Reduction of non-conforming through statistical process control charts in textile industry

DOI: 10.35530/IT.073.05.202166

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ABSTRACT – REZUMAT

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The textile industry of Pakistan is a growing sector that contributes to the economy. Pakistan exports depend heavily upon textile goods. A minor defect in the finished good can cause a major loss of the export goods. Due to the involving the number of workers checking the product repeatedly can be very expensive therefore the quality engineering techniques of Statistical Control Charts are used in the textile industry. This research study aims at developing process control charts for the textile industry in Pakistan. For this purpose, the textile industry was taken into consideration. P-chart was developed to monitor the variation in the process with a Six Sigma standard deviation. The collection of data was for six months from various departments of the textile industry. The attribute data were collected for the analysis from 4 different units of the industry. The construction of the P-Chart includes the Control Limits (CL), Upper Control Limits (UCL), 3 sigma deviations from the mean Control Limit (CL), Lower Control Limits (LCL), –3 sigma deviation from the mean Control Limit (CL). The result showed that the processes of the production units were under control, however, the mean was not centred which was due to some common cause of the process which is acceptable. The P-chart can serve as a standard for the new process to be developed.

Keywords: *statistical process control, attribute charts, process monitoring, Control Limits, Six Sigma*

Reducerea neconformităților prin diagrame de control statistic al proceselor în industria textilă

Industria textilă din Pakistan este un sector în continuă dezvoltare, care contribuie cu o cotă importantă în economie. Exporturile din Pakistan depind în mare măsură de produsele textile. Un defect minor al bunului finit poate cauza pierderi majore ale mărfurilor de export. Pentru că numărul de muncitori care se ocupă de verificarea produsului în mod repetat, poate fi foarte costisitor, prin urmare, tehnicile de inginerie a calității Diagramelor de control statistic sunt utilizate în industria textilă. Acest studiu de cercetare își propune să dezvolte diagrame de control al procesului pentru industria textilă din Pakistan. În acest scop, a fost luată în considerare industria textilă. Diagrama P a fost dezvoltată pentru a monitoriza variația procesului cu deviația standard Six Sigma. Colectarea datelor a durat șase luni de la diferite departamente ale industriei textile. Datele atributelor au fost colectate pentru analiza din 4 unități diferite ale industriei. Construcția diagramei P include limitele de control (CL), limitele superioare de control (UCL), abateri de 3 sigma de la limita medie de control (CL), limitele inferioare de control (LCL), abaterea de –3 sigma de la limita medie de control (CL). Rezultatul a arătat că procesele unităților de producție erau sub control, totuși, media nu a fost centrată, ceea ce s-a datorat unei cauze comune a procesului care este acceptabilă. Diagrama P poate servi ca standard pentru noul proces care urmează să fie dezvoltat.

Cuvinte-cheie: *controlul statistic al procesului, diagrame de atribute, monitorizarea procesului, Limite de control, Six Sigma*

INTRODUCTION

Asian countries are the largest exporters of textile products. In Pakistan textile sector is defined as a backbone for economic price growth and it contributes the most to other sectors [1]. The total contribution to the GDP of Pakistan's textile sector shares more than 60% of the economy [2]. Textile companies are striving hard to maintain their growth but the increase in the manufacturing overheads is causing difficulties and making it very hard for the sector to survive and provide the best product at a minimal cost. With the increase in the commodity and the service price, industries have shifted their focus from being a production-oriented manufacturing organizations to quality-oriented manufacturing to eliminate the non-value-added activities and provide the best quality product to the consumers at the best possible cost [3, 4]. Due to the involving the number of workers checking the product repeatedly can be very expensive therefore the quality engineering techniques of Statistical Control Charts are used [5].

The implementation of statistical process control has been in many industries, for example, Health care industries including hospitals, clinics etc., automobile industries, defence industries, chemical and electronic industries and food chains as well [6]. Statistical quality control identifies the process improvement methods and provides the most economical, sustainable solution. Statistical Quality Controls are widely used for the sampling plan, identifying the conformance of the process or the process deviation for achieving the required quality [7].

The deviation in the process or the variability of the quality is caused due to the common causes and specific causes [8]. The common causes are the natural cause which cannot be eliminated until the business module of the production environment has been changed in terms of large investment. These are the reasons occurred during the condition of working, raw material nature or the technological level requirement. Specific reasons are caused by unexpected process deviation. Specific variation is not related to the worker ergonomics, raw material compliance or machine settings. They are variations which can only be determined by statistical process control [9].

Statistical Process Control charts are developed by obtaining the observations for the calculations. The process mean is calculated for developing the centre line (CL), and the standard deviation is calculated for the development of the Upper Control Limit (UCL) and Lower Control Limit (LCL) which are plus and minus 3-sigma. The observation points are then connected to plot the process characteristics [10]. The SPC charts are useful as they provide the direction of the process upward and downward from the origin due to the non-conformance produced during the production operations, which fails the final product [11].

To identify the area of improvement and severity of the process deviation, analysis is performed by using the statistical tools of control charts which establish the process deviation during a certain period and also determine the limits of deviations are under the control limits or exceeding the limits [12]. To analyse the deviation in the process from its mean position the design of the experiment is based on the collection of data from the real-time production. The experiment data was collected for six months through check sheets in which real-time data was recorded by the in-line quality controllers. Collected data is then analysed and interpreted to obtain the capability and the deviation of the process.

Every textile company aims to provide quality products and on-time deliveries to achieve the highest level of customer satisfaction. For that company is striving to enhance its process and product quality to eliminate the additional cost of reworking and rejection of customer complaints/claims which will be resulting in lower manufacturing costs and an increase in production levels. The research which will be conducted in an industry is the manufacturers and exporters to the different countries of the world in home textile products of bedding and curtain. It is a vertical industry consisting of in-house capacity from dyeing to packaging and shipping.

METHODOLOGY

The methodology which will be used in this study is based on Statistical Process Control (SPC). The scientist Walter A. Shewhart at Bell Laboratories developed that the process should be in statistical control chart [13].

Statistical Process Control (SPC) is a methodology used by industries for measuring and controlling the quality of ongoing manufacturing processes [14]. Quality data in the form of check sheets of a Product or Process is measured in real-time during manufacturing. The collected data is then used for plotting the graphs with pre-determined control limits. Process capability defines the limits of the process whereas the specification limits are determined by the client's standards. Data measured falls within the control limits to determine the process is in control and any variation within the process can be due to the common cause of the natural variation which is expected throughout the process. Whereas if the process falls outside the control limits indicates the process variation and is likely to deviate from its mean position causing defects during production [15]. The selection criteria for control charts are shown in figure 1.

X-R Chart

Control charts are used to understand the inside variation of the process. There are diverse types of control charts depending upon the factor on which the data is collected. It is used for the variable data when the information is available. This chart usually consists of two parameters

- The X chart shows the amount of variation in the process during the interval of time.
- The R chart shows the variation that occurred in the different sub-groups. A process of the r chart has the control limits the upper control limit and the lower control limit.

When XR charts are under control limits the distribution of the subgroup is steady and the process reliable. Control limits are not the same as the specification limits of control charts but it is both critical to performing analyses.

Control limits are the normal range. The minor deviation is monitored and recorded. It is observed that variety can be considered as the normal distribution which lies within the location between the three layers of standard deviation. The +3sigma and the –3sigma deviation.

To decide the control limit of the XR chart and to analyse the process variation [16].

$$\text{Range} = (X_{max} - X_{min}) \quad (1)$$

$$UCL = X + AR \quad (2)$$

$$LCL = X - AR \quad (3)$$

$$UCL = DR \quad (4)$$

$$LCL = DR \quad (5)$$

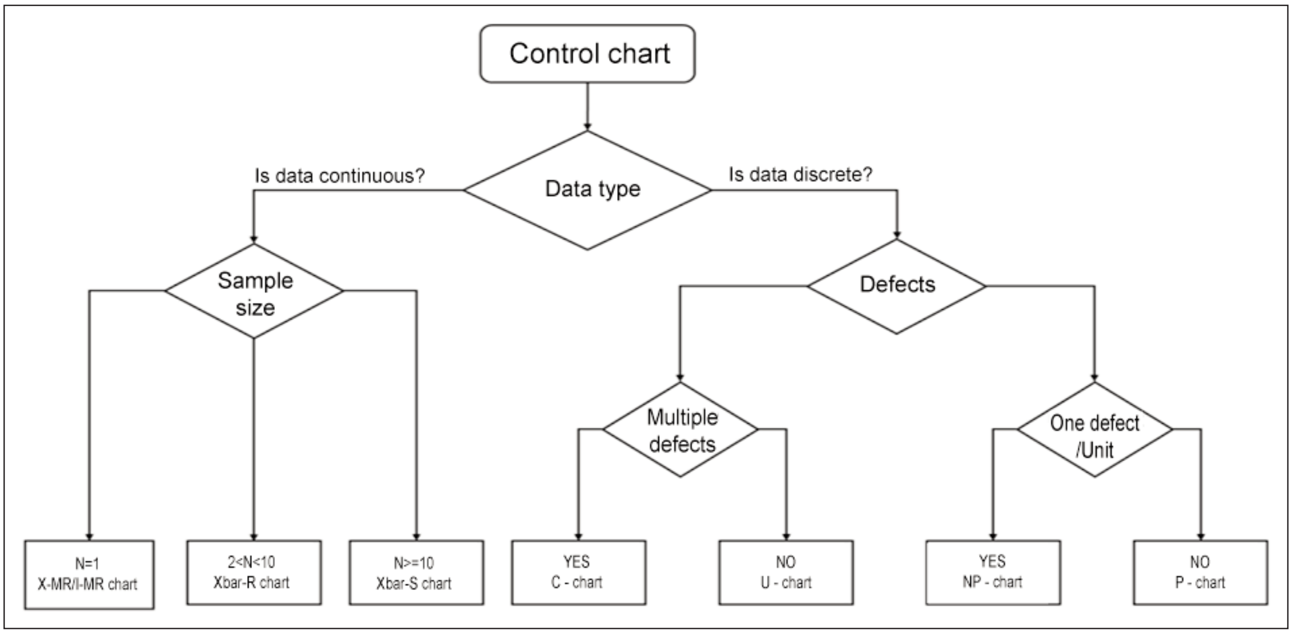

Fig. 1. Selection criteria of Control Charts

C Charts

C Chart are used to analyse the quantity of the defects on a unit of process against the total number of units taken against the process. It is used to monitor the number of defects in the process and the control limits are created to evaluate the process. It helps to identify the variation in the process and when the control chart is set up and any point which goes outside the control limit shows that the process has a variation which caused the non-conformance on the individual point [16].

$$c = \frac{\sum Di}{\sum K} \quad (6)$$

$$LCL = c - m\sqrt{c} \quad (7)$$

$$UCL = c + m\sqrt{c} \quad (8)$$

NP Charts

NP charts are used to monitor the quantity of non-conforming products during production for which samples can be taken on an hourly basis, shift-wise, day-wise, weekly or monthly. Once the data is collected and the control charts are set up the situation of the control chart is monitored and at the point, and if the point is outside the control limits it represents the quantity of the defectives that occurred at that point during the process [16].

$$\text{Control Limit} = np \quad (9)$$

$$LCL = np - m\sqrt{(np(1-p))} \quad (10)$$

$$UCL = np + m\sqrt{(np(1-p))} \quad (11)$$

P-Chart

P-Charts are defined as Attribute control charts having discrete data. P-Charts are selected based on sample size variation in the process and display the proportion of defective products, conforming or non-conforming. P-chart identifies the process variation and the variability over the period within the process. The process deviation is monitored by the control limits and the shifting of the process through its mean position [16].

P-charts are based on the variable sample size. To obtain the P-bar [10].

$$P = \frac{\sum \text{number of defectives in deliveries}}{\sum \text{sample size}} \quad (12)$$

For the sample size variation Upper limit

$$\sigma = p + 3 * \sqrt{\frac{P(1-P)}{n}} \quad (13)$$

For the sample size variation Lower limit

$$\sigma = p - 3 * \sqrt{\frac{P(1-P)}{n}} \quad (14)$$

Sigma Levels in Control Charts

The process mean or the centre line of control charts is always divided into three standard deviations i.e., +3σ the Upper Control Limit (UCL) and –3σ (Lower Control Limit), these limits are considered as the boundaries of the control charts and the process deviated if any of the plot points stands outside the limits. The level close to 3σ is +2σ and –2σ and next to the mean position lies the +σ and the –σ levels. This in combination states that the mean is dived into 3σ levels [17].

In the identification of the process and the capability of the control charts, some standards have been defined for the σ-level deviation [18].

1. If one data point is outside the ±3σ level the process is considered unstable.
2. If the two data points are outside ±2σ level the process is considered unstable.
3. If four or five data points are outside the ±σ level the process is considered unstable.

4. If eight continuous data points plot on the same σ level.
5. If five data points are in the continuous decrease the process is considered unstable.
6. If two data points out of three are outside the process needed to be monitored but are in control.

The statistical process has a normal distribution. A rule of 68%–95%–99.7% is applied to the control charts ±1σ fall in the 68% of the normal distribution, ±2σ lies in the 95% of the normal distribution and 99.7% will fall within ±3σ [19].

RESULTS

The industry consists of four production units (figure 2); each unit receives raw material. The cutting department is where fabric batches are sized into the finished product, which then proceeds to the stitch department and operations are performed. During the stitching operation, the process of random inspection (figure 2 - Point; A D G J) is carried out to make sure the requirements and specifications are met to produce a quality product. After the stitching process products are moved to the quality control department where all the physical characteristics of the product are inspected, during the inspection process random (figure 2 - Point; B E H K) samples are picked to confirm the products are being checked as per the required quality. Inspected products are then processed for packing as per the customer's requirement and style. Some random inspection (figure 2 - Point; C F I L) samples from the packing process are taken to inspect that it meets the customer requirements. The data of the random inspections from each section of the production units are collected in the form of check sheets, these check sheets are then fed into the MS Excel format for storing and gathering data in the form Excel Workbook. The data in the MS Excel sheet is extracted and used on the Minitab software from which statistical control charts are developed to analyse the process capability.

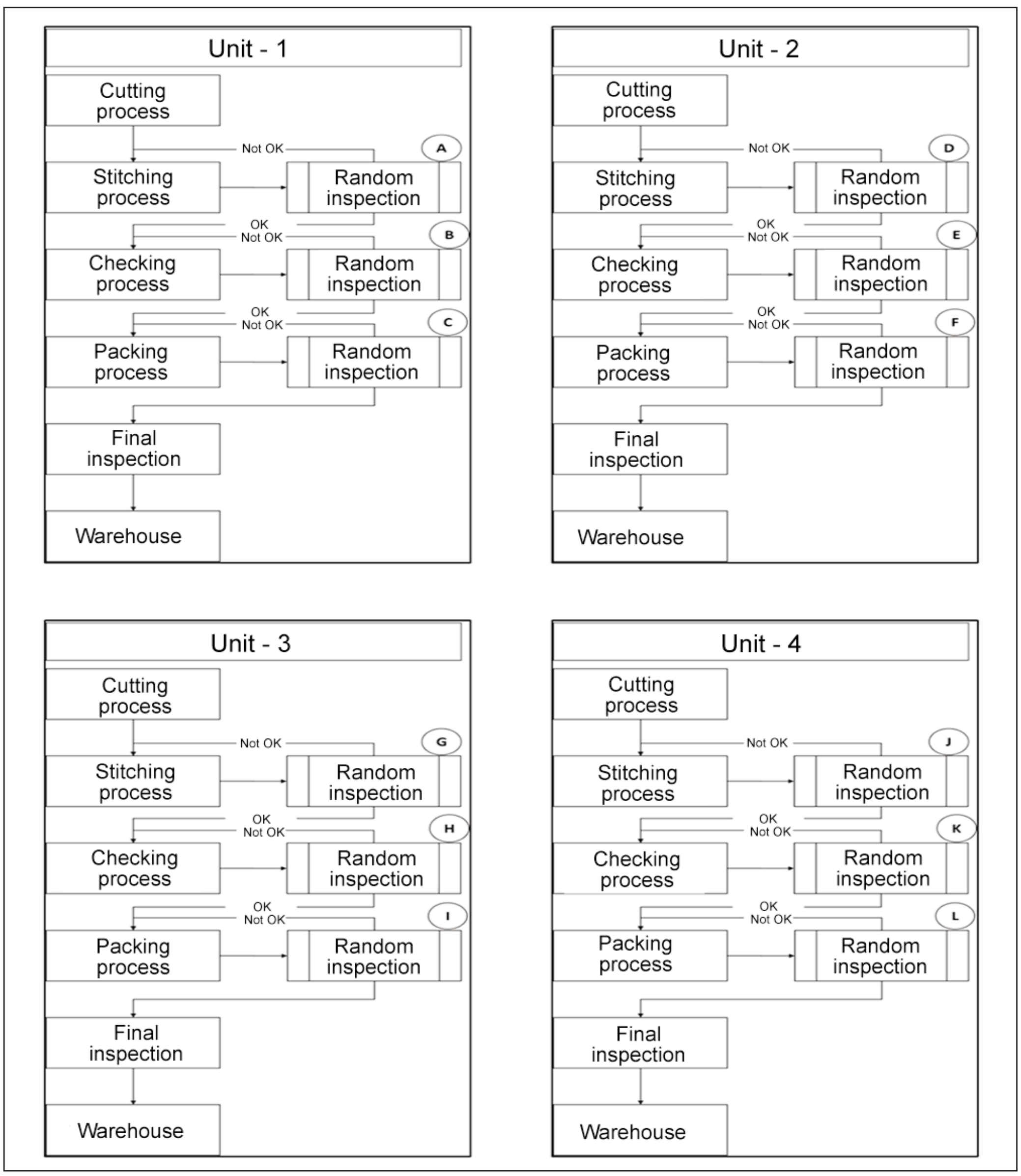

Fig. 2. Process flow of production units

Production Floor Unit-1

The production process consists of the Stitching Section (figure 3), Checking Section (figure 4) and the Packing Section (figure 5). The collection of data on the production floor in real-time shows that the process of the Production floor Unit-1 is under control as per the conditions mentioned above. Although the process seems to be under control but not centred because they might be some special or common cause affecting the process.

The process in figure 3 shows the deviation but the process is well within the control limits according to the conditions mentioned above. The process in figure 4 seems to be well within the limit and there is no significant deviation from the analysis. The chart in figure 5 shows that the process is stable and well within the control limits.

Production Floor Unit-2

The process of the Production Floor Unit-2 Stitching Section (figure 6), shows the deviation in the process but it is well within the control limits. The Checking Section (figure 7), of unit-2, is the most stable section as the deviation of the process points is minimum. Packing Section (figure 8), is also under control but not centred.

There is no significant deviation found in figure 6, from the mean and the process is under the UCL and LCL. The process is stable. Therefore, in figure 7, the process is not in any of the conditions mentioned above, therefore the process is well-centred and found stable in figure 8.

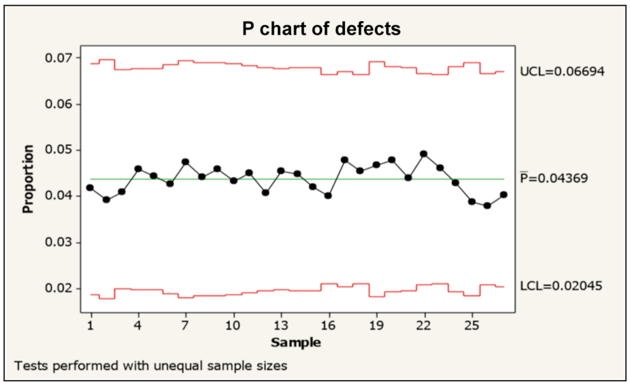

Fig. 3. Stitching Section Unit-1

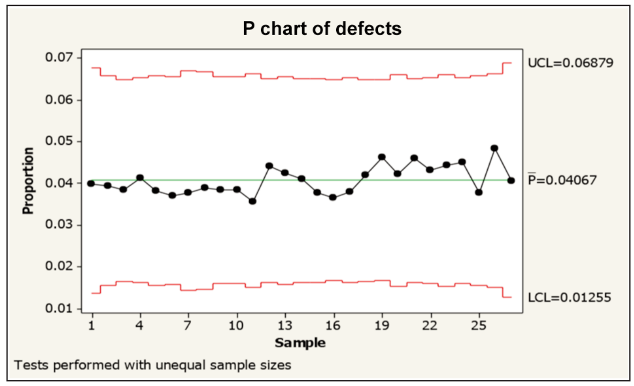

Fig. 6. Stitching Section Unit-2

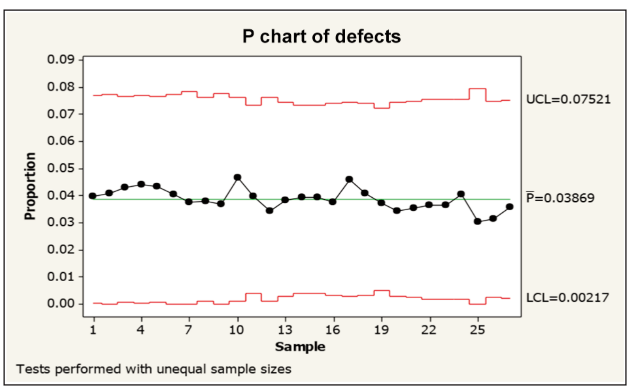

Fig. 4. Checking Section Unit-1

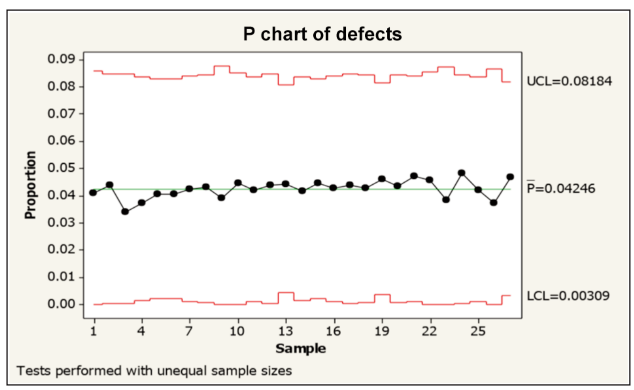

Fig. 7. Checking Section Unit-2

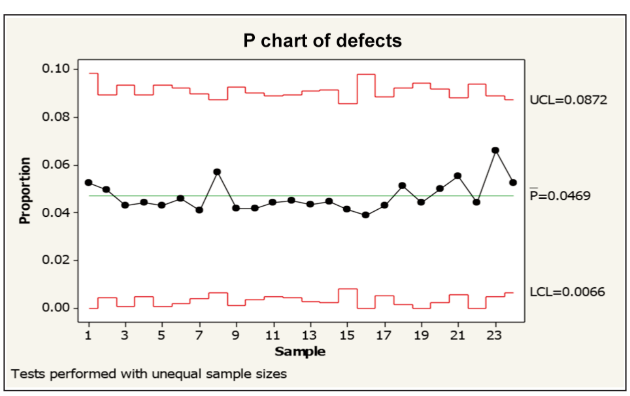

Fig. 5. Packing Section Unit-1

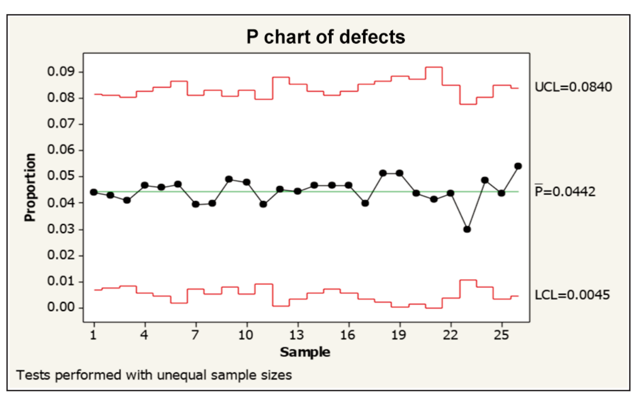

Fig. 8. Packing Section Unit-2

Production Floor Unit-3

The data points for Stitching Section (figure 9), show that the process is well within the control limits and the process is capable. The Checking Section (figure 10), also shows the control deviation in the process. Packing Section (figure 11), is under control and there is no significant deviation over the period.

All the data points are in the centreline and under the control limits in figure 9, figure 10 graph shows that the data is distributed on its mean position, and in figure 11, point number 21 has deviated from its mean position but the process is well controlled.

Production Floor Unit-4

The results from the analysis of the Stitching Section (figure 12) Checking Section (figure 13) and the Packing Section (figure 14) determine that the process is stable but there are some deviations in the mean point of the control chart which can be due to the special causes and can be removed by process improvement.

The process of all the units is well within statistical control. During the analysis, there is no significant deviation found throughout the process but the statistical control charts show the controlled deviation present in the process at every section of each production floor. These deviations can be due to the natural cause that exists within the system which cannot be eliminated but can be minimized or some special causes have caused the deviation of the process for example unqualified workers or malfunctioning machines etc. these are the causes which can be eliminated and the process can be stabilized.

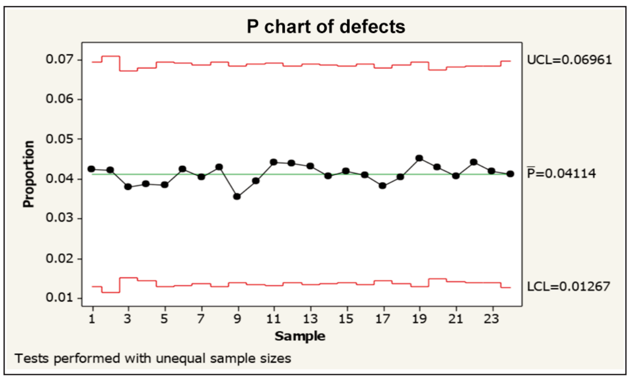

Fig. 9. Stitching Section Unit-3

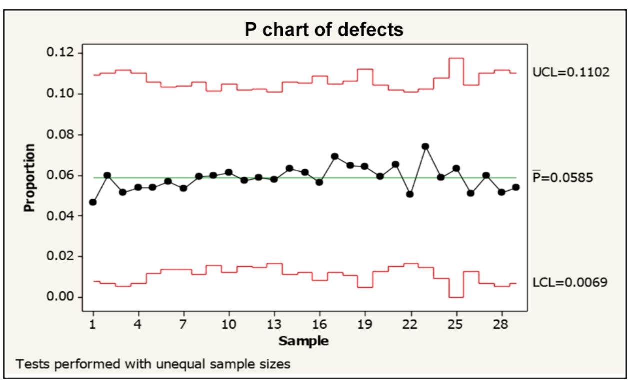

Fig. 10. Checking Section Unit-3

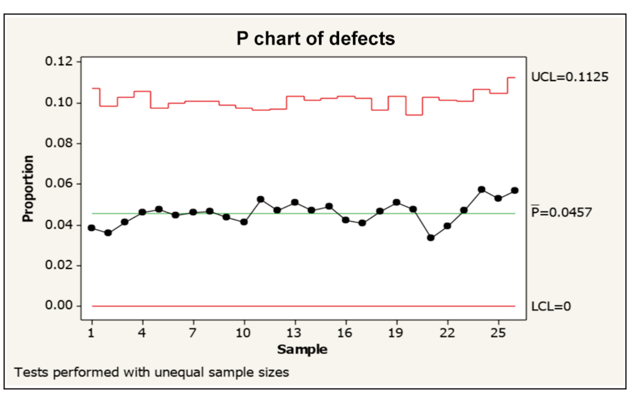

Fig. 11. Packing Section Unit-3

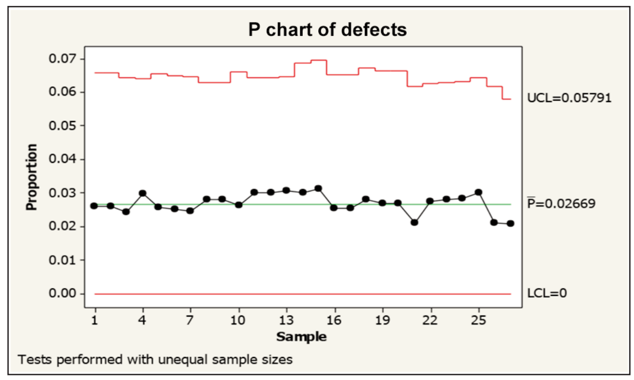

Fig. 12. Stitching Section Unit-4

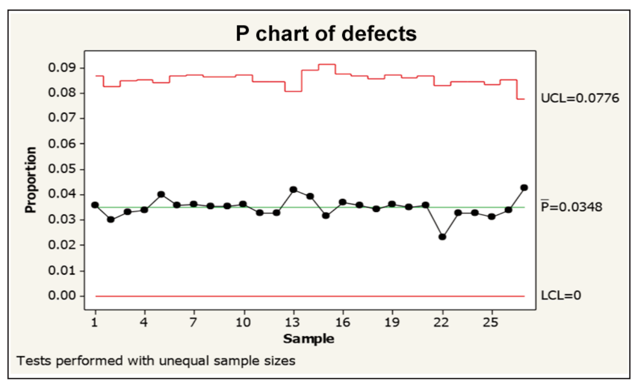

Fig. 13. Checking Section Unit-4

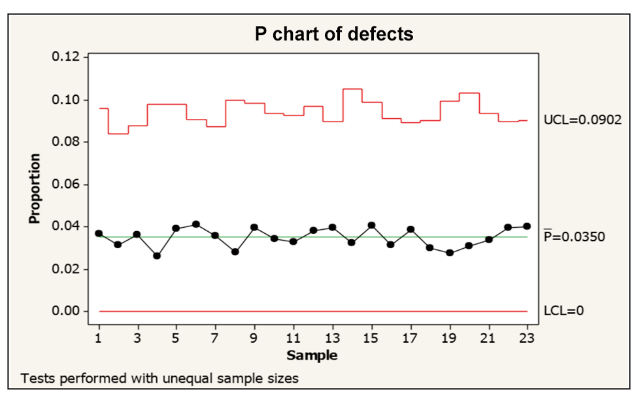

Fig. 14. Packing Section Unit-4

CONCLUSION

Statistical process control allows an organization to identify the process deviation which results in the product's non-conformance and failure. The technique of SPC can be opted by the organization to identify the process capability and allows for to eliminate the non-value-added activities during the process. Implementation and the development of the process control charts improve the quality of the process by identifying the capability of the process. The analysis was performed in an organization by collecting the real-time data of the production units to identify the capability and the deviation in the process. Results of the analysis conclude that no significant deviation was found with in the process and satisfies the points of the section above, although the process was not centred at any production unit but is stable and each section of all the production units was found to be under the 99.7% of the normal distribution. The deviations within the process are due to the special cause or common cause depending upon the factors for example man factor, machine factor or the material factor and these can be eliminated by training or the awareness of the process thus resulting in a stable production process and eliminating failures.

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