Optimization of Paint Formulations with the Taguchi Method.

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Thursday 1st February 2007

Content Overview

Introduction RvD and Duvaro
Research Methodologies
Introduction to Taguchi Method
Example
Discussion

Introduction Drs. Rogier van Duin

1989 : M.Sc. Physical Chemistry
1989 : Philips, NL
1991 : DSM Resins, NL
1994 : ICI Packaging Coatings, D
2001 : Valspar, CH
2004 : Stahl, NL
2007 : Duvaro, NL
Introduction Duvaro

Products and Services DUVARO

• Business Solutions, Due Diligence
• New Product Development & Innovation
• Human Resource Management
• Career Development & Coaching
• Interim Management
• Product Stewardship: REACH
• Industrial and Technical Marketing

Research Methodologies

High Throughput Formulation Techniques

Whom of you are familiar with:

Trial and Error?
One Factor at the Time?
Full or Fractional Factorial Design?
Taguchi?
Classically R&D work with coatings involves a fair amount of:

- trial & error experimentation,
- empirical techniques,
- and “black-box” approaches to interpret results.

“Panic Mode”

**Trial & Error** experimentation

Based upon knowledge, just give it a shot…

- Fast result
- Frustration
- Poor Understanding
- Low Chance of finding Optimum
- Accepting (temporary) solution

The classical view of experimentation is to change one factor at a time, run the experiment, observe the results, and move on to the next factor.

This approach has several drawbacks:

- It takes much longer and
- uses up more resources;
- the optimum combination of all variables may never be revealed;
- and the interaction between factors may never be revealed.
Research approaches Simplex method

More structured, danger of sub optimization

Research approaches RSM
Response Surface Method

Choose hypothetical model

FIGURA A. Otimização da adição de glúten a dieta em crianças de baixo peso

Research approaches full factorial

Choose hypothetical model

DOE versus Taguchi

Design of Experiments

3 variables at 2 levels: $2^3 = 8$ experiments

Taguchi made a significant contribution by adopting traditional factorial orthogonal arrays to experimental design so that time and cost of experimentation are reduced while validity and reproducibility are maintained.

Taguchi

7 variables at 2 levels: 8 experiments!

With same effort more information; efficient!

DOE versus Taguchi

A classical $2^3$ design to investigate the effects of factors A, B, and C, and also the 3 associated two way interactions, and the single three way interaction.

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<tr>
<th>Classical $2^3$ Design</th>
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Taguchi $L_8$ Array

A Taguchi $L_8$ array, to investigate the effects of up to 7 factors in 8 runs. This corresponds to the same classical design above.

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<th>Taguchi $L_8$ Array</th>
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Unlike classical experimentation, Taguchi experiments can provide the following benefits:

- Many factors can be examined simultaneously.
- Some input factors that cannot be controlled, which are called noise factors, can influence the output; however, other input factors can then be controlled to reduce the effect of the “noise.”
- In-depth statistical knowledge is not necessary to perform these tests and reap their benefits.
- Relatively few experiments can look at a large number of factors and separate the trivial from the important.
- In most cases, quality and reliability can be improved without increasing costs.
Dr. W.E. Deming once said: “Any technique is useful as long as the user understands its limitations”.

Dr. Genichi Taguchi

Born in Japan, 1924

Credited for starting the “Robust Design” movement in Japan in 1950s.

In 1964 he became professor of engineering at Aoyama Gakuin University, Tokyo.

In the eighties and nineties, he introduced Taguchi method to Bell Labs, Ford Motor Company, Xerox and AT&T.

Collaboration with Yuen Wu and Madhav Phadke.

Since 1982 Taguchi has been an advisor to the Japanese Standards Institute and executive director of the American Supplier Institute, an international consulting organization.
The Taguchi method grabs a quality problem by the throat. It goes directly to the basic physics and thermodynamics of whatever's causing trouble, and solves the problem during the early design phase.

Cost increases when defect is passed along supply chain

Development Stages in Taguchi

- Innovation
- Creativity
- Robust Design
- Cost Reduction
- Reduce Variability

- System Design
- Parameter Design
- Tolerance Design

Generating and pre-selection of new ideas, concept and free scoping.

Concept: control, signal and noise factors optimization. Parameter Design experiments should be conducted with low-cost alternatives to present design settings.

Which tolerance to tighten.

Where do you think lie the partition in % for above design phases in the West compared to the East?
"Six sigma yields parts that meet specs, while Taguchi produces parts that avoid failure. The six-sigma process is okay, but the Taguchi method is more robust both in its logic and its methodology."

**Taguchi Quality Loss Function**

Classical: black / white approach

Quality Loss = Loss to Society quantified through "Quality Loss Function"

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Taguchi: dealing with Interactions

Orthogonal Designs

- Classical
- Taguchi

Taguchi: Factors are preferred above interactions.

Reason: in many cases one or more interactions are forgotten.

Recommendation: Screening designs, interactions are leveled out over all factors.
Taguchi L12 screening design

As many factors as possible should be identified to enhance improvement potential. Control factors are usually tested at two or three levels in orthogonal array experiments.

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High Throughput Formulation Techniques

Statisticians comment:

Taguchi assumes most interactions are small and those that aren't are known ahead of time.

He claims that it is possible to eliminate these interactions either by correctly specifying the response and design factors or by using a sliding setting approach to those factor levels.

These designs are very useful for economically detecting large main effects, assuming all interactions are negligible when compared with the few important main effects.

What experts say about Taguchi

<table>
<thead>
<tr>
<th>Interactions</th>
<th>Classic</th>
<th>Taguchi</th>
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<tbody>
<tr>
<td>Preference at Strong Interactions</td>
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What experts say about Taguchi

My comment:
Taguchi very user friendly;

- It doesn’t require lots of statistical knowledge.
- The design can be tailor-made upon your specific situation.
- Robustness by simulating noise.
- Especially with new technology no “blockage of experience.”
- Fast and reliable, consistent results.

In over 500 Taguchi experiments more than 2/3 were successful in either generating knowledge or solving the problem / generating a new product.

Example

Yellowing Hot Melt

Problem:
Existing combination of anti oxidants do not prevent Hot Melt from yellowing (In the dark).

System uses following combinations of anti-oxidants:
- Primary Anti Oxidant (pAO)
- Secondary Anti Oxidant (sAO)
- Hindered Amine Light Stabilisator (HALS)

- pAO + sAO
- pAO + sAO + HALS
- pAO + HALS

Maximum Dose
- pAO: 0.1%
- sAO: 0.2%
- HALS: 0.1%
Yellowing Hot Melt

Solution:
Use for the combinations an empty level in the factor.

Primary Anti Oxidant (pAO)
pAO1, pAO2, pAO3, pAO4 \( df=3 \)

Secondary Anti Oxidant (sAO)
sAO1(empty), sAO2, sAO3, sAO4 \( df=3 \)

Hindered Amine Light Stabilisator (HALS)
HALS1(empty), HALS2, HALS3, HALS4 \( df=3 \)

Dose Level 1 Level 2
pAO: 0.025% 0.075%
sAO: 0.05% 0.15%
HALS: 0.025% 0.075%

200 Hazen = 1 Gardner

Number of experiments: 2 x 16 + 2 confirmation runs of the PC.
Epilogue (1):

By solving the yellowing problem on short notice, the customer could be re-supplied without line-stop.

The new anti-oxidation system is not only more effective, but also less expensive.

The yellowing decreased by a factor 5 – 10, depending on the binder system.

Within a short period an enormous knowledge build up had taken place.

Commitment through all company layers; especially Marketing & Sales – Research & Development.
Epilogue (2):
The binder system became more stable in production (less variation; more ROBUST Taguchi would call it). This significant improvement revolved a potential claim into increased business. Total time invested: approx. 60 hours = 4.5k€. The Taguchi experiment delivered 500k€.

After the paper champion, a second smaller experimental design was set up, which led to the discovery of another important factor. Which originally was hiding in the “noise”.

After ½ year the turn-over sharply rose to access to new, higher quality demanding markets.

Questions?