

**IE 361**  
**Quality Control**

**Mini Culture Project**  
**“ROBUST ENGINEERING”**

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### History Behind Robust Engineering (Taguchi Methods)

The whole idea of the Taguchi methods started after World War II when the Allies were trying to help rebuild Japan. One area of the infrastructure that needed work was the communication network. The communication network in Japan was much less efficient than those used in Europe and North America. Dr. Genichi Taguchi was employed by the Electrical Communications Laboratory, which undertook the work of revamping the telecommunications system. In producing a successful system, Taguchi had a very large impact in the project due to the attitude that he brought and the questions that he asked. His thinking and logic has been evolved into what is now known as "Taguchi Methods for Robust Engineering"

### Descriptions and Definitions of Robust Engineering

Taguchi said, "Robustness is the state where the technology, product, or process performance is minimally sensitive to factors causing variability (either in the manufacturing or users environment) and aging at the lowest unit manufacturing cost." [Taguchi p.4]

As explained by Taguchi (p.1) there are two main types of quality in a product. These types are (1) customer quality and (2) engineered quality. Robust engineering is associated with engineered quality. It is the kind of quality that ensures that the product will produce acceptable performance throughout the intended lifespan of the product. Engineered quality describes a product without any unwanted defects or drawbacks in performance. Customer quality could be described as the quality at the time of purchase, the features that the product has, color, style, etc. Engineered quality becomes relevant after use.

Three areas in robust engineering that ensure engineered quality are: (1) The earlier the Taguchi methods and techniques are used in the design process, the more impact they will have. (2) Set a clear statement of the ideal function of the product. (3) Choose the best nominal values of design parameters to optimize performance reliability.

### Loss Function

In 1981, Genichi Taguchi developed a different method of measuring quality. Taguchi developed a loss function, which defines quality in a negative manner -

**"Quality is the loss imparted to society from the time the product is shipped"**

. This "loss" would include the cost of customer dissatisfaction that leads to the loss of company reputation. A traditional method of measuring quality is based on a step

function that labels a product good if the product falls within a set of control limits. The Taguchi method takes the measure of quality away from a step function and turns it into a quadratic function of the satisfaction level of the customer. Taguchi believed that a customer becomes increasingly dissatisfied with a product as the products quality get farther away from the target value. The traditional control limits were defined as specification tolerances where the Taguchi method uses customer tolerances to indicate when a product is dissatisfactory to the customer. The customer tolerances can be more difficult to define than specification limits however; customer tolerances are a more accurate way to measure quality as viewed by the end customer. This differs greatly from the traditional producer-orientated definition, which includes the cost of re-work, scrap, warranty and services costs as measures of quality. The customer is the most important part of the process line, because quality products and services lead to customer satisfaction which ensure the future return of the customer (Taguchi Methods). In general, there are four quality concepts devised by Taguchi:

1. Quality should be designed into the product from the start, not by inspection and screening.

Quality cannot be determined by inspection, or random testing. Implementing engineering techniques from the design phase and carrying them out even though the production phase create quality. "This is often called an "off-line" strategy (Taguchi Methods).

2. Quality is best achieved by minimizing the deviation from the target, not a failure to confirm to specifications.

Quality can be reached by drastically decreasing variations from the target. The product should be designed so that it is robust or immune to uncontrollable environmental factors - noise, temperature, and humidity. This concept deals with the actual methods that effect quality. Specifying a target value for critical parameters can reduce variation, and ensuring manufacturing meets the target value with little deviation, the quality may be greatly improved.

3. Quality should not be based on the performance, features or characteristics of the product.

Adding features to a product is not a way of improving quality, but only of varying its price and the market it is aimed at. The performance and characteristics of a product,

can be related to quality, but should not be the basis of quality. Instead, performance is a measure of product capability (Taguchi Methods).

4. The cost of quality should be measured as a function of product performance variation and the losses measured system- wide.

The cost of quality should be measured as a function of product performance, variation, and the losses measured system. Deviations from a target are measured in terms of the overall life cycle costs of the product, which include costs of re-working, inspection, warranty servicing, returns, and product replacement. It is these costs that provide guidance as to which major parameters need the most controlling.

#### Signal to noise ratio

“Robustness” and signal-to-noise ratio relate to the concept of robust design. One of the main questions encountered when trying to build a robust product is trying to quantify “robustness.” Many of the commonly used quantities are measured too late in the development of the product. These would include; warranty information, scrap, rework, %defective, failure rate, etc. As you can see from these examples, trying to measure robustness, is an after the fact evaluation, whereas robust engineering involves making the right decisions as the product is being designed. According to Taguchi, the only way to measure robustness is by a quantity known as the Signal-to-Noise ratio.

#### Orthogonal Array Experiments

Orthogonal array experiments are essential to robust design. They give a much better representation than the representation given previously when used one factor at a time experimentation. An example of a test setup for one factor at a time experimenting is shown in Table 1. Columns A-G represent 7 design parameters that are being tested. The numbers 0 and 1 in the table represent two different values for these factors. As you can see in Figure 1, for each new test that is run, only one factor is changed. All other settings stay the same as they were for the previous runs. For the one factor at a time design, for parameter A you only get to see the results of parameter A being at level 0 one time. With the orthogonal array design, there are always 4 tests with the parameters at the high level and 4 tests with the parameters at the low levels (might not always be 4, but it will not be biased). An example might be if we were cold rolling sheets of steel to make them stronger. Some design parameters might be the temperature of the steel, the thickness prior to rolling, the thickness after rolling, the level

of impurities in the steel. Assuming that for each of these parameters there are two levels. If parameter A was temperature, when using one factor at a time design, you would only know the effects of temperature change when the other variables were at a set level. With orthogonal array design you get to see the effects of temperature as the other parameters are changing. This gives you an overall average value for the effects of changing the temperature. An overall average is a much better number to use than the value determined while all other things are held constant because you might be getting a max or min and that would throw your model off. The goal is to have the outcome change the least as the process parameters change. If you use averages to calculate the effects of the design parameters, you will have less variation. Less variation is good because, “**Variation is the Villian.**”

Experiment Number	Design Parameter						
	A	B	C	D	E	F	G
1	0	0	0	0	0	0	0
2	1	0	0	0	0	0	0
3	1	1	0	0	0	0	0
4	1	1	1	0	0	0	0
5	1	1	1	1	0	0	0
6	1	1	1	1	1	0	0
7	1	1	1	1	1	1	0
8	1	1	1	1	1	1	1

TABLE 1 – ONE FACTOR AT A TIME DESIGN

Experiment Number	Design Parameter						
	A	B	C	D	E	F	G
1	0	0	0	0	0	0	0
2	0	0	0	1	1	1	1
3	0	1	1	0	0	1	1
4	0	1	1	1	1	0	0
5	1	0	1	0	1	0	1
6	1	0	1	1	0	1	0
7	1	1	0	0	1	1	0
8	1	1	0	1	0	0	1

TABLE 2 – ORTHOGONAL ARRAY DESIGN

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