

Implementation of Karakuri Kaizen to Improve Productivity and Ergonomics in Wire Rope Industry

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Abstract

Wire rope manufacturing industry in Malaysia is thriving and demands are rising for the products. Productive workers are needed to fulfill the work orders however, the existing work stations designs have detrimental effects on workers' health. This is because the productivity level is always linked to the wellbeing of the workers. In response, Karakuri Kaizen concept implementations has been selected to improve the current workstation designs. The relationship between Karakuri Kaizen with productivity and ergonomics during the concept implementations is studied. A case study on the proposed concept had been performed in a wire rope manufacturing factory by means of questionnaire and experiments concerning both previous and improved workstation designs. Validation of the results are done by using productivity reports throughout the year, REBA analysis and Paired Samples t-test. Reba analysis shows significant improvement from REBA Level 3 and 4 on previous designs to Level 2 after concept implementation. Productivity increases around 5.8% throughout the study. Compelling differences between two samples have also been recognized through Paired Samples t-test. Therefore, the implementation of Karakuri Kaizen concept on the workstation designs has positive impacts on both productivity and ergonomics in wire rope manufacturing industry dictated by the results of this study.

Keywords

Productivity, ergonomics, karakuri kaizen and wire rope.

1. Introduction

A wire rope maker factory was established in Malaysia in the early 1980s with the aim of developing high quality wire rope to be marketed globally. Generally, the manufacturing process can be divided into two major departments. The first department will consist of batch pickling, pre-drawing, inline patenting, pickling and coating. Second department will comprise of intermediate drawing, stranding, closing and lastly packaging. Most of the processes during rope manufacturing require manual handling by the operators to move heavy bobbins at the workstations and around the production floor. Manual Handling involves manual lifting, lowering, carrying, pushing and pulling loads and have always being associated with musculoskeletal disorders (MSDs) (Deros et al., 2015). Musculoskeletal disorders have reduced operator's productivity and detrimental effects on the health of the workers. Pain and discomforts experienced by the workers have been recorded in wrists, arms, neck and back as the aftermath of their job specifications.

Nowadays, wire rope manufacturing industry is receiving high customer demand for their product from all over the world and price competition from China. One of the solutions for the said issue is to improve the productivity on the production floor to fulfill the demand and reducing the manufacturing cost to compete with the price offered by the China-based competitors. Reducing or optimizing the cycle time will directly increases the overall productivity as it is inversely proportional to throughput time (Khumbar et al., 2014). The effect of ergonomics on individual productivity in various occasion settings has been reported, e.g., processed food (Cocci et al., 2005), garment industry (Kaya, 2015) and automotive manufacturing industry (Sundin et al., 2004). Companies who already implemented Kaizen method has only aimed for productivity improvement without considering the ergonomic of the workplace. Company must favor both productivity and ergonomic instead of just focusing on the productivity level. This matter must be revised as ergonomic and productivity must both be the goals of a successful adaptation of Kaizen method by the company. Company with positive environment for the employee will abide to the changes in the workstations which supports both objectives of productivity improvement and in the same time be ergonomically conducive (Hoffmeister et al., 2015)

Previous studies can be extended by investigating the influence of workstation's design on productivity through Karakuri Kaizen concept implementation on individual or group (process) and also considering individual's perceptions of pain at the workstation. This alteration in returns will reduce wastage of cycle time and be ergonomically suitable for the operators.

Karakuri Kaizen is a Japanese term that can be defined as an automation mechanism which has been introduced and used during the Edo-era in Japan. The Karakuri Kaizen technology helps to make objective operations easier and also to increase productivity (Murata et al., 2013). Murata et al. (2013) carried out study by finding the relationship between visual management, Poka-Yoke and Karakuri to improve the leanness degree by focusing on elimination of useless operations, worker training, energy conservation and so on. Rani et al. (2015) stated that through Karakuri concept, material handling process will rely on gravity force and centrifugal force. They carried out study by implementing Karakuri technology to increase the productivity by eliminating pneumatic system dependent facilities due to frequent power shutdowns cases in India. Both studies carried out by previous researches did implement the Karakuri technology but only to improve the productivity. This study can be extended by including other factors that might have relationship with Karakuri technology. A factory may use Karakuri Kaizen to transfer boxes from a moving device to a rail by the use of mechanical (Karakuri) interface allowing the boxes to move or stay in position till movement was desired. Karakuri aims to reduce or eliminate the waste such as human movement with simple construction of machine. Waste management is an essence in method as wastage is going to tremendously affect the efficiency of the production (Singh and Singh, 2018). According to the study conducted by Singh and Singh (2018), aside from productivity improvement, the company which implemented Kaizen method has seen a new peak in terms of their company's profit.

As a conclusion, this study will emphasis on the productivity improvement and ergonomics via Karakuri Kaizen concept implementation to improve workstation designs in wire rope industry. There is no prior study of this matter thus the aim of this study will be met and validated through the findings of this research. The ultimate objective of this study is to design ergonomics workstation for the production process by implementing Karakuri Kaizen concept and evaluate it in term of operator's productivity and health.

2. Methodology

2.1 Research Design

This study was carried out on three stages that covered both experimental and perceptions analysis on the workstation designs. The first stage would be the data collection stage. Second stage would be the data analysis stage followed by third stage which was the result discussion stage. Descriptive time study, monthly production report, REBA score sheet and set of questionnaires will be used throughout this study based on quantitative method design. Quantitative method design will gather information on the background of the working environment and

operators, information on operator's current routine on the production floor, information of operator's body posture and total productivity. For the quantitative data collection, time-study tool, REBA score sheet and set of questionnaires will be used.

Pilot study has been conducted to collect the opinions of the operators on the easiness to understand the prepared questionnaires. Feedbacks obtained from the operators will be analysed and improvement will be done to the questionnaires to suit the target respondents. The questionnaires were aimed to collect data to support the results of the developed work stations designs through Karakuri Kaizen implementation since the research focused on the drawing process. The subject pools will be from those who were not from the drawing process namely Stranding and Closing. This step was taken as a precautionary measure to avoid bias.

2.2 Fabricate Implemented Karakuri Kaizen Concept Drawing Workstation

Fabricate workstations by implement Karakuri Kaizen will be designed and developed by the factory's Engineering Team and outsources based on the data and feedbacks from worker regarding current manual material handling process at the existing workstation at the Drawing process.

2.3 Data Collection Method

There were several methods that will be carried out, each with a different purpose namely for productivity, ergonomic considerations and discussions and perceptions analysis. Firstly, to gather the productivity data, time study is chosen to be done at the existing workstations design in order to identify non-value-added time activities. Average process cycle time to produce one bobbin will be calculated through the same process. Monthly production report will be used to calculate the productivity at the Drawing process throughout the improvement activities on monthly basis.

Moreover, operator's movements and body postures during working was recorded through video recording process for ergonomic considerations. It was followed by the cropping of the video to get the snapshots for analysis of postures of the workers. REBA analysis was constructed on the snapshots by filling in the scores based on the already established assessment sheet. Lastly, questionnaires were distributed in Bahasa Malaysia instead of English for discussions and perceptions analysis as the workers were facing difficulties to understand the language other their mother tongue.

2.4 Development of Questionnaires

Questionnaires were developed based on the contents of the literature studies as well as modifications from Ahmadi (2013) Deros et al. (2015) and Azhar (2009) to suit the proposed manufacturing industry. The questionnaire was divided into Section A, Section B and Section C. Section A was focusing on the demographic profile of the workers such as age, nationality and year of services. Section B and C was constructed to tackle the individual's perceptions of individual's perceptions on before and after the workstation's designs improvement and ergonomics respectively.

In this study, 31 operators participated for the questionnaire and Likert scale is used to evaluate their perspective regarding before and after workstation design improvement from 1 to 5, with 1 being strongly disagree and 5 being strongly agree on the opinion questions given.

2.5 Data Analysis Method

The data gained from the respondents will be analyzed into three different parts which are (1) analyses of existing workstation design, (2) analyses of Karakuri Kaizen implemented workstation design for productivity and ergonomics and (3) questionnaire analyses regarding existing and Karakuri Kaizen implemented workstation design from the operator's perception as shown in Table 1.

Table 1. Methods Used

Study Part	Data Collection Tools	Method Data Analysis
Analysis of exiting workstations designs	Time Study Report Monthly Production Report REBA Score Sheet	Analysis of cycle time and productivity Analysis of operator's body posture
Analysis of Karakuri Kaizen workstations designs	Time Study Report Monthly Production Report REBA Score Sheet	Analysis of cycle time and productivity Analysis of operator's body postures
Questionnaire Analysis	Questionnaire	SPSS Statistic 23.0 Paired Sample T-Test Analysis

Data obtained through questionnaire has been analyzed using SPSS Statistic 23.0. Data obtained from the operators were divided into two parts; frequency and percentage table. Descriptive analysis was used to explain the respondent's demographics. Besides that, questions involving workstation in term of productivity and ergonomics will be evaluate by using Paired Samples t-test. For both parts; mean score, standard deviation and significant difference (Sig(2-Tailed) value) were determined. This method was used to understand the level of productivity and ergonomics of the current workstation design based on operator's perception. On top of that, Paired Samples t-test also will be conducted in order to test the hypothesis and to find out the significant difference of two samples. The outcome of the data allows researcher to continue with the next step which is to design more ergonomically and user-friendly workstation.

3. Results and Discussion

3.1 Data Analysis Method

For productivity, main contributors of non-value-added activities that exist at previous Drawing process workstation design shall be identified first in order to reduce or eliminate it through Karakuri Kaizen implementation. Therefore, by reducing the non-value-added activities time, cycle time will be reduced and improved the productivity at the same time.

Time study has been carried out in this study in order to record the time spent by operators on variety of tasks at previous Drawing process workstation design and to identify the non-value-added activity time. Same individual operators who was working in both previous and improved workstation design will participate in this controlled time study (no any outliers such as temperature, humidity etc.).

At previous Drawing process workstation design, change bobbin process has been identified as the major contributor to the non-value-added activities which contribute 33% out of total non-value-added activities time. Second is pull wire process (27%), third is change supply process (16%), fourth is cut wire process (14%), fifth is welding process

(6%), sixth is insert bobbin process (3%) and lastly bring bobbin process which contribute to 1% as shown in Figure 1.

Time study analysis has been carried once again with improved Drawing process workstation design through Karakuri Kaizen implementation. Figure 2 shows the Pareto Chart of average non-value-added activities time exist at improved workstation design through Karakuri Kaizen implementation.

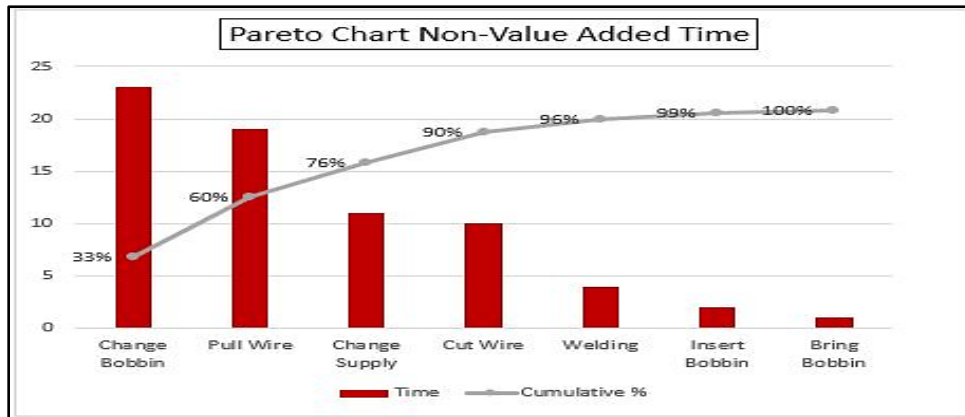


Figure 1. Pareto chart NVA time (previous workstations)

At improved Drawing process workstation design, change bobbin process no longer be the major contributor to the non-value-added activities time. It has been replaced by pull wire process as the major contributor to the non-value-added activities which contribute 33% out of total non-value-added activities time. Second is chance bobbin process and change supply process (both 19% respectively), forth is cut wire process (17%), fifth is welding process (7%), sixth is insert bobbin process (3%) and lastly bring bobbin process which contributes to 2%.

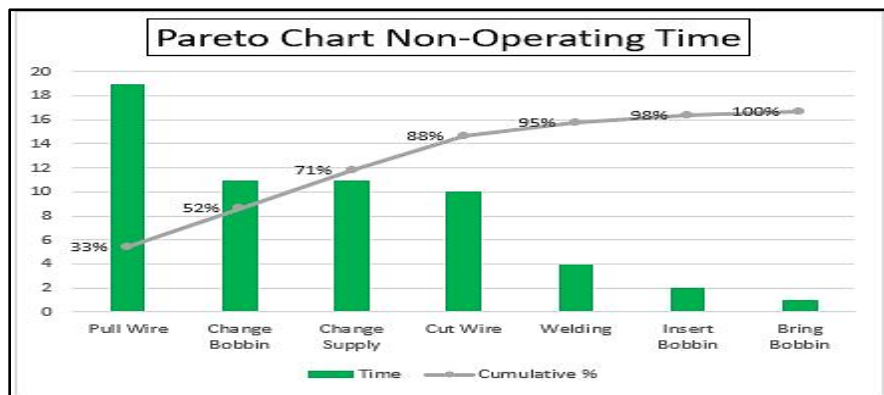


Figure 2. Pareto chart NVA time (improved workstation)

3.2 Cycle time

Khumbhar et al. (2014) stated that the one of the available methods to increase the productivity is by reducing the cycle time. Below is the calculation of the time taken for an operator to produce one bobbin at previous and improved Drawing process workstation design. At previous workstation design, operator requires 67 minutes averagely to produce one bobbin supply. Therefore, the cycle time calculation is as below:

$$\text{Cycle Times, } C = \frac{67 \text{ min}}{1 \text{ bobbin}} = \frac{67 \text{ min}}{\text{bobbin}} \quad \text{Equation 1}$$

$$\text{Production Rate, } p = \frac{1 \text{ bobbin}}{67 \text{ min}} = \frac{0.0149 \text{ bobbin}}{\text{min}} \quad \text{Equation 2}$$

At the improved workstation design, operator require 65 minutes averagely to produce one bobbin supply. Therefore, the cycle time calculation is as below:

$$\text{Cycle Times, } C = \frac{65 \text{ min}}{1 \text{ bobbin}} = \frac{65 \text{ min}}{\text{bobbin}} \quad \text{Equation 3}$$

$$\text{Production Rate, } p = \frac{1 \text{ bobbin}}{65 \text{ min}} = \frac{0.0154 \text{ bobbin}}{\text{min}} \quad \text{Equation 4}$$

3.3 Productivity

Partial productivity throughout the year 2017 (from January till November) at Drawing process has been observed as a group perspective to check the effectiveness of improved Drawing process workstation through Karakuri Kaizen implementation. The study duration can be divided into three stages which are “Before improvement stage”, “1st improvement stage (improvement in-progress)” and “2nd improvement stage (stabilization)”.

Throughout this study, increasing of productivity in Drawing process after improved the Drawing process workstation design through Karakuri Kaizen concept has been observed from starting of the experiment and stabilized till now. Production rate increase 3.3% after implementing the Karakuri Kaizen concept at Drawing process workstation design.

In wire rope industry, production length and tonnage has been commonly used as the outcomes when calculating their process productivity. Drawing production record that been reported by monthly basis indicates the productivity getting increase between starting phase January 2017 and stabilized phase October 2017 for both production length and tonnage productivity around 5.76% and 13.08% respectively.

3.4 REBA Analysis

The selected snapshots of operators performing manual material handling at previous and improved workstation design are been observed. The REBA Score were calculated by using pen and paper technique through REBA score sheet to verify the results. Then, ergonomics risk factors were observed and identified by result analysis through this method.

Figure 3 shows previous Drawing process workstation design and Table 4 presents the different categories of the risk levels as obtained by the operators after analyzing their body posture when performing manual material handling at previous Drawing process workstation design.



Figure 3. Previous workstation design

Table 4. REBA analysis at previous workstation design

REBA Level	0	1	2	3	4
REBA Score	1	2-3	4-7	8-10	11-15
Risk Level	Negligible	Low	Medium	High	Very High
Required Action	None	Maybe necessary	Necessary	Necessary Soon	Necessary Now
Total workers	0	0	0	2	4
Workers Percentage (%)	0	0	0	33.33	66.7

Figure 4 shows improved workstation design and Table 5 presents the different categories of the risk levels as obtained by the operators after analyzing their body posture when performing manual material handling at improved Drawing process workstation design through Karakuri Kaizen implementation. 100% of total number of operators has been grouped into REBA Level 1 which required action is maybe necessary.



Figure 4. Improved workstation design

Table 5. REBA analysis at improved workstation design

REBA Level	0	1	2	3	4
REBA Score	1	2-3	4-7	8-10	11-15
Risk Level	Negligible	Low	Medium	High	Very High
Required Action	None	Maybe necessary	Necessary	Necessary Soon	Necessary Now
Total workers	0	6	0	2	4
Workers Percentage (%)	0	100	0	0.0	0.0

3.5 Questionnaire Analysis

3.5.1 Questionnaire Reliability

Table 6 and Table 7 show the reliability statistics and the Cronbach's Alpha for productivity and ergonomics perspectives. According to the rule of thumb for Cronbach's Alpha value and internal consistency, individual Cronbach's Alpha for productivity that obtained 0.68 will be classified as Acceptable ($0.7 > \alpha \geq 0.6$) while individual Cronbach's Alpha for ergonomics that obtained 0.762 will be classified as Good ($0.9 > \alpha \geq 0.7$). Based on the reliability statistics, this questionnaire is reliable enough to be test on the large scale.

Table 6. Reliability statistic on productivity perspective

Reliability Statistics		
Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
0.629	0.680	4

Table 7. Reliability statistic on ergonomics perspective

Reliability Statistics		
Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
0.730	0.762	8

The feedback from the operators through questionnaire will be analyzed in order to obtain the frequency and the percentage of operator's individual perception on both previous and improved Drawing process workstation design in term of productivity and ergonomics perspectives. Consequently, their feedback will be turn into quantitative data and will be analyses whether the opinions have significance difference between previous and improved workstation design.

3.5.2 Demography

Table 8 indicates the frequency and percentages of questionnaire participants out of total 31 respondents according to the age category, nationality and year of services.

Table 8. Demography data

Categories		Frequency	Percentage (%)
Age (years)	30-39	6	19.4
	40-49	17	54.8
	50-59	8	25.8
Nationality	Malaysia	18	58.1
	Indonesia	7	22.6
	Nepal	2	6.5
	Bangladesh	3	9.7
	Pakistan	1	3.2
Year of services	<4	6	19.4
	4-6	3	9.7
	7-9	14	45.2
	10-12	4	12.9
	>12	4	12.9

3.5.3 Paired Samples t-test

3.5.3.1 Efficiency of Production Activity Between Both Workstation Design

There was a significant difference (Sig(2-Tailed) value is less than or equal to 0.05) in the scores for before improved workstation design (M=4.0, SD=0.365) and improved workstation design (M=1.74, SD=0.445) conditions; $t(30) = 19.932$, $p = 0.000$.

3.5.3.2 Fatigue Recover Often Time Between Both Workstation Design

There was a significant difference (Sig(2-Tailed) value is less than or equal to 0.05) in the scores for before improved workstation design (M=3.71, SD=0.461) and improved workstation design (M=3.19, SD=0.792) conditions; $t(30) = 3.376$, $p = 0.002$.

3.5.3.3 Physical Exhaustion Condition Between Both Workstation Design

There was a significant difference (Sig(2-Tailed) value is less than or equal to 0.05) in the scores for before improved workstation design (M=4.03, SD=0.315) and improved workstation design (M=3.77, SD=0.497) conditions; $t(30) = 2.278$, $p = 0.030$.

3.5.3.4 Awkward Body Posture Between Both Workstation Design

There was a significant difference (Sig(2-Tailed) value is less than or equal to 0.05) in the scores for before improved workstation design (M=4.10, SD=0.310) and improved workstation design (M=1.97, SD=0.547) conditions; $t(30) = 17.681$, $p = 0.000$.

4. Conclusion

This study was conducted to identify the relationship between Karakuri Kaizen concept with productivity and ergonomics especially at Drawing process workstation in wire rope manufacturing industry. This study also has been conducted out in order to achieve the three main objectives which are: to evaluate and analyze the manual material handling activity at existing workstation design that effect operator's productivity and health, to design ergonomics workstation by implementing Karakuri Kaizen concept, and to identify the relationship between productivity and ergonomics consideration through before and after Karakuri Kaizen concept implementation at Drawing process workstation.

Through the study, implementing Karakuri Kaizen concept at workstation design does give impacts on both productivity and ergonomics. This study can be as reference for any other manufacturing industries that looking for a solution to increase their process productivity and at the same time consider the ergonomics factor to improve their worker's health on the production floor.

During implementation of the study, several areas had been identified to work on the future work which are,

- i. This study can be use as reference but with extend the scope by implementing the concept on other wire rope manufacturing processes such as Stranding and Closing process to view the effectiveness as overall.
- ii. Running the same study but evaluate it in term of electric current energy cost saving since through this concept, there are no electric motors or sensors involved. Only by using gravitational potential energy and that can be considered as a green energy aspect.
- iii. Evaluate the relationship between Karakuri Kaizen concept with other factors such as machine breakdown ratio and height of the facilities or worktable and determining the optimum level of these factors that can increase the productivity.

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