Quality System and Product Quality

Maurice Pillet

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Maurice Pillet
University of Savoie – France
maurice.pillet@univ-savoie.fr

1. Quality and the Industrial Challenge

In the context of international competition, companies nowadays are confronted with 3 problems:
- Reduction of lot size
- Increasing demand for quality
- Increasing demand for decrease production cost

It is really difficult to satisfy together this these three specifications. At first sight, there is an incompatibility between quality, small lot size and low production cost. Traditionally companies used to work in large batches in order to decrease production costs. But the production process was not really formalized. With the increase of the mix product, we are now obliged to reduce the lot size. On the other hand, international competition forces companies to turn out ever-better quality products. In order to respond to this pressure, production processes have to be better formalized.

Such a transition constitutes a real industrial challenge: "try to move from craft manufacturing in large batches to industrial manufacturing in small batches."

Therefore firms must control their techniques, process flows, and, naturally their quality. Quality has become a basic requirement to be present on the market. It is an imperative for all companies to implement a quality policy. This can be an opportunity in the people management policy. Indeed Quality is a driving force for improvement. Good quality brings the personnel:
- Pride in good work
- Motivation
- Firm durability

This analysis is obvious for all managers. But the problem is: How to manage this quality policy? Where to start?

2. Different approaches in Quality

There are two ways of t tackling the problem in most firms:
- The first, which is the most traditional, consists in building a quality system. The firm typically sets up a quality system very often like the ISO 9000 model. This approach brings about a formalization of all processes that contribute to customer satisfaction, both industrial and administrative processes.
- The second way of attacking the problem focuses more on the product. This approach generally uses other methods like “six sigma” or “Target objective”. The goal in this case is the improvement of product performance through the increase of process capability and design robustness.

“Six sigma” [5] is a method initially developed by Motorola Company. It has become a real standard in the quality area and a lot of companies have integrated this method.

The“Target Objective” is yet another approach to Quality product. We have developed this approach in a research laboratory of University of Savoie (LLP, Laboratoire de Logiciels pour la Productique). This approach has been tested in several companies and we have shown its efficiency.
These two ways (**Quality system** and **Quality Product**) are complementary. The goal of a company is to put in place both approaches. Most companies start by the quality system. Sometimes it is a manager's choice; sometime it is a response to customer demand. Is it the best way to start a Quality Policy?

We can summarize the advantages of the first approach (**quality system**) followingly:
- A Quality system formalizes the firm’s know how
- It guarantees reproducibility in the same circumstances
- Writing procedures helps to better understand the roles of the employees and the relations between them
- Once in place, ISO 9000 allows the firm to improve the quality of its products and customer service.

But there are some disadvantages:
- Building a quality system is time-consuming
- The personnel doesn’t always understand the need for a Quality system and its procedures
- Results on the product quality are not immediate and motivation is difficult to maintain
- A Quality system may sometimes lead to rigid rules and it is detrimental to creativity.

But the principal disadvantages of a quality system like ISO 9000 appear when the companies haven't a true Quality product policy. In this case, if the production process is ill adjusted to the required quality, only poor quality is formalized!

If we focus our effort on **product quality** (the second approach) we have numerous advantages such as:
- A higher understanding of the product and production process
- Quick results on product quality
- Quick customer satisfaction
- Good motivation for the employees

Then, naturally, this approach generates
- The need to formalize product improvement
- The need to involve all the firm actors in the improvement process
- The motivation to start a good and true work on the quality system

The analysis of numerous firms' quality policy shows that a quality policy must start with product quality. The quality system is not an objective, it is a result of product quality. Customers buy the product not the quality system. So, a quality system must be turned toward the product and the customer. The best way to achieve this is to start by a product quality approach.

However, most people in firms will tell you that they are implementing a product quality approach. But product quality is not simply solving quality problems in the short term. It is a global philosophy and a method that requires tools.

We will present a combination of the two methods on which product quality is based: First the target objective will be described and second we will quickly give some indication on the “six sigma” approach.

3. The “Target Objective”

3.1. Basis of the target objective

When we talk about Quality, we must use conformity. Conformity is defined in the ISO 9000 by “Satisfaction to the specified requirement”. This definition is very fuzzy and must be made more precise in the case of assembled industrial products. All assembled products have two levels of Quality evaluation: the level of the finished product and the level of the elementary characteristics. When we talk about conformity, we must dissociate these two levels.

Traditionally, we define conformity by:
- **At finished level:** It’s the level of performance of the product and the aptitude to maintain this level of performance for a long time.

- **At characteristic level :** It's conformity to tolerance

The target objective originates from the following observation: The only important conformity is the conformity of the finished product. So, we can ask an important question "Does conformity to tolerance at the level of the product characteristics induce conformity at the level of the finished product?"

In fact, customer satisfaction always results from a combination of numerous characteristics. For example, the noise of a fridge compressor depends for a part on the assembly of a crankcase and the crankshaft. This assembly depends on clearance, roughness, and lubrication, clearance depends on the shaft diameter, bore diameter, and geometry. Etc…

If we want to assure the final customer satisfaction, we must then take this combinatory aspect into consideration in order to define the conformity of the characteristics. We can define the final result Y (in terms of customer appreciation) in function of the elementary characteristic (X_i) by relation (1)

$$Y = f(X_1, X_2, \ldots, X_i, \ldots, X_n) \tag{1}$$

Sometimes, the f relation is easy to find (for example in the case of simple mechanical assembly). But it is sometimes difficult or impossible to find this relation. If we make a Taylor development near the target of Y at the first order, it is possible to define the function by relation (2).
Another way of establishing relation (2) is experimental. We use the design of experiment in order to evaluate α_i. This relation is discussed in [8] by Parlar in the case of assembly manufacture.

$$Y = \alpha_1.X_1 + \alpha_2.X_2 + \alpha_3.X_3 + \ldots + \alpha_i.X_i + \ldots + \alpha_n.X_n \tag{2}$$

It is easy to show that the traditional way that is used to define conformity at the characteristic level (all parts within the tolerances) is not the right definition.

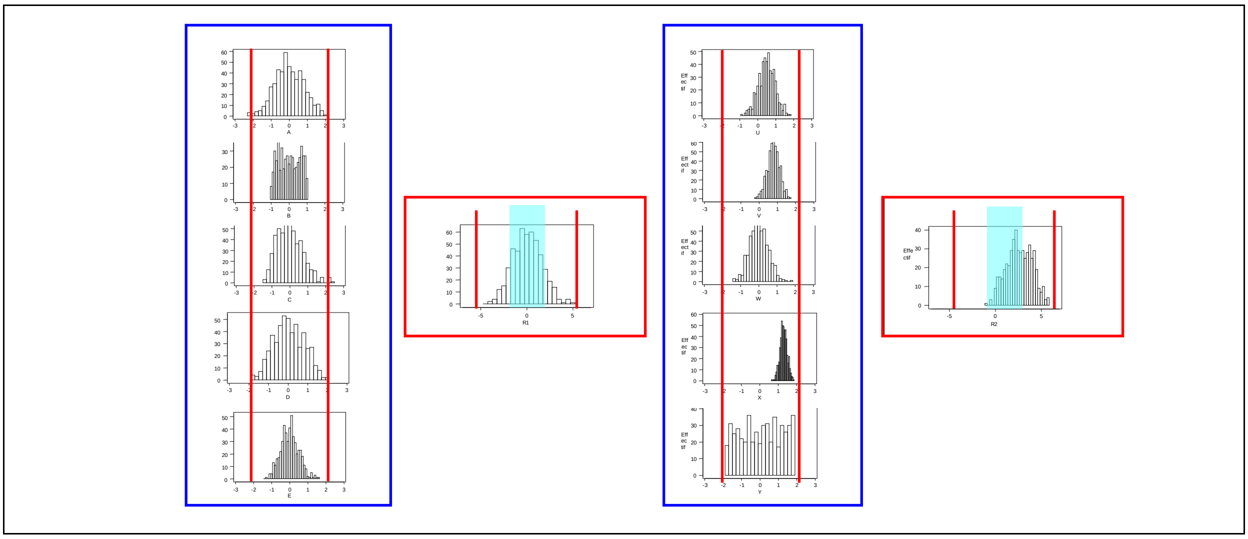

Figure 1

Figure 1 shows a function that results from 5 elementary characteristics.

$$Y = X_1 + X_2 + X_3 + X_4 + X_5 \tag{3}$$

- In the first case, the resulting function is centered and guaranteed, and yet, the elementary characteristics are not all within the tolerances. But in this case all elementary characteristics are centered on the target.
- In the second case the resulting function is not guaranteed even if all characteristics satisfy conformity to tolerances. But in this case all the characteristics are not centered on the target.

As we can see on figure 1, it is in the first case that the customer will be most satisfied. A better definition for conformity at the characteristic level is not "specification within tolerances" but "production on the target".

We can demonstrate that the final quality of a product depends less on conformity to tolerances than on centering the process on the target. We use for this demonstration relation (2). If we calculate the expected values (E(Y)) and the variance (V(Y) of these final results Y.

$$E(Y) = \alpha_1.E(X_1) + ... + \alpha_i.E(X_i) + ...+ \alpha_n.E(X_n) \quad (4)$$
$$V(Y) = \alpha_1.V(X_1) + ... + \alpha_i.V(X_i) + ...+ \alpha_n.V(X_n) \quad (5)$$

If we use the Taguchi target function $L(Y)= K(V(Y) + (E(Y) - Target)^2)$ [11] in order to evaluate the loss in financial term for the society, we can say that the minimum loss will be obtained when V(Y) is lower and when E(Y) is close to the target.

If we have relation (2), we have relations' (6) and (7)

$$Target(Y) = \alpha_1.Target(X_1) + ... + \alpha_i.Target(X_i) + ... + \alpha_n.Target(X_n) \quad (6)$$
$$E(Y)\text{-}Target(Y)=[\alpha_1.E(X_1)\text{-}\alpha_1.Target(X_1)]+...+[\alpha_i.E(X_i)\text{-}\alpha_i.Target(X_i)]+...+[\alpha_n.E(X_n)\text{-}\alpha_n.Target(X_n)]$$
$$E(Y)\text{-}Target(Y)= \alpha_1.[E(X_1)\text{-}Target(X_1)]+...+ \alpha_i.[E(X_i)\text{-}Target(X_i)]+...+ \alpha_n.[E(X_n)\text{-}Target(X_n)] \quad (7)$$

- In order to decrease V(Y), we must decrease $V(X_i)$. The priority of the actions depend on α_i
- In order to place Y on the target, we must assure than all X_i are close to their target in order to have $[E(X_i)\text{-}Target(X_i)=0]$. The priority of the actions depend on α_i

Final quality depends on two elementary things: variance and process centering of the elementary characteristics

Compare now two populations with the same percentage outside the tolerances.

- Production 1 is on the target and a variance V(Y).The loss function will be: $L(Y) = K(V(Y))$ (8)
  We will study a basic situation with tolerance $\pm 3\sigma$. The percentage outside the tolerances is 0.27%.

- Production 2 is not centered by z sigma, and a variance V'(Y) then the loss function will be:
  $L'(Y)= K(V'(Y) + (z.\sigma)^2)$
  $L'(Y) = K(V'(Y)+z^2V'(Y)) = K(1 + z^2)V'(Y)$ (9)

If we want to have the same loss function in both cases, we have $V(Y) = (1 + z^2)V'(Y)$ (10)

If we draw the percentage of tolerance in the second case as a function of z we have:

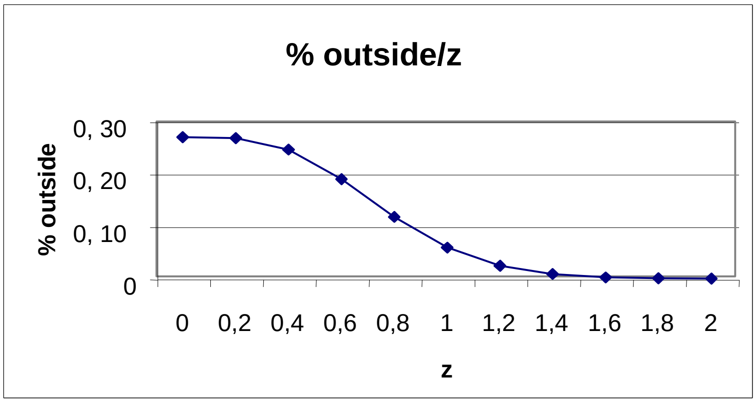

Figure 2

As we can see on figure 2, for the same loss function, when there is a centering error, the percentage outside tolerances decreases when the centering error increases. In this condition, we see that the percentage of tolerance is not the right criterion for quality, the right criterion is the loss function and we must place the mean of all characteristics on the target. In this situation we can accept the higher V'(Y) which is linked to lower production costs.

If one is content with “tolerance conformity” for all elementary characteristics, the centering of the resulting function is not guaranteed and both the loss function and the percentage outside tolerance on the finished product are not guaranteed. We do not have good quality, we do not have good reliability and customer satisfaction will be low.

If one tries to “Aim at the target” on each characteristic, one considerably decreases the variability of the resulting function.

Based on this observation, we can enunciate the principle of the target objective:

“Every variability won on the characteristic is paying on the finished product, and the first variability that we must eliminate is on the mean. We must maintain the production mean on the target.”

The target objective approach consists in focusing all quality actions and other activities on the respect of the target first and on the reduction of variability secondly.

3.2. The Target Objective and robustness

As we have said, customer satisfaction always results from a combination of numerous characteristics.
If we want to assure the final customer satisfaction, we must then take this combinatory aspect into consideration in order to define the conformity of the characteristics

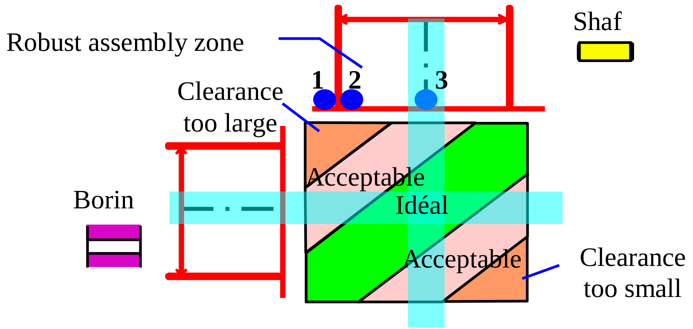

figure 3

Figure 3 illustrates this point. If one considers a function (clearance) that results from 2 elementary characteristics (shaft and bore diameters)

The clearance will be on the target in the first area. In this case, customer satisfaction will be higher. If one moves away from this zone, the clearance moves away from the ideal clearance and customer satisfaction decreases.

As we can see, when the shaft is on the target, whichever the position of the boring, the clearance will be acceptable. When the shaft is within the tolerance but near the limit, if the boring is in the same case the clearance will be in a critical situation. Placing a characteristic on the target allows a larger variability on the other characteristics.

It is easy to generalize this principle to a higher number of specifications as shown in figure1. If you place a characteristic on the target, your system will be **robust** despite the variability of other characteristics.

3.3. The target objective in a production system

TheTarget objective consists in achieving the centering on the target. A lot of simple methods or tools can help to reach this result. First, there are statistical tools such as control charts. But it is not sufficient. For all characteristics, we must try to meet the target. Sometimes it is easy as in the following example (figure 4).

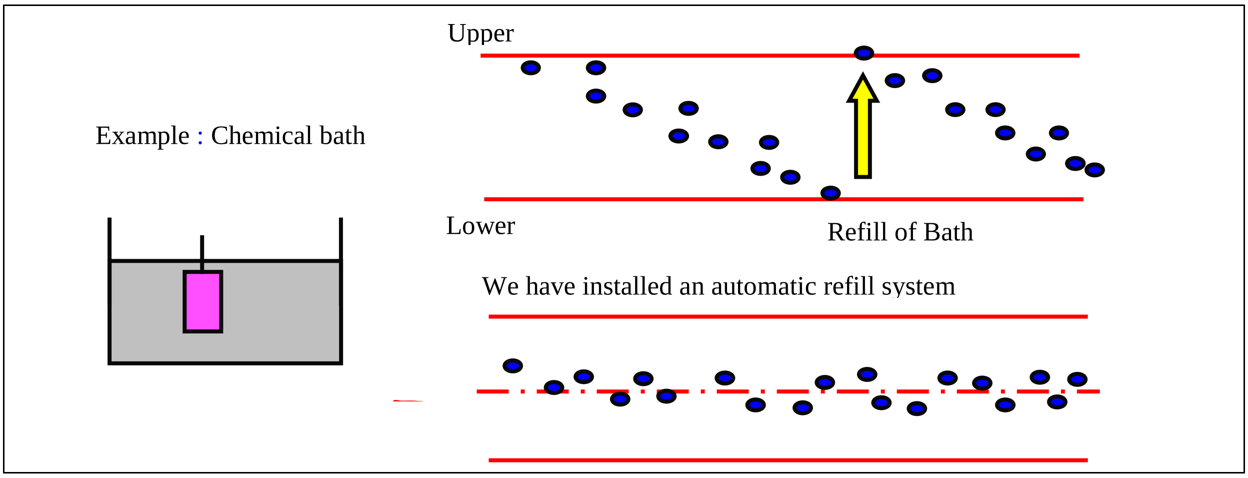

figure 4

In an electronics company we have worked on a chemical bath. Traditionally, the bath is placed on the upper limit and one waits for it to reach the lower limit to refill it. In the "target objective" method, we try to systematically eliminate variability. We have installed an automatic refill system controlled by power consumption. With this system, we have made a twenty-percent gain on the final product. However in the past, we never showed that the limits were wrong. We have won only by using the combinatory aspect.

The target objective can be applied without statistical tools as shown in the previous example. But control charts such as Shewhart charts are often used to better monitor the system.

In "the target objective", all the firm concentrates its effort on enabling the operators to reach the target and particularly:

- In the draft of documents -the target must appear clearly, No calculation by the operator is needed.
- In the choice of the control tools – we prefer measurement to go/no go
- In the choice of machines – We prefer the machines that are easy to center

The Target objective implies a complete change in industrial philosophy. We have to replace the tolerance culture by the target culture.

4. The six sigma approach

Another method, which is close to the target objective, is the six-sigma method. It is a rigorous way to solve problems in order to decrease the variability of characteristics. The objective in "six sigma approach" is to reach a level of quality such that the distance between the mean and tolerances is higher than six standard deviations. We only accept a centering error of 1,5 standard deviation. This method has five steps:

1. Define the problem
2. Measure – Verify the capability of the measurement process, and collect the facts
3. Analyze – We use statistical tools to examine and analyze data
4. Improve – We use experiment designs such as Taguchi's method to experiment, modify, improve and optimize the process
5. Control – we apply the solution and place the process under control.

But beyond a simple problem solving method, the six-sigma approach implies a whole quality philosophy. The organization for a six-sigma approach is very strict. For example in the classical method, we have to have a team around a "black belt" and assisted by a "champion". The heart of the six-sigma approach is teamwork on time-limited topics.

TheTarget objective is much more all encompassing than the six-sigma approach. One starts from the definition of the specifications in the engineering office where one takes into account the combinatory aspect in order to define the targets and tolerances. At engineering level also, the choice of the machines, the draft of documents, is greatly influenced by the target objective. At production level, we apply the centering on all characteristics in order to produce a robust product.

The Target objective is not incompatible with the six-sigma approach, on the contrary, they greatly complement each other

5. The Target Objective and the quality system

As we have shown in this paper, the "target objective" is very close to product quality. But what is the right place of product quality in a global quality approach? We think that it is preferable to start investing time and money in the product quality approach before moving toward the quality system. The approach we recommend is the following:

1. Involve the general management in order to start a process of improvement of product quality
2. The general management selects some test sites and appoints the pilot processes
3. The general management organizes the training of all personnel and their involvement in the cultural switch
4. The general management monitors the progress of the test sites and organizes the generalization of the quality process
5. The general management encourages the personnel to put in place the necessary procedures to maintain the achieved improvements
6. The general management formalizes all the procedures in a quality system like ISO 9000 in order to attain quality assurance

This approach entails:

- Good motivation
- Customer perception of good results.
- Low cost for implementing the quality policy

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