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EMPLOYING THE TECHNIQUE OF EXPERIMENTAL PLANS FOR A WIND BLADE DESIGN

BY

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Abstract. This paper presents the mains parameters values for an analyze employing an experimental plans technique according to the Taguchi method of experimental plans.

Keywords: experimental plans; wind blade; Taguchi method; design; cost.

1. Introduction

The competitiveness of industrial products is mainly based on criteria of cost, quality, innovation and availability. Until a few years ago, in a context characterized by a uncertainly growing market, industry was the main way to reduce production costs.

Today, the world market is experiencing a new phase of growth and technological processes once considered alternative or unconventional are being used extensively in the field of making new products.

Businesses are looking to reduce costs but at the same time improve product quality, all while reducing lead times. However, factors such as quality, cost, delivery time are often in conflict. It is very important to optimize the

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mentioned factors to ensure a high customer satisfaction, but also an increase in profit. This means ensuring a detailed study before the start of the design phase, in order to eliminate the problems that may occur throughout the life of the product (design, execution, operation, recycling).

2. The Technique of Experimental Plans. How to Use it for a Wind Turbine Blade Design

The technique of experimental plans today stimulates and keen interest in the industry; this allows the companies a test campaign as economically as possible, having the aim to optimize a product and / or a manufacturing process, thus responding to a mature and highly competitive industry, whose concerns are to point, as soon as possible, the products and manufacturing processes that allow to reach the required level of quality, with a minimum cost (Antony *et al*., 2013).

A process is well known only through experimentation because theoretical models are created on the basis of simplifying hypotheses, which lead to the emergence of deviations from reality.

The methodology of scientific programming of experiments, modeling and model testing, contributes to the improvement of design and manufacturing processes. The need for experimental research is given by the answers that must be given to a series of problems that arise when developing a process or product.

The technique of experimental plans can be applied to all technical problems: to optimize the design of the product (process), to investigate and understand as accurately as possible a phenomenon or to implement a test procedure.

To solve these problems using the method of experience plans, it must be formalized in the form of a system. The objective of the method is to quantify with maximum accuracy, but with a minimum number of tests, the effect of several parameters on one or more of the answers.

In this experiment, the following objectives will be pursued:

a) Determining the influence of the parameters involved in the deformation of a wind turbine type part;

b) Establishing the interaction between the parameters;

c) Establishing a mathematical model that expresses the effects of the input parameters and of the interactions between them on the studied quantities.

The collection of experimental data involves the following steps:

1. Establishing with the help of the Solid Works program the values of the researched parameters;
2. Establishing the values of the pressure exerted on a surface, so that it does not deform plastically;
3. Establishing the area where the pressure will be exerted;
4. Establishing the values of the elements for making the mash;
5. Determining the value of materials that can be used.

3. Selection of Parameters and Values that Can Be Tested when Designing a Wind Turbine Blade

Genichi Taguchi worked in the field of quality and developed a method known as the "Taguchi Method". This allows controlling the quality of product design.

Taguchi's method allows the study of only a small number of experiments. This is an important advantage in practice, if we consider that we could have reduced the number of attempts and we would have the certainty that the result obtained using this method does not differ from the one obtained by the classical method of complete experience plans.

When performing an experiment, not all factors are so easy to change. Some of them require special operations that are sometimes very difficult to perform (Titu *et al*., 2018).

In this case, the factors that can be easily modified will be changed at each experiment, on the contrary those that are difficult to modify will be changed only once during the experiments if possible.

Out of all the parameters that could influence the response size for designing a wind turbine blade, 5 parameters were retained for experimentation, each of them being tested at three different levels of values (Ibrahim *et al*., 2009; Datta *et al*., 2008). We specify that, due to the technical conditions at the time of the tests, conditions were established such as:

a) The type of material will be characterized by its density in kg/m^3, so that materials with the hardnesses indicated in the table below were used as materials. We searched materials that can be printed on a 3D printing machine (Table 1).

Table 1
Type of Material

Type of material	ABS	PA6	Delrin 2700
Density [kg/m^3]	1020	1120	1410

b) The mesh elements will be characterized by quantity of mesh elements that are included in a circle (Table 2).

Table 2
Mesh Elements

Mesh elements	Level 1	Level 2	Level 3
Qty	3	6	9

c) The pressure that is applied on the exposed side to the wind. These pressures correspond to a wind factor of 50 km/h, 100 km/h and 150 km/h (Table 3).

Table 3
Pressure

Pressure	50 km/h	100 km/h	150 km/h
Pressure [N/m^2]	95	383	862

d) The structure types that are used in our experiment are a shell, a grid and a full volume part. The shell dimension is 1 mm in thickness. For the grid part, there are 5 elements orientated in 2 dimension with the width of 1 mm each (Table 4).

Table 4
Structure Type

Structure	Level 1	Level 2	Level 3
Type	shell	grid	full

e) Mesh dimension is oriented to the length of the mesh elements that are take into account (Table 5).

Table 5
Mesh Dimension

Mesh	Level 1	Level 2	Level 3
Dimension [mm]	1	3.5	6

How to build the appropriate experience plan? Mathematicians have focused on this question, which has a considerable practical importance, and have formulated criteria for optimality. These criteria give rise to a matrix, a new notion that we must define (Taguchi, 1978, 1981, 1987, 1989).

Each plan can be associated with a matrix composed of rows, one for each experiment and columns, and one for estimation (Bervian, 2018).

The question that arises is the following: are all the experiences of the factorial plan necessary to evaluate the evolution of the studied system?

This question aroused the interest of a significant number of researchers who wanted to develop fractional plans starting from a complete factorial plan that allow finding the coefficients of the model with much less experience.

Taguchi's experience plans are part of this type of fractal plans, only with an important advantage, the possibility to put these plans into practice thanks to tables that simplify the operator's work.

4. Conclusions

Building a fractional plan is not easy. It must fulfill a certain number of properties. These conditions are indispensable to be able to calculate the effects of a factor independent of the other factors starting from the results of the plan.

The first necessary but insufficient condition for the orthogonality of two disjoint actions (which have no common factors) is that at each level of one of them all the other levels of the other factor / action are associated with the same number of experience plans.

The orthogonality of an experimental plane determines that all disjoint actions of the model are orthogonal in the experimental plane.

A second condition necessary for establishing the orthogonality of two two-disjoint actions is the number of degrees of freedom of a model. It indicates the number of values that are needed to perform the calculation and to determine the set of model coefficients.

In order to be able to calculate the independent values, at least the independent values must be entered in the calculations. The values entered in the calculations are the tests performed. It is necessary to perform at least as many tests as the degree of freedom of the model.

It is therefore possible to estimate the quality of a plan a priori, before carrying out the planned tests.

Not long ago, the basic principle of experimentation was to “vary only one factor at a time”. The example of the weighing plan shows us that if this strategy is safe, “we know what we are doing”, then the results are mediocre.

It is more efficient to vary all the factors together according to certain rules that we have specified. As we will see, this principle applies, whatever the objective of the study: research of influencing factors, modeling or optimization.

REFERENCES

Antony J., Warwood S., Fernandes D., Rowlands H., *Process Optimization Using Taguchi Methods of Experimental Design*. *Work Study*, Asian Journal of Scientific Research, **6**, *1*, 27-37 (2013).

Bervian A., *Application of Taguchi Method to Study Morphological Evolution of TiO_2 Nanotubes Obtained via Anodization Process*, ISSN 1516-1439, *Mat. Res.*, 2018.

Datta S., Bandyopadhyay A., Kumar Pal P., *Grey-Based Taguchi Method for Optimization of Bead Geometry in Submerged Arc Bead-on-Plate Welding*, The International Journal of Advanced Manufacturing Technology, **39**, 1136-1143 (2008).

Ibrahim A., Al-Darrab I., Zahid A.K., Mohamed A.Z, Sheikh I.I., *Application of the Taguchi Method for Optimization of Parameters to Maximize Text Message Entering Performance of Mobile Phone Users*, International Journal of Quality & Reliability Management , ISSN: 0265-671X (2009).

Taguchi G., *Off-Line and On-line Quality Control System*, International Conference on Quality Control, Tokyo, 1978.

Taguchi G., *On-Line Quality Control During Production*, American Suplier Institute, S.U.A., 1981.

Taguchi G., *System of Experimental Design*, Unipub/Kraus International Publication, S.U.A., 1987.

Taguchi G., Elsayed A., Hsiang T., *Quality Engineering in Production System*, Mc Draw – Hill International, S.U.A., 1989.

Titu A.M., Sandu A.V., Pop A.B., Titu S., Ciungu T.C., *The Taguchi Method Application to Improve the Quality of a Sustainable Process*, IOP Conference Series: Materials Science and Engineering, **374**, Euroinvent ICIR, 2018 .

UTILIZAREA PLANURILOR EXPERIMENTALE PENTRU PROIECTAREA UNEI PALETE DE TURBINĂ EOLIANĂ

(Rezumat)

Această lucrare prezintă valorile parametrilor de bază pentru o analiză care utilizează o tehnică de planuri experimentale în conformitate cu metoda Taguchi a planurilor experimentale.