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A Project Based Approach To Doe In Materials

Abstract

At Iowa State University, the Materials Science and Engineering Department teaches a course in the statistics of materials. Approximately one third of this two credit course is devoted to the design of experiments (DOE). A relatively brief introduction to the theory of DOE sets the stage for the inclusion of a software package used to assist materials engineers to design and analyze the results of experiments.

Texts for engineering statistics (1-3) contain chapters dealing with the design of experiments. Literature in materials journals routinely contains references to DOE (4-8). Coupling these texts and recent articles with some practical exposure to design of experiments and the software used to do this, allows students some exposure to industrial practice. In this course students are assigned a major project (20 % of the grade) to be performed in teams. In this project students are encouraged to draw from their co-op and internship experiences. They are also asked to consider to expand upon experiments encountered in other courses in the curriculum.

Disciplines

Curriculum and Instruction | Engineering Education | Other Materials Science and Engineering | Science and Mathematics Education

Comments

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A Project-Based Approach to DOE in Materials

Lawrence J. Genalo
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1. Introduction

At Iowa State University, the Materials Science and Engineering Department teaches a course in the statistics of materials. Approximately one third of this two credit course is devoted to the design of experiments (DOE). A relatively brief introduction to the theory of DOE sets the stage for the inclusion of a software package used to assist materials engineers to design and analyze the results of experiments.

Texts for engineering statistics (1-3) contain chapters dealing with the design of experiments. Literature in materials journals routinely contains references to DOE (4-8). Coupling these texts and recent articles with some practical exposure to design of experiments and the software used to do this, allows students some exposure to industrial practice. In this course students are assigned a major project (20 % of the grade) to be performed in teams. In this project students are encouraged to draw from their co-op and internship experiences. They are also asked to consider to expand upon experiments encountered in other courses in the curriculum.

2. Desired Learning Outcomes

Some of the learning objectives for this course are for students to be able to...

1. Choose control variable settings to design experiments that improve the likelihood of finding statistically significant results which improve the performance of a material or system.
2. Conduct experiments, gather data, analyze data, and report on the experiment.
3. Present oral and written reports on an experiment designed, run, and analyzed by teams of students.
4. Function in teams.

These objectives are being met through the use of a project-based approach to learning design of experiments (DOE). The project, which counts for 20 % of the student's grade, is performed in teams of 3 or 4 students. Students are required to choose a materials-related, multi-factor experiment and then design, run, and analyze the results of this experiment. They submit a brief project proposal and then report on the results through a 10 minute oral presentation and a 10 page paper. They are encouraged to choose topics from their industrial or national lab co-ops and internships. Those students who haven't had such experiences yet (97 % of our graduates do), are encouraged to partner with others who have or choose a topic related to another materials course they

have taken.

The students are given guidelines for the written report and oral presentation and are graded on presentation as well as content.

3. Course Description

In addition to the DOE portion of this course, “traditional” introductory engineering statistics topics are covered. Introductory probability, random variables, probability plots, confidence intervals, linear regression, and control charts are covered with greater emphasis on doing and usage than on the theory. Significant use of computing tools such as Excel and Minitab is employed.

Students are assigned to work in collaborative teams for the semester. These teams are not the same teams as the self-selected project teams. The project teams are self-selected because some of the students have done co-ops at the same company and naturally choose to work together. The collaborative teams have weekly meetings to discuss course topics and solve homework problems.

The software used in design of experiments is CARD, Computer Aided Research and Development, from S-Matrix Corporation. Besides the usual Users Manual, this package comes with a Tutorial Manual to accompany a guided tour through three experiments. The software is divided into the pre-experiment stage, where the user designs the experiment to be run, and the post-experiment stage, where the user analyzes the data from the experiment. The tutorials cover both portions of this process with materials-related experiments and have proved very useful in getting new users going. An excellent, brief text is also available from S-Matrix (9) which covers the theory in concrete terms that engineering students appreciate. A student-run, departmental computer room has copies of the manuals and software for CARD, as well as the other software used in this course. This room itself promotes the teamwork desired in this and other engineering courses.

A graduate assistant has been used in this course to act as a mock engineering supervisor looking for an answer to a company problem which requires the design, execution, and analysis of an experiment. He presents each collaborative team with a “company memo” outlining the problem and their responsibilities in solving it. The first assignment is for the team to present their design for the experiment. After some discussion a second memo is sent to them with the raw data (simulated) from their design and they are asked to analyze the data and draw conclusions.

4. Sample Student Projects

Two types of project assignments are used to help students learn statistical design of experiments as applied to materials problems. Short term, more specified project assignments that ask students to design an experiment and, later, to analyze the data from this experiment make use of CARD software. Long term projects of their own choosing

as described above are the second type of project assignment. In addition, the final exam has a take-home portion which is devoted to the design and analysis of an experiment.

In the short term project, a simulated memo from the students' "work supervisor" asks them to design an experiment, for example, to test for the appropriate mixture to maximum ionic conductivity in thioborate glass consisting of B_2S_3 modified with Ag_2S and Na_2S . This glass is to be used in high capacity rechargeable batteries in place of crystalline materials that degrade each time the battery is charged. Since the cost of running the experiments is important, a design that keeps costs under control during the testing is being sought.

Students create a design for this experiment using CARD. They enter the mixture parameters and their desired ranges and make design selections leading toward the final design. After creating the design they are given simulated data for their design and asked to analyze it. This is their first experience with the package after looking at the on-line tutorials.

After this experience they are able to use CARD to design and analyze their own experiments from their term-long projects. Student projects have included experiments that they devised and ran locally such as mechanical analysis for confectionery problems using Griffith's theory, brittle fracture of soda lime silicate glass, and Rockwell hardness testing on knife blades. Others have been the outcome of co-ops and internships in industry. A project with Guardian Glass was entitled "Analysis of Possible Factors Affecting Glass Temperature" and tried to help find a correlation between the crown temperature in the glass furnace and the temperature of the glass before it enters the tin bath. The best correlation was found with the back-wall optical temperature (see Figure

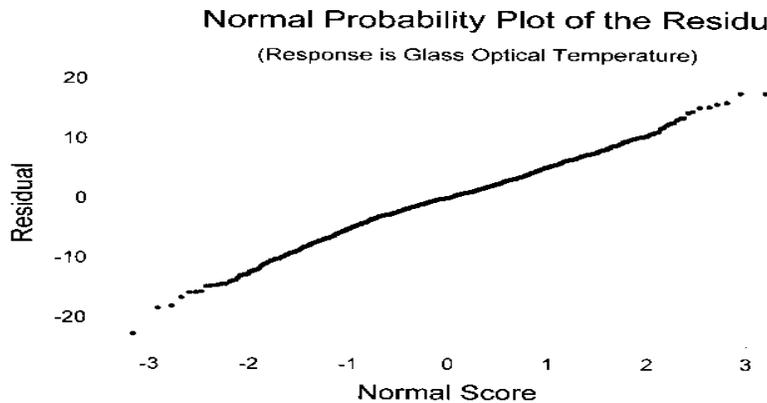


Figure B-4: Residual Plot of the Normal Score

1).

Figure 1 : Normal Probability Plot, Guardian Glass Project

Another involved finding the grain size for gas atomized aluminum powder and grew out of an internship at Ames Lab. A third project, in collaboration with a co-op at Kohler Co., investigated viscosity and drain in measuring the thickness of slip. Figure 2 shows the first page of the data recording sheets that were developed using CARD to design an experiment consisting of 13 runs.

DESIGN GENERATOR DOCUMENT			Planner:	MSE
Design Sub-Type:			Company:	Iowa State University
Comprehensive			Date:	04/02/97
			Design Type:	S-Matrix Mixture & Process
			Plan Name:	Plan 013

Remarks:	Sample Preparer:			
	Preparation Date:			
	Start Time:			
	End Time:			
	Sample No. Start:			
	Sample No. End:			

SAMPLE PREPARATION WORKSHEET		
Sample No.	water (g)	105 (g)
#1	15	450
#2	15	450
#3	5	450
#4	10	300
#5	0	150
#6	0	450
#7	15	0
#8	5	0
#9	0	0
#10	15	0

Figure 2 : Data Recording Sheet, Kohler Project

A final example of a student project in this course involved a comparison of three microelectronic interconnect methods used on circuit boards at Rockwell. This project grew from a co-op and was used not only in this statistics course, but as a follow-up project in senior, capstone design. Figure 3 shows the rate of failure for the boards. The testing involved hundreds of chips and 30 different boards.

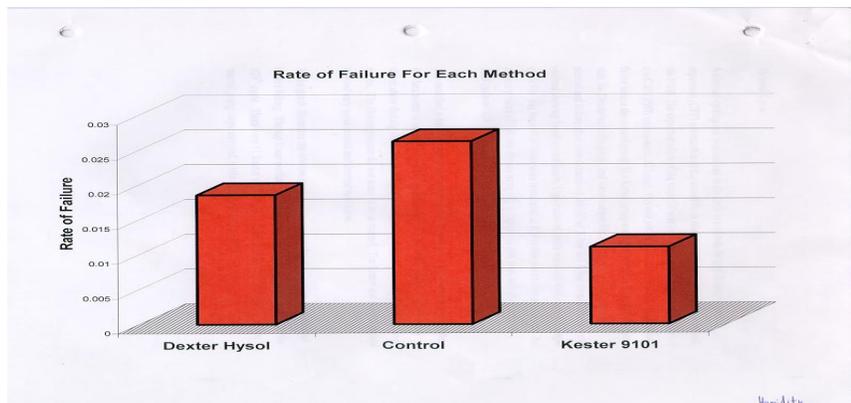


Figure 3 : Failure Rates, Rockwell Project

Another experience with the software package takes place as part of a take-home final. The students are asked to find the maximum strength glue for a polymeric mixture of three compounds. Figure 4 shows one of the graphs that a student printed to show the strength as a function of two of the polymeric compounds. Figure 5 shows the optimal values found for mixing.

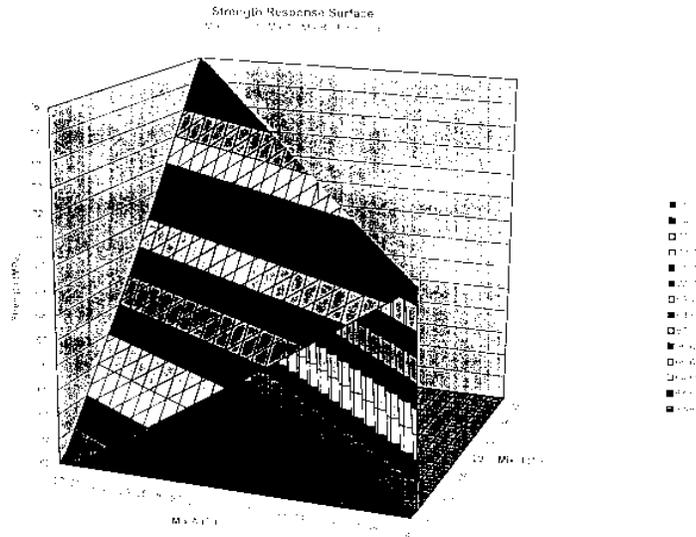


Figure 4 : Glue strength as a function of mixtures A and B

Response Model Data

Response Name	Starting Point Predicted Response	Optimizer Answer Predicted Response	Lower 95% Confidence Limit	Upper 95% Confidence Limit
Strength	46.9645768	78.10454688	27.86601862	207.8482013

Independent Variable Data

Variable Name	Starting Point Level Setting	Optimizer Answer / User Input Level Setting
Mix A (X1)	23.33333333	20
Mix B (X2)	33.33333333	40
Mix C (X3)	43.33333333	40
Time (X4)	15	36.45881894

Variable Combination Restrictions

Restriction Name	Level Setting
Mixture	100

Figure 5 : Maximum strength mixture

5. Conclusions

Students' responses on end-of-term course evaluations suggest that students feel they are getting a valuable learning experience with this project-based approach to DOE. Those students who have been in the co-op program beforehand recognize this immediately and others learn to appreciate it later when they co-op or interview for jobs. The desired learning outcomes are being met in this course and they are adding to the final outcomes as prescribed by EC2000.

As our department moves toward a single degree in Materials Engineering (formerly degrees were offered in Ceramic and Metallurgical Engineering), this course will expand to a three credit course including other computational tools for materials. In particular, finite differencing and finite elements are to be added. The course will maintain its emphasis on industrially related projects, teamwork, and computational applications.

1. Introduction to Probability and Statistics for Scientists and Engineers, Rosenkrantz, McGraw-Hill, 1997.
2. Statistics for Engineering Problem Solving, Vardeman, PWS, 1994.
3. Probability and Statistics for Engineering and the Sciences, 4th Ed., Devore, Wadsworth, 1995.
4. "Improving durability of gold decoration," Ceramic Industry, October, 1996, pp26-28.
5. "Optimized Backgrind Wafer Process Minimizes Stress Effects," Semiconductor International, October, 1996, pp221-226.
6. "Statistical Process Control for Semiconductor Metrology Systems," Semiconductor International, October, 1996, pp167-172.
7. "The New Mantra: MVT," Forbes, March 11, 1996.
8. "Multivariable testing increases output for clay company," Ceramic Industry, November, 1996.
9. Designed Experiments and Information, Verseput, S-Matrix Corporation, 1997.

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