The Quality Control Function

Introduction

Routine quality control can not be avoided but it is expensive. It requires space, capital equipment, time, and above all skilled manpower. The last two especially are scarce resources in most manufacturing operations so the quality control operation must be carried out with the utmost cost-effectiveness. If a rational quality assurance scheme is introduced into an operation which has a low level of quality awareness, then it will usually more than pay for itself through reduced second quality items, lower waste, less reprocessing, and better customer service.

It has been estimated that around 25% of total manufacturing costs can be ascribed to the cost of non-conformance to the specified quality. This means that the specific functions of the quality control department have to be closely defined, its priorities clearly determined, its operations narrowly targeted, and its costs and benefits well known.

One of the most common problems in quality control operations is that, due to a lack of focusing of priorities and objectives, large amounts of unnecessary data are gathered by making routine measurements or inspections at the end of the production line, only for the data to lie filed away in a cabinet because no one ever has the time to study it properly and to draw the obvious conclusions. Management is confronted with weekly tabulated data sheets which are a mass of figures that do not reveal the underlying trends or enable rational decisions to be made about whether the manufacturing operation is actually under control, or what action to take. The product is often on its way to the customer before the quality control data sheets have been completed.

What is worse, quality control tests are often carried out in a way that does not allow the factory to either control its operation or to find out where the source of any deficiencies really lies, so that the effort is completely wasted. A good example of this is the common practice of measuring the weight per unit area of grey knitted fabric straight from the knitting machine. This is an almost completely worthless parameter, which does not give any reliable indication of whether the knitting process is under control nor any guide as to how the fabric should be processed. And yet there are many knitting factories that use the grey weight as their main quality control tool and their guide to finished dimensions.

We should start by focusing on the different reasons for making quality control tests and define each one as a separate quality function. Each identified function should be analysed, to decide what are its key control parameters and what is the minimum amount of testing that has to be done to achieve its objectives. A schedule of operations, with corresponding techniques, should be drawn up which will guarantee that the objectives are met. Time spent on this kind of analysis will be well rewarded by lower quality control costs for a better level of reliability of the manufacturing operation.

As an example, we can envisage the following five key functions of a quality control operation.

1. To satisfy customer requirements for reporting (or maintaining records) on the achievement of specific quality targets.
2. To satisfy internal requirements for routine product monitoring, to ensure that they conform to established internal targets or specifications.

3. To satisfy the requirements of process control, to ensure that the various manufacturing processes are being operated correctly, or are correctly calibrated.
4. To provide the test data required for new product developments.
5. To provide concise and meaningful management information which allows a rapid and realistic overview of the general situation on a continuous basis.

The type and frequency of quality testing is different for each of these different functions, although the first two are often seen as being one and the same.

The customer may have no specific reporting requirements, but the management may deem it prudent to keep some testing records - and even a sample - in each customer file against the chance that goods may one day be returned, or a claim for compensation may be made. Some large multiple retailers insist that certain quality tests should be undertaken or that certain performance standards should be guaranteed against specific quality testing methods. Sometimes the only way to know if a product conforms to a certain standard is to install the appropriate test method and carry it out at least on an occasional basis. The most obvious example for this is the need to obtain precise shade matching in dyeing and a specified level of colourfastness in the dyed fabric. In this case, colour matching and fastness testing will be indispensable.

However, even in such cases, and also in the case of testing for internal purposes, it is important not to do more testing than is strictly necessary. A good example is the case of shrinkage testing. Many companies spend an enormous (and usually unknown) amount of time and money on the routine measurement of shrinkage. However, if the factory is being run according to STARFISH principles, then the Reference State Dimensions should be well established for every quality that is being processed.

If the Reference courses per cm are known, then it is only necessary to count the courses in the delivered fabric in order to know whether the length shrinkage will be within specification. Similarly, if the Reference width is known, then it is only necessary to measure the width of the delivered fabric to know whether the width shrinkage is on target.

If the delivered courses and width are correct, and if the knitting has been correctly done according to the STARFISH specification, and if the wet process route has not been changed since the calibration was established, then it follows that all other dimensional properties of the fabric, such as weight and shrinkage, must also be according to specification.

Thus, so far as the dimensional properties are concerned, the routine quality control checks for fabric at the end of the production line need only consist of counting courses and measuring width. Since these are also the finisher's manufacturing targets, routine quality control is actually built into the manufacturing system.

This does not mean that shrinkage should never be tested but it need not and it should not have to consume such a large proportion of the time and effort of the quality system. Provided that the quality has been properly set up in the first place, and the finisher has the appropriate equipment and techniques at his disposal, then limited random sampling plus occasional quality audits should be all that is required to keep the production on target.

Many companies are very proud to insist that they maintain 100% inspection of their products. What they are really saying is that the manufacturing process is not under adequate control.

On the other hand, when a new product is being introduced, or when new wet processing equipment is being commissioned, then the testing should be rigorous and comprehensive. For the new product, it is essential to establish what are the average Reference Dimensions with a good degree of certainty, so that the correct finishing targets can be issued to the finisher. For the equipment, it is essential to know whether the process calibration has been changed and, consequently, whether any existing products will have to be re-engineered to make allowance.

In both of these cases, a few samples are not enough to establish reliable averages. Even so, there is no need to measure everything about the fabrics. The essential parameters are the Reference courses and wales and these should be gathered as quickly and as comprehensively as possible. It may also be necessary to establish whether the relationship between the Reference Dimensions and the dimensions after the normal routine QC relaxation test are different, so that a series of comparative relaxation tests has to be launched. Other properties, such as the relaxed weight may have to be determined but these are all subsidiary to the Reference courses and wales, and can be established at a slower pace.

What we are suggesting here is that quality testing should be a precision tool, which is directed at specific product parameters and at specific locations in the manufacturing process. It should never be simply a blanket method for creating records or for grading products into first- and second-class quality. In this context, it is the **process control** function that has the highest level of importance, especially in a factory that is operating according to STARFISH principles.

This is because the STARFISH philosophy is that product quality must be guaranteed by design and by control from start to finish. If all of the manufacturing processes are correctly set up and correctly controlled, (and there is no change in raw materials purchased) then the quality must be correct at the end of the line.

Therefore, the major functions of a quality system are:

- To identify the critical manufacturing stages.
- To establish the correct control parameters for each of those stages and the appropriate target values for each parameter and for each product.
- To set up written procedures for maintaining the control parameters at the correct levels during manufacturing of specific products.
- To make sure that the process operatives fully understand about the critical parameters, are properly trained in how to carry out the control procedures, and are given easy communication channels when they feel that the process is not under control, or when they are experiencing difficulties.
- To develop appropriate and cost-effective quality testing procedures to ensure that the control parameters are being correctly monitored.
- To set up written procedures which outline the corrective action which has to be taken when it is discovered or suspected that a particular critical stage is going out of control.

Quality Charts

Once the important control parameters have been identified, and the required levels have been specified for a given product and manufacturing stage, they have to be monitored continuously. This must be done in such a way that any drift in the control parameters away from the specified levels can be quickly detected, so that the appropriate action can be taken before the drift is sufficient for second grade quality to be made.

One of the most useful and powerful tools for monitoring the process is the quality chart.

Quality charts are important because they can be made to focus very precisely on single, simple parameters. They can be used to control not only the average levels but also the variability of a process. They illustrate what level of performance is practically attainable, and they provide an instant and instantly understandable picture of how the level of control stands in a particular area. Thus, they serve to focus management attention on the current capability and state of control in the factory and, hence, on exactly where further investment is needed - whether it be in the form of manpower, training, or capital investment.

Quality charts, often known as control charts, or Shewhart charts, form part of the quality system known as "statistical process control". The total system is rather complex and it is not necessary to study it in detail for our purpose. However, the basic concept of control charts is rather simple, is easy to introduce into the factory, and it can be a very valuable aid to quality assurance. Four different types of control chart are worth considering at this stage. To construct these charts, three data items are required, namely:

- the Target Value,
- the Normal Tolerance, and
- the Action Tolerance.

The **Target Value** is of course the specification value for the control parameter, for example the target stitch length to be knitted on a given machine for a given quality, or the yarn count which is supposed to be delivered by the spinner.

The **Normal Tolerance** allows us to define the range of values within which we can safely assume that the process is operating within its normal capability. The usual way to determine the Normal Tolerance is to calculate the standard deviation (or the standard error) of a run of measurements, when the process is known to be under control - usually about 25 values are needed to get a good idea of the standard deviation. Then the Target Value plus two standard deviations is the Upper Normal Tolerance, and the Target Value minus two standard deviations is the Lower Normal Tolerance.

The **Action Tolerance** allows us to define the range outside of which we can be pretty sure that the process is not operating within its normal capability. When values outside this range are recorded then some positive action must be taken to find out what is going wrong and, if necessary, to adjust the process or the quality assurance procedures. The Action Tolerance is usually taken as three standard deviations (or standard errors) from the Target Value.

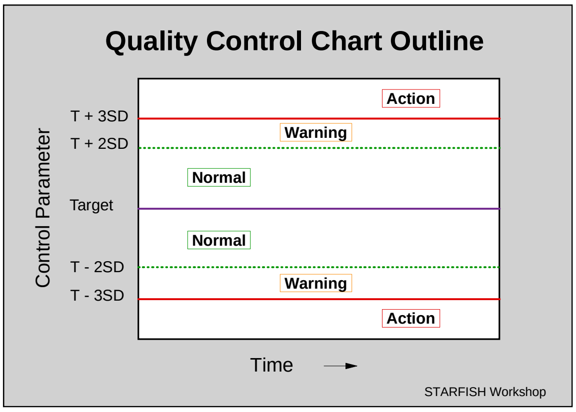
Note that Control Tolerances are an objective indication of the actual current state of control of the particular process. They should not be confused with the most desirable tolerances, or tolerances for performance targets which have been requested by customers. Control Tolerances reflect all of the variations due to materials, equipment, and operators, which affect the actual performance of a process. The process can not deliver a better result under current conditions. There is no point in simply setting Control Tolerances at less than two standard deviations, in an attempt to achieve better control - this is an exercise in futility. If the current performance is not good enough, then steps have to be taken to identify the sources of variation and to bring them under better control. Only after the standard deviations have been successfully reduced can the Control Tolerance range be narrowed.

Simple Control Chart

The simple control chart is the most direct and easiest type of control chart to deal with. It is suitable for the case where one or two simple parameters are responsible for the control of an operation, each of which have specified target values, and where the operation is self-contained in the sense that the values for the control parameters are used only to control that operation. The objective is to ensure that, for example, the knitting machines are indeed being properly set up to the right quality and that this is being maintained over time and across different machines.

For a simple control chart for course length, daily checks on the course length can be recorded, for a given machine running a given quality, and compared with the Target Value. After about 25 values have accumulated their standard deviation can be calculated so that the Normal and the Action Tolerances can be calculated. A chart is set up with: -

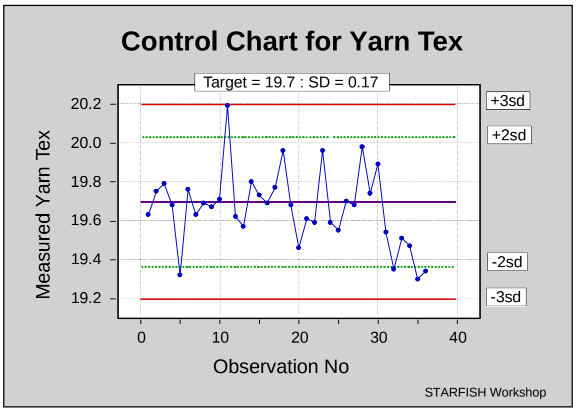
- a vertical scale representing the control parameter,
- a central horizontal line set at the Target Value,
- two further horizontal lines above the Target Value set at distances representing two and three standard deviations, respectively, and
- two further horizontal lines set at corresponding distances below the target line.



The chart is now divided into four horizontal bands. The two middle bands, inside the Normal Tolerances, represent an area where, in principle, the control parameter is allowed to lie. This is because we expect to see the normal random distribution of measurements, 95% of which will lie within plus or minus two standard deviations of the mean, and we also expect that the long-term average will correspond to the Target Value. In addition, we also expect to see the actual measured values for the control parameter more or less equally distributed above and below the Target line, with more of them lying close to the Target line than towards the upper and lower edges of the bands.

The two outer bands, which lie between the Normal Tolerances and the Action Tolerances, are warning bands; areas where we expect to see the control parameter only about five percent of the time.

Action is not required if only the occasional measurement (one in twenty) falls into the upper or lower warning bands, but we would expect to see such occasional entries to be equally shared between the upper and lower bands.



If the number of entries in only one of the warning bands is more frequent than expected, then the average value of the control parameter has probably drifted away from the Target. If the entries in both of the outer bands are more frequent than expected, then the variability of the control parameter has grown. In either case this is an indication that action should be taken to get the control parameter back on target or to reduce its variation.

If the control parameter lies outside the Action Tolerances, then action is clearly indicated because this should happen only about once in 300 observations under normal circumstances.

The main problem with the control chart is that it is not a very sensitive way to detect a gradual drift in process control because the natural variability of single, independent observations can obscure the underlying trend. For this reason, two simple additional guidelines are usually adopted as indicators for taking action:

- If there are two consecutive observations which fall in one of the outer warning bands,
- If there is a run of seven observations which all lie on one side of the Target line.

The first action to be taken is simply to make a further series of measurements, to confirm that the "run of seven", or the "consecutive two" are not simply a statistical freak. It is important not to make frequent, unnecessary adjustments to equipment because this only causes a greater level of variation. Therefore, some effort has to be devoted to ensuring the soundness of the diagnosis.

If the new measurements confirm that the process is running out of control, then an immediate investigation should be launched to find the source of the deviation. Generally, it will be found that there are three main types of reason for deviations.

Equipment

The machinery may require adjustment or maintenance - for example the positive feed unit on a knitting machine has become contaminated with wax and fly and is not functioning properly. In such cases, the reasons why the fault has arisen should be carefully considered. It may be that a new delivery of yarn has excessive wax or generates unusual levels of fly. The yarn supplier should be consulted. In any case, action should be taken which will reduce the likelihood of the fault occurring again. Standard written procedures may need to be modified and operatives may need to be re-trained. If the machine actually needs mending then preventive maintenance schedules should be reviewed. For example, it is not a very good idea to wait until excessive numbers of faults begin to appear before replacing all of the knitting needles.

Materials

A change in the incoming material will usually cause a corresponding change in the product. For example, a change in the Reference courses or wales after finishing is most likely to have been caused by changes in the knitting, or in the yarn supply. When a new yarn supplier is adopted, the influence of his material on the final product should be thoroughly tested so that appropriate adjustments can be made, if necessary, or the new supplier can be advised to modify his deliveries (for example the level of twist may be different). Special attention should be paid to the level of variation in yarn quality, not just the average values.

Operator

It is too easy to blame the operator when problems occur. Research has shown that over 80% of failures are for reasons that are not under the operator's control. Any operator can make a mistake from time to time but if he is not keeping the process under adequate control over a period, or is generating an unusually large number of faults, then the reasons should be investigated. Most often it will be found that the operator does not have sufficient understanding of exactly what is required of him, or his morale is low. The solution is communication and retraining. Training of operatives, and the maintenance of good morale, should be regarded in the same light as the upgrading and maintenance of capital equipment - both are vitally important to continuous production of good quality products. Training should be thorough and clear, with the operative encouraged to supply his own ideas about how the job could be done better.

The great advantage of the simple control chart is that it is very quick and easy to maintain. Large deviations from target can be spotted immediately so that causes can be discovered quickly. Small drifts need less immediate attention and can be left to the alternative techniques described below. It is often a good idea to display a control chart in a prominent position so that the workforce can see at a glance how the process (and they themselves) is performing.

One point which has to be remembered is that, by using the pre-existing standard deviation to calculate the Normal and Action Tolerances, no pressure is being placed on the operatives and the procedures to *reduce the variability* of the control parameter or to *improve the process*. The pressure is directed primarily at maintaining the average at the specified level and preventing the variability from increasing. Therefore, separate steps have to be taken to ensure that the variation in the control parameter is already as low as is technically and economically feasible. Whenever the variation has been successfully and consistently reduced then new Normal and Action levels should be established to ensure that the variability does not begin to drift upwards again.

As new data are collected over the weeks and months, the grand mean and the overall standard deviation can be continually recalculated, over longer time intervals - say monthly - so that even longer-term drifts can be detected. This is especially important when the control chart approach is being used to monitor the calibration level of a wet finishing process. In this case, the control parameters are the Reference State values of courses and wales which will be used to set finishing targets or to calibrate the STARFISH model.

Sample Average Control Chart

This type of chart is used when the measurements reported are not individual, independent observations but the means of small numbers of samples. The sample means are much less variable than the individual observations, so the way of calculating Normal Tolerances and Action Tolerances is slightly different, being based on the *standard error* of the mean rather than the standard deviation. The standard error is simply the standard deviation of the independent, individual observations divided by the square root of the number of observations that were used to calculate the sample means. There are special techniques for pooling standard deviations from any number of samples, which can be found in basic statistics textbooks.

For example, if a certain fabric quality is being knitted on several different machine sizes, then the data for the different machines can be compared by dividing the measured course length by the target before calculating the mean and standard deviation for each machine. The average of all the machines, and its standard error can be calculated and followed on a quality chart. The resulting chart is then monitoring the average level of control between machines, with a Target Value of 1.0. Similar manipulations will allow comparisons to be made over different fabric qualities, or for successive time periods, say monthly.

This type of chart can provide powerful summary information, indicating the overall level of control in the factory. It can even be used to compare different types of equipment. For example, the factory may have positive feed control devices from two different manufacturers. If an equal number of similar machines are selected having the different devices, separate charts can be maintained (or a single chart with both sets of data plotted) for the two groups and compared.

Range Control Charts

The range is simply the difference between the highest and the lowest value within the group of observations that form a sample. Range control charts are used when we have groups of small numbers of samples, and when we want to control the *variability* of a process independently of the average value of the control parameter. For example, the average values of course length will be different for the different machine diameters that are knitting fabrics for a set of body-widths, but the range (or especially the percentage range) will be about the same.

In this case, the Target Value, the Normal Tolerance, and the Action Tolerance have to be calculated by referring to a table of factors, which depend on the sample size. These tables can be found in British Standard No. 600. For example, if the average range of a series of samples is R, then for a sample size of five, the Target value is R, the Normal Tolerance is 1.81 x R, and the Action Tolerance is 2.34 x R.

The Range chart can also be used to discover when a significant improvement has been made to the variability of the process. For a sample size of five, if the mean range consistently falls below 0.37 x R then there is a strong suspicion that the process has improved; if it falls below 0.16 x R then the process has almost certainly improved. If such results have not been caused by deliberate attempts to reduce the variability of the process, then they should also be investigated because they may lead to the discovery of a technique or a set of conditions which can be utilised to improve the overall process reliability.

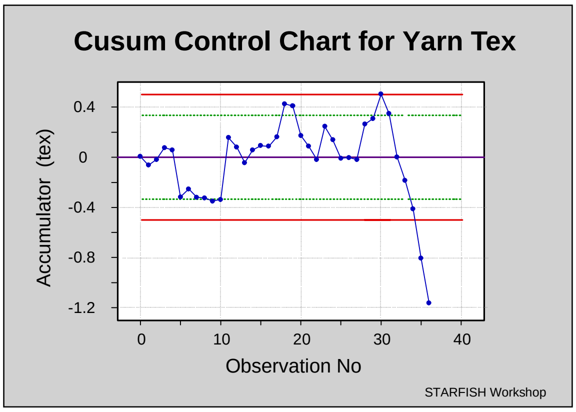
Here again, after the variability of the process has been permanently improved, then the new Normal and Action Tolerances should be calculated, to make sure that the improvement is maintained.

Action criteria are the same as before but, in this case, the action to be taken will be such as to reduce variability in the process which, of course may not be being caused by the process itself but by the variability of the products being fed to it. In addition, it must always be remembered that the instrumentation, or the test methods being used to measure the control parameter, or the operatives who are making the measurements can also contribute to the variability. Therefore, the first step is to recheck the variability of measurement.

The Cusum Chart

The Cusum chart is a sensitive way of detecting small amounts of drift in a control parameter, which might not easily be visible on the simple chart or the sample average chart. Cusum is a contraction of "cumulative sum of deviations".

With a Cusum chart we do not plot the actual measurements but the accumulated *differences* between the measurements and the Target Value.



Thus, for every observation, the Target Value is first subtracted and the difference is added to an Accumulator. At the start, the Accumulator is zero. For every successive observation, the value of (Observation minus Target) is added to the Accumulator and the new Accumulator value is plotted. Sometimes the difference will be positive and sometimes negative, depending on whether the observation is greater or smaller than the Target Value.

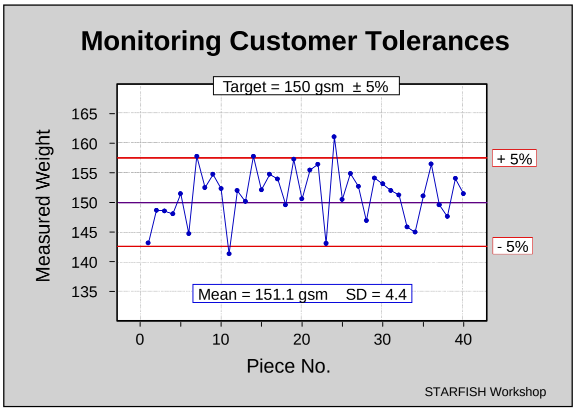
If the process is operating normally, then the successive values of the Accumulator will wander around the zero line. How close they are to the zero line will depend on the standard deviation of the observations. For example, the standard deviation of course length will be greater for a large diameter machine than for a small diameter machine.

To eliminate the effect of the standard deviation, the differences can be divided by the standard deviation, before they are added to the Accumulator, in order to "normalise" the scale. However, as soon as the mean of the control parameter starts to move away from the Target Value, then the observations will show a tendency to lie on one side of the zero line. By accumulating the differences, this drift away from target will very quickly become noticeable.

There are no Normal and Action Tolerances for a Cusum chart. A tendency for drift can usually be spotted fairly easily by subjective inspection.

Design Limits and Control Limits

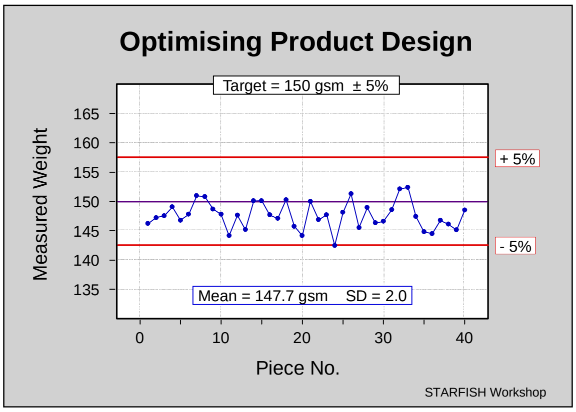
Quality charts can also be used to check whether a process is operating within the design specification for the product.



In this case, instead of Normal and Action Tolerances, we have Design Tolerance boundaries, which can be, for example, in terms of a desirable maximum percentage deviation from the specification.

Such charts should not be used to control a process, only to see how it is performing with respect to some desirable standard. If the Design Tolerances are regularly being exceeded, then this may be grounds for launching an investigation into the sources of variation in materials, equipment, or operating procedures.

This type of chart can sometimes be used to optimise the cost of manufacturing to a given customer tolerance.



For example, if the customer lays down a specification for 150 grams per square metre with a tolerance of plus or minus 5%, then this means that he is prepared to accept a proportion of deliveries which are at or about 142.5 gsm and a proportion which are at or about 157.5 gsm.

From the point of view of cost control, we would prefer to deliver all of the cloth on the lighter side, and none of it on the heavy side (provided that this did not compromise other quality characteristics).

Fabric Weight is not a key process control parameter but, If we are making regular measurements of weight, and if these show that we can consistently deliver fabrics with less than 3% variation, then we would be fairly safe in targeting our weight a little on the light side.

On the other hand, if the weight measurements show that we are not controlling the product weight to better than 5%, then we may be forced to deliver on the heavy side to avoid complaint. In this case we might be well advised to put some effort into discovering how to control the variability of the weight more closely. If only 1% of material costs can be saved in this way, then the cost of close process control will be more than repaid.

