THE CHOICE OF CONTROL CHARTS IN A SMALL SIZED ENTERPRISE - A CASE STUDY

L.Cattani, S.Pellicelli, A.Chiarini and F.Fantini*

DII, University of Parma, Viale delle Scienze, 43100 Parma, Italy

*also with DSI, University of Modena, Via Campi 213/B, 41100 Modena, Italy

THE CHOICE OF CONTROL CHARTS IN A SMALL SIZED ENTERPRISE - A CASE STUDY

L.Cattani, S.Pellicelli, A.Chiarini and F.Fantini*

DII, University of Parma, Viale delle Scienze, 43100 Parma, Italy

*also with DSI, University of Modena, Via Campi 213/B, 41100 Modena, Italy

Summary

In this paper the implementation procedure of control charts is described for application in a small sized enterprise. A particular attention is payed to the problems connected with this specific context such in particular the economical aspects.

KEY WORDS : On line quality control   Control Chart   Statistical Process Control

1. Introduction

In recent years the use of Statistical Process Control (SPC) has become increasily popular being largely recognised its effectiveness in the process of quality improvement [1]. Among the techniques included within the SPC tools [2] control charts are surely the most powerful [3, 4]. However the adoption of control charts in small sized enterprises is still limited because of the relative complexity and cost of control charts implementation.

For the use of control charts an important factor is the control chart design, i.e. the selection of the sample size, the control limits and the sampling frequency. In designing a control chart one mainly uses statistical considerations. However, expecially in a small industrial environment, the economic point of view should also be taken into account considering the cost of sampling and testing, of measurement equipment, of the unit sample in case of destructive test, etc...

This paper reports of the use of control charts in a small sized mechanical enterprise with particular regard to the problems connected with the particular context.

The work comes from the Laurea thesis of a student in Electronic Engineering, who worked for 6 monthes in the plant.

A short presentation of the enterprise under study is followed by a description of the quality characteristic to be studied by means of control charts. Then the implementation of the charts is presented togheter with a discussion of the problems appeared during this process and the corrective actions taken. Considering that in a small enterprise the economic point of view takes up primary importance, we also present a cost estimation of the established procedure. In the last paragraph some conclusions are drawn.

2. The enterprise

This study was carried out in a small mechanical enterprise, specialized in aluminium, steel and cast-iron machining. The enterprise mostly executes turning and milling on pulleys, covers and flanges, obtained by sand casting and gravity die casting. Besides the traditional machine tools, several CNC machine tools are used and in particular lathes and milling machines.

This enterprise is in the process to be certified according to ISO 9002 standard and intends to obtain in the future also the QS 9000 qualification. The reason for introducing the SPC was connected to the procedure to obtain this qualification.

SPC was gradually implemented and the project was developped using the Deming cycle [6] approach. Control charts were initially set up only for few production processes in order to limitate the discomfort resulting in the workers from their introduction.

3. Experimental

3.1 First chart implementation

The first process chosen for SPC implementation was the bearing housing milling. This machining is carried out on batches of one thousand pieces, each being worked in about 2 minutes. The diameter of the bearing housing, which is a critical value for the safety of the final product, was chosen as the critical quality characteristic to be monitored. The specification value for this diameter is 40 mm with a tolerance of 25 μm.

As in the common practice [4] 20 samples (k) were collected, each formed by 5 items (n), one sample every 20 minutes. Since collected data are a measurable quality characteristic two control charts were required to monitor the process. To monitor the process average the $\overline{X}$-chart (mean) was used. To monitor the process variation two options are available: Range-Charts (R) or Standard Deviation-Charts (s). R-chart was chosen in the first instance because of its simplicity, being the sample ranges easier to be calculated than the sample standard deviations.

Moreover the efficiency of R-chart is comparable to that of s-chart when n is small [4], as in our case. The measurement was performed immediately close to the machine by means of a centesimal bore-gage and the difference respect to the specification value was computed.

The mean ($\overline{X}$) and the range (R) of these values for every sample were calculated. These values were used to obtain the overall mean ($\overline{\overline{}}$) and the mean range ($\overline{R}$), as shown in the following formulae.

$$\overline{\overline{X}} = \frac{\sum \overline{X}}{k} = 17.75\mu m$$

$$\overline{R} = \frac{\sum R}{k} = 5.5\mu m$$

The values for the control lines were calculated according to the formulae provided by standard books on the statistical quality control [5,6]. The same books give values for the constants A_2, D_3 and D_4, employed to calculate upper and lower control limits in both charts. The results obtained in our case are for the $\overline{X}$-chart :

$$UCL = \overline{\overline{X}} + A_2 \overline{R} = 20.82\mu m$$

$$LCL = \overline{\overline{X}} - A_2 \overline{R} = 14.48\mu m$$

and for the R-chart :

$$UCL = D_4 \overline{R} = 11.63\mu m$$

$$LCL = D_3 \overline{R} = 0$$

Because of the difficulties in obtaining cost information, a very simple model was used to estimate the cost of the control charts. It takes approximately t_m=30 seconds ($8.33*10^{-3}$ h) to measure and record the bearing housing diameter of each item. The cost of sampling and testing, neglecting the cost of the test equipment, can be calculated as:

$$C_1 = k \cdot n \cdot t_m \cdot C = 0.83 \cdot C$$

being C the technician salary per hour.

3.2 Charts analysis

Figure 1 shows the mean and range control charts obtained by this preliminary study. We found that in the R-chart all the points are within the control limits, whereas in the $\overline{X}$-chart the first two points are found to be beyond the upper control limit. This is likely due to a machine regulation occurred between sample 2 and 3. The remaining points are very close to the central line. Moreover it's worth to observe that in the R-chart most of the points display the same value. This behaviour was ascribed to the poor resolution of the measurement instrument. In fact, the smallest interval measurable by the centesimal bore-gage available is 5 μm, which is the same value of the variation range.

3.3 Corrective actions

In order to reduce the added costs to the project, rather than to buy a better resolution bore-gage, it was decided to take advantage of the available instruments. The only one with a sufficient resolution was a Coordinate Measurement Machine (CMM) with a resolution better than 1 μm, placed in the gauging room, thermoregulated at a temperature of 20°C. Unfortunally this instruments was not close to the manifacturing machine. Therefore the measurement procedure required to transport the sample to the gauging room, to wait for its acclimatization at 20°C (about 3 hours), to perform the measurement on the n items and eventually to bring them back to the production line. It takes approximately t_t=5 minutes (0.083 h) to transport to and fro the sample and t_m=1 minute (0.0167 h) to measure and record the bearing housing diameter of each item. The cost of sampling and testing in this case, again neglecting the cost of the test equipment, can be calculated as:

$$C_2 = k \cdot \left(t_t + n \cdot t_m\right) \cdot C = 3.33 \cdot C$$

The management considered this cost, which is 4 times higher than C_1, has to be unacceptable.

To solve this problem, the adoption of a X chart-moving range was proposed. In this case, the sample size is n=1 and the variability of the process is estimated by calculating the moving range, i.e. the difference between the range of two successive samples. Because in this case there is no assurance that the X values are normally distributed, it was necessary to verify that individual items fit a normal distribution before the control chart was prepared. k=20 samples were collected, one every 30 minutes, and carried to the gauging room all at once. Figure 2 shows the X and moving range charts obtained with this study.

The cost of sampling and testing in this case is:

$$C_3 = (t_t + k \cdot t_m) \cdot C = 0.42 \cdot C$$

Therefore the cost can be reduced at a value which is lower than that calculated with the instrument used in the production line.

4. Conclusion

In this paper, the choice and introduction of control charts in a small sized mechanical enterprise has been reported. The aim of the study, rather than describe the control chart implementation procedure, was to point out the problems connected with the particular context in which control charts were introduced.

In particular, it has been inlighted that in implementing SPC methodology in a small sized enterprise, besides the statistical considerations, the economic aspects, such the cost of the sampling and testing, of the test equipment and of the staff training, must be taken into account.

In conclusion this experience shows that SPC can be successfully implemented also in a small industrial environment at a limited cost provided that the optimum choice has been done.

References

[1] M.Al-Salti and A.Statham, “A Review of the Literature on the Use of SPC in Batch Production”, *Quality and Reliability Eng. Int.*, **10**, 49-61 (1994).

[2] K. Ishikawa, *Guide to Quality Control*, Asian Productivity Organization, Hong Kong, 1983.

[3] L.J.Porter and R.Caulcutt, “Control Chart Design a Review of Standard Practice”, *Quality and Reliability Eng. Int.*, **8**, 113-122 (1992).

[4] A. Mitra, *Fundamentals of Quality Control and Improvement*, Macmillan Publishing Company, New York, 1993.

[5] D.C.Montgomery, *Introduction to Statistical Quality Control*, John Wiley & Sons, New York, 1997.

[6] W.E.Deming, *Out of the crisis*, Center for Advanced Engineering Study, MIT, Cambridge, 1986.

Figure Captions

Figure 1 (a) Mean chart obtained by the preliminary study

Figure 1 (b) Range chart obtained by the preliminary study

Figure 2 (a) Mean chart obtained by the second study

Figure 2 (b) Moving range chart obtained by the second study

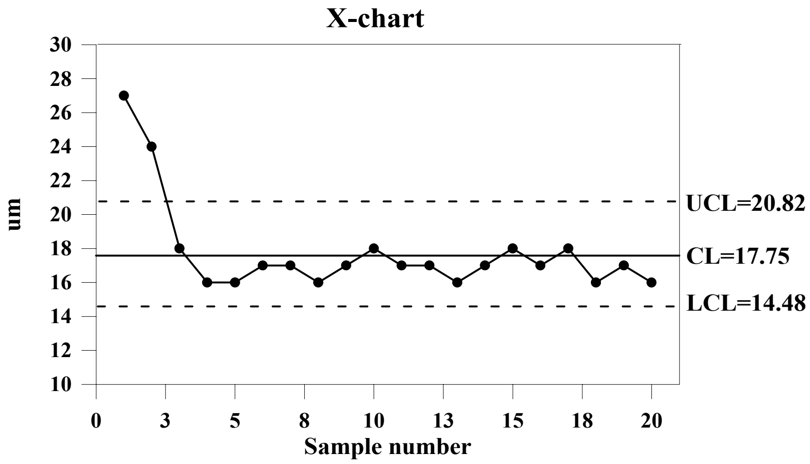

Figure 1 (a)

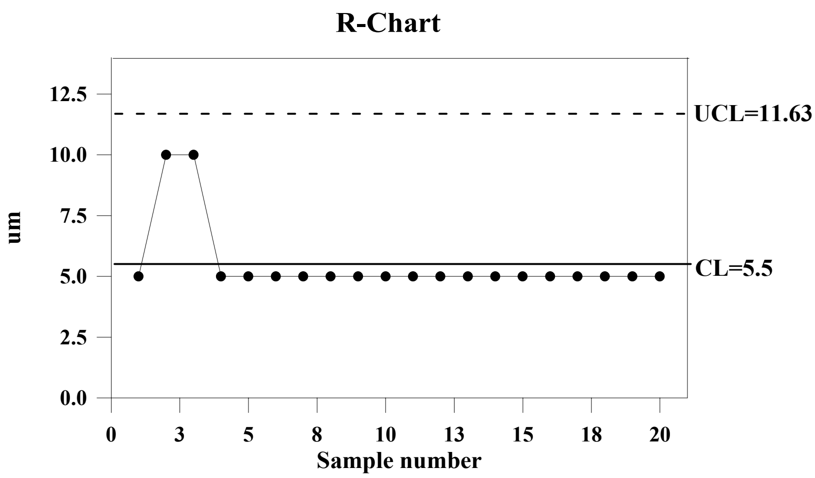

Figure 1 (b)

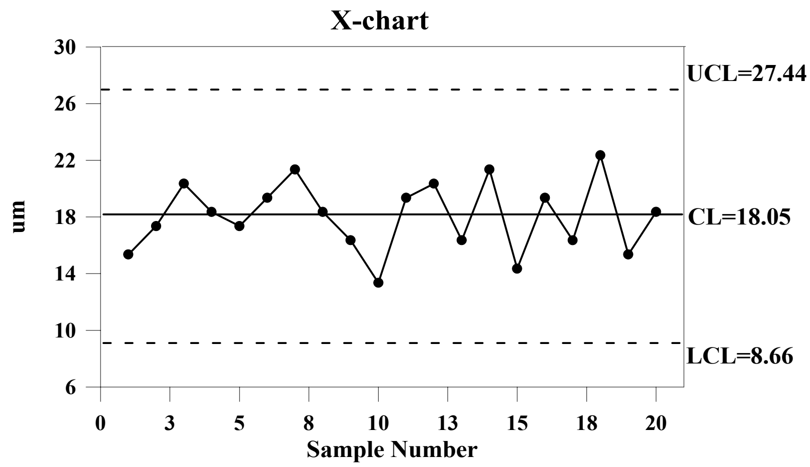

Figure 2 (a)

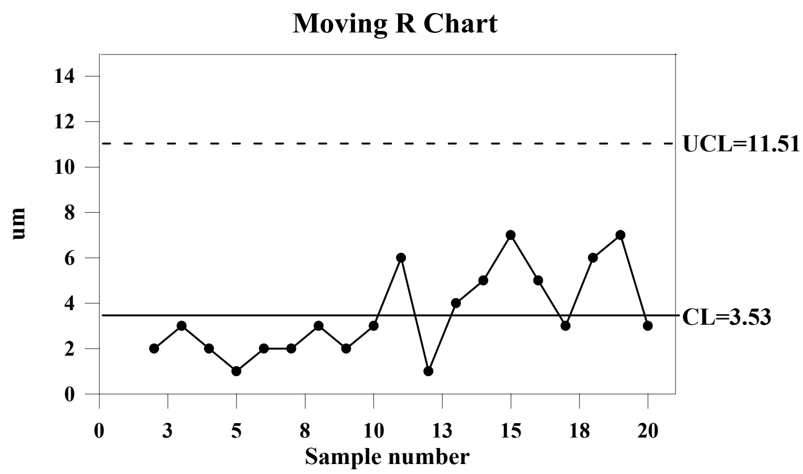

Figure 2 (b)