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Ergonomics Evaluation for Turning Machinists in Oil and Gas Industry

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Abstract: It was discovered that there were ergonomics risk factors towards machinists during manual handling of large work pieces that may affect the health of the machinists based on the initial ergonomics risk assessment conducted on the CNC turning machine shop in oil and gas manufacturing company. The study aims to determine and improve the ergonomics risk factor that the machinists may be exposed to. In this study, the data were collected and analyzed using Cornell Musculoskeletal Questionnaire, Rapid Entire Body Assessment (REBA) and torque analysis. Survey result from Cornell Musculoskeletal Questionnaire found that most of the turning machinists experienced ache, pain and discomfort on their lower back, right hand shoulder and upper back. REBA analysis indicated that body posture applied during tightening headstock jaws is categorized as very high risk with REBA score of 11 and immediate improvement action is required. The root cause was identified using 5 Why methodology where torque wrench design limitation has been identified as the main contributor to the very high REBA score. The input torque applied by the machinist was reduced, and the location of the tightening torque applied for clamping and adjusting purposes was changed using manual torque multiplier equipment. The input torque applied by machinist reduced from 1200Nm to 44.4Nm, and the pulling force applied was reduced from 128.7kgf to 9.1kgf, significantly lowering the REBA score from 11 (very high risk) to 3 (low risk). The objective of the study has been achieved by significant improvement of REBA score for the very high-risk postures that the machinists are exposed to.

Keywords: Ergonomics, REBA, musculoskeletal disorder

1. Introduction

Literally, ergonomics is defined as the laws of works where the term 'ergonomics' was derived from the two Greek words which are 'ergon' which means "work" and 'nomos' which means "natural laws" [1-2]. Bridger [3] defined ergonomics as the study of the interaction between people and machines, and the factors that affect the interaction between people and machines. The focus of ergonomics is on the interactions among humans and machines and the interface design between these two [3]. The main objective of ergonomics is to fit the task or job scope to the workers, not to fit the workers to the task or job scope to ensure that workers are more effective in completing tasks at the workplace [1, 4]. In short, the ergonomics purpose is to make a better function of the work system by improving the users and machines interaction [3]. In general, the ergonomics studies cover the relationship between human, job design, machine systems, and the work environment [1]. Work related musculoskeletal disorders (WMSDs) are the most prevalence ergonomics problem occurring in the workplace of various industries which affects the musculoskeletal system of the human body [4]. Aside from that, ergonomics problem may also reduce the quality and productivity, increase medical cost, and decrease workers' morale and efficiency [5-7].

There are four main occupational risk factors for musculoskeletal disorders in the workplace which are force, posture, repetition rate and fatigue, and duration of task while the external (task) counterparts are layout, load, cycle time, working

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shift and rest pattern [3]. Exposure to one or more risk factors may cause an increase in the prevalence of the disorder [3]. Previous studies have proven that many ergonomic research have been performed in manufacturing and construction industries with various types of ergonomics assessment methodologies. The most common ergonomics assessment methodologies are the survey and posture analysis. Discomfort, pain and fatigue survey indicating where the body is experiencing strain can be useful as precursors of injury for further detailed study [8]. Individual characteristics, occupational factors, social and extra-work activities, areas of pain or discomfort, other health issues, and history of back pain are among the questionnaire variables laid out by Buckle et al. [9]. Awkward posture analysis using Rapid Entire Body Assessment (REBA) has been widely used in the industry [10-12]. In REBA, the body parts being assessed are trunk, neck, legs, upper arms, lower arms and wrists [13]. Hignett and McAtamney [13] highlighted that the REBA system was developed to meet the sensitivity of postural analysis to musculoskeletal risks in various tasks and activities.

Based on the machinists' complaints, it is observed that turning process involved a lot of manual material handling and awkward postures which increase the risk of work-related musculoskeletal disorders. Therefore, this study was conducted to identify the ergonomic risk factors that turning machinists are exposed to while operating the CNC turning machine in oil and gas industry. The study also aims to implement improvement on ergonomic risk factors that have been identified as very high risk to machinists' musculoskeletal.

2. Experimental Methods

According to the Department of Occupational Safety and Health Malaysia guidelines, initial ergonomics risk assessment has been conducted to understand the ergonomic risk factors that the machinists are exposed to [14]. Three survey forms and one checklist were used in this initial ergonomics risk assessment, namely self-assessment musculoskeletal pain and discomfort survey form, Cornell musculoskeletal as well as hand discomfort questionnaire, additional information survey form, and initial ergonomics risk assessment checklist. The completion of initial ergonomic assessment checklist may provide information on the improvements needed in advanced ergonomic risk assessment for each risk factor. In order to collect data related to risk factors for analysis, video camera has been used as a recording device and was located at the turning machine area. The scope of the project covered the whole machining process of one piece of wellhead housing which took around 50 working hours to complete. The video camera used was closed-circuit television (CCTV) video camera type due to the need to operate 24 hours to enable recording of both day and night shift without fail. Fig. 1 shows the schematic diagram of experiential work done using video camera. The use of video in collecting data may improve the efficiency of data collection for analysis. In addition, it will be provide flexibility in terms of time to capture the awkward posture effectively.

REBA has been used for assessing ergonomic risk factor for awkward postures as well as for static and sustained work postures. REBA score sheet has been used as a guideline during REBA assessment [13]. REBA analysis covers 5 main body parts which are neck, trunk, leg, arm and wrist which comprise most of the machinists' working posture conditions. The REBA assessment method is well known in the industry where it was proven in previous studies that REBA has been successfully applied to analyze awkward postures in the manufacturing industry [10,11]. The 5 Why methodology has been used to identify the root cause of the very high-risk posture. The 5 Why methodology is an iterative interrogative method used to discover the cause-and-effect relationships underlying a specific problem. The main objective of the method is to determine the root cause of a problem by repeating the question "Why?". Finally, improvement action was taken based on the root cause identified from this methodology to reduce the ergonomics risk factor to the machinists.

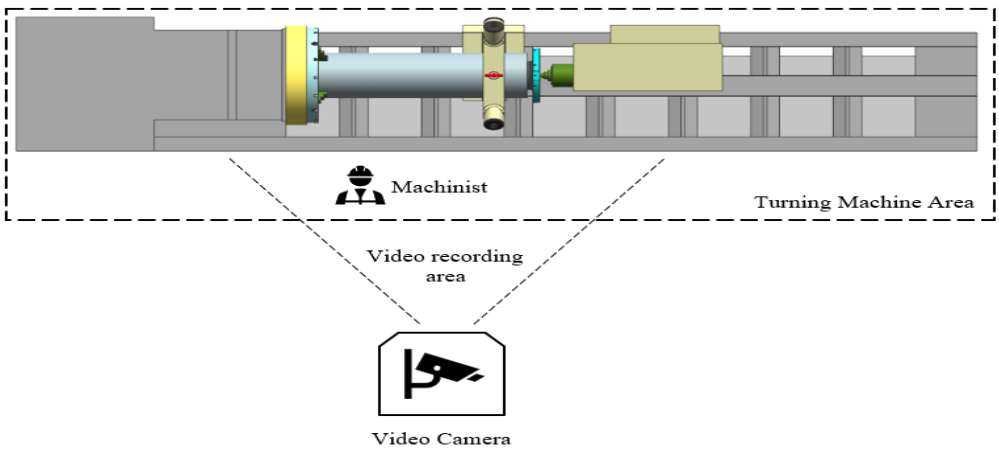

Fig. 1 - Schematic diagram of experiential work (aerial view)

3. Results and Discussion

In this research, the survey for musculoskeletal assessment has been conducted by using self-assessment discomfort survey and Cornell Musculoskeletal Questionnaire. The survey and questionnaire were distributed to 13 CNC turning machinists who are all male, aged between 29 and 48 years old. As a result, it is found that the lower back was rated the highest score which means that the lower back was the most affected body region followed by the shoulder and upper back (Fig. 2). REBA analysis was conducted on the awkward posture photo captured in the video as recorded data. There were 40 awkward postures identified and being used for the REBA analysis as shown in Fig. 3. Summary of the REBA score has been consolidated in Table 1 and the analysis from Table 2 shows the number of frequency of the REBA score for each risk level. One posture was categorized as very high risk to the machinists' musculoskeletal system and immediate corrective action is deemed necessary as can be seen in Posture 12. Posture 12 occurs when the machinist tightens the headstock jaw after loading the part onto the machine. The other six postures were considered to have the second highest risk level with scores of 8 to 10, indicating that corrective actions need to be taken soon.

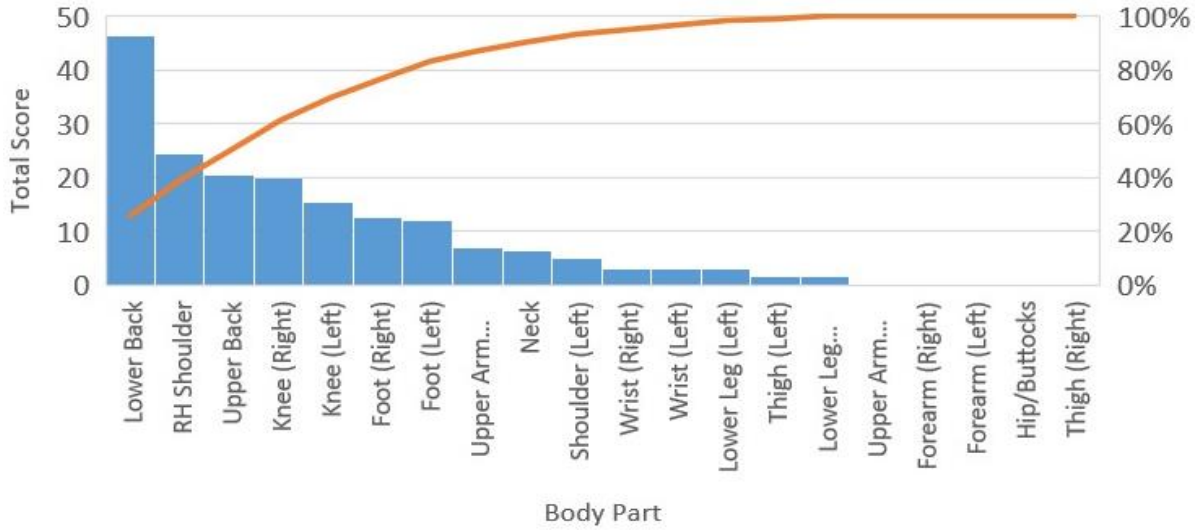

Fig. 2 - Total Score from the Cornell Musculoskeletal Questionnaire

Table 1 - Summary of REBA score for each posture

Posture #	REBA score	Posture #	REBA score	Posture #	REBA score	Posture #	REBA score
1	5	11	5	21	7	31	3
2	6	12	11	22	4	32	4
3	6	13	4	23	5	33	4
4	5	14	6	24	5	34	3
5	9	15	6	25	8	35	6
6	8	16	8	26	6	36	3
7	7	17	4	27	2	37	7
8	5	18	5	28	4	38	4
9	5	19	5	29	3	39	8
10	4	20	8	30	3	40	4

Table 1 - Total frequency for each risk level

REBA Score	Risk Level	Action	Frequency
1	Negligible	None necessary	0
2 to 3	Low	May be necessary	6
4 to 7	Medium	Necessary	27
8 to 10	High	Necessary soon	6
11+	Very High	Necessary NOW	1

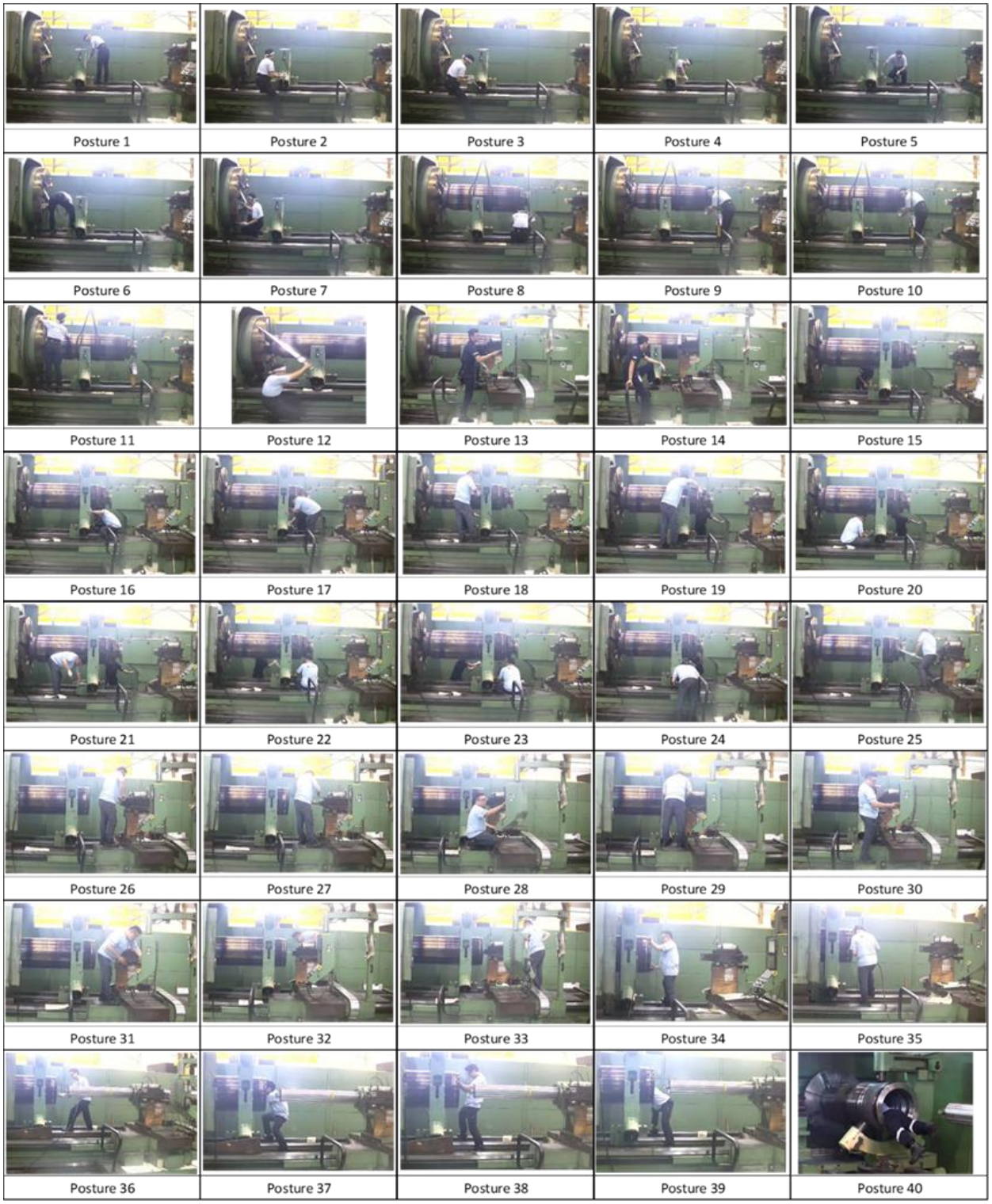

Fig. 3 - Photos of all awkward postures for REBA analysis

The photo of posture 12 in Fig. 4 shows the machinists' postures while tightening the headstock jaw to ensure that the wellhead housing was clamped securely on the machine chuck. It was done by applying 1200Nm torque on the pinion shaft that provides clamping force to the headstock jaws towards the wellhead housing. The same amount of torque has been applied to all 4 units of headstock jaws by using 0.95m length torque wrench. The high amount of torque was required to withstand the 3 tonne weight of the wellhead in both static and rotating mode. The main root cause of the high REBA score for posture 12 has been identified by using the 5 why analysis (Fig. 5) and it is found that the root cause was the excessive force applied during the tightening of the head stock jaws which is due to the torque wrench design limitation. By understanding that the torque required was 1200Nm by using the 0.95m length torque wrench, the

machinist was forced to apply pulling force of 128.7kgf. Since the pulling force required was too high, the machinist was forced to pull the torque wrench with additional support of their own body weight. By doing so, all the body posture experienced rapid large range change in posture which poses a very high risk to their musculoskeletal system.

Since it is very critical for the clamping force to withstand the weight of the wellhead, the tightening torque of 1200Nm shall not be changed to improve the ergonomics risk towards the machinist. Therefore, the improvement action taken was to use the manual torque multiplier equipment to reduce the input torque applied by the machinist and at the same time maintaining the 1200Nm torque applied towards the headstock jaws.

Fig. 4 - Photo of Posture 12 (Very High-Risk Posture)

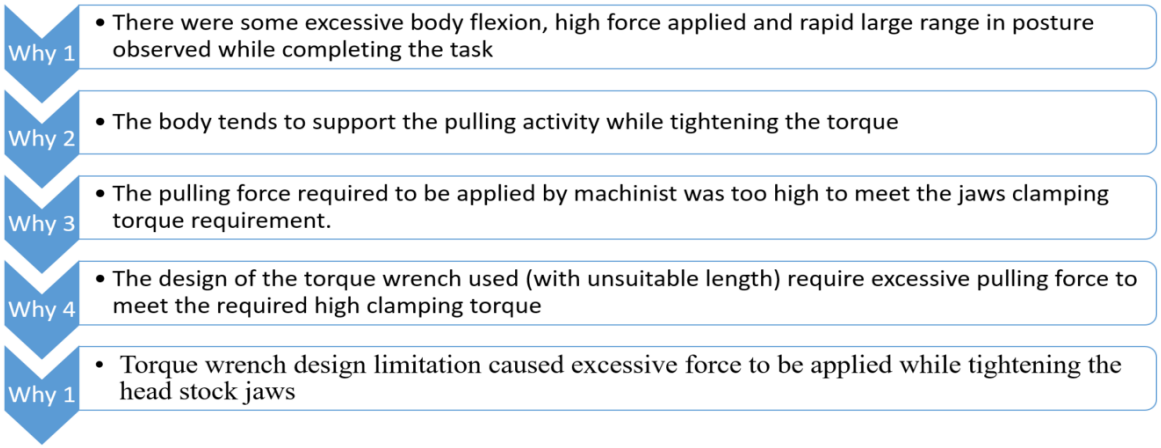

Fig. 5 - 5 Why analysis for the question of why the REBA score was high for Posture 12

Fig. 6(a) shows the torque multiplier being used during the tightening process, while Fig. 6(b) illustrates the new equipment being used which consists of manual torque multiplier and torque wrench. The torque multiplier being used was HT-72/27 model from HT-72 Compact Series manufactured by Norbar company with part number 180212 [15]. By applying the manual torque multiplier, the input torque required showed 27 times reduction from the output torque to be applied. This means that in order to apply the output of 1200Nm torque, the input torque required was only 44.4Nm. The pulling force required to tighten the 44.4Nm by using 0.5m length torque wrench was only 9.1kgf. This is a significant improvement compared to the previous pulling force of 128.7kgf. Improvement action taken was to change the location of the tightening torque applied for the clamping and adjusting purposes as well as aligned with the direction of dial clock for run out check. The concept has been simplified in a diagram as shown in Fig. 7. Verification on the effectiveness of the improvement action has been conducted through REBA analysis by using the photo after improvement as shown in Fig. 8. The result showed that the REBA scoring has been reduced significantly from 11 (very high risk) to 3 (low risk).

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(a) (b)

Fig. 6 - (a) Torque multiplier being used during the tightening process; (b) The manual torque multiplier and torque wrench

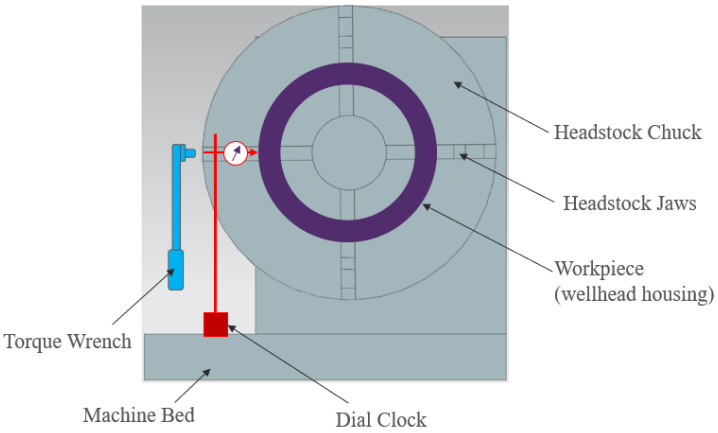

Fig. 7 - Diagram of the improved location of torque wrench and dial clock during the tightening of the torque and part alignment

Fig. 8 - Photo of the machinist tightening the headstock jaws by using the manual torque multiplier and applying new methods

4. Conclusion

The study had identified the ergonomics risk that turning machinists are exposed to during the operation of the CNC turning machine in oil and gas industry. The ergonomics risk factor has been evaluated by using questionnaire survey and REBA assessment methodology. The findings from the REBA analysis found that one of the awkward postures has been identified as a very high risk to machinists' musculoskeletal system and requires immediate corrective action to reduce the risk.mThe very high-risk postures identified from the REBA analysis were improved through root cause analysis and eventually the process has been improved by reducing the tightening torque applied during the tightening of the headstock clamping jaws. The action has been supported by changing the torque wrench type with assistance of manual torque multiplier equipment. The machinists' body posture during the tightening of the headstock jaws by using the new improved equipment has been verified using REBA analysis and it was proven that the risk has been lowered from very high-risk level to lower risk level.

References

[1] Marilyn, P. R., & Phillip, C. W. (1994). Ergonomics is good for business. Work Study, 43(8), 7–12.
[2] David, C. A., & Mustafa, B. P. (1991). Industrial ergonomics case studies. USA: McGraw-Hill.
[3] Bridger, R. S. (2003). Introduction to ergonomics. London: Taylor & Francis.
[4] Jeffrey, E. F. (1995). Ergonomics in the workplace. Facilities, 13(4), 20–27.
[5] Hsu, Y. W., Chung, Y. C., Chiu, C. C., Chen, C. P., & Tsai, C. H. (2008). A study of the ergonomics evaluation of a water heater's case manufacturing factory. Asian Journal on Quality, 9(1), 22–40.
[6] Meral, I., Mehmet, K., & Mucella, G. (2018). Ergonomic assessment of working postures in clothing sector with scientific observation methods. International Journal of Clothing Science and Technology, 30(6), 757–771.
[7] Alexander, D. C. & Pulat, B. M. (1991). Industrial ergonomics case studies. USA: McGraw-Hill.
[8] John, R. W. & Nigel, C. (2005). Evaluation of human works. USA: CRC Press.
[9] Buckle, P. W., Stubbs, D. A., & Baty, D. (1986). Posture recording by direct observation, questionnaire assessment and instrumentation: A comparison based on a recent field study. In Corlott, N. & Wilson, J (Eds). The ergonomics of working postures, London: Taylor and Francis.
[10] Nieves, S. P. J., Juan, L. H. A., & Carmen, N. G. (2015). Task analysis and ergonomic evaluation in camshaft production operations. Procedia Manufacturing, 3, 4244–4251.
[11] Lu, Y. & Matthew, B. (2015). Ergonomic evaluation of scaffold building. Procedia Manufacturing, 3, 4338–4341.
[12] Zimi, M. Z. M., Rozlina, M. S., Masine, M. T., Hasrul, A. N. N., Azanizawati, M. & Aini Z. A. K. (2018). Ergonomic improvements in an aircraft component manufacturing company. Jurnal Mekanikal, 41, 1–8.
[13] Hignett, S., & McAtamney, L. (2000). Rapid entire body assessment (REBA). Applied Ergonomics, 31, 201–205.
[14] Department of occupational safety and health (DOSH). (2017). Guideline on ergonomics risk assessment at workplace. Retrieved from: https://www.dosh.gov.my/index.php/competent-person-form/occupational-health/regulation/guidelines/ergonomic/2621-01-guidelines-on-ergonomics-risk-assessment-at-workplace-2017?path=guidelines/ergonomic
[15] Norbar torque tool. (2021). Hand torque HT-72 compact series kits technical data, Issue 1. Retrieved from https://www.norbar.com/products/view/range/categoryname/compact-series/rangename/compact-series-ht-72/category_multid/95/range_multid/553