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AN EDUCATIONAL PACKAGE ON STATISTICAL QUALITY CONTROL FOR ENGINEERING STUDENTS

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ABSTRACT

The greatly increased precision demanded of manufactured products has been accompanied by the need for better methods to measure, specify, and record quality characteristics. Over the years statistical quality control methodology has become more and more widely used and generally accepted throughout industry as quality improvement tool. With the availability of today's computer systems and advanced data processing equipment their practical application continues to win ground over other techniques. Within actual competitive market, modern companies are expecting the engineer and the technician they hire to have strong training in quality improvement techniques and ideas. The present paper is dedicated to present an educational package developed at the metrology and quality control laboratory at the Hail College of Technology for the purpose of demonstrating the basic steps in the statistical quality control approach used by modern industry to improve quality.
Fortran programming has been used to build up the main frame for the statistical quality control calculations. Future developments of the package are planned using object oriented programming (Visual basic or Java). The package is demonstrated through several series of laboratory work undertaken by the students. Graphical frequency distributions are obtained and analyzed to demonstrate to the students the basic steps used by modern industry in the analysis of a manufacturing process and quality control.

1- Introduction:

The environment in which modern industry is operating has dramatically changed over the last decade, and further dramatic changes are likely to occur. Competition has intensified, and many products invented in one place are no longer manufactured in that place. The cause of this are very complex. One aspect is the significant improvements in product quality. Many American and Japanese companies have embraced quality improvement programs (often called Total Quality Management or TQM).

Total Quality Management (TQM), also known as Total Quality Control (TQC), is the application of quality principles to all facets of an organization. In the United States of America and Japan, most efforts in quality during the 40 years after World War II were relegated to the factory floor. Statistical process control (SPC) became the mainstay of quality efforts during this period. SPC is a method for assessing statistical variation and determining if any measurements fall outside what would be expected from the statistical characteristics of the data gathered. Hence, SPC became a methodology used to determine if parts conformed to specification, simply by measuring parameters of parts and comparing these measurements to the specifications. In contrast, TQM is a much broader concept. It is applying quality methods to the entire organization, from management, to accounting, to manufacturing, service, and every other subentity in the organization. How could be this possible? One clear definition of quality involves satisfying one's customer. This satisfaction has different meanings for different parts of an organization. In manufacturing, conformity to specifications may well satisfy a customer. However, in sales, simply conforming to specifications is unlikely to satisfy the customer. Hence, other metrics of quality must be sought. In the sales example, a customer might well be satisfied if his needs are adequately met; however, if his expectations are exceeded he would surely purchase that company's products again. Thus, another definition of quality: exceeding customer expectations.

Improving quality means gathering and analyzing data to assess the state of a process, experimenting with methods to improve the process and assessing the benefits of alternative process designs. Within actual competitive market, modern companies are expecting the engineer and the technician they hire to have strong training in quality improvement techniques and ideas. In the present paper, we shall present an educational package developed at the metrology and quality control laboratory at the Hail College of Technology for the purpose of demonstrating the basic steps used by modern industry to improve quality.

2 – Basic Qualiy Improvement Techniques :

Many quality improvement techniques are discussed in text books ([1] to [7]) and technical papers and repports ([8] to [10]); The World Wide Web offers an impressive documentary fund dedicated to quality

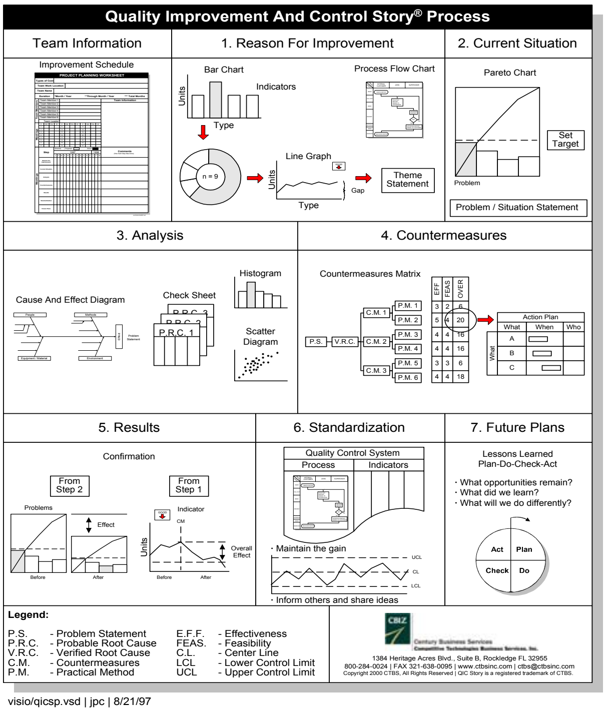


Figure 1 – The basic quality improvement techniques [9]

control, its roots and applications. The basic techniques widely used by modern industry are summurised in figure 1. These techniques would include the bar chart, process flow charts, the Pareto diagram, cause-and-effect diagram (Ishikawa), check sheets, histogram, scatter diagram, matrix analysis, process capability, control charts, run charts, brainstorming and Taguchi (design of experiments) technique.

In order to improve a product quality, one has to acquire a sufficient amount of data and analyse them. This would allow to assess the state of the production process, detect any poor quality causes and mainly experiment with methods to improve the process and assess the benefits of alternative process designs. Over the years statistical techniques and statistical methodology have become more and more widely used and generally accepted throughout industry as quality improvement tool. With the availability of today's computer systems and advanced data processing equipment their practical application continues to win ground over other techniques. Statistical Quality Control plays a major role in modern programs for Total Quality Control. It is based on the application of statistical techniques to control a product characteristic to ensure it meets product specification or the engineering design specifications.

3 - Presentation of the Statistical Quality Control Package:

The academic program leading to a diploma in mechanical technology includes theoretical teachings and laboratory training in metrology and quality control. In order to demonstrate to the students the basic concepts and the applications of statistical quality technique, a computer package has been developed using Fortran language programming.

The basic steps used in the package are:

- Data collection (using sampling, dimensional and mass metrology techniques)
- Application of Statistical Quality Control technique (statistical parameters and grouping the data and construction of the frequency distributions)
- Analysis of the results to assess the production process.

4 – Results and Analysis:

Tests of the statistical quality control package have been done using a sample of parts manufactured at the mechanical technology department's workshop by the students during their practical training. Typical results of the output of the program are shown in figure 2.

A graphical representation of the computed statistical parameters is then produced using graphical package such as TECPLOT or any other package. Histograms of the frequency and the cumulative frequency are shown in figure 3. Design specifications have been added to the graph in order to have a thorough understanding and analysis of the manufacturing process, its capability and its control.

The use of the frequency distributions is made mainly to emphasize that variations are inevitable in any manufactured parts. That is to teach to the students that manufacturing variations have a universal nature. One characteristic of modern manufacturing is that no two pieces are ever made exactly alike. Many factors can contribute to these variations; These include tool wear, bearings that loosen, machine vibrations, faulty fixtures, poor raw materials, careless or untrained operators and weather changes.

Characteristic Name : Height H (mm)
Number of Experimental Data N = 50

The measured data are :

1	12.2300
2	12.6500
3	12.4100
49	12.0700
50	12.2600

Sorting Data in ascending order

1	11.3200
2	11.4100
49	13.2700
50	13.3100

Calculated Statistical Parameters :

Xmin = 11.32000 X max = 13.31000
Range = 1.99000
Median = 12.18000 Average Xm = 12.26460
Standards Deviation Sigma = 0.48935
Skewness = 0.14770 Kurtosis = 2.35361

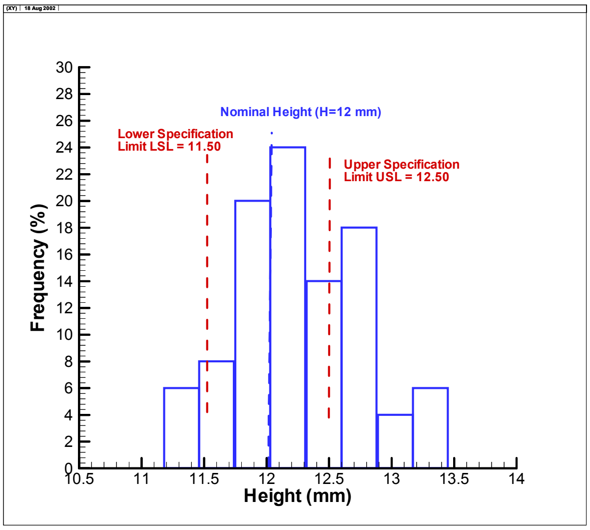
Frequency Distribution (Histogram)

CELL BOUNDARIES	CELL MIDPOINT	FREQUENCY (%)
11.1779 / 11.4621	11.3200	6.0000
11.4621 / 11.7464	11.6043	8.0000
11.7464 / 12.0307	11.8886	20.0000
12.0307 / 12.3150	12.1729	24.0000
12.3150 / 12.5993	12.4571	14.0000
12.5993 / 12.8836	12.7414	18.0000
12.8836 / 13.1679	13.0257	4.0000
13.1679 / 13.4521	13.3100	6.0000

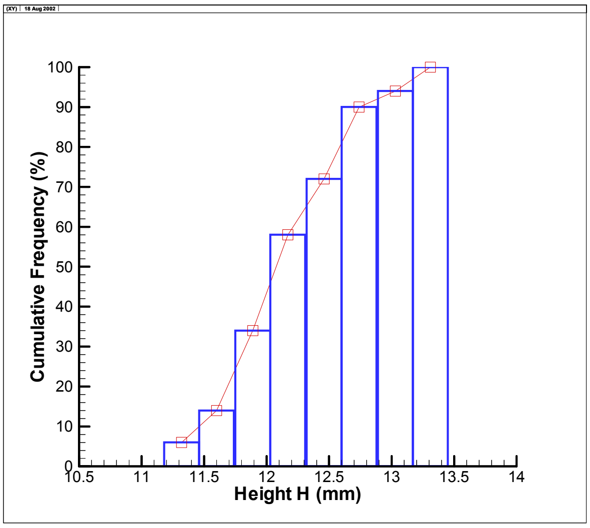
Figure 2 – A Sample of the SQC Program results

The computed statistical parameters permit to analyze the manufacturing process and obtain important features about the product quality; These quality features can be shown such as:

- **The mean value (Xm)** : usually reflects the dimension at which the machine tool was set up;
- **The spread of the values** characterized by the range (R) and the standard deviation (sigma): This will reflect the variability of raw materials or possibly that of the machine tool itself (process capability);
- **The relation of the values to the specified tolerances** (lower and upper specification limits): This is very important as a guide to any necessary corrective action for quality improvement purposes.



a – Histogram (frequency distribution



b – Cumulative frequency distribution

Figure 3 – Frequency and relative frequency Distributions obtained by the Statistical Quality Control Package for the Height H (mm) of the manufactured part

The above arguments are well illustrated by examining the results obtained from the package and summarized in table 1, for two characteristics of the manufacturing parts (the diameter D and its mass). Graphical representations are presented in figure 4 (a) and (b) which show the variability of the manufacturing process through the different trends of the frequency distributions (skewed frequency distribution for the diameter D and bimodal frequency distribution for the mass M).

Table 1 – The calculated statistical parameters obtained from the SQC package for two characteristics of the inspected parts

Diameter D (mm)	Mass (g)
Xmin = 18.50000 X max = 20.61000 Range = 2.11000 Median = 20.13000 Xm = 19.97029 Sigma = 0.50524 Variance = 0.25526 Skewness = -1.14374 Kurtosis = 3.50994 Cx = .02530	Xmin = 150.00000 X max = 200.00000 Range = 50.00000 Median = 180.00000 Xm = 174.85290 Sigma = 14.11454 Variance = 199.22010 Skewness = -.37890 Kurtosis = 2.05068 Cx = .08072

5 – As a Conclusion : What does the student learn from this approach?

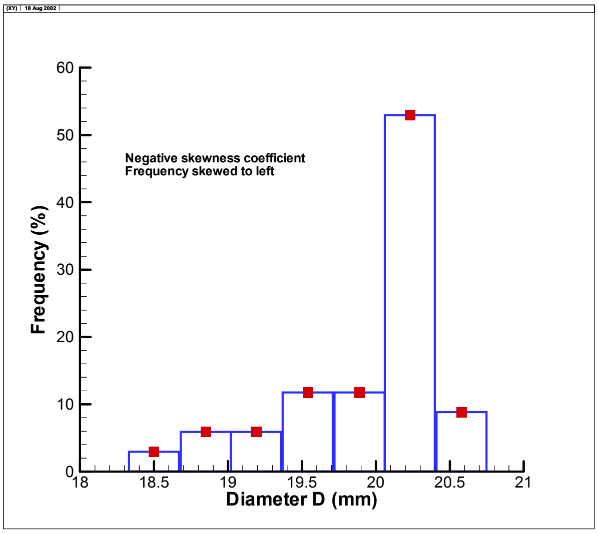
It is the aim of this work to show to students that statistical quality control approach, mainly the frequency distribution (histograms) tool, is a way of thought for the engineer and the technician in manufacturing plants. It helps to establish the principle that some variation must always be expected among manufactured parts and that variation has a general nature or trend which would help to understand the manufacturing process and the factors influencing its outcome. Hence very important questions regarding quality can be easily answered , such as:

- Is the variation in the process such that parts can be produced within specification limits as far as a particular quality characteristic is concerned?

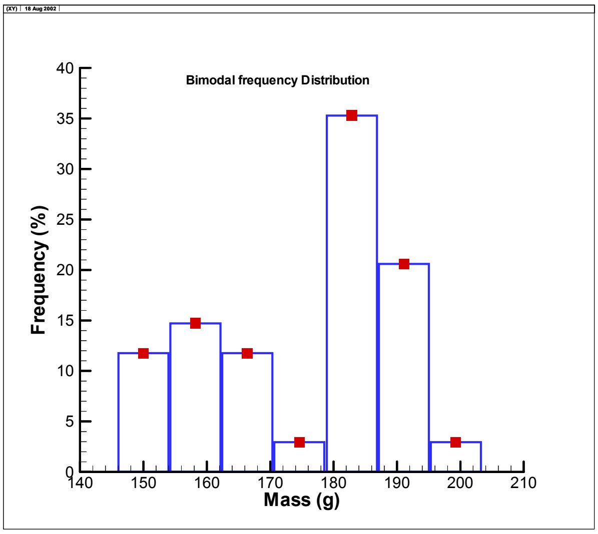
- How does the average value for the quality characteristic compare with specification limits?

Answers to such questions can be obtained by a careful analysis of histograms showing frequency distributions such those presented in figures 3 and 4 obtained from the Statistical Quality Control package developed here. It is important to note here, that the student gets a strong and evident training on the four basic steps used in modern industry to analyze manufacturing processes and engineering designs; These are:

- Taking readings and recording data
- Analyzing the data
- Determining if the data represent an economical operating condition
- Taking corrective action when necessary.



(a) Left skewed frequency distribution



(b) Bimodal frequency distribution

Figure 4 – Typical frequency distributions obtained for two characteristics

Frequency distribution has been shown to be very useful in each of these four steps; It furnishes a useful form for taking readings and a practical method for analyzing them. It gives an indication of the economy of he process by comparing the resulting process limits with the specification limits, and furnishes a graphical and analytical guide for corrective action. This will have a direct impact on the control of the product quality.

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