Ergonomic Improvements in An Aircraft Component Manufacturing Company

Mohd Zimi Mohd Zain, Rozlina Md Sirat*, Masine Md Tap, Nor Hasrul Akhmal Ngadiman, Azanizawati Ma'aram and Aini Zuhra Abdul Kadir

School of Mechanical Engineering, Faculty of Engineering
UniversitiTeknologi Malaysia
81310 UTM Johor Bahru
Johor, Malaysia

ABSTRACT

Ergonomics may give indirect contribution in terms of productivity level. The objectives of this study are to identify ergonomics problems that exist in a case study company and to propose improvements on method of the problems identified. The project was conducted at Singapore Aircraft Manufacturing (SAM) Sdn. Bhd. located in Seremban. Hazard Identification, Risk Assessment and Risk Control (HIRARC), Rapid Entire Body Assessment (REBA) and Pareto diagram were used to identify and analyze the problems. It is found that pre-cleaning process was one of the top three ergonomics problems identified in the company. A new design of tool was proposed to support the manual handling of workers while doing the pre-cleaning. REBA analysis was done to determine the score for the existing posture and movement after the improvements. Morphological chart, function analysis and SolidWorks simulation software were implemented to design and analyze the strength of the new design. The objectives of study were achieved in which the score of ergonomics hazard has been reduced from 10 (high risk) to 7 (medium risk).

Keywords: *Ergonomics methodology, HIRARC, REBA, Pareto diagram, aircraft component*

1.0 INTRODUCTION

Ergonomics can be defined as the interaction between human biological science and engineering sciences in order to achieve optimum compatibility between man and his work. The benefits are measured in terms of comfortability of the way man works and adopt good safety practices at the workplace.

Aerospace component manufacturing industry is one of the industries that is growing fast in Malaysia due to high demand and investors interest. It can be categorized as a large sized company due to the significant number of workers employed in the sector. The aerospace industry has been designated by the Government as a strategic sector with high growth potential in the country's industrial and technological development programs.

In order to ensure the sustainability of the aerospace component manufacturing industry, an ergonomic concept should be applied in a workplace to increase the labor productivity, in particular. It is indeed a very important aspect because ergonomics considers the workers' comfortability which is directly related to their work since unergonomic working conditions typically lead to discomfort, annoyance and detrimental effects on the performance, productivity, health and safety [1]. The proper design and implementation of good working environments is necessary to ensure the safety, health and work efficiency of the workers.

*Corresponding email: rozlina@mail.fkm.utm.my

Therefore, the study was carried out with the objectives of identifying an ergonomic problem, from the perspective of worker discomfort and suggesting a suitable method to improve their work comfortability.

2.0 LITERATURE REVIEW

Ergonomics is also related to the interaction between human and machine and to improve the performance of systems by improving the interaction [2]. According to DOSH (2018) [3], the effect of working posture, force exertion and task frequency reportedly has a positive relationship to upper limb musculoskeletal disorders (MSD). [4]. Several key risk factors can lead to injuries caused by poor ergonomics. On the other hand, by considering the ergonomics practice at workplace, in most cases it resulted in improved quality and productivity [5, 6]. The following is a list of risk factors that can be associated with various types of jobs:

i. *Repetition*: When you perform the same or similar motions repeatedly, this can lead to trauma in the joints and surrounding areas. Without rest and recovery, repetition can lead to injury.
ii. *Static posture*: This occurs when a single position is maintained for an extended period of time.
iii. *Awkward postures*: Incorrect postures keep joints held in unnatural positions.

In Malaysia, ergonomics problem, particularly MSD has been reported as the main cause that was on the rise nationwide, attributing it in part to the lack of safe work practices at the workplace. It is an upward trend, with 161 cases in 2009, 238 in 2010, increased to 268 cases in 2011 and 449 in 2012 [7]. In the article, the chairman of NIOSH Tan Sri Lee Lam Thye mentioned that this is a jump of almost 18 times compared to the statistics of 2006. The number of cases could be higher as he believed that many cases are under reported. According to Koma *et al*., generally in developing countries, the health of workers is plagued by MSD symptoms due to poor workstation design [8]. Nowadays, Malaysia is one of the countries that starts to have the awareness in occupational ergonomics [9]. This study is one of the awareness initiatives intended for the company under study and improvements are duly suggested to reduce the ergonomic risks in the company.

3.0 METHODOLOGY

Figure 1 shows the methodology that was implemented in the study. It starts with a literature review and at the same time, a company was identified for a case study. Observation was done and a safety and health audit presented. Then HIRARC was done to assess the risk. *Pareto* chart was used to identify the top critical problems that may emerge for further investigation. REBA analysis was also performed to further identify the postures and movements of the working activities done at the related workstation. Lastly, an improvement was suggested by based on a morphological chart, function analysis and application of SolidWorks software. Validation was later carried out by interviewing the company's engineer and comparing the postures before and after to suggest improvements via a REBA analysis.

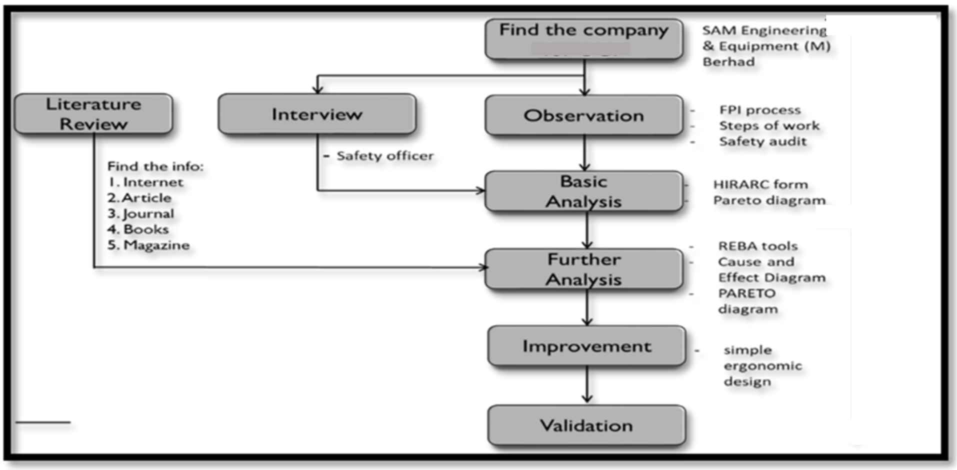


Figure 1: Methodology of study

4.0 CASE STUDY OF A COMPANY AND ANALYSIS

An aircraft component manufacturing company was chosen for the case study. After identification and analysis, HIRARC shows that the top three highest score of the risk for hazards were related to the pre-cleaning processes in the inspection department. This chart was generated based on HIRARC for all the processes involved in the company as shown in Figure 2. The highest level of risk was found to be pre-cleaning using water jet and the inspection in the dark room, both producing a joint score of 12 marks followed by ultra-violet (UV) lamp utilization (10 marks). Other activities were considered less important and not significant. For this study, pre-cleaning was chosen as the main process to be improved.

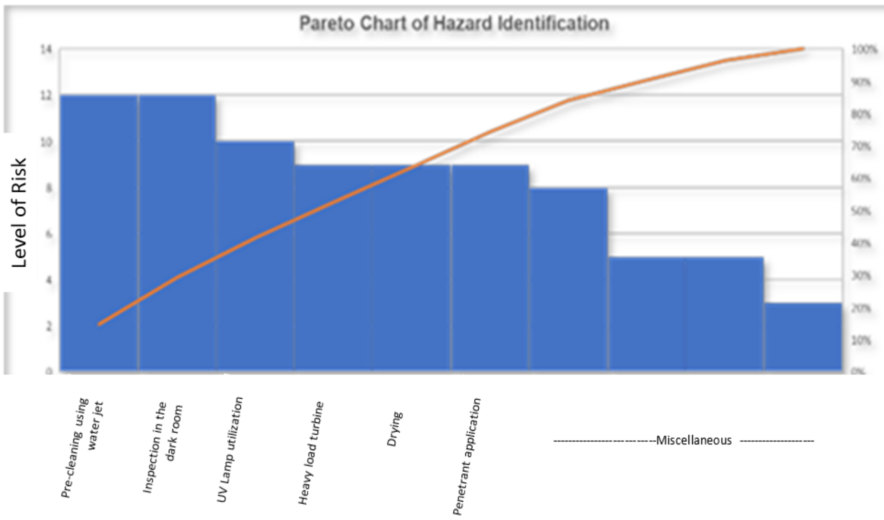


Figure 2: *Pareto* chart based on HIRARC result

4.1 Proposed Solution and Analysis

Figure 3 shows the existing activity of pre-cleaning process in a factory environment (company) selected for the case study. The component to be washed was thoroughly cleaned with water plus chemicals thrice by a worker to ensure that it is completely cleaned. This was done manually and it took an average of about 15 mins to finish the process. It must be thoroughly and consistently sprayed inside and outside the component.

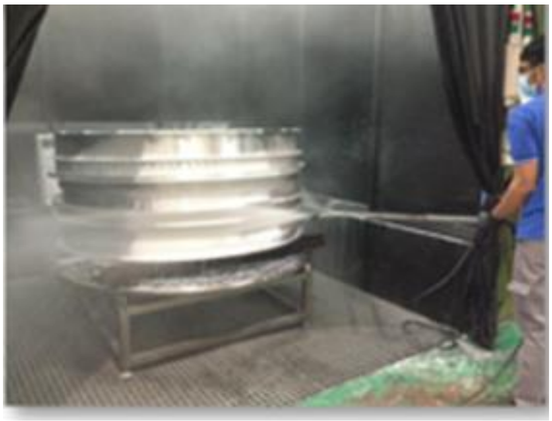


Figure 3 The pre-cleaning process was done manually using a spray of water jet

The worker needs to hold the physical water jet nozzle assembly in a sustained manner as the water jet produces high pressure fluid. This causes the worker to consume a lot of energy to ensure that the water jet is only directed to the components without producing a big splash. At the same time, the worker should rotate the component by using a turntable while using the water jet/chemical jet. The space is very limited and there should be no big splash since there are an isle for workers and other components nearby. The curtain available does not cover the overall splashing.

After some design concept generations, a morphological chart was developed as illustrated in Figure 4. The chart enables the design solutions to be explicitly and clearly expressed and provides a structure for considering various alternative combinations. This also allows early planning of the product 'architecture' through the generation and different combinations of various 'sub-solutions' that have not been previously thought of. By identifying the suitable moving sequences for the worker, movements for the heavy component, cleaning methods and tilting angles of the nozzle, a number of design options were finally obtained.

Two design options shall be considered and explained in greater detail. In the first option, Design Idea 1 is shown in Figure 5(a). The main body of the system remains the same due to the space limitation at the workstation. The improvement focuses on the technique to hold the nozzle with the water jet without doing any adjustment to the product moving platform (existing turntable). The main nozzle adapter uses a 75 cm long straight pipe with inner diameter of about 1.25 cm (0.5 inch) without considering the tilt angle. There are four nozzles attached as the outlets for the water. The water supply comes from the water jet and flow through the inlet (at the top) of the nozzle adapter. The nozzle adapter is connected to the arm and the arm is in turn fixed to the post which is firmly mounted on the floor.

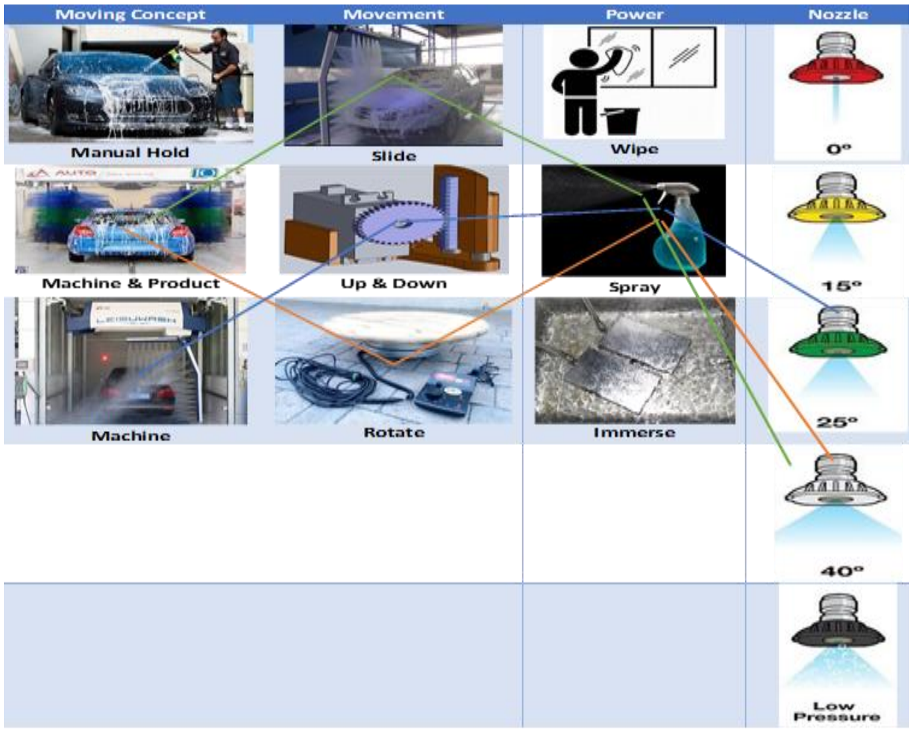
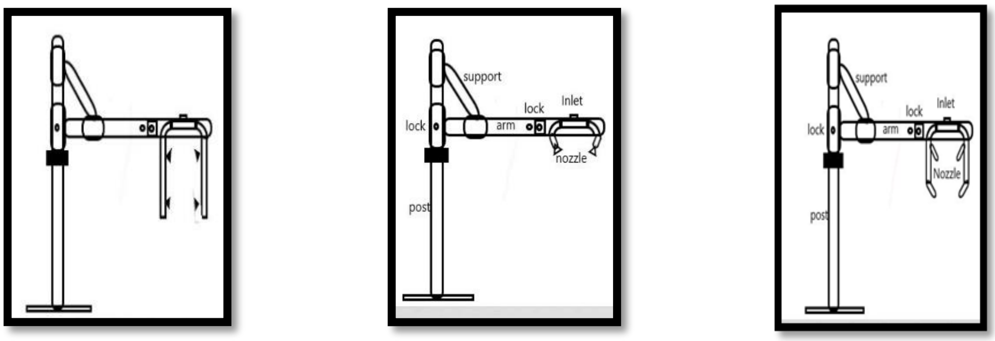


Figure 4: Morphological chart



(a) (b) (c)
Figure 5: (a) Design Idea 1 (b) Design Idea 2 (c) Design Idea 3

Design Idea 2 is shown in Figure 5(b) that is quite similar to the Design Idea 1. The main difference lies at the outlet in which only two nozzles were used instead of four and the nozzle adapter was constructed with a 45° tilt angle. The angle is for the purpose of covering larger area of cleaning during the spraying process. For both Design Ideas 1 and 2, the operator only needs to set-up the device by rotating the arm and the nozzle adapter to the 'ready' mark position and then lock the mechanism by placing the locker shaft into the hole. After the washing process has been completed, the operator just has to set it back to the original position (normal condition). Table 1 shows the concept matrix related to the three conceptual designs for further evaluation.

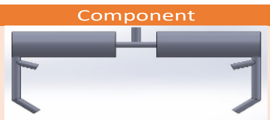
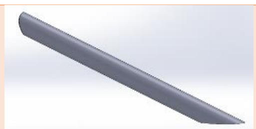
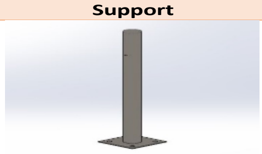
Table 1*:* Concept selection matrix

Criteria	Description	Weightage	Idea 1		Idea 2		Idea 3	
			Score	(w)x	Score	(w)x	Score	(w)x
Reliability	Product can function well for specific period of time	3	2	6	1	3	6	3

Material	The strength of material to support the load	5	1	5	2	10	5	15
Cost	Reasonable and affordable	2	1	2	2	4	3	6
Size	Can be placed in workstation	3	1	3	2	6	3	9
Safety	Give no risky hazard	5	1	5	2	10	3	15
Maintenance	Long term maintenance	4	1	4	3	12	2	8
Performance	High performance of product	2	1	2	2	4	3	6
Manufactura-bility	Able to fabricate based on available equipment	3	3	9	2	6	1	3
User-friendly	Easy to control	4	1	4	2	8	3	12
Installation	Mechanism is easy to install	4	1	4	3	12	2	8
Quality	High quality of product	3	1	3	3	9	2	6
	Total			47		84		91

After considering some concept solutions as shown in Table 1, the combination of Design Idea 1 and Design Idea 2 produces the Design Idea 3 (Figure 5(c)). Design Idea 3 was deemed to be the best option since it yields the highest score (91 marks). It was in fact modifications of the earlier design after a number of improvements were made. The criterion for the material selection is important since the task deals with water and chemical. For the body, the alloy steel was selected due to its strength and for the nozzle adapter, stainless steel was chosen because it offers the best protection from water, chemical and high pressurized condition [10]. This is summarized in Table 2.

Table 2: Description of the proposed design of the related components

Component	Description	Material	Dimension
 **Nozzle Adapter**	Acting as the nozzle adapter. Water supply inlet in on top. The nozzle attaced (4) at bottom outlet.	316 Stainless Steel	Diameter: 0.5 inch Width: 60cm Height: 30cm
 **Arm**	Arm act as the holder for the nozzle adaptor. It can rotate horizontally.	Alloy Steel	Diameter: 4 inch Width: 180cm
 **Support**	Support attached to support the whole body of product. It attached to the post and the arm.	Alloy Steel	Diameter: 3 inch Length: 42.43cm
 **Post**	Since the nozzle need their specific height, post are needed to support the height.	Alloy Steel	Diameter: 4.5 inch Height: 200cm

The designed force that applied to the system was set as 1000 N. However, in the real world situation, the maximum applicable load is 285.13 N. Thus, a safety factor of about 3.0 was used in the study. The main advantages of the proposed design are that it is easy to control, user friendly and having reduced ergonomic problem due to the manual handling operation involving forceful exertion caused by the water or chemical jet.

4.2 Ergonomic Improvements

Based on REBA analysis as shown in Figure 6, it shows a reduction of the score from 10 (high risk) to score of 7 (medium risk). It still has some risks due to the manual handling from the turntable that is still carried out manually. It can be further suggested that the turntable design should be fully automated.

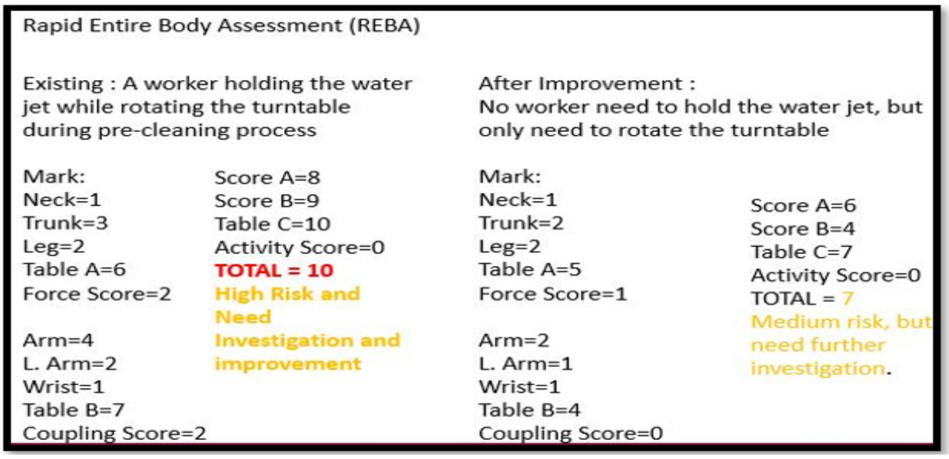


Figure 6: REBA analysis before and after the suggestions for improvement

5.0 CONCLUSION

As a conclusion, after the identification of the ergonomic problems in the pre-cleaning process that was carried out in the company involved in the case study, a new water or chemical jet mechanism was proposed based on the design method. The final design was selected from the three possible solutions proposed in the study. The design procedures followed by a REBA analysis show improvements in the design to counter the ergonomic problems identified earlier.

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