Statistical Process Control Systems in Apparel Production

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***Abstract*—The apparel production is the one of important sector which supporting an economy countries, especially in developing country such as Indonesia. In the era of globalization, Small and Medium Enterprises should process the competence to produce an acceptable product to stimulate enhance of business. Therefore, defective rates product should reducing, more over in the process of apparel production. The process design of apparel consist of various phase with the base fabric component, cutting, tailoring until finishing and inspecting. The research aims to develop a quality control system on Small and Medium Enterprises in apparel production as the case study in Kudus, Indonesia. In the mechanism control proposed with mobile application to send the data defect into main storage and Statistical Process Control technique as the primary analysis. p-chart is used to monitor characteristics product that requires only single decision, such as good or bad and counting number of defect. In addition to control the production process, the final result of the research will be measuring process capability to see how the process capability in apparel production. At the end the defective chart was displayed into online web systems. The result of the research shows the quality control systems are capable of performing data analysis product.**

Keywords—Statistical Process Control, Small and Medium Enterprises, Quality Control Systems.

I. INTRODUCTION

The apparel industry in Indonesia will be continue to evolve and driven to be on of mainstay in subsector creative industry sector [1]. According to the statistic, the numbers of Small and Medium-sizes Enterprises (SMEs) companies are increased from 2010 organized on 31.738 to 50.165 in 2014. This number is expected to continue to increase of data statistic [2]. In addition, an increasing number of production houses must be supported with quality production result. The quality of production is the key success factor of the product itself, so the resulting product can give satisfaction to customers. It makes a range of industry applying a quality control mechanism product either by manual or computerized. Quality Control (QC) on SMEs apparel industry had a challenge to maintain product quality. SMEs have different characteristics with big companies. The difference is partly related to the resource, the number of customers, strategy, and corporate structure. SMEs has a number of resources and the number of fewer customers, operating in a limited market, the structure is flat and flexible, and have a strategy that is informal and dynamic compared to large companies [3]. Thus, the process control of production is not same among production houses. Studies by [4], [5] have shown that SMEs are prefer to select Advanced Manufacturing Technology (AMT) and Computer Integrated Manufacturing (CIM) systems as the effective tools. it is align with [6] that Implementation of Information and Communication Technology (ICT) on SMEs have significant impact on productivity improvements.

For measuring of production process, Laurence et.al [7] applying Statistical Quality Control (SQC) approach by grouping product based on Pareto rules. However, this grouping has not used Information Technology (IT) as a tool to get data and manage defects. Meanwhile, according to [8], using IT on statistical quality control is very helpful to streamline the process and quality of production. Yu [9] have implemented IT of quality, but the formula used is not yet evident in the obvious to get the data as well as a description of the system. Therefore, to complete the gap the research was conducted.

Statistical Process Control (SPC) selected as a tools to analyze the data. This method is a famous widely used as a

978-1-5386-3100-3/17/$31.00 ©2017 IEEE

tool for quality control of production in industry and services. This research aims to develop quality control systems which mobile technology selected as a tool to transmit data, so the process of quality control can be shortened from production house to central production.

II. Statistical Process Control System

A. Statistical Process Control (SPC)

SPC is a method for monitor process based on statistical method to distinguish two type of variant i.e. random variants (errors) or common causes and abnormal variants (errors) or special causes. The next step is taken to eliminate abnormal variant of the process against quality control and satisfaction of needs. Main tool used is control chart, invented by Walter. A. Shewhart [10] and has been used in manufacturing industry such a long time. There are three lines, namely Upper Control Limit (UCL) the maximum value is acceptable variation from the average value on the process, Lower Control Limit (LCL) is the minimum value acceptable variation from the average value of the process and Central Line (CL) is average value on the control chart. In addition, the points are calculated from the sample illustrate in line sequence time.

If the process is in control, the features of the statistical distribution such as the situation, width and shape would not change following with time sequence, and there are only common causes or random variations (errors) existed, the process is stable.

Basic theory concerning the control chart is a data flow shape of normal distribution. But, at SMEs business not always can shaped normal distribution due to business process which is not yet structured, lack of socialization about Standard Operational Procedure (SOP) and lack of the skill of employees. Calculation of control chart is core of design stage of the system. First step is calculating value of CL, UCL, and the third is LCL that can be seen in Equation (1)

$$\begin{aligned} P &= \frac{Defect}{Observasi} \\ CL = \bar{p} &= \frac{total\ defect}{total\ observation} \\ UCL &= \bar{p} + z(\sigma_p) \\ LCL &= \bar{p} \quad z(\sigma_p) \end{aligned} \tag{1}$$

Where $\bar{p}$ is total of damage divided by total observation, z is the value of a standard normal variable on SMEs business used 3 with 93.3% acceptance rate [11], while σ_p is standard deviation p that value resulting from root values of $\bar{p}$ multiplied with (1-$\bar{p}$) and divided by the number of data i.e. n as can be seen in equation (2)

$$\sigma_p = \sqrt{\frac{\bar{p}(1-\bar{p})}{n}} \tag{2}$$

The monitoring process can be seen in p-chart, but have not provided assurances that the process was feasible or out of specification. Process capability index with the formula

$$\begin{aligned} Cp &= \frac{USL-LSL}{6\sigma} \\ CPU &= \frac{USL-\mu}{3\sigma} \\ CPL &= \frac{\mu \quad LSL}{3\sigma} \\ Cpk &= \min(CPU:CPL) \end{aligned} \tag{3}$$

Where Cp (capability) is the index of ability process that can measure the performance potential of the process, Cpk is an actual process performance measurement [9], the Upper Specification Limit (USL) is equal to the value of the UCL, Lower Specification Limit (LSL) is equal to the value of the LCL, μ is the average number of defect, and σ is the standard deviation potential. The formula for calculating the value can be seen in the formula (4). CP and Cpk values is to be good if it has value at least 1 [9].

$$\sigma\ potential = \frac{\bar{R}}{1.13} \tag{4}$$

In addition to calculating the ability of the production process, the system is able to calculate the value of six sigma to know the performance of SMEs. Defect per Opportunities (DPO) is a measure of the failure to increase the quality of six sigma. Critical to Quality (CTQ) showed the characteristics of a critical flaw in production process. Defect per Million Opportunities (DMPO) indicated the number of product defects that are tolerated by million. As for the calculation of six sigma gained from formula (5)

$$\begin{aligned} DPO &= \frac{Total\ defect}{Total\ Production\ x\ CTQ} \\ DMPO &= DPO\ x\ 1.000.000 \\ Sigma\ Value &= normsinv\ \frac{1.000.000-DMPO}{1.000.000} + 1.5 \end{aligned} \tag{5}$$

B. Apparel Process

In apparel industry on SMEs, the production process is carried out with the stages as following in Fig. 1. Stage consists of a design pattern, grading, marker making, sorting, cutting, sewing, finishing and inspecting. All stages are performed manually. In Fig. 1 describe of the inspection stage looks that are on the final stages of production process. Inspection stages aims to conduct quality control of products that have been produced, before the product is up to consumer.

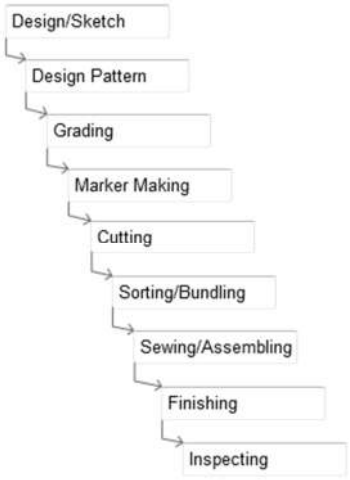

Fig. 1. Process production of apparel

In the last phase conducted audit product by auditor which used mobile tools to record the defect production. The indicator to known the defective product, this work identified some component that able used as variable. There are two main components that become variable quality assessment in fabrics and accessories [12]. However, defective production divided into defect in the cutting, pressing, assembling and finishing. The detail from defect process phase as shown in Table 1.

TABLE I. TYPE OF DEFECT COMPONENT

No.	Type of Component
1.	Ripped Clothes
2.	Uneven Colors Clothes
3.	Loose Studs
4.	Zippers Do Not Work
5.	Loose Lace
6.	Loose Stitches
7.	Hoop and Loop is Not Good
8.	Button Placket Off
9.	Dirty Clothes
10.	Brittle Thread
11.	The components of the mixture is not correct
12.	Edges Frayed Fabric
13.	Jagged Edge Fabric
14.	Uneven Stitching
15.	Fold the fabric does not neatly

III. METHODOLOGY

Methodology of this research consists of four phase major as study of literature, data collection, system design-implementation, and result. Study literature is used to understand the domain research and identify the appropriate methods to solving the next step of research. Data collection using qualitative approach, this step is interview to the officers and leadership of the design process apparel. The system design phase and implementation is using the Object Oriented Analysis and Design (OOAD) which used Unified Modeling Language (UML). In this steps conducted programming code and testing. The final of research phase is result, which describe all the result with report.

The statistical Process Control Systems is designed using mobile devices on an android basis as a system development technology. In the process of quality control, data is sent to the server using the internet connection with consideration of the need for large data so that the storage used is a server with a more flexible capacity and can reach the data needs in the apparel industry.

There were three main actors namely Manager, Administrator and Auditor. Manager and administrator use web system for process data and view report production. However the auditor is using a mobile application to do the quality control inspection products. Before the product is distributed, then the product through the process of checking by the auditor. Furthermore, the data input from auditor calculated using statistical approaches such as the formula described. The systems process data and display it in the form of p-chart and showed the ability of the production on process. The system also shows that defects that occur can be detected and unknow species. So that management can do the next process improvement.

To find out the quality control system functionality are using the use case. Where the administrator perform data processing and auditor data processing, auditors checked production goods and input the data goods defect, while the leadership viewed reports of the defects that are found in the form of a report or chart detail.

In designing the system of quality control used two tools to run the system. First, web application used by the administrator to manipulate data master who later used by auditor, as well as perform data manipulation. Second, android application are used as tools for data input defect from auditor when performing an inspection after the product is finished and before distributed to consumers. The leader can see report of production by web application too. After the data defect is entered by auditor, then the data will be stored in database. Java Script Object Notation (JSON) is used to display the data in the format of android that uses PHP code using the function *json_format()*. The architecture of quality control system as following in Fig. 2.

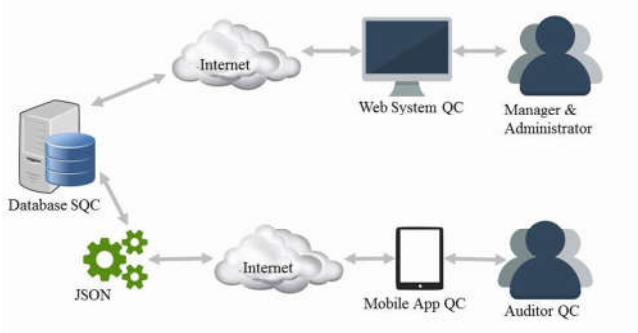

Fig. 2. Quality control system architecture

IV. RESULT

After all phase of the research methodology is performed, furthermore each step are describe in this session. Base on the results of data analysis, proposed a form of model system architecture that integrates multiple components as mobile device and web systems against different user with connected database. This integration chosen so that information about quality of the product can be integrated between users [9].

The administrators process the data into database through web systems which integrated internet connection. The data apparel transferred into mobile application QC with Application Program Interface (API) request. There are several methods to transfer data from server database to mobile device such as Extensible markup Language (XML) or JavaScript Object Notation (JSON). However JSON is preferred over XML as it is light, fast and can be easily handled [13]. JSON file format is hierarchical data structure in the array format, which makes it easy to extract data in any platform and environment.

On implementation, auditor checks the quality of goods using mobile devices. From the inspection, Auditor will look at the detail of goods as seen in Fig 3. The result of control limit describe in Table 3 of this data collected from 3 months of 13 April, 2016.

Fig. 3. Mobile auditor interface

In conducting an inspection of the product, the type of damage could get more than one product type. The system will calculated the type of defect base on the number of defect found, but only count one defect for each product. This is because the data used for the calculation of statistical data is defect unit and not the type of defect. Type of defect is a way to find out the causes of defect.

After the auditor checked quality of products such as the one in Fig. 3, then the data would be classification based on type of defects. From this data, it will be obtained the information about the type of damage based on the most defects. This information can be used by management to rectify the causes of damage such as machines that used or workers who are less conscientious in work.

Checking data production described production quality from data product audition which gave result of quality by show p-chart, capability index as Cp and Cpk Value, and six sigma levels. Each sample product checking is performed the criteria serve as an assessment of the damage. The amount of data collected as followed in Table II. The formula is applied using the formula (1) and (2)

TABLE II. DEFECTIVE PRODUCT

Date	Defect (unit)	Prod (unit)	Obser vation	Proportion per Period
04/13	17	1500	125	0.1360
04/14	13	1500	125	0.1040
04/15	9	1500	125	0.0720
05/14	23	1500	125	0.1840
05/14	16	1500	125	0.1280
05/15	7	1500	125	0.0560
06/15	24	1500	125	0.1920
06/14	11	1500	125	0.0880
06/15	5	1500	125	0.0400

Value for Proportion from first data (13th April) is 0.136, standard deviation proportion is 0.028, UCL is 0.195, LCL is 0.027, and CL is 0.111. The calculation of Table II uses the form of binomial distribution. Therefore, if the value of LCL is minus then rounded to zero. Furthermore, the calculation can be made a diagram of p-chart to monitor changes in the production process and help determine the cause of occurrence of a variety.

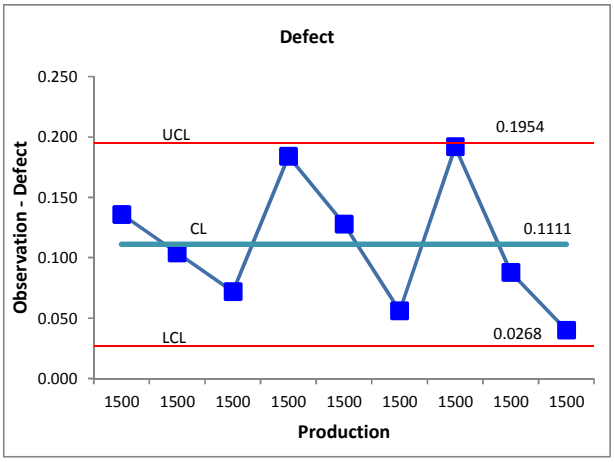

Fig. 4. Control chart (p-chart) apparel production

In Fig. 4 shows a pattern of fluctuating proportion. Some of the data shows the proportion of approaching the line of UCL and LCL. Therefore, this data is almost out of control, indicating the increasing number of defects. In order for the value of defect to the next production can be reduced, then management can take preventative measures after seeing this chart.

As for the value obtained the calculation of Cp and Cpk is as follows: USL = 19.5, LSL = 2.7, Mean = 13.9, σ *potential*

= 8.19, Cp = 0.342, CPU = 0.228, CPL = 0.456, and Cpk = 0.228. The result of the calculation capability process shows that the production process in the next production industry apparel need to do repairs, because the value of Cp and Cpk is smaller than 1.

Besides being able to compute the value of capability production process, sigma level is calculated using the formula (5) that produces the value of DPO = 0.00076, DMPO = 755.56, Sigma Value = 4.673 (information shown in Fig. 5 for the first chart). The value of sigma 4.673 indicated that the value of the performance production outfit's been good. Due to the value of sigma approach the number 6, than SMEs in better performance. Sigma level manufacturing process can be described in Fig. 5.

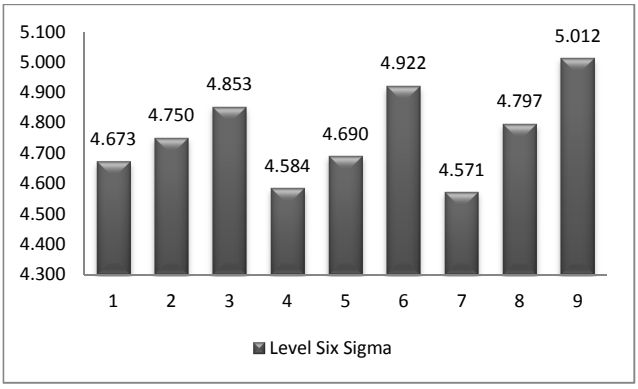

Fig. 5. Level six sigma production process

V. SUMMARY

Statistical Process Control is used for the production of apparel on SMEs can help to ensure product quality and process quality with process control by performing inspection before product sale. Classification of defect may give an idea of the amount of defect and other types of defect. This information can be used to repair the damage in order to reduce the defect on the next production process. The combination quality system approach using SPC can provide a device to effect the quality of process information integrated, to feedback and information sharing knowledge on the manager and administrator.

REFERENCES

[1] Indonesia Ministry of Industry, "Penjualan Produk Pakaian Jadi Melonjak," 2011. [Online]. Available: http://www.kemenperin.go.id/artikel/846/Penjualan-Produk-Pakaian-Jadi-Melonjak.

[2] BPS, "Jumlah Perusahaan Industri Mikro dan Kecil Menurut 2-digit KBLI, 2010-2014." [Online]. Available: https://www.bps.go.id/index.php/linkTabelStatis/1072.

[3] M. Hudson, A. Smart, and M. Bourne, "Theory and practice in SME performance measurement systems," *Int. J. Oper. Prod. Manag.*, vol. 21, no. 8, pp. 1096–1115, 2001.

[4] G. S. Dangayach and S. G. Deshmukh, "Advanced manufacturing technology implementation: Evidence from Indian small and medium enterprises (SMEs)," *J. Manuf. Technol. Manag.*, vol. 16, no. 5, pp. 483–496, 2005.

[5] M. Zain, A. B. Rahman, and M. Nopiah, "Design an Online SMEs-SPC Computer Based System," pp. 437–440, 2009.

[6] S. Rachman and M. A. Gregory, "The Role of ICT Services on Indonesian Small to Medium Enterprise Productivity," pp. 166–172, 2015.

[7] C. P. Utama and J. Hanafi, "Statistical Quality Control Measurement on Furniture Manufacturer 1,2,3," pp. 420–423, 2011.

[8] J. Cheng, A. Wang, and Y. Ge, "The Technology of Quality Statistical Process Control based on AOI Inspection Results," 2016.

[9] Z. Yu, X. Cao, and M. Yang, "Statistical Quality Control in Production of Infusion Solutions," *Int. Conf. Inf. Manag. Innov. Manag. Ind. Eng. Stat.*, pp. 238–241, 2009.

[10] D. C. Montgomery, Introduction to Statistical Quality Control 6th Edition, Sixth edit. 2009.

[11] K. Linderman, R. G. Schroeder, S. Zaheer, and A. S. Choo, "Six Sigma : a goal-theoretic perspective," vol. 21, pp. 193–203, 2003.

[12] C. N. Keist, *16 - Quality control and quality assurance in the apparel industry*. Elsevier Ltd, 2015.

[13] S. Talati and G. Mcrobbie, "Developing Business Intelligence for Small and Medium Sized Enterprises using Mobile Technology," pp. 164–167, 2012.