A Case Study On The Improvement Of Productivity And Efficiency Of A Quality Control Line For A Cutting Tool Manufacturer

Muhammad Farhan Mohd Suhaimi,
*Noor Azlina Mohd Salleh**

Faculty of Mechanical Engineering,
Universiti Teknologi MARA (UiTM),
40450 Shah Alam, Malaysia

**noorazlinamohdsalleh@gmail.com*

ABSTRACT

A case study conducted at a quality control line of a cutting tool manufacturer in Malaysia aimed to improve the line balancing and maximise the productivity. Line Balancing (LB) plays an important role to enhance the productivity and efficiency of a production line. Current situation at the line is considered very critical since the operator exhibits high tendency to skip a few procedures while performing the inspection processes. It is due to the manpower shortfall in the line that overwhelmed the operator to meet an irrelevant required target output from the line. This situation resulted in some customer complaints on the company's product. In order to overcome the problem, observations and time study using the stopwatch technique had been conducted to identify the flaw concerning the workload at the quality control line. Then, from the data obtained, LB is introduced into the quality control line. The data collected are then analysed by using the takt time calculation, Yamazumi Chart and a new layout of the quality control line are designed and proposed. Apart from that, a pre-filled check sheet acts as a Lean Manufacturing (LM) approach named Poka-Yoke is also introduced with regard to eliminate a few wastes existed in the line. As a result, the productivity and efficiency of the quality control line recorded an increment up to 9.73% and 89.94% respectively. With the aid of this study, it is greatly help the company to establish a better monitoring system to thoroughly

ISSN 1823- 5514, eISSN 2550-164X

Received for review: 2017-02-16
Accepted for publication: 2017-04-27
Published: 2018-01-15

utilise the resources especially in terms of time and manpower needed for the line.

Keywords: *Time Study, Line Balancing, Lean Manufacturing, Cutting Tool Industry*

1.0 Introduction

In the present day, the advancement of precise machining lead to the increasing of demand for cutting tools industry worldwide. It is because of the rapid production of various products such as smartphones, automotive parts and medical equipment. Cutting tools is used to make the die or mold so that these products can be produced. Aligning with the industry revolutions in terms of autonomous and mass production, cutting tools manufacturers around the globe are competing aggressively with each other to satisfy their customers. The situation lead to the existence of various types of cutting tools offered with affordable prices. According to the National Statistic in 2014, this industry in Europe experienced a steady comeback in between the year of 2009 until 2012 after the economic crisis in 2009.

Malaysia is also known to be one of the reliable cutting tools exporter worldwide especially in the European region. The availability of resources such as cheaper labours and raw materials compared to Western countries are one of the factor contributed to the situation. In fact, with the ease of technologies exchanged nowadays affected the industry's supply chain so that the products can be delivered to the customers efficiently. However, to be sustainable, delivering the finished products to customers is not the main concern. It is the customer's loyalty that the manufacturers seek for. To earn that, they must maintain their product's quality at highest point to satisfy their customers.

Generally, there are two doctrines of production for most manufacturing companies which are mass production and LM. It is easy to be puzzled because both mass production and LM aim to reduce waste during manufacturing of the products. As an employer, the biggest concern is how to address the problem of waste during production. If not fixed, the impacts are to the tardy of projects and worthless spending [1, 3, 14, 15]. In the end, the finished product inclines to rise in term of overall production cost. Nowadays, lean manufacturing is widely applied in the manufacturing industry. This phenomenon involves the use of relevant tools with the aim of working smart instead of working hard [4]. It is maneuvered in regard to produce only the necessary products with quantity required to surpass deficits or unnecessary stock expenditures [12]. In contrast, mass production is the producing of products in larger volume than the actual demand. The main concept of this method is that more goods are produced within short time and consumes lesser resources. Even though the overall production cost can be reduced, yet the need of warehouse or inventory is really essential to store the surplus goods, awaiting customers' orders.

The application of latest machine and technology only do not guarantee it is the best manufacturing practice. In fact, in order to maximise profit, the manufacturers must efficiently blend the manufacturing system and management as well [2]. Due to this reason, LM system has been widely applied by many manufacturers across the globe. As in Malaysia, the LM system was pioneered by the automotive players especially the stockholders from Japan such as Toyota, Daihatsu and Honda. Nowadays, Malaysia's local automotive companies and its vendors also adopting the same manufacturing practice. The key point of LM is the identification and elimination of waste such as waiting, transportation, delay and others through continuous improvement known as Kaizen [1]. Originated from Toyata Production System (TPS), LM employ a number of systematic techniques with a set of powerful tools such as LB, Kanban system, Poka-Yoke and others had become major approaches in tackling problems that occurred during the manufacturing process.

This research will utilize the case-based method to demonstrate and document the changes due to the implementation of LB and LM tool, namely Poka-Yoke in one of Malaysia's finest cutting tool manufacturer, XYZ Machining Sdn Bhd. This study was conducted in a real production line, which is in a quality control line for special uncoated Ballnose type cutting tool. Currently, the line is practicing conventional production system; with the operators in the line are performing all of the inspection processes from start to end for the visual quality control inspection processes as stated in the Standard Operating Procedures (SOP). Meaning that, there was no precedence relationship in term of work elements among the operators. In this case, only the respective operator that carried out the inspection will comprehend the tool's defects. Technically, due to this practice, the flow of information along the line is poorly dispensed. In addition, current layout for the line is considered quite conventional as it exercises linear floor layout in which the operators had to travel to each workstation for completing the inspection processes. Scattered arrangement of digital equipment is also worsening the circumstance. As a result, these problems caused discomfort toward the operators which lead to the overwhelmed of workload and directly decreasing the work performance.

In pursuing the most favourable result for the case study, the goals and findings has been set. The objectives of this project are:

I. To identify the problem related to the overwhelming of workload at the quality control line by using time study and line balancing analysis.
II. To improve the line Cycle Time (CT) by introducing a pre-filled check sheet for defect tool as a Poka-Yoke approach and Yamazumi Chart.
III. To design and propose the new layouts for the line and to analyse the productivity and efficiency before and after implementation of proposed solutions.

2.0 Literature Review

In cutting tool manufacturing industry, the main concern regarding the quality control is to enhance the tool life especially for micro size tool. Quality control is an important methodology for asserting standards in manufactured products by testing some samples from output against the specification [4]. Since the tools are produced in mass production, a method known as visual inspection is used for quality control inspection to identify tool's defects. The core of visual inspection is to make sure that the dimension and surface finish is in the tolerances. Inspection of surface defects has become a critical task for manufacturers who strive to improve product quality and production efficiency [5]. It is carried out based on the quantity as well as tool's batch predetermined by the quality control line leader.

The main focus in maintaining cutting tool's quality is to enhance the tools life by effectively employing the quality control for the manufactured tools. Quality control is an important methodology for asserting standards in manufactured products by testing some samples from output against the specification [8]. In the quality control prospective, the accuracy in quality control inspection is highly emphasized. Some people may argue that to enhance the tools life it is not necessary to just employing the quality control. Other approaches are also can be easily introduced such as coating or using different types of materials that have greater hardness. However, in favour to reduce the manufacturing cost, the existing resources need to be fully exploited rather than investing new ways in enhancing the tool's quality. On the other hand, it is true that the capitals spent for research and development are essential to help the growth of the products in the long run.

In mass production, effective management on the production line is very crucial. One of the useful tool used to obtain the effective management of a production line is by implementing the LB. Pioneered by Henry Ford back in 1913, it is practically efficient in developing the throughput of an assembly line while fully utilise the resources. LB is usually undertaken to minimize imbalance between machines or personnel while meeting a required output from the line [4]. In general, the concept of line balancing is to ensure that every line of the production can be met equally within the time frame assigned earlier. LB also ensure that the workload among the workers is distributed almost evenly throughout the production line. Theoretically, an ideal balanced production line is expected to consist of minimal inputs and maximum output while at the same time maintaining the quality of the product. In reality, however, it is almost impossible to get a perfect balanced production line as there is always space for improvements following the number of workstations, manpower as well as non-added-values activities that create the abnormalities. These activities such as lunch, downtime and toilet break can be reduced and improved significantly by balancing the production line determined by the root cause of the problems.

TPS is dynamic applications of integrated organizational work design that enhancing the interaction between people and technology in the workplace. To it extends the interaction among suppliers, manufacturers and customers across the supply chain also covered in the TPS to allow only high quality products are to be delivered to customers [13]. Originally called Just-In-Time (JIT) production, it builds on the approach created by the founder of Toyota, Sakichi Toyoda, his son Kiichiro Toyoda, and the engineer Taiichi Ohno. The concept of TPS is abide by two main conceptual pillars namely JIT and Jidoka. JIT is the idea to produce only what is needed and only when it needed and together with the only amount it needed. On the other hand, Jidoka is a term refers to the automation when there is the existence of human interaction with the machines. The cores of the TPS are to wipe out overburden (muri) and inconsistency (mura), and to eliminate waste (muda) [5]. Following the implementation of TPS, the consequences on process value delivery are obtained by working out on a process capable of achieving the desired outcomes effectively; by extracting "mura" (inconsistency). It is also vital to ensure that the process is as flexible as necessary without creating overload or "muri" (overburden) since this generates “muda" (waste). Finally, the influential enhancements of decreasing waste or the disposal of “muda” are highly beneficial [5].

In LM, Poka-Yoke is an approach that is used to either detect or prevent defects from occurring [11]. Invented by Shigeo Shingo in the 1960s, Poka-Yoke is developed to eliminate defects in a product by preventing or correcting errors as early as possible. The essential idea of Poka-Yoke is to design the process so that mistakes are impossible or at least easily detected and corrected [6]. The main objective of Poka-Yoke technique is to obtain zero faults products, by using simple approaches of fixing, assembling, warning and other related tools, which prevent people to make mistakes, even if they wanted to. Poka-Yoke acts as a tool that is normally used for an indication or warning to the operators if something is wrong. It even used to stop the machines in the event of emergency. The anti-error devices apply in all the fields where equipment is involved and even in the offices and they are devices aimed at preventing and detecting the errors [7, 9, 10]. Since it is considered as relatively cheap control system, the Poka-Yoke concept may be implemented in other activity domains, such as selling, purchasing or developing products, where the errors cost can be very high.

3.0 Methodology

This paper focuses on analysing the existing quality control line for the special uncoated micro size Ballnose cutting tool. It was done according to the identified methodology which consists of five key phases which are (i) line observation; (ii) data collection; (iii) data analysis; (iv) utilisation of LB and Kaizen activity implementation, and (v) results evaluation as well as documentation of findings. Figure 1 illustrates Research Design Flow for implementation of this research. All of the findings are based on the activities carried out throughout this research in the line.

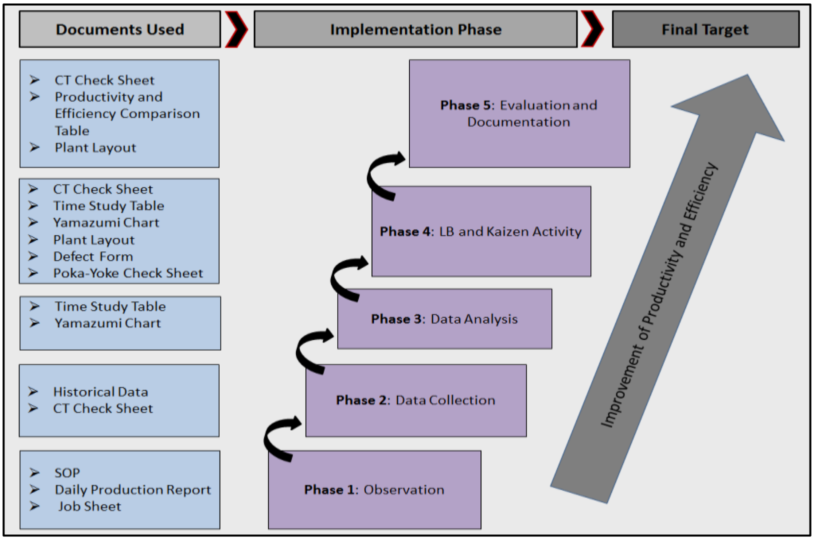


Figure 1: Research Design Flow

The first phase is Observation that involves the activity named Gemba Walk. It was done purposely to give better understanding on the current situation of the line. At the same time, the SOP, developed by the Production Department also reviewed. Other production documents such as Daily Production Report and the Job Sheet were also interpreted. The second phase is Data Collection. At this phase, two main activities were carried out which are analysing historical data on the production records as well as conducting stopwatch method to obtain the CT for the quality control inspection processes. The documents used are the historical data for production and CT Check Sheet. Third stage is Data Analysis. The main activity executed was analysing the data obtained in previous phase. It was done by using a set of LB tools which began with Time Study Table analysis and followed by constructing and analysing the Yamazumi Charts. The Yamazumi Charts were constructed for both before and after implementation of Kaizen activity. The fourth phase is LB and Kaizen Activity implementation. During this phase, the development of LB and Kaizen activity were successfully implemented. There are one major Kaizen activity was exercised named Poka-Yoke Check Sheet that replaced the Defect Form that is currently being used by the operators. The Poka-Yoke Check Sheet was designed by applying the concept of Poka-Yoke that aims to eliminate any kind of waste at earliest stage as possible. At the same time, another document used at this phase is the current layout that is being applied. The layout is used to help in configuring the new layouts that will be proposed. Lastly, the final phase is Evaluation and Documentation. It was done to analyse the deliverable of the case study after its implementation. Two main parameters known as productivity and efficiency are taken into account to analyse the performance of this study. The status of these parameters is measured and compared both before and after implementation of LB and Kaizen activity into the line. Apart from that, the documentation of all the findings is done and conveyed to the company's top management for review and further evaluation.

4.0 Scope of Work

This study is conducted at the quality control line in XYZ Machining Sdn Bhd which inspects the quality of finished cutting tool on daily basis. The tool selected in this study is only the special uncoated micro size Ballnose cutting tool. The duration of this research is about four months from August 2016 to November 2016. However, the data for production demand is retrieved from April 2016 to July 2016. Currently, the quality control line has four workstations with conventional linear layout. The line is divided into two category namely standard tool and special tool in which each of these categories is then divided again into another two sub-categories which are uncoated and coated tool. As of August 2016, there are a total number of twelve operators in the line where all of them are performing the inspection procedures from start to end for the quality control inspection as stated in the SOP. Figure 2 is the overall layout of the quality control line that currently being applied.

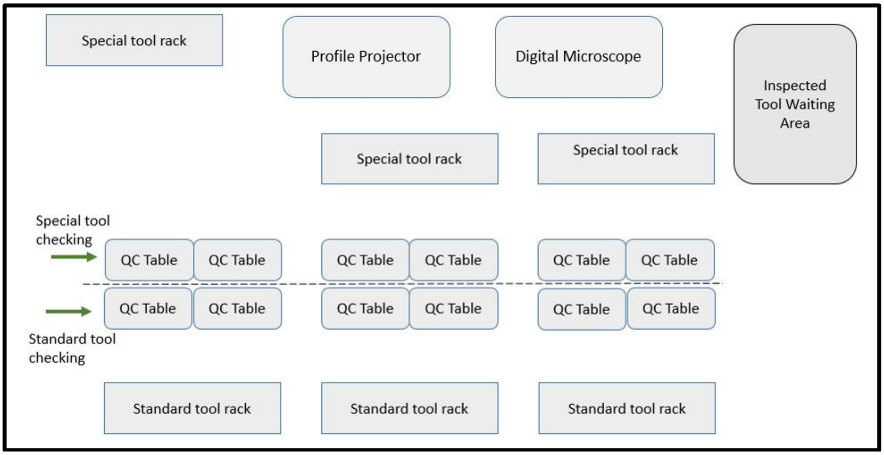


Figure 2: Overall layout of the quality control line in XYZ Machining Sdn Bhd.

For this study, the equations that were used are as follows;

$$\text{Takt Time} = \frac{Available\ Working\ Hours}{Output\ Demand}$$

$$\text{Theoretical No. of Manpower} = \frac{Total\ Time\ Required\ to\ Complete\ demand}{Takt\ Time}$$

$$\text{Productivity} = \frac{No.\ of\ Tool\ Produced\ per\ Day}{No.\ of\ Workers \times Working\ Hours} \times 100\%$$

$$\text{Efficiency} = \frac{Total\ Cycle\ Time}{(No.\ of\ Workstations \times Longest\ Operation} \times 100\%$$

5.0 Results and Discussion

Takt Time calculation for the quality control line for selected tool is shown in Table 1. The data collected for output demand is from April to July 2016.

Table 1: Time Study for Special Uncoated Micro Size Ballnose Cutting Tool

Normal Working hour (8 hrs/day) - (Briefing + Break + Lunch + Break + 5S)
Mon-Sat : 8.30 am to 5.15 pm - (5 + 10 + 45 + 10) = 455 minutes
Wed : 8.30 am to 5.15 pm - (5 + 30 + 10 + 45 + 10) = 425 minutes
Fri : 8.30 am to 6.30 pm - (5 + 10 + 90 + 10) = 485 minutes

Month		April '16	May '16	June '16	July '16	Average
Normal Working Hour Mon-Sat Wed Fri		17x455 = 7735 4x425 = 1700 5x485 = 2425	17x455 = 7735 4x425 = 1700 4x485 = 1940	17x455 = 7735 5x425 = 2125 4x485 = 1940	16x455 = 7280 3x425 = 1275 5x485 = 2425	
Grand total(min)		11 860	11 375	11 800	10 980	**11 504**
Output(unit)		3 072	2 580	3 169	2 825	**2912**
Takt Time (min)	Plan(100%)	3.86	4.41	3.72	3.89	**3.97**
	Actual(90%)	3.47	3.97	3.35	3.51	**3.58**
Cycle Time(min)		10.62				
Necessary Manpower	Plan(100%)	3 people	2 people	3 people	3 people	**3**
	Actual(90%)	3 people	3 people	3 people	3 people	**3**

This study has been able to improve the total cycle time for inspection processes from 10.62 minutes to 9.96 minutes. The maximum cycle time for the work elements assigned to the operator after improvements also reduced significantly about 64.12% to only 3.81 minutes compared to before improvements which is 10.62 minutes. The comparison of actual takt time obtained also shows a reduction of time from 10.62 minutes to about 3.58 minutes. The reductions occurred after the line balancing is introduced resulted to the addition of another two operators instead of only one operator in the line in order to satisfy the output demand. The improvements eventuated in increasing of the productivity and efficiency up to 9.73% and 89.94% respectively. Table 2 below shows the status of the quality control line before and after line balancing has been applied.

Table 2: State of Quality Control Line for Selected Tool

	BEFORE (1 Operator)	AFTER (3 Operators)
Total Cycle Time, min	10.62	9.96
Maximum Cycle Time, min	10.62	3.81
Takt Time for Present Demand, min	3.58	3.97
Actual Takt Time, min	10.62	3.58
Theoretical No. of Operator	1	3
Actual No. of Operator	1	3
Productivity, %	9.42	9.73
Efficiency, %	78.56	89.94

From the time study, the Yamazumi Charts were constructed to represent the workload in detail for the operator. It is a simple stacked bar chart that will explain the critical workload that need to be improved. For this study, the charts were constructed for both before and after line balancing is applied to emphasize the comparison.

From Figure 3, the Yamazumi Chart discovers that the cycle time before line balancing is exceeded far above the takt time for the inspection process. Note that the operator has to perform all the tasks for the quality inspection process for the tool at all four of the workstations in the line. Table 3 indicates in detail the work elements in the inspection process done by the operator. It obviously shows that the operator has to extremely speed up his working pace in order to complete the output demand. This situation leads the operator to do the inspection without maintaining the working standard towards lean manufacturing. Even worst, the operator might skip one or two procedures because of the urgency. Thus, line balancing is done to overcome the problem and from the time study that had been conducted, theoretically it shows that the quality control line is really in need of additional operators to meet the output demand.

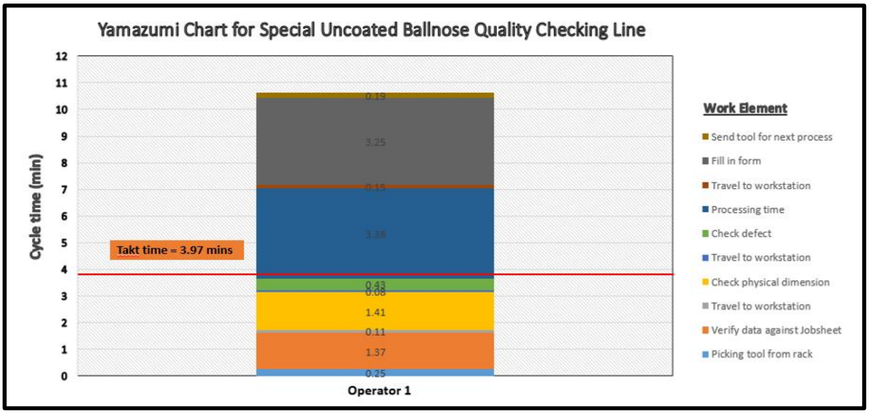


Figure 3: Yamazumi Chart before Line Balancing

Table 3: Details of the Yamazumi Chart before Line Balancing

Work Element	**Cycle Time (min) Special Uncoated Ballnose**
Picking tool from rack	0.25
Verify data against Jobsheet	1.37
Travel to workstation	0.11
Check physical dimension	1.41
Travel to workstation	0.08
Check defect	0.43
Processing time	3.38
Travel to workstation	0.15
Fill in form	3.25
Send tool for next process	0.19
Total Cycle Time To Complete Inspection (min)	**10.62**

Figure 4 illustrates the improvements made on the quality control line for the selected tool. It can be seen clearly that there is no urgency for each operator to complete their assigned tasks. This is because of the line balancing introduced into the line. It was done practically by breaking down almost evenly all the inspection processes into smaller work elements and merge together to suit with the operators. In fact, the idle time for each operator also considered almost the same. Without any kind of urgency created before, the operators can be more focus while doing the inspection as well as eliminating the tendency to skip the inspection procedures. Even though the addition of new operators affect the company's turnover in terms of capital invests in manpower, yet it is unlikely that the company will face substantial loss in a long run if lack of manpower jeopardize the quality inspection of the manufactured tools. Table 4 explains the details of the work elements for respective operators after line balancing.

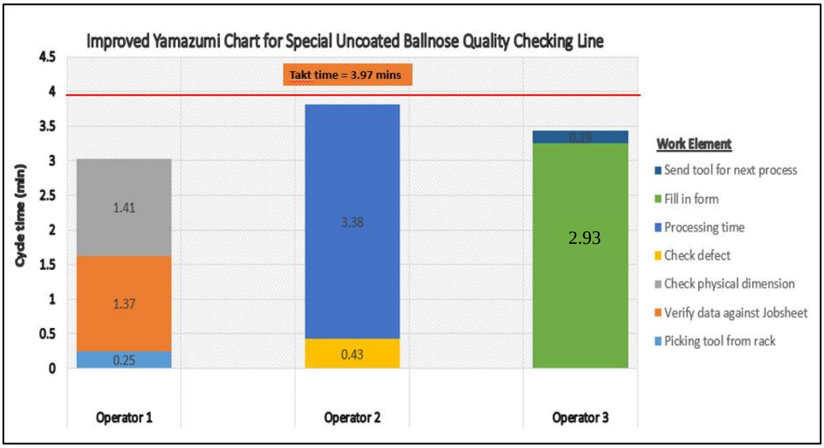


Figure 4: Yamazumi Chart after Line Balancing

Table 4: Details of the Yamazumi Chart after Line Balancing

Operator	Work Element	Cycle Time (min) Uncoated
1	Picking tool from rack Verify data against Jobsheet Check physical dimension	3.03
2	Check defect Processing time	3.81
3	Fill in form Send tool for next process	3.12
Total Cycle Time To Complete Inspection (min)		**9.96**

Another improvement introduced is a lean manufacturing tool namely Poke-Yoke. It was done by designing an improved check sheet for the defect tool. While collecting the data, a number of observations is done in order to counter the wastes existed in the line. From the observations, the major waste faced by the operator is the over processing regarding the time spent while fill in the defect form. It is because the operator has to fill up the form for each particular details and information regarding the tool description and its defects. This situation slows down the overall production process and affected the productivity as well as efficiency. Besides, there were delays that occurred as the Work In Progress (WIP) tools that were placed in the racks waiting for inspected. As for the improvement, a pre-filled check sheet for the defect tool was designed and a few trials for implementation had been done and the data was recorded. The check sheet consists of the defects that frequently recorded by the operator. As a result, the time spent to fill up the new check sheet has reduced slightly for about 19.2 seconds or 10.06% compared to before improvement. The check sheet for defect tool before and after improvement are show in Figure 5 and 6 respectively.

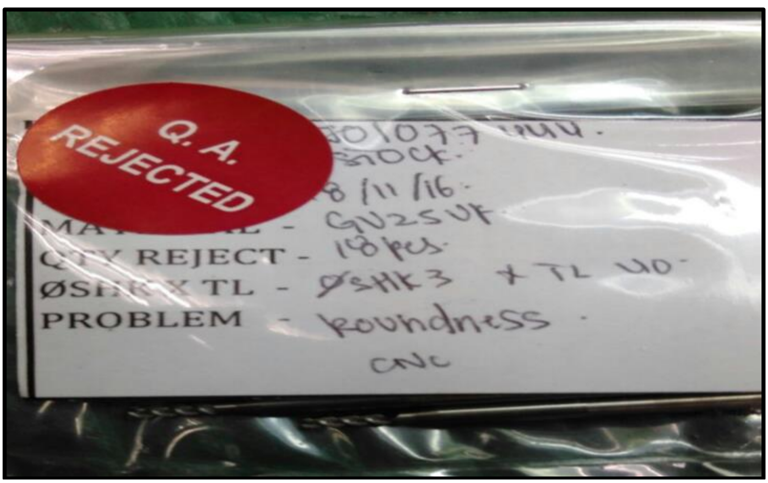
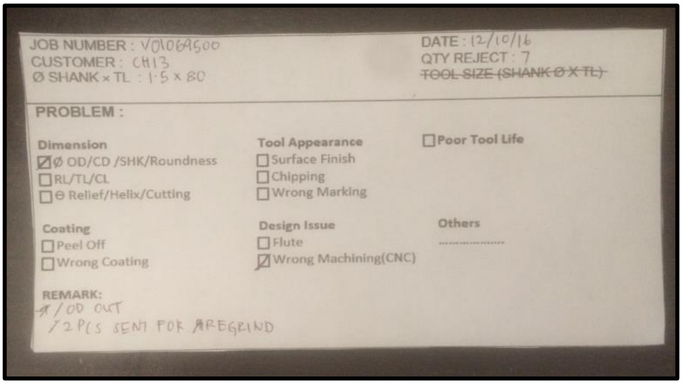


Figure 5: Defect tool Check Sheet before improvement


JOB NUMBER : V01064500
CUSTOMER : CH13
Ø SHANK × TL : 1·5 × 80
DATE : 12/10/16
QTY REJECT : 7
~~TOOL SIZE (SHANK Ø X TL)~~

PROBLEM :

Dimension
☒ Ø OD/CD /SHK/Roundness
☐ RL/TL/CL
☐ Θ Relief/Helix/Cutting

Tool Appearance
☐ Surface Finish
☐ Chipping
☐ Wrong Marking

☐ Poor Tool Life

Coating
☐ Peel Off
☐ Wrong Coating

Design Issue
☐ Flute
☒ Wrong Machining(CNC)

Others
....

REMARK:
Ø / OD OUT
/ 2 PCS SENT FOR REGRIND

Figure 6: Defect tool Check Sheet after Poka-Yoke improvement

After determining the number of manpower required obtained from the line balancing, the current layout had been reviewed to assign the operators at the right position so that they can take the advantages of the resources to maximise the output. Figure 7 shows the current layout of the quality control line where there are 4 workstations including all the digital microscopic equipment and profile projectors are located. The critical thing in the line is that all the operators are using the same equipment for inspection which compelled them to travel from and to the workstations. Sometimes, there is also situation in which the operators have to queue up before using the equipment because of the ineffective management in the line. Through several observations, it is obvious that the current layout arrangement is messy, scattered, conventional, and only known by the line leaders thus making the line uneven and poorly distributed.

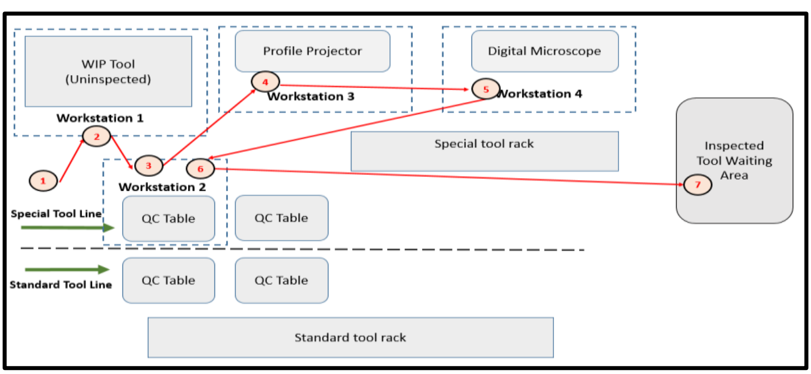


Figure 7: Current Layout of the Quality Control Line

The line was improved by adding another two operators that are needed to do the inspection processes for the special uncoated micro size Ballnose cutting tool. The improvement process is done by transferring the work elements evenly for each of the operators in term of the cycle time. The transferred work element is then to be bundled together until the total cycle is maximised just below the takt time in the Yamazumi Chart. The idle time for each operator is allowed for their allowance time. Figure 8 shows the proposed layout for the quality control line. As illustrated in Figure 8, the travel distance of the operators to the workstation had been eliminated as there are operators assigned to the respective workstation. The operators are assigned accordingly based on their experiences, rating and performance as well. After the workstation was reduced to three workstations, the cross-trained operators are available to work together and helping each other depending on the situation. The proposed layout also might reduce the waiting or delays in between the workstations due to the cross-trained operators can assist each other and at the same time the equipment was placed in better arrangement. As in the Figure 8, the U-shape of Workstation 2 is purposely designed to enhance the flow of information between the operators. It is because the operator that was assigned at Workstation 2 has the highest rating of performance and can do multiple tasks.

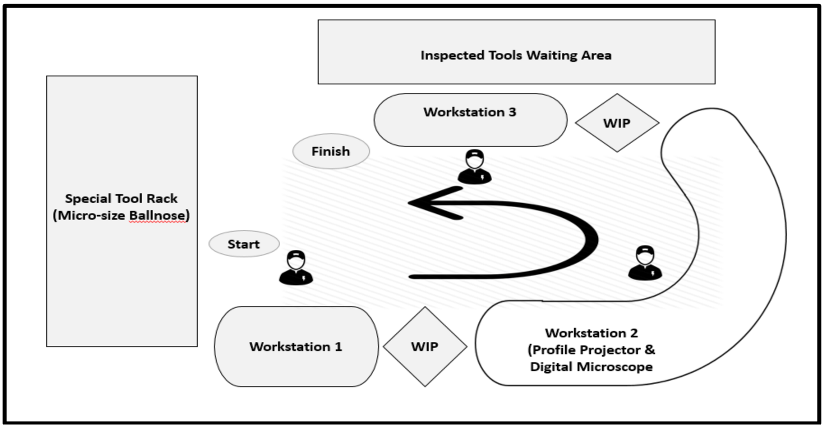


Figure 8: Proposed Layout for the Quality Control Line

For the process flow in the proposed layout, it begins with the uninspected tool will be fed by the line leader at Workstation 1 and the operator will be checked the physical dimension of the tool. Once done, the tool will be put into a basket at the WIP area to be fed for another operator at Workstation 2. At this point, digital microscopic equipment is used by the operator for inspection process. After that, inspected tool will be send to operator at Workstation 3 verification process. The inspection process ends with the inspected and verified tool is placed to Inspected Tool Waiting Area.

After the improvements, there are few wastes that had been eliminated and reduced. Table 5 below is the summary of these wastes before and after improvements.

Table 5: Types of Wastes eliminated or reduced

Types of Wastes	**Before**	**After**
Motion or travel	Yes	No
Waiting or delay	Yes	Reduced
Over-processing	Yes	No

Once calculated using the mathematical equation stated above, the productivity and the efficiency of special uncoated micro size Ballnose cutting tool quality control line are represent in the Table 6 below;

Table 6: Productivity and Efficiency of Quality Control Line before and after Line Balancing

	Productivity (%)	**Efficiency (%)**
Before	9.42	78.55
After	9.73	89.94

As stated before, the productivity and efficiency of the line clearly will experience increments after the lean manufacturing approaches of line balancing, wastes elimination and Poka-Yoke are introduced. Although the calculations are merely theoretical, it is a proof that through these methods, major improvements can be accomplished. All of the improvements had been proposed to the company's top management for review and further evaluation. As for the moment, this study is still waiting for top management's response for its immediate implementation.

6.0 Conclusion and Recommendation

As a conclusion, the objectives of the case study are achieved through the success of this study. The time study had been done and carefully evaluated in order to determine the status of the quality control line. Analysed data from the time study is then used to improve the line in which the wastes and abnormalities are identified, reduced and eliminated. Another major improvement introduced based on the time study and line balancing is the addition of another two operators to justify the overload of tasks for the line instead of one operator at current state. Other than that, an improvement on overall line cycle time about 64.12% is obtained by implementing a pre-filled checksheet for the defect tool as an approach named Poka-Yoke. One of the important improvements is also introduced in this study is in term of line layout. The new line layout consists of only three workstation is designed that helps to increase the line's productivity and efficiency up to 9.73% and 89.94% respectively. In the future, perhaps a deeper research concerning on SOP improvement and internal database retrieval system can be conducted at the line to get better outcomes.

7.0 Acknowledgement

This contribution was developed from Research Study funded by Ministry of Education Malaysia 600-RMI/FRGS 5/3 (143/2014). A special thanks to XYZ Machining Sdn Bhd for the cooperation in completing this project. We also thanks the Dean of Faculty of Mechanical Engineering UiTM Shah Alam Malaysia.

8.0 References

[1] Noor Azlina Mohd. Salleh, Salmiah Kasolang, Hj Ahmed Jaafar (2012),"Review study of developing an integrated TQM with LM framework model in Malaysian automotive industry", The TQM Journal, Vol. 24 Iss: 5, pp. 399 – 417.

[2] Ahmed Jaffar, Nurul Hayati Abdul Halim, Noriah Yusoff (2012) , Journal of Mechanical Engineering, Volume 9, Issue 1 Effective Data Collection and Analysis for Efficient Implementation of Standardized Work (SW).

[3] Noor Azlina Mohd. Salleh, Salmiah Kasolang, Ahmed Jaafar, Nurul Hayati Abdul Halim, "Lean TQM Leadership Management Practices in Malaysian Automotive Companies", Jurnal Teknologi, Vol 76, Issue 6 (2015) 1-6.

[4] A. J. Kumar & B. L. Kumar, "Quality Control Based Tool Condition

Monitoring”, Discipline of Mechanical Engineering, Indian Institute of Technology Indore, India, 2014.

[5] H. D. Lin, Y. S. P. Chui, S. Y. Hsu, “A Visual Inspection System for Quality Control of Optical Lenses”, Department of Industrial Engineering and Management, Chaoyang University of Technology, Taiwan, May 2011.

[6] J. Kumar & B. L. Kumar, “Quality Control Based Tool Condition Monitoring”, Discipline of Mechanical Engineering, Indian Institute of Technology Indore, India, 2014.

[7] T. F. Swapnil & K. H. Inamdar, “Productivity Improvement of Automotive Assembly Line Through Line Balancing”, Department of Mechanical Engineering, Walchand College of Engineering, Sangli, India, June 2014.

[8] S. Y. Lai, C. H. Tsai, L. Y. Wei, R. K. Li & M. J Lu, “The Dilemma of Toyota Production System Implementation: A Case Study of Taiwan Machine Tool Industries.” Department of Industrial Engineering and Management, National Chiao-Tung University, Hsin Chu, Taiwan, January 2015.

[9] Y. Dave & N. Sohani, “Implementation of Poka-Yoke Technique in a Gear Industry – A Case Study” Dhar Polytechnic College, India, June 2015.

[10] Niranjan & Y. Sharma, “Implementation of Poka-Yoke in Indian Manufacturing Industry by: Enablers, Barriers and Questionnaire Based Survey.” Mechanical Engineering Department, CBS Group of Institution, Jhajjar, India, February 2015.

[11] A. J. Kurhade, “Review on Poka-Yoke Technique to Prevent Defects”, Department of Mechanical Engineering, Kolhapur Institute of Technology's College, India, November 2015.

[12] A. V. Kovacheva, “Challenges in Lean Implementation.” Aarhus School of Business, University of Aarhus, Aarhus, Denmark, January 2010.

[13] M. Maria. “Lean Production, Lean vs Mass Production, TPM as a Tool of Lean Production.” Faculty of Operation and Economics of Transport and Communications, Department of Road and Urban Transport, Univerzitna 1, Slovakia.

[14] K. F Qistina, “Case Study on the Improvement of Productivity on a Sewing Line at An Automotive Industry”, Faculty of Mechanical Engineering, Universiti Teknologi MARA, Selangor, Malaysia, January 2016.

[15] A. A. Naufal, N. A. Ain & I. Azianti, “Improvement of Overall Efficiency of Production Line By Using Line Balancing”, Faculty of Mechanical Engineering, Universiti Teknologi MARA, Pasir Gudang Branch, Malaysia, June 2016.