IDEAS

1. Introducing the Taguchi System in a Laboratory Course

by Vedaraman Sriraman

Since the early 1980s, starting with Ford Motor Company and AT&T, many Fortune 500 companies have incorporated the Taguchi system. The keen interest shown by industry towards this system of quality engineering is evidenced by the many seminars conducted by the American Society for Quality Control (ASQC) on this subject. Therefore, it is essential that technology educators incorporate this concept into their curriculum and, above all, be very familiar with the concept themselves. In the preceding issue of this journal, an IDEAS article provided general background information on the Taguchi system of quality engineering. In the following section a case study illustrates the applications of the Taguchi methods.

THE STUDY

The objective of the study was to identify a robust concrete design that would result in a product with the least variability in compression strength. The robust design thus identified would be used by the manufacturer of the concrete to prepare mixing instructions for customers.

This exemplifies a typical quality problem, where the manufactured product is a concrete structure and the quality characteristic is compression strength. Further, in this study, off-line methods of Taguchi rather than on-line methods of SPC were used to control product variability. Concrete strength depends on two factors: the water content and curing condition used. These two factors are referred to as Factors A and B, respectively. Each factor, such as water content, was tested at two levels—0.9 gallon level was Level 1; 1.1 gallons was Level 2. Likewise, the two curing conditions—curing in lime water and in air—were referred to as Levels 1 and 2, respectively. Next, concrete specimens that included all possible combinations of Factors A and B were built and tested to determine the compression strength in each case.

Each combination called a "run" was tested using five identical specimens, or a sample size of five. The details of each run are shown in Table 1. Four runs were done using five specimens for each run for a total of 20 specimens on a compression testing machine. Figure 1 shows a tested specimen. Table 2 lists the experimental data along with the sample mean and standard deviation.

The experimental data were then analyzed, and some of the important results are highlighted. The specifics of the statistical procedures involved in the analysis may be found in any good book on design of experiments such as the book by Lochner and Matar (1990). The object of the analysis is to identify factor effects on the mean and variability of the compression strength. Product optimization in this case is achieved by maximizing the mean and minimizing the standard deviation of the compression strength. Graphics were used to more easily present and interpret the experimental data and are shown in Figures 2 and 3.

Figure 2 shows the effects of Factors A and B acting independently and an additional factor called AB on the mean response value. Factor AB takes interactions between Factors A and B into account. The Y axis represents compression strength and the X axis represents the three Factors A, B, and AB. Each factor effect is represented by a bar. The ends of each bar representing Levels 1 and 2 are labeled appropriately. The wider a bar, the greater the effects of that particular factor. Figure 2 indicates that the interaction AB is small, whereas Factors A and B are significant and must be set at Level 1 in order to optimize (maximize) the compression strength.

Figure 3, which was constructed along lines similar to ones used in Figure 2, shows the effects of Factors A, B, and interaction AB on the standard deviation (variability) of the compression strengths. Since we are dealing with variation, the smaller the bar the lower the variation. In this graph, we note that Factor B has a strong effect and that Factors A and AB are also significant. From a cursory examination, it appears that Factors A and B should be set at Level 2 in order to minimize variability. The existence of an AB interaction necessitated construction of an interaction graph (see Figure 4). This reveals that when Factor A is set at Level 1 and Factor B is set at Level 2, the least variation results.

The results of the experiment reveal

Table 1

Experimental Runs

Run	Factor A	Factor B
1	1	1
2	2	1
3	1	2
4	2	2

Table 2

Experimental Data

Standard Order Number	Observed response values X 10^3 psi					Sample Mean X 10^3 psi	Sample Standard Deviation X 10^3 psi
1	99.0	119.0	104.0	117.0	114.0	110.6	8.677
2	79.0	80.0	78.0	79.5	84.0	80.1	2.302
3	73.5	84.0	75.0	86.0	78.0	79.3	5.495
4	42.0	47.0	48.0	45.0	43.0	45.0	2.550

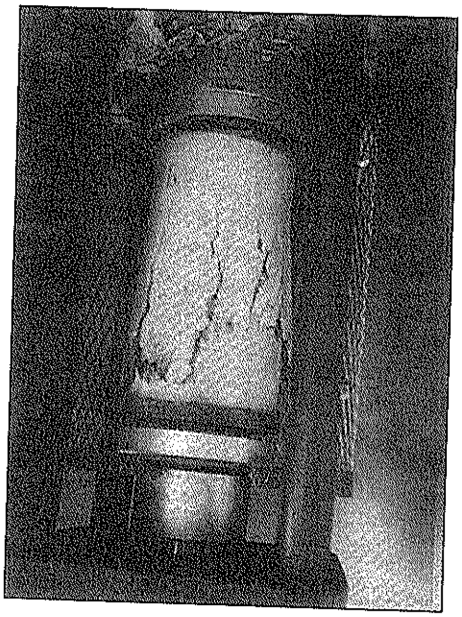

Figure 1. **Test Specimen**

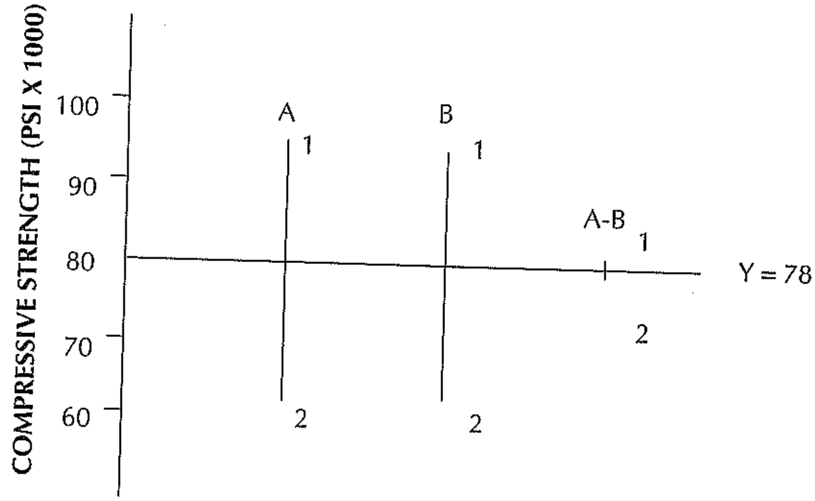

Figure 2. **Factor Effects on the Mean Response Value**

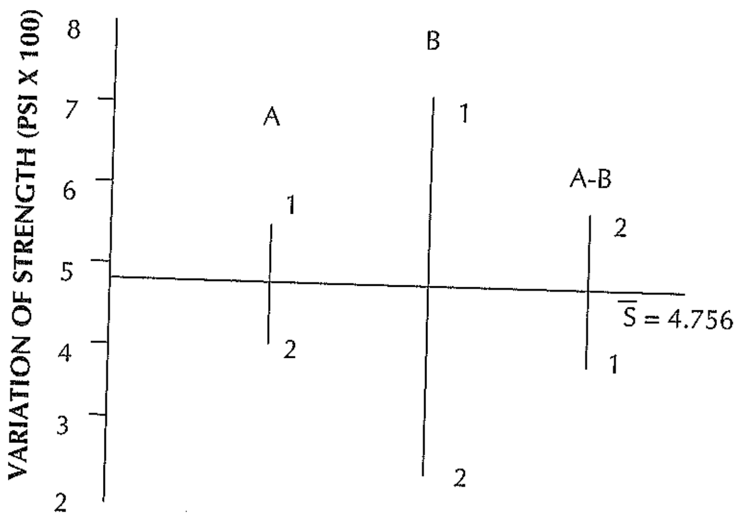

Figure 3. **Factor Effects on the Variance of the Response Value**

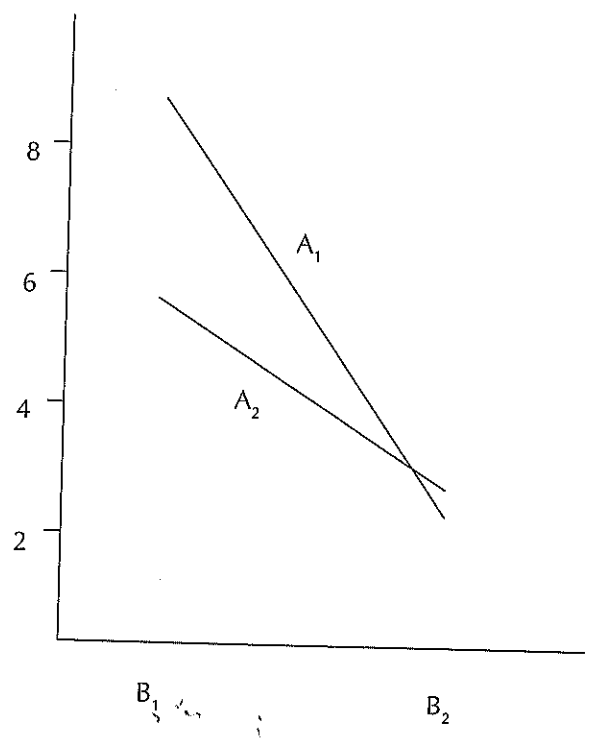

Figure 4. **AB Interaction**

that Factors A and B should be set at Level 1 to maximize compression strength. Also, Factor A should be set at Level 1 and Factor B at Level 2 in order to minimize variability. Consolidating the two results, we found that setting Factor A (water content) at Level 1 (0.9 gallons) and Factor B (air curing) at Level 2 (1.1 gallons) results in a concrete design that not only shows good compression strength, but least variability of the same. In this process, quality has been designed into the product during the concrete design stage. Western experimental designs have focused traditionally on identifying factor levels that optimize the response values. Taguchi extended this idea by applying experimental designs for identifying factor settings that minimize product variations. Fundamental Taguchi methods can be introduced into the manufacturing curriculum, and two possible experiments are outlined below.

Experiment 1: Machining

A key objective in teaching machining operations is students' understanding the importance of machining parameters—speed rate, feed rate, and depth of cut on the quality of the finished product. These parameters are normally listed in machinists' handbooks. However, many industries now deal with materials such as polymers, titanium alloys, and special steels—classes of materials for which parameter data are not readily available. Therefore, it is a very realistic to expect practicing manufacturing technologists to plan experiments to determine parameters that optimize a quality characteristic such as surface finish for these materials.

The specifics of the experiment are (a) *controlled variables*: speed, feed, and depth of cut; and (b) *measured response*: surface finish.

Experiment 2: Injection Molding

The quality of an injection-molded product may be determined by measured quantities such as wall thickness or by attribute-type quantities such as presence of air bubbles and other blemishes. The parameters of the process in this case may include melt temperature, mold temperature, and cure time. Thus, experiments could be conducted to determine optimum process parameters so that a consistent product is obtained. The specifics of the experiment are (a) *controlled variables*: melt temperature, mold temperature, and cure time; and (b) *measured response*: critical wall thickness.

Properly applied, the Taguchi system yields optimum product and process levels that lead to a robust product. Since the procedure identifies these levels during the design stage, it not only lends itself to development of robust products but it is also cost effective and decreases development cycle time.

Hopefully, students and faculty will be encouraged to apply and build upon the fundamental experiments described here. The Taguchi system, experimental design concepts, testing, collection of data, and statistical analysis of data ought to be vital parts of production courses. More advanced work in this area along with other related QA methodologies such as TQM and ISO 9000 are suitable candidates for a second senior-level or graduate class in QA.

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2. Preparing Industrial Technology Students for the Impact of the Americans with Disabilities Act

by Kenneth W. Stier

Approximately 48 million people in the United States have one or more physical or mental disabilities (Donaldson, Helmstetter, Donaldson, & West, 1994). This number is expected to grow in the future. People with disabilities represent a significant portion of the population of this country and deserve every opportunity to achieve their full potential.

Historically, the disabled have not had the opportunities that are available to them today. Gautschi (1992) stated that people with physical and mental disabilities were "isolated, segregated, and discriminated against in employment, housing, public accommodations, education, transportation, communication, recreation, health services, voting, and public services" (p. 154).

In 1990 President Bush signed into law the Americans with Disabilities Act (ADA), written to provide equal opportunities to individuals with disabilities. The law took effect on July 26, 1992, for businesses with more than 24 employees. Those with 15 to 24 employees had to comply by July 26, 1994 (Hubbartt, 1991).

Definition

As more research is conducted, new disabilities emerge while others are removed from this classification (Thompson et al., 1994). The ADA defined the term *disability* as "a physical or mental impairment that substantially limits one or more of the major life functions" (Gautschi, 1992, p. 154). According to Gautschi (1992) and Kinsella (1992), this definition would include the wheelchair bound, asthmatic, diabetic, epileptic, manic depressive, dyslexic, HIV-infected, deaf, blind, cancer infected, heart diseased, learning disabled, and rehabilitated drug users. According to Kinsella, individuals with emotional or psychological disorders or mental retardation would also be covered under this definition.

At first glance it would appear that the ADA is all inclusive. However, there are some exceptions that allow employers to circumvent the mandates of the ADA. These exceptions only apply where the employer could show that significant difficulty or expense is involved in order to accommodate the disabled person. According to Gautschi (1992), these include such things as "the nature and cost of the accommodation, the financial resources of the facility, the impact on operations, and the number of employees" (p. 154).

IMPACT OF THE ADA

Thompson, Thomas, and Fernandez (1994) pointed out that one of the most significant aspects of the ADA legislation was that it removed barriers that excluded the disabled from aspects of our society. They quoted President Bush