ADVANTAGES OF THE ORTHOGONAL ARRANGEMENTS OF THE METHOD TAGUCHI IN THE DESIGN OF EXPERIMENTS IN ERGONOMIC

Alois Fabiani-Bello[1], Humberto García-Castellanos[2], and Rosa M. Reyes[2]

[1]Programa de Doctorado en Ciencias de la Ingeniería (DOCI)
Universidad Autónoma de Ciudad Juárez
Ave. Del Charro 450N, C.P. 32190
Cd. Juárez, Chihuahua, México.
e-mail: fides.sde@gmail.com

[2]Departamento de Ingeniería Industrial
Instituto Tecnológico de Ciudad Juárez
Av. Tecnológico Nro. 1340
Cd. Juárez, Chihuahua, México.

Resumen: Los métodos estadísticos basados en la función Chi-Cuadrada son frecuentemente utilizados por los ergónomos y estas técnicas por su naturaleza no paramétrica usualmente requieren de una gran cantidad de datos experimentales con el correspondiente uso de recursos y contienen una importante dosis de subjetividad basada en la experiencia del experimentador. Las metodologías de experimentación podrían ser más rápidas y más económicas para tomar decisiones con la mejor información estadística posible utilizando técnicas apropiadas del Diseño de Experimentos. El autor Fabiani-Bello et.al. (Conergo, 2008) expone un método conceptual basado en simulación Monte Carlo y experimentos sin réplicas que fueron utilizados para planear la experimentación en ergonomía al categorizar la fatiga visual o astenopia. En base a la misma línea de trabajo Reyes-Martínez et.al. (Conergo, 2009) muestra los primeros resultados del método caracterizando la fatiga visual según publicaciones recientes dando a lugar la identificación clara de los factores que influyen en la astenopia y pone a prueba los métodos estadísticos tradicionales. Después de dos años de investigar las ventajas y limitaciones del método Taguchi en varias aplicaciones experimentales se propone en este artículo el método validado del diseño experimental basado en arreglos ortogonales del Método Taguchi que podría ser usado en los experimentos de la ergonomía donde, según el ajuste de niveles factoriales de diseño, es posible medir el impacto de estos arreglos en alguna variable de interés retomando las conclusiones obtenidas hasta la fecha sobre el tema.

Palabras Clave: Metodo Taguchi, Arreglos Ortogonales, Diseño de Experimentos

Abstract: The statistical methods based on the Chi-square of test (χ^2) are much used by the ergonomics and these need from a significant and big size of the sample with the corresponding use of resources and it contains an important dose of the subjectivity. Due to the cost of opportunity the methodologies must be more rapid in the treatment of the information, must be more economic and to take decisions with the best statistical information. Fabiani (2008) proposes a conceptual method based on simulation Monte Carlo that was used to plan the experimentation in ergonomics to the categorizer the visual fatigue. Based on the same line of work Reyes-Martínez et.al. (2009) it shows the first results of the method characterizing the visual fatigue as recent publications. The authoress identifies in a clear way the factors that influence the astenopia and it puts to test the statistical traditional methods. After two years of investigating the advantages and limitations of the method Taguchi in several experimental applications there is proposed in this article the validated method of the experimental design based on orthogonal arrangements of the Method Taguchi. The method that might be used in the experiments of the ergonomics where according to the level adjustment factorials of design it is possible to measure the impact of these arrangements in some variable of interest recapturing the conclusions obtained up to the date on the topic.

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Key words: Taguchi Methods, Orthogonal Array, Experimental Design.

1. INTRODUCTION

The visual system is one of the principal organs of the human being since 80% of the emotions are perceived across the sight. The sciences that study the system of the sight begin to be interested in the labor matters at the end of the XIXth century turning into a more and more specializing professional activity and into a world more industrialized (Reyes-Martinez et.al, 2005).

The new places and forms of work, the beginning of the automation and the systems of industrial production based on the competition for the quality (De la Vara, 2002) give place to a symptom that starts attracting attention of some specialists and especially of the companies because they realize that sometimes his workpeople can suffer a serious damage: The most common complaint, as for visual inconveniences, is vaguely described as " tired sight ". Other symptoms

indicate blurry sight or the difficulty to focus objects closely or of far, the unsteady vision and the double image. The headache is the most common general symptom, but not always it must be related to the visual weariness. Specifically, the symptoms of weariness or visual fatigue can be aggravated by diverse factors. On the other hand, the sight deteriorates gradually in the adults and this decrease is marked especially between 30 and 50 years (Reyes-Martinez et.al. 2005).

The system of vision of the human being perceives the reality across the eyes, by means of these the brain perceives the signs and processes them; these signs are received in an environment with lighting, the color, the moisture between others they generate changeability in the system of vision. With the time, the visual system deteriorates for the rhythm of industrial repetitive work. The signs of Visual Fatigue as the frequency of blinking might be abstracted as exits of the effort of the system to face his fatigue (Okada, 2002).

The relation between the Engineering of Quality and the Ergonomics is real because both want to improve the yield of a system, in the first case the experimentation has an important role in new products design, in developing manufacturing processes and in the improvement of processes and in the second case the characterization of factors so that the health is not damaged in the persons. With regard to the experimentation one of the most used methodologies and recognized for its efficiency is the one proposed by Dr. Genichi Taguchi. In Quality Engineering, it is mandatory to select the operative levels of the control factors that affect to critical characteristic of quality, and then abstracting the Visual Fatigue as a "characteristic of quality" it is necessary to minimize it.

2. METHODOLOGY FOR SELECTING THE PARAMETERS

To understand and to talk about the interaction between the persons and his environment implies respecting many methodological, statistical restrictions and even of anthropology; the experience says to us that these models that to the moment can be only theoretical, help to understand the behavior of the system more they do not allow to manipulate it. Our methodology is designed only for knowledge of relations cause - effect between the factors and the variable of exit of the

system. In this sense the method Taguchi for the prophecy of the output variable in the process is most adapted for our case; the process can be divided into five stages summarized in Table 1.

Table 1. Stages for the experimental design

No.	Stage	Activity Content
1	Preparation	1.1 Determine the experimental objective and target-characteristic values. 1.2 Determine whether it is worthwhile to carry out the experiment under the current conditions.
2.	Determination of factors and levels	2.1 List all factors that relate to the objective (more than 50) with a Focus Group 2.2 Select and determine factors and levels to be tested.
3.	Assignment	3.1 Assign factors and levels to the orthogonal array.
4.	Experiment	4.1 Eliminate the obstacles hindering the experiment. 4.2 To continued the process of randomized experimentation generating only an experimental reply. 4.3 With the simulation Monte Carlo all the possible outputs will be obtained
5.	Data analysis	5.1 To construct the correlogram and to interpret the coefficient of Pearson to characterize the incidental factors. 5.3 Determine the optimum condition and to confirm them with the existing norms in the legal environment of Occupational Health.

The sequence of the methodology and the recommendations of his application are based on the interpretation that the Dr. Teuro Mori does to the method Taguchi in his work titled originally " Taguchi Mesoddo or tsukatta yasashii shinjikken keikakuho nyumon " (1946).

2.1. Experimental Design Application: First and Second Stage – Preparation and Determination of factors y levels.

The target of the experimentation applied to the ergonomics will have to maximize or minimize an effect and it is clear that to maximize a variable sometimes implies minimizing his complement. The clear identification of the variable of exit of the interaction between the man and the system is important. The scope of the experiment is to know the factors that they affect in the awaited result and to arrange them according to his contribution to the changeability of the system.

At first more than 50 potential factors must be put in a list and to obtain this number it is necessary to ask medical specialists that have worked with the topic, it is key to confirm points of view of the participants and to assume a position based on the nature of the industry at which one is employed. The information will be better if it is investigated in the arbitrated publications, catalogues and tests previous.

Another key of the ergonomic experimental process is to classify the factors and to define the levels of the experimentation, for this activity it is necessary to identify clearly the class of factor (Mori, 1946). As well as to classify to the factors in the function to his relation with the studied effect and to avoid the strong interaction between them, this is important for the complexity of the system in study. We cannot experiment with all the factors but the target here is to consider all the important factors. In this stage of the experimentation the people can have different opinions, in such a situation, we do not have to classify rigorously the factors and that's why we make use of orthogonal series to confirm his effect.

After defining the factors, we determine his levels. The number of levels should be two, three, or four. The use of three levels is recommended in particular (G.Taguchi, 1986). The works of the theoretical investigation demonstrated that this type of level determination they generate quadratic’s terms in the model (Fabiani-Bello, 2008).

2.2. Experimental Design Application: Third Stage – Assignment.

It is known that the most usual criterion to select the experimental design is the reduction of the variance of the regression coefficients. The key element to select a design that diminishes the variance is the orthogonality concept used by Taguchi in experimental designs. In fact, the complete factorial designs of two levels and the fractions of resolution III are orthogonal.

In the ergonomic experimentation is possible to separate main effects and interactions using either of the following methods: (1) assign the main effect to the points to the linear graph assuming that interactions between three factors does not exist; (2) use a special orthogonal array where interactions confound equally with every level of the main effects. The first method uses the columns corresponding to the points on the linear graph en orthogonal arrays L_8, L_{16}, L_{32}, L_9 and L_{27}. For the second method L_{12}, L_{18} and L_{36} orthogonal arrays are used which are of practical use in the industry for their effectiveness and reduction of costs (Wu, 1992).

If we cannot anticipate possible interactions between factors, we can obtain quite a lot of information from past experience. But, if we cannot anticipate interactions, we can take any of the following approaches: (1) Assign the interaction between two factors. (2) Use orthogonal arrays L_{12}, L_{18} or L_{36} that does not generate interaction information. (3)Ignore interactions when you assign factors.

For experiments in ergonomics it is of interest principally to know the principal effects of factors, from what the second option is most recommended since it uses three levels and does not need to stop in the study of interactions that might be subjective in this stage of the process although the ability to anticipate is a part of technological know-how (G.Taguchi, 1986). For this reason the Taguchi methods for the case of study have been programmed in spreadsheets because these allow flexibility of programming for this type of algorithms. In fact, it contains statistical tools.

2.3. Experimental Design Application: Fourth Stage – Experimentation.

In the industry the resources are in general limited it is very probable that the number of experiments is limited to the available budget, in this case a design factorial finished and with only one experimental response can be used, nevertheless the principal effects can contain an error generated by the external noise (Montgomery, 2006). The principal disability of this method consists of the fact that is known that to certain number of factors this process is expensive.

The methodology Taguchi usually guarantees less experimental tests and makes use of the big advantage of the orthogonal arrangements then to construct a reliable model to know the value of the average of the process with the following equation:

$$\hat{y} = \bar{y} + (A_k - \bar{y}) + (B_r - \bar{y}) + \ldots + (N_s - \bar{y}) \quad (1)$$

Where:

$\hat{y}$ = theoretical average of the process.

$\bar{y}$ = real average of the process.

$A, B, \ldots N$ Are the experimental factors.

$k, r, \ldots s$ Are the levels of the experimental factors.

In this way, the Monte Carlo method is used to simulate all possible iterations in a predictive model of values of the average. This means that in our methodology there will be randomized the order of the capture of information to only one reply and later to obtain the theoretical model of the average based on the contribution of the principal effects, with the equation (1) there will be generated all the possible values of the average making use of the Simulation Monte Carlo. In studies realized with regard to the MAPE of the theoretical model his value is usually 4 % (Fabiani, 2008).

With regard to the person chosen for the experiment, the International Organization of the Work tells that the "average" worker does not exist in the reality, but based on the requests of the

industrial work for which is experienced it is known that the profile of the person who executes the task and the Ergonomist jointly with the Engineer can suggest the conditions of an operator qualified for the position, this is that person who has necessary fitness, with required intelligence and instruction and who has acquired the workmanship and necessary knowledge to carry out the current work as norms of quality, quantity, health and safety (OIT, 1986).

2.4 Application of experimental Design: Fifth Stage – Analysis of the information.

Changing the levels of the factors, it is possible to know the interrelation between variables of entry and variables of exit to the system, the distributions of frequency for every variable and to the simulation of the experiment. Finally, the simulated population is validated comparing the levels of interrelation between variables and the percentage of obtained contribution of the ANOVA.

The method allows to obtain a graphic report of different iterations to select the best combination of parameters. The relationship between the response variable and the independent variables is obtained based on the experience in previous investigations, which has found a narrow relation between coefficient of Pearson with the ANOVA (García-Castellanos and Fabiani-Bello, 2007). The following step is to verify the law with regard to the important factors in the response of the model and if norms do not exist on this matter it is necessary to choose the most appropriate levels of operation that maximize or minimize the response.

3. CONCLUSIONS

It has been demonstrated that Taguchi methods are an important tool. Due to its simplicity, the use of these methods has become frequent in different areas and different productive processes. After the statistical experimentation, the Taguchi methodology allows to predict the performance of a process by means. The implementation of this methodology is simple and practical and it does not require of advanced statistical knowledge. Also, the validation of the method presented here could be by means of a case of study.

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