Worker Safety Improvement at Paper Pleating Production Line Using Poka-Yoke Concept - A Case Study in Automotive Industry

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ABSTRACT

For any industry, every worker is entitled to safe and healthy workplace. Laws, acts and regulations have been established by the authorities to ensure the employer conduct proper assessments on safety and health conditions and continuously reduce the hazard risk to protect their employees. One of the common safety issues that can cause injury is due to improper use of tools and equipment to perform the job. On top of that, this issue can also contribute to other waste as well as quality issue in the production line. In this study, Hazard Identification and Risk Assessment (HIRAC) was done on paper pleating production line that assembled air filter product for automotive industry. Based on the assessment, the cutting process had the highest risk score value that triggerred for improvement as to reduce the risk level. Poka-yoke concept, which was considered as one of the engineering control methods, was used to identify the root cause of the problem. The solution of implementing a new cutting tool design significantly reduced the risk by more than 55%. The new process also made the pleating process became easier to handle; hence, it increased the production linearity and improved the product quality.

Keywords: *HIRARC, Hazards, Workplace injury, Engineering Control, Poka-Yoke.*

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Introduction

Safety and health at workplace have been the main concern since long time ago. A number of practices have been introduced and applied in industries to prevent accidents from happening as the impact will involve worker's health and cost that will cripple production flow [1]. There are various sources of accident at the workplace such as working environment, human error, and technical matter. Accidents that tend to happen frequently are usually caused by improper working condition. For instance, sharp tool usage can be a source of hazard due to worker's carelessness. Corresponding to that, repetitive process and harsh working condition; for example, machine noise, heat stress, and air quality can contribute to body fatigue; thus, workers tend to make mistakes. On top of that, performance decrements can also happen due to the nature of task especially jobs that require sustained attention and monotony [2]. Because of that, more studies should be done to solve problems related to workplace accident. At the workplace, the employers are responsible to care for the safety and health of the workers by providing them suitable and protective equipment [3].

Every employer has a responsibility to provide safe work environment to their workers. One that is required by the Malaysian government is to conduct a Hazard Identification and Risk assessment (HIRARC) [4] at the workplace as a way to predict, analyse, and control the hazards at the job area that can harm the worker. Engineering method is one of the ways used by the management in order to control the worker's exposure to hazards by redesigning the process or equipment. The engineering control somehow must not compromise the productivity and quality of the product.

This research took place at an automotive air filter assembly line and the area of focus was at paper pleating process that produced pleated paper for air filter assembly line. This study emphasized on reducing workplace injury at this area using engineering control method specifically using poka-yoke system. Poka-yoke has been used in a variety of contexts for problem solving and not necessary associated only with lean production implementation activity [5 - 7].

HIRARC

Referring to the case study, risk assessment is carried out using Hazard Identification, Risk Assessment, and Risk Control (HIRARC) method as introduced by Department of Occupational Safety and Health (DOSH). The step of this method is explained in the flowchart as shown in Figure 1.

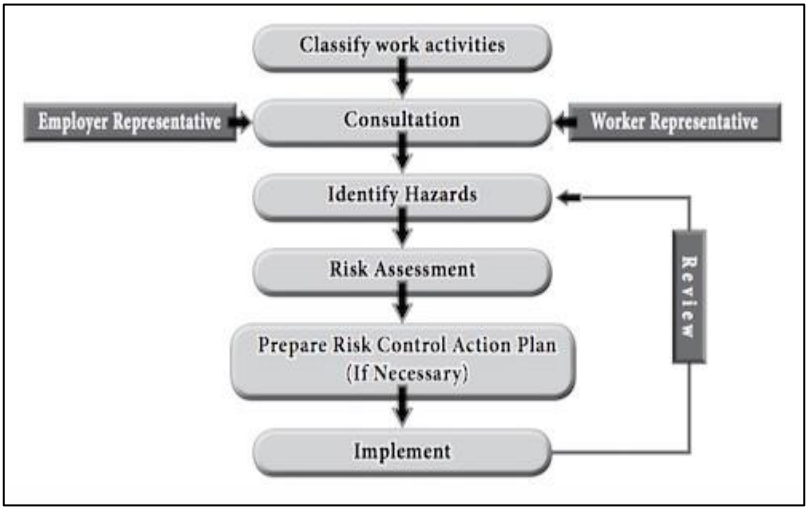


Figure 1: Flowchart of HIRARC method [4]

The first step for this method is to list down the classification of the work activities at the work station by grouping the activities based on the nature of the work such as tool usage and its environmental factor. Next is the hazard identification process which listed any potential hazard that might affect the worker, environment and financial growth. Hazard can also be identified using the statistical analysis of the recent accident.

Risk assessment is the method of evaluating the risk of the identified hazards. Higher risk indicates the severity and the likelihood of the accident to happen because the hazard is greater; thus, it needs to be addressed by the management quickly. Examples of risk assessment rating are shown in Table 1 and Table 2. The hazard is evaluated using the risk matrix of likelihood times the severity that has been rated based on the safety approach as in Figure 2.

Table 1: Table rating for accident severity

Severity	**Example**	**Rating**
Fatal	Can cause major property damage and fatalities	4
Serious	Non-fatal injury, permanent disabilities	3
Minor	Injured but not permanent	2
Negligible	Bruises, cuts, first aid type injury	1

Table 2: Table rating for accident likelihood

Likelihood	**Example**	**Rating**
Most likely	As expected consequences due to hazard	4
Possible	Possible to occur	3
Remote	Do not occur in a long time	2
Inconceivable	Possibly not to occur at all	1

	Severity			
Likelihood	1	2	3	4
4	4	8	12	**16**
3	3	6	9	12
2	2	4	6	8
1	1	2	3	4

Figure 2: Risk matrix for the result as the part of risk evaluation process

Poka-Yoke

Poka-yoke or mistake proofing is a term of a method initially formed by Shingo Shigeo as the part of Toyota Production System in his first application to the production in the 1960s for the purpose to prevent error. A poka-yoke mechanism is expected to work independently on the operator's attention in detecting errors and defects on 100% of the pieces [8]. Middleton [9] stated that poka-yoke is a systematic practice of excluding error by detecting the main problem. Other practitioners simply consider the poka-yoke as a device that is substituted or implemented in the process to eradicate error or detect the error that occurs. Such similarities on opinion nevertheless have prompted ideas on its wide application in a diversified field as poka-yoke is not restricted only on production line. In this research, the main idea is to prevent and detect error that relates to health and safety (H&S). Source of defects and accidents can be inflicted by many factors and a variety approach of poka-yoke can overcome those mistakes.

Methodology

Paper Plating Process

The pleating of the paper is fully done by the machine and being fed to the next workstation for further processes whereby two operators are assigned to cut and tear the pleated paper according to the size demanded by the customer. The process and the final product are shown in Figure 3 and Figure 4.

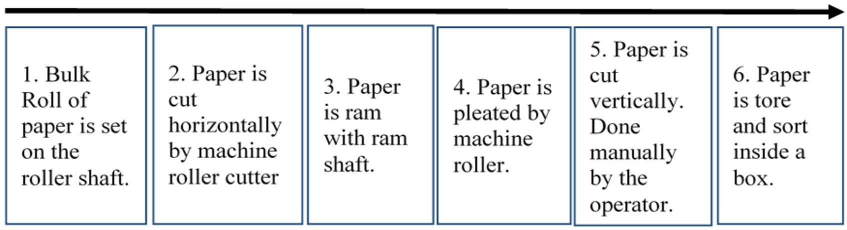


Figure 3: Flow of the process of paper pleating

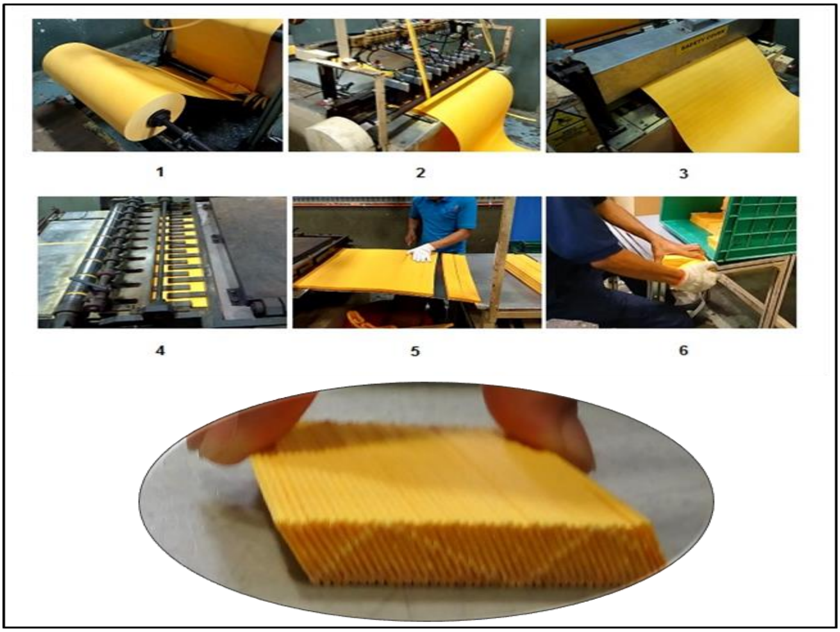


Figure 4: Steps and final product of paper pleating production

Hazard Identification and Risk Assessment

Collecting existing information about site hazards

Hazards identification is a method to identify any source of hazards that exist all around the work place. According to website from the United State Department of Labour [10], the first step of hazard identification is to collect the existing information about the site hazards. To do that, the current information on the HIRARC assessment is gathered to assess the risk condition of the workstation. The result is shown in Figure 5. The figure shows that hazards that came from the cutting process indicated the highest risk. From previous safety reports, at least two accidents were reported at this process. In the first accident, one worker injured his left hand finger while holding the paper. In the second scenario, two workers accidentally dropped the cutter and it went through his shoes and injured his feet. The first accident can be concluded as human error where the method used by the worker did not ensure the safety of the task. However, repetitive work and working condition build up worker fatigue; hence, it increases carelessness and promotes accidents to happen.

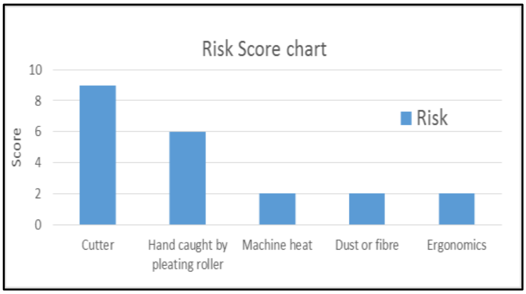


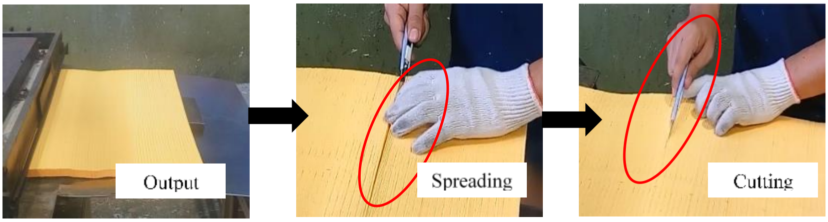
Figure 5: Risk score chart at paper pleating production line

<u>Inspect the workplace</u>

The next step is to inspect the workplace [10]. It is an effort to investigate the root cause of the problems that contribute to the injury caused by the cutter. To do that, the process of cutting the pleated paper is investigated and the steps are as follow:

1. Pleated paper is constantly fed out from the output of the machine. Figure 5(a) shows the pleated paper condition being compacted at the output.
2. Figure 5(b) shows the worker uses the left hand to hold the pleated paper and uses the right hand to spread the compacted pleated paper. The purpose of spreading is to find the point for cutting.
3. Finally, pleated paper is cut with the cutter in the right hand and the left hand is holding the paper to prevent it from moving as shown in Figure 5(c).

Figure 5(c) shows the tool sharp edge is facing up; thus, it can be the main source of hazard. The method used by the operator did not follow the standard operating procedure (SOP) but rather it is according to their own methods and preferences. After spreading the paper, the cutting point at the other side of pleated area is selected. Subsequently, the paper is cut with a single stroke with the cutter being hold at the position where the blade is facing up. At this point, it has the potential to strike the finger that holds the paper. Besides causing injury, the process yields uneven product quality and production time as it does not follow the standards.



(a) (b) (c)

Figure 5: (a) Output of the pleating machine, (b) Spreading pleated paper, and (c) Cutting stroke

Risk Control

Engineering Control: Poka-yoke tool design

Engineering control is an effective way on how to limit or contain worker exposure to the source of hazards through proper design of process and equipment [11]. In the current operation, hand knife is equipped as a tool to the worker and it is a source of hazard. For this study, an operation chart is constructed as in Table 3 in order to understand left and right hands activities involved in the usage of knife. With this attribute, a new tool using a poka-yoke principle is designed.

Table 3: Operation chart for the cutting method

Process	Duration	Left hand	Both hand	Right hand
1. Receive pleated paper feed from the machine.	10s			
2. Pick cutter.	1s			⇨
3. Spread pleated paper.	2s			⇨
4. Hold the spread area.	3s	◗		
5. Pick cutting point.	2s			⇨
6. Cut the stroke.	1s			⇨
7. Transfer cut pleated paper to next operator.	2 s		⇨	
8. Tear paper to final size and sort inside box.	33s		⇨	
Total Time	**54 s**			
⇨	Movement of the workers, materials or equipment.			
◗	Delay in the process, or an object laid aside until required.			

Operation chart in Table 3 shows the hand movement for the cutting method and the time required for one cycle to finish the process. Step no 4 has delayed operation which refers to left hand that holds the paper to prevent it from moving. The operation exposes the worker's left hand to hazard for 3 seconds in every cycle of cutting process. Development of the tool involves the modification to isolate the risk source from the receiver. In the process, both hands are used and multiple movements occur to complete one cutting operation and there are moments when the cutter passes the worker's left hand finger and it can be considered as a near miss. Other than that, the condition of the tool that exposes the blade can inflict injury in various ways such as it can fall to the worker's feet or struck the finger. This method is suitable to be implemented as the worker has no choice but to follow the new modified cutting process. Moreover, the usage of poka-yoke tool also reduces the unnecessary motions and avoid mistakes due to human factors.

Results and Discussions

Poka-yoke Tool

The design of the tool involves CAD software CATIA V5. Material for this tool uses Aluminum sheet metal with the thickness of 0.5mm and 1mm. The tools contain 4 parts and the blade attached to this tool uses the universal cutter blade that can be obtained almost everywhere. The full assembly of the part as shown in Figure 6 is fully done by bending process. The tool parts and part assembly are shown in Figure 7 and Figure 8.

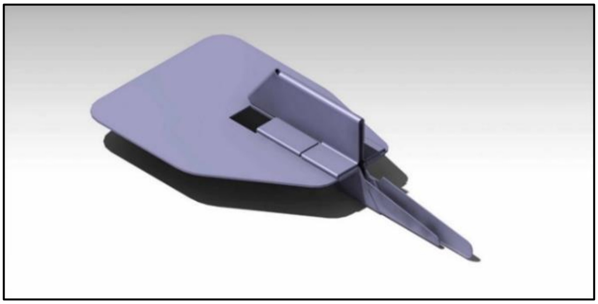


Figure 6: Full assembly

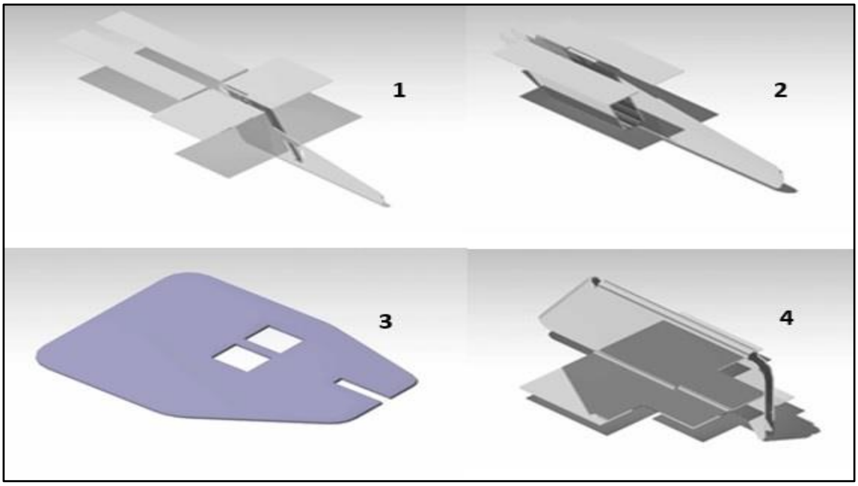


Figure 7: Designed tool parts. (1) Blade holder, (2) paper spreader, (3) tool base, and (4) tool holder

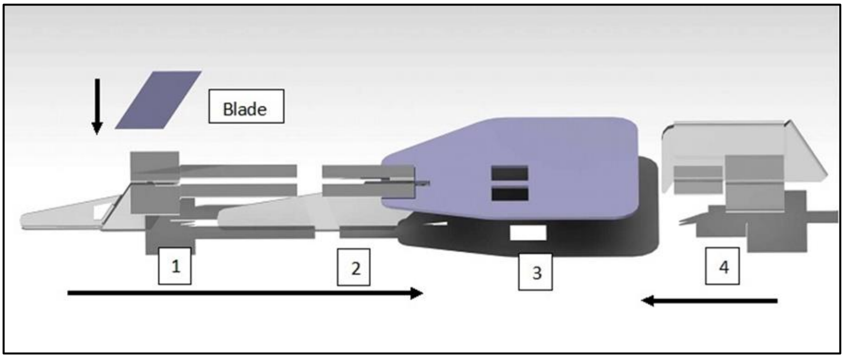


Figure 8: Part assembly

The blade is placed inside the blade holder and the method used to hold the blade is using the bending itself. The bending holds it at two spots which are the front and the back of the blade. The blade is placed before the case and is assembled together. Then, the holder (1) is attached together with the spreader (2) before it is assembled with the base (3) and lastly the case (4). Besides providing a holding spot for the worker, the case also acts as a barrier for the hazard. The bending for locking the assembly is completed after all the parts are assembled. The dimensions of the final product is shown in Figure 9.

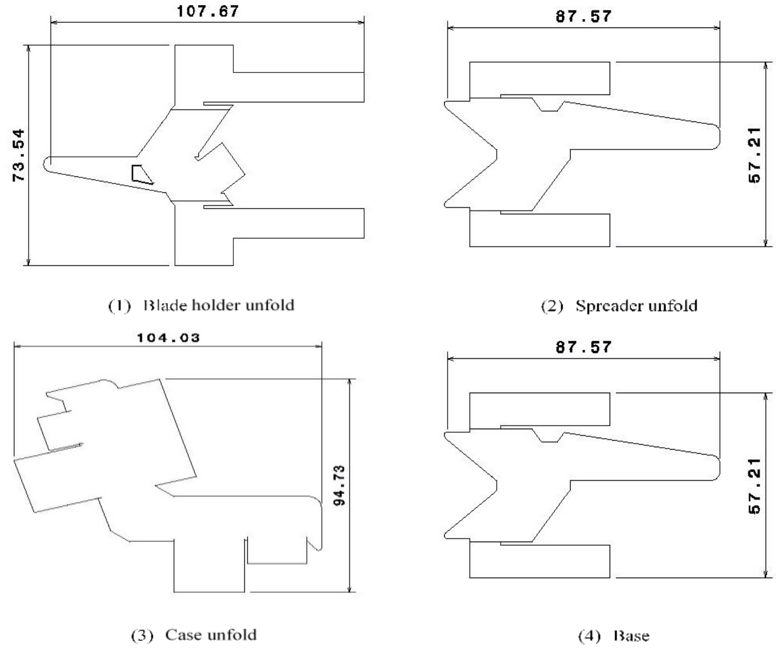


Figure 9: The dimensions of the final product in millimetre

As considered at the early stage of the design, development of the tool resulted as a preventive component to avoid accident from happening with the assumption that the condition of the worker varies from best until worse; yet the tool is able to exclude risk from the process. Comparing to the previous cutting process, the designed tool performed both spreading and cutting in a single step which maintained the original cutting procedure. The two-in-one step proposed by this tool is the main advantage of this design. In pursuing the objective of the poka-yoke, the usage of this tool has excluded the left hand operation from the original step of cutting process; hence, the probability to inflict injury to the worker's left hand has lowered. Other than that, the task for holding the paper is shifted to the tool base; hence, it has covered most of the operations in a simple procedure. Figure 10 illustrates the hand position in holding the new design spread and cutting tool.

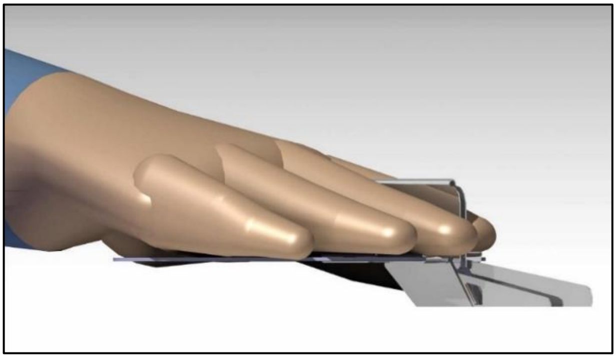


Figure 10: Gesture for handling the tool

Activities Flow after the Implementation

Due to the tool added features, the paper cutting process is modified where the motion for the left hand to hold the pleated paper is eliminated; thus, it improves the safety as the primary receiver is excluded from the risk. Other than that, the cycle time for the process is reduced; hence, it improves the productivity. Operation chart after the implementation is presented in Table 4 to view the modification made. It can be seen that the total operation time has been reduced from 54 seconds to 49 seconds.

Table 4: Operation chart after new tool implementation

Process		Duration	Left hand	Both hand	Right hand
1.	Receive pleated paper feed from the machine.	10s			
2.	Pick cutter.	1s			⇨
3.	Spread pleated paper.	1s			⇨
4.	Pick cutting point.	1s			⇨
5.	Cut stroke.	1s			⇨
6.	Transfer cut pleated paper to next operator.	2 s		⇨	
7.	Tear paper to final size and sort inside box.	33s		⇨	
Total Time		**49 s**			

As for the containment of the blade inside the tool, it has resolved the possibilities of sharp tool to cause unintended careless such as slipping. Although the mistake tends to happen, the seriousness of the impact is reduced. In terms of ergonomics, the mass of the tool is less than 0.1kg, thus the worker can effortlessly handle the tool which makes it viable for every user. Because of the new tool design, the risk and injury severity of the worker due to the sharp cutting edge and improper working procedure reduced tremendously. It can be seen after revaluation of the Risk Assessment (HIRARC) which is shown in the next section.

HIRARC after Implementation

As informed before, the poka-yoke tool is viewed in terms of health and safety to prevent such accidents to happen. At the workstation, the selection on the field of focus is determined by the area that inflicts the most risk in the process. Thus, as the poka-yoke approach is implemented, risk evaluation is made to review the effectiveness of the tool. The result can been seen in Table 5 and Figure 11.

Table 5: Risk evaluation after new tool implementation

Hazard	Risk	Likelihood	Severity	Score
1. Sharp cutter	• **Hand injury**	**1**	**3**	**3**
2. Hand caught on pleating roller machine	• Hand injury	2	3	6
3. Hot from rotating machine	• Heat stress, skin burn	1	2	2
4. Dust or paper fiber	• Respiratory problem, ill health	1	2	2
5. Standing at work	• Body pain	1	2	2

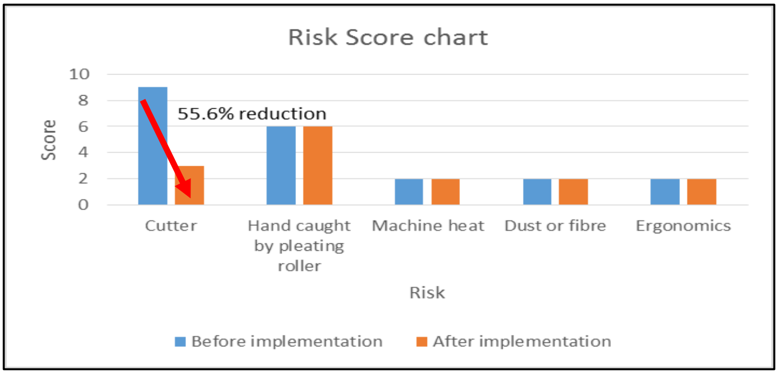


Figure 11: Risk score chart for before and after implementation

Risk evaluation as shown in Table 5 stated the score for the sharp cutter hazard has lowered as the likelihood to happen was reduced. It is because the tool contains the risk that has the possibility to cause injury as it has happened before. From the previous incident, the tool used has lack of protection for the worker and it depends on worker to concentrate on the task given. Risk score chart in Figure 11 shows a 55.6% risk reduction on the tool used after the implementation.

Conclusion

As a conclusion, the design of the poka-yoke tool has met the objectives of this study which are to improve the safety at the workplace and simplify the work process; thus, it increases the production linearity and improves the product quality. The risk score at the workplace has improved tremendously from 9 to 3 that is equal to 55.6% of total reduction.

The implementation of the tool has simplified the process flow of the current method that reduces the number of motion in the routine. Motion is one of the seven wastes; hence, the elimination of process promotes lean production. Small change in reducing all types of waste at each workstation can promote improvement for the whole production line. For this study's objective, the development of the tool is successful in controlling risk which prevents workers to commit mistakes with the tool without changing the actual process. However, risk assessment needs to be conducted periodically as risk cannot be fully eliminated. Furthermore, the purpose of poka-yoke tool as lean production tool is viable by eliminating inappropriate motion and providing reduction in cycle time.

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