felt by staff are recorded in the neck, shoulders, arms, hands, back, legs and ankles on the basis of several studies [9]. The grievances from the MSD resulted in low productivity of the assembly line as the business was unable to reach the regular production goal, thus requiring overtime to cover the output losses [31]. The additional working hours needed during the assembly process impact the costs that the industry has to bear and the output rating of the customers is reduced. The automotive industry is negatively affected by overtime in terms of business efficiency and sales.

2.3 Identify of Musculoskeletal Disorders and Data Collection During the Assembly Line

Direct observations were made on the assembly lines of selected automotive industries in Indonesia in this case study. These findings were made to get an understanding of how workers function during working hours on the production line. This involves the positioning, and the distance needed to transport, of the instruments and components used in the process. This approach includes the workload of employees and the time needed in the assembly process. In addition to findings, interviews were often performed by workers to find out what the complaints they felt were. Interviews were often performed with supervisors and foremen in addition to workers, who were the representatives who managed the assembly process from upstream to downstream. These interviews were aimed at gathering data on the application

of assembly principles and the usage of workstation tools [32]. The data obtained from the observations and interviews were used for the assessment of the results of the Nordic Body map (NBM) questionnaire by the workers. The assessment aims to determine the complaints that employees feel fall into the category of a low, medium, high or very high. This will affect the action that will be given.

2.4 Data Validation of Consistency

Then the next stage is the validation of the consistency ratio of the data obtained if the value of CR > 0.1 then the data is not acceptable and must be repeated. In contrast, if the value of CR $\leq$ 0.1, then accept the data so that it can perform other processes. CR values measure of consistency and not a consideration of paired comparisons.

2.5 QRM-Ergonomic Improvement

This process is a suggestion that can be given to experts in the assembly line to minimize the overtime needed by workers by reducing the risk of MSD complaints. Recommendations are given based on the results of data and analysis of preparations performed on the work process of workers in the assembly line.

3 Results and Discussion

3.1 Study the Work Process at Assembly Production Line

This study observes and analyses the work process performed by workers on the assembly line of car products so that it becomes a whole unit. The assembly process is done by assembling components from the smallest to the largest components. The work process in the assembly line consists of the retrieval of components and tools to be used, lifting, installing, pulling and running. Figures 2 and 3 show the way the liaison workers in Malaysia and Indonesia work. It can be seen that the work process performed by the automotive industry part of the assembly line in Malaysia and Indonesia can be said to be similar and use the same body posture.

Figure 2 shows some of the methods and postures used by workers during the assembly process. The way it works consists of bending while attaching components to the car body, squatting with the side of the body sideways. The neck rotating, placing the components into the car body with a slight bend, the position of the arms and hands bent and rotating during the installation process and using both feet as a force in limb defences during the process.

Fig. 2 The Malaysian automotive assembly line

Fig. 3 The Indonesian automotive assembly line

Figure 3 describes the work done by workers consisting of bending while taking components to be placed inside the car body, taking components that have been placed for the assembly process, bending during work processes for external work, body bending forward and backward during component assembly process on the roof of the car with the foot position not resting on the floor and the position of the hand raised outside the body as well as rotating and bending during the installation of components on the front of the car by focusing on the foot as a strength to hold.

3.2 Identify of Musculoskeletal Disorders and Data Collection at During the Assembly Line

Identification of musculoskeletal (MSD) complaints that workers feel through the results of observations, interviews and questionnaires Nordic Body Map (NBM) by workers. The NBM questionnaire to be filled by the workers has a choice of not sick (NS), slightly Sick (SS), Sick (S) and very sick (VS). Table 1 is the percentage of workers' complaints in the assembly line. The number of respondents used in this study is 51 workers.

Table 1 describes the percentage of MSD complaints felt by NS category workers of 27.94%, SS of 36.76%, S of 29.69% and VS of 5.60% of 51 workers in the assembly line. The largest percentage is in the SS and S categories, meaning that remedial action is needed in minimizing MSD complaints. MSD complains to assembly workers in severe pain in shoulders, arms, back, waist, buttocks, wrists and hands. Workers feel complaints about body posture due to work factors, workload, layout and equipment used. All these factors greatly affect the smoothness of the assembly production process, which affects working hours. The causative factors of MSD complaints are obtained from direct observation and brainstorming with experts in the assembly line.

Minimizing MSD complaints of assembly line workers can be done by improving the way they work and designing tools that can simplify the work process. There is no overtime in job completion related to the QRM principle.

3.3 Validation of Consistency

Validation is essential to check the accuracy of the results. The stage in the validity test is to create a pairwise comparison matrix to determine and calculate the weight of the criteria and alternative weights of each assessment criterion in the respondent's answer. The next step is to validate the consistency of the paired matrix. If the CR value is > 0.1, should make a pairwise comparison again until the CR value is ≤ 0.1 (consistent). Repeat the same steps for each comparison matrix between alternatives. Next, calculate the total of the multiplication between the alternative weights and the

Table 1 Percentage of assembly line workers' complaints during the work process

No	Type of complaint	Level of complaints after work									
		NS		SS		S		VS		Total	
		Amount	%	Amount	%	Amount	%	Amount	%	Amount	%
0	Upper meet	9	0.63	23	1.61	15	1.05	4	0.28	51	3.57
1	Lower neck	9	0.63	21	1.47	19	1.33	2	0.14	51	3.57
2	Left shoulder	7	0.49	27	1.89	16	1.12	1	0.07	51	3.57
3	Right shoulder	7	0.49	13	1.26	23	1.61	3	0.21	51	3.57
4	Left upper arm	11	0.77	18	1.26	22	1.54	0	0.00	51	3.57
5	Back	8	0.56	14	0.98	18	1.26	11	0.77	51	3.57
6	Right shoulder	11	0.77	11	0.77	27	1.39	2	0.14	51	3.57
7	Waist	6	0.42	17	1.19	19	1.33	9	0.63	51	3.57
8	Buttock	14	0.98	13	0.91	22	1.54	2	0.14	51	3.57
9	Bottom	18	1.26	22	1.54	9	0.63	2	0.14	51	3.57
10	Left elbow	11	0.77	2S	1.96	8	0.56	4	0.28	51	3.57
11	Right elbow	11	0.77	21	1.47	14	0.98	5	0.35	51	3.57
12	Left lower Ami	13	0.91	14	0.98	20	1.40	4	0.28	51	3.57
13	Right Lower Ami	13	0.91	9	0.63	24	1.68	5	0.35	51	3.57
14	Left wrist	13	0.91	13	0.91	24	1.68	1	0.07	51	3.57
15	Right wrist	12	0.34	12	0.84	24	1.68	3	0.21	51	3.57
16	Left hand	16	1.12	13	0.91	21	1.47	1	0.07	51	3.57
17	Right hand	11	0.77	14	0.98	21	1.47	5	0.35	51	3.57
I8	Left thigh	18	1.26	21	1.47	11	0.77	1	0.07	51	3.57

(continued)

Table 1 (continued)

No	Type of complaint	Level of complaints after work									
		NS		SS		S		VS		Total	
		Amount	%	Amount	%	Amount	%	Amount	%	Amount	%
19	Right thigh	21	1.47	22	1.54	3	0.56	0	0.00	51	3.57
20	Left knee	17	1.19	27	1.89	5	0.35	2	0.14	51	3.57
21	Right knee	15	1.05	23	1.61	12	0.34	1	0.07	51	3.57
22	Left calf	26	1.82	20	1.40	4	0.28	1	0.07	51	3.57
23	Right calf	22	1.54	21	1.47	3	0.56	0	0.00	51	3.57
24	Left ankle	21	1.47	25	1.75	5	0.35	0	0.00	51	3.57
25	Right ankle	21	1.47	17	1.19	S	0.56	5	0.35	51	3.57
26	Left foot	19	1.33	21	1.47	10	0.70	1	0.07	51	3.57
27	Right foot	19	1.33	20	1.40	7	0.49	5	0.35	51	3.57
	Total	399.00	27.94	525.00	36.76	424.00	29.69	80.00	5.60	1428	100.00

Table 2 Test the validity of the consistency of criteria and alternative factor elements

No	Elements factor	CR consistency validity value	Description
1	Comparing the level of importance of factor elements based on alternative objectives selects the level of process available on the assembly line	0.0708	Valid
2	Compare the level of importance of factor elements based on job position criteria	0.0441	Valid
3	Compare the level of importance of factor elements based on workload criteria	0.0557	Valid
4	Compare the level of importance of factor elements based on work layout criteria	−0.0460	Valid
5	Compare the level of importance of factor elements based on Equipment criteria	−0.0007	Valid

criteria weights. The validation test in this study uses Microsoft Excel Programming. Table 2 is the result of the consistency validation of the criteria paired matrix and the alternative paired matrix. The average consistency validity value CR ≤ 0.1.

3.4 QRM-Ergonomic Improvements

Complaints of MSD felt by workers in the assembly line belong to the medium category. This means that corrective action is needed to minimize these complaints by considering the ergonomic aspect with the QRM approach. This is because the solution that will be provided should have an impact on the reduction of overtime required by workers in completing car product units in accordance with production capacity. The solution provided can be in the form of improvement of work procedures performed by employees by considering the ergonomic aspects so that complaints of MSD can be minimized. In addition to changes in work, procedures improvements can be done with the design of ergonomic aids for workers. As for the aids that can be provided in the form of a lift car that can be adjusted up and down so as to suit the working posture condition. Figure 4 car lifter design in the car product assembly process.

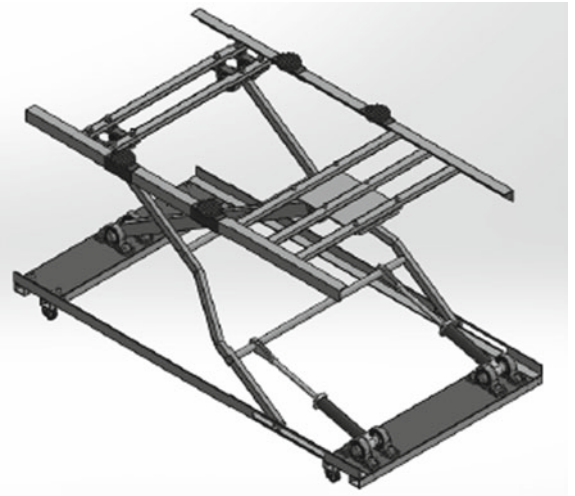

Fig. 4 Desain Lifter car in the car product assembly process

4 Conclusion

Studies conducted with ergonomic methods show that workers' MSD complaints during work are in the category of not sick (NS) of 27.94%, slightly sick (SS) of 36.76%, sick (S) of 29.69% and very sick (VS) of 5.6%. The biggest complaints are in the SS and S categories. The most dominant body posture complaints are shoulders, arms, back, waist, buttocks, wrists and hands. This complaint is at a moderate level, meaning that corrective action is needed to minimize MSD complaints to assembly line workers as soon as possible to reduce overtime in completing work using the QRM principle. Corrective action should be based on work factors, workload, the layout of facilities and equipment used for the smooth running of the work process without causing MSD complaints to employees. The improvements made can be in the form of refinement of work procedures and design of aids such as automatic lift cars that can adjust workers' height to work in comfortable conditions without having to bend and squat.

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