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PROMOTING 'DESIGN OF EXPERIMENT' TECHNIQUES TO MANUFACTURING INDUSTRY IN MALAYSIA VIA THE WORLD WIDE WEB

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ABSTRACT

Acceptance of the usefulness of modern statistical methods in quality improvement initiatives is growing among engineering and management personnel in the manufacturing industry in Malaysia and elsewhere. Among the contributing factors are the use of quality as a competitive instrument and the introduction of the ISO 9000 Quality Management Systems by the International Organization for Standardization. Among the most powerful of modern statistical methods for quality improvement purposes are 'Design of Experiment' (DOE) techniques. When used for designing and conducting experiments involving multiple variables of a process or system, DOE enables joint effects of the variables; this being often the major cause of quality problems, to be assessed. Yet, the use of such methods among technical personnel in manufacturing companies in Malaysia, as highlighted by a survey of 650 randomly selected manufacturing companies [1] is low. The lack of knowledge on how to apply DOE was cited by the survey respondents as one of the main reasons for their lack of use of DOE. In order to address the latter, practical information on DOE have been placed on the World Wide Web (www1.eng.usm.my/ee/acad/zalina) to allow quick access to them by manufacturing companies. In this paper, the policy that was used for developing and testing the material for the Web site will be described, as well as the response that have been obtained from manufacturing companies towards the above endeavor.

Keywords: *Statistical methods, Design of Experiment techniques, quality improvement, manufacturing industry in Malaysia, World Wide Web*

(1) INTRODUCTION

Quality improvement initiatives in the manufacturing industry in Malaysia and elsewhere encompass a wide range of activities including the use of experimentation in order to gain information about a process or a system. The traditional approach of experimentation is the one-variable-at-a-time approach (henceforth referred to as OVAT) in which one variable is varied while all other variables that could also affect the performance of the process or system are held fixed at some reasonable values. This process is then repeated for each of the other variables.

An alternative approach of experimentation, which is based on statistical principles, is known as design of experiments (henceforth referred to as DOE). In DOE, the variables are varied simultaneously in pre-determined combinations. Compared to OVAT, DOE involves a smaller number of runs, thereby reducing the cost and amount of time required for the experiment.

The conclusions obtained from DOE are also more accurate since OVAT may cause you to miss the best settings if the variables interact, that is if the effect of a variable on the performance of a process or system depends on the setting of another variable(s). The data obtained from DOE can be analyzed using statistical methods in order to obtain objective conclusions.

A review of the literature shows that DOE has been used in the manufacturing industries in the West and in Japan for not only troubleshooting manufacturing problems but also for determining the critical variables in the process or system (either an existing one or one that is about to be developed) and the best settings for such variables [2-3]. For instance, in [2], an experiment was performed in a semiconductor manufacturing plant using DOE to search for processing conditions that would minimize the variability in the oxide thickness of the wafers while taking the mean oxide thickness to its target value of 200 Angstrom. Based on the results of twelve runs, the manufacturer was able to determine that both of the above criteria could be achieved with the following processing conditions; high level of hydrogen flow, low level of hydrogen to oxygen ratio, and heat plug on.

In Malaysia, the utilization of DOE among manufacturing companies is low as shown by the results of a random survey of 650 manufacturing companies in Malaysia [1]. Only 15% of the survey respondents use DOE. The lack of awareness of the benefits and advantages of the DOE approach of experimentation as well as the lack of knowledge on how to apply DOE was cited by the respondents as the major reasons for the low use of DOE.

In order to help eliminate such problems, practical information on DOE has been placed on the World Wide Web to allow vast access to the information by manufacturing companies in Malaysia. The subsequent section presents the policy that was used for developing and testing the Web site.

(2) GENERAL WORK POLICY

DOE is actually made up of a wide collection of techniques, ranging form techniques involving only one variable to those involving multiple variables. For companies who are about to use DOE for the very first time, selecting the most appropriate techniques can be a daunting task. In order to identify which DOE techniques are relevant to those companies in Malaysia who are about to embark on the use of DOE for the very first time, it was decided that in-depth discussions be held with several manufacturing companies in Malaysia. One such company was BCM Electronics Sdn. Bhd; a 100% Malaysian-owned electronic company.

A total of three months was spent at BCM, during which time the DOE techniques that would be relevant to the company were investigated. Among the DOE techniques that were identified as being relevant were 'factorial designs' and 'fractional factorial designs'. Information on these two DOE techniques was included in the Web site.

The areas to which DOE techniques are applicable in manufacturing companies were also identified during the discussion sessions with the companies. For the case of BCM, the surface mount technology (SMT) process was identified as one of the possible areas.

The next step was to form a team, comprising of the relevant company personnel and the researcher, in the companies in order to go over the actual mechanics of applying DOE. For the case of BCM, the team was made up of production engineers, QA engineers, QA manager, and the researcher. The details of the discussions and subsequent work that was carried out at BCM and other companies were then included in the Web site as case study material. The Web site case study material on BCM is reproduced in Figure 1.

The Web site material was tested among 50 manufacturing companies which had agreed to provide feedback on the material. The feedback that was obtained was used to revise the material. For instance, a flowchart was created in order to enable the readers of the Web site determine the sections that were relevant to them.

(3) CONCLUSIONS

On the whole, the feedback from the manufacturing companies that participated in the testing phase of the Web site indicates that the information in the Web site can be easily understood and is relevant to the manufacturing companies. We hope to include more case studies from the manufacturing companies in Malaysia as part of our on-going effort to improve the Web site.

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Fig.1 *Case Study from BCM Electronics*

We will now describe the work which we have carried out at a manufacturing company in Malaysia; BCM Electronics Corporation Sdn. Bhd.. The latter is a locally-owned electronic company with plants in Pulau Pinang. It was established in 1993 due to an agreement between Motorola (Malaysia) Sdn. Bhd. and the Malaysian government as part of a request by the Malaysian government on the need to transfer technology to Malaysians. Telecommunication products are its main products such as surface mount technology (SMT) circuit boards, printed circuit boards, Motorola speakers and microphones, hand-held control heads, modems, etc. Europe and the United States of America are its main markets.

Among the DOE techniques which we identified as being relevant to BCM during our three-month stay are factorial designs and fractional factorial designs. When there are many variables, say m, full factorial designs would need many runs, and would therefore not be feasible. For instance, if each of the variables is at two levels, the number of runs needed is 2^m . Fortunately, the essential information can usually be obtained by carrying out only some of the runs. A suitable choice of runs is known as fractional factorial designs. With the help of BCM's senior QA manager, we identified the SMT process as one of the possible areas for the application of these two techniques. Basically, this process is made up of the following four sub-areas; screen printing, glue dispensing, chip mounting, and reflow curing. We decided to focus first on screen printing since this is the first and most critical of the four sub-areas.

A quality problem that can occur at screen printing is excessive variability in the height of the solder paste deposits. Not only can this occur from site to site on each solder pad, but also from solder pad to solder pad on each circuit board, and from circuit board to circuit board in each lot. Besides wanting to minimize the variability, the company would also like the solder height to be at the nominal specification limit. A team was formed, comprising of SMT production engineers, QA engineers, QA section manager and us. The objective of the team was to go over the actual mechanics of applying the DOE techniques of factorial designs and fractional factorial designs to screen printing. The first step was to use brainstorming technique in order to identify the variables that could affect the solder height such as squeegee speed, squeegee pressure, stencil thickness, etc.

The questions that were of interest to the team members were then formulated as follows: which identified variables were the ones that actually affected the height, what should their settings be, and what action(s) should be taken based on the answers to the first two questions. Among the things that were then discussed were the range of acceptable values for each of the identified variables, the number of runs to perform, the details of each of the runs, the number of circuit boards to use for each of the runs, the location of the solder pads on the circuit boards and the location of the sites on the solder pads for taking the solder height measurements. The repeatability of the solder height measuring instrument was also investigated.

Training sessions on how to plan experiments using the above designs, and how to analyze the results of the experiments using both graphical and statistical methods were then held for the company's engineers and managers. The training sessions also included the use of Taguchi Methods; which is a modified form of fractional factorial designs.

After the training sessions, the team used a DOE technique known as a full 2^4 factorial design on the screen printing process. Four variables; squeegee speed, squeegee pressure, snap value, and movement type, were investigated using 16 runs. The first three variables were varied over two different levels; a low level and a high level. Two movement types; the forward and backwards movement, were used. All other variables were held fixed at a particular level. For each of the runs, the height of the solder paste deposits was measured from three circuit boards, and at 10 randomly selected sites on each board. This resulted in a total of 30 solder height measurements for each individual run.

The mean and standard deviation of the 30 measurements from each of the 16 runs were analyzed using graphical and formal statistical methods. The variables that were found to have a great influence on the mean of the solder heights were snap value, squeegee speed and the interaction between snap value and squeegee pressure. Variability in the solder height was greatly influenced by movement type. In order to obtain the required solder height value (i.e. solder height near the nominal specification limit) with minimal variability, the following settings were recommended based on the analyses; high level of squeegee speed, high level of squeegee pressure, low level of snap value, and forward movement type. The next step is to conduct a few runs using the recommended settings.