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CONTENT

The Appendix of the first number of Balkan Journal of Applied Mathematics and Informatics, is devoted to the reports of the First Modelling Week in Macedonia, which was held in Stip, 12-16 February 2018.

The First Modelling Week in Macedonia was organized by Faculty of Computer Science - Department of Mathematics and Statistics, Faculty of Electrical Engineering and Faculty of Technology with the support of the TD 1409 MI-NET Cost Action. The aims of the Modelling Week were: widening, broadening and sharing knowledge relevant to the Action's objectives through working on modern and actual problems which can be solved with mathematics and mathematical modelling.

The Modelling Week was organized under auspices of Prof. Blazo Boev, Rector of the Goce Delcev University, Stip, Macedonia.

The Program Committee of the First Modelling Week were:

1. Vineta Srebrenkoska, PhD – Macedonia
2. Tatjana Atanasova – Pachemska, PhD – Macedonia
3. Poul G. Hjorth, PhD – Denmark
4. Wojciech Okrasinski, PhD – Poland
5. Joerg Elzenbach, PhD – Germany
6. Gregoris Makrides, PhD – Cyprus
7. Biljana Jolevska – Tuneska, PhD – Macedonia
8. Limonka Koceva Lazarova, PhD - Macedonia

In the First Modelling Week in Macedonia participated 34 participants from Macedonia, Bulgaria, Portugal and Denmark. The Modelling Week was aimed towards Masters, PhD students, Early Career Investigators (up to 8 years after their PhD). All the participants were split in three groups in order to solve the three problems which were set:

Problem 1 - Scheduling in kindergarten, proposed by Limonka Koceva Lazarova

Problem 2 - Determining the optimal number of cash boxes to increase the efficiency of the customer service and determining the way of storage of products in the warehouse. How to manage stocks in the warehouse, proposed by Tatjana Atanasova – Pachemska.

Problem 3 - Optimization of the industrial processes for production of advanced polymer composites by implementation of the full factorial experimental design, proposed by Vineta Srebrenkoska.

The third problem was split in three subproblems.

All of the solutions are presented in form of reports in this appendix.

Thanks for the editors of the Balkan Journal of Applied Mathematics and Informatics, about their support for publishing of the results from The First Modelling Week in Macedonia.

UDK: 519.248:678.7-021.385

APPLICATION OF TAGUCHI METHOD IN PRODUCTION OF SAMPLES PREDICTING PROPERTIES OF POLYMER COMPOSITES

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Abstract: The purpose of the study is to access the applicability of Taguchi Method in predicting properties of polymer composites. The preparation of the composites was conducted by applying Taguchi L9 Method. Voids are one of the most common defects in composite components and are known to degrade mechanical performance. As a result, void content measurement is often used both to assess the quality of a composite part and to determine its acceptability. For composites the calculate void in composite materials were determined in a lab according standard ASTM D 792, ASTM D 2734 and ASTM D 3171 with calculate experimental and theoretical density. From received results with minimal number of experiments and signal-to-noise ratios used as objective functions for optimization, data analysis and prediction of optimum results was shown that factor 1 has the biggest impact on the voids of manufacture samples.

Keywords: taguchi method, polymer composites, voids.

Introduction

Taguchi method is a statistical method developed by Taguchi and Konishi [1]. Dr. Taguchi's standardized version of DOE, popularly known as the Taguchi method or Taguchi approach, was introduced in the USA in the early 1980's. Today it is one of the most effective quality building tools used by engineers in all types of manufacturing activities. The DOE using Taguchi approach can economically satisfy the needs of problem solving and product/process design optimization projects. By learning and applying this technique, engineers, scientists, and researchers can significantly reduce the time required for experimental investigations. Taguchi method is a technique for designing and performing experiments to investigate processes where the output depends on many factors (variables, inputs) without having tediously and uneconomically run of the process using all possible combinations of values.

The Taguchi approach is a form of DOE with special application principles. For most experiments carried out in the industry, the difference between the DOE and Taguchi approach (Fig.1) is in the method of application [2]. Taguchi Method involves identification of proper control factors to obtain the optimum results of the process [3], [4], [5]. Orthogonal Arrays (OA) are used to conduct a set of experiments. Results of these experiments are used to analyze the data and predict the quality of components produced.

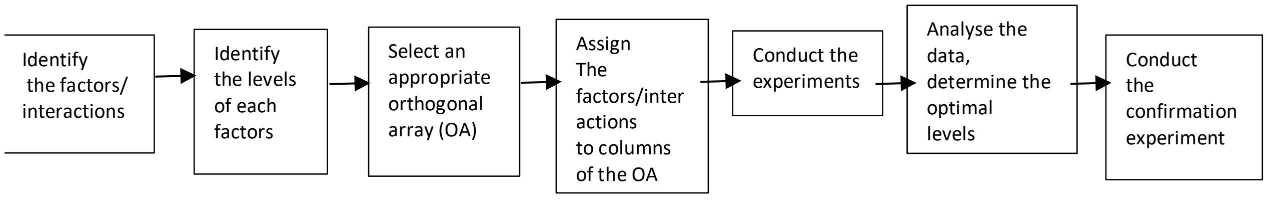

Fig. 1. Scheme of the major steps of implementing the Taguchi method [3].

1. Experiment

Voids are critical imperfections in fiber reinforced composite materials. They mainly arise from the entrapment of air or the presence of volatiles during the curing. The presence of voids can severely affect the mechanical performance and lifespan of the composites.

Regardless of resin type, fiber type and fiber surface treatment, the inter-laminar shear strength of composite material decreases by about 7% for each 1% of voids, up to a total void content of about 4%. For a loaded carbon fiber laminate composite, a 1%-5% increase in void content can reduce the mechanical properties of the composite by up to 20% [6]. As a result, void content measurement is often used both to assess the quality of a composite part and to determine its acceptability [7], [8], [9], [10]. There are lots of factors that influence the filament winding process, but there are only four important that have a big influence on the output which we have used in the experiments:

- Fiber tension (N) (factor 1),

- Winding speed (m/min) (factor 2),

- Number of layers (factor 3)

- Temperature curing (factor 4),

Table 1: Level of process parameters

Symbol	Factor	1	2	3
X_1	Fiber tension (N)	20	40	60
X_2	Winding speed (m/min)	5	10	15
X_3	Number of layers	7	10	15
X_4	Temperature curing	1,5h@100C	1,5h@120C	1,5h@130C

Table 1 shows four factors in three levels used in the experiment. If three levels were assigned to each of these factors and a factorial experimental design was employed using each of these values, number of variations would be 3^4. The fractional factorial design reduced the number of experiments to nine. The orthogonal array of L_9 type that was used is represented in Table 2. This design requires nine experiments with four parameters at three levels. The interactions were neglected. The voids of the part should be maximized. Each result obtained represents the average of five samples.

Table 2: Taguchi L_9 (3^4) Orthogonal arrav

Experiment Number	Factor			
	X1	X2	X3	X4
1	20	5	100	7
2	20	10	120	10
3	20	15	140	15
4	40	5	120	15
5	40	10	140	7
6	40	15	100	10
7	60	5	140	10
8	60	10	100	15
9	60	15	120	7

2. Results and discussion

Nine different rings experiments were performed using the design parameter combinations in the specified orthogonal array table. Three specimens were fabricated for each of the parameter combinations. The completed response table for these data appears in Table 3. In order to estimate the effect of factor X1 (fibers tension) on the average value of response variable, were summed together three observed response at level 1 of factor X1. Then the sum was divided by 3 to obtain the average response at level of factor X1. The average responses at level 2 and 3 was obtained in the similar manner. The test results (calculate voids properties) for the composite parts manufacture from filament winding technology are presented in Table 3.

The standard deviation was calculated for each composite part in five steps [11]. First, Y was subtracted from each measurement in the sample (sample mean), then the square differences obtained prior were calculated [11]. Next, the squared obtained difference was divided by the sample number minus one (s^2) [11]. Finally obtain the square root of s^2. The sample variance is written as formula:

$$s^2 = \sum \frac{(y - y^-)^2}{n-1}$$

$$s = \sqrt{s^2}$$

Table 3. Experimental data and sample statistics

Experiment number	Observed response values for voids (%)					Mean	Standard deviation	S/N Ratio
1	3,8	3,2	3,7	3,4	4	3,6	0,2	11,3
2	4,5	4,8	3,8	4,3	5	4,5	0,8	12,6
3	3,8	4,3	5	4,9	4,5	4,5	0,4	13,6
4	4,2	3,7	4,6	4,4	3,3	4,0	1,0	12,0
5	1,8	3,2	2,4	1,9	3,3	2,5	1,0	7,4
6	4,5	3,8	3,1	4,1	4,3	4,0	0,9	11,4
7	2,4	2,3	2,3	1,9	2,7	2,3	0,3	7,0
8	2,8	1,2	1,5	2,7	1,1	1,9	1,4	3,3
9	2,5	1,5	2,7	1,6	1,4	1,9	1,0	4,6

Table 4. Rank of filament winding parameters

Level	Average S/N Ratio by factor level			
	X1	X2	X3	X4
1	12,51	10,08	8,66	7,78
2	10,26	7,78	9,74	10,33
3	4,95	9,87	9,33	9,62
delta	7,56	2,30	1,08	2,55
Rank	1	3	4	2

The above analyses of Table 2 and Table 3 are summarized in Table 4, where the levels of key factors optimizing the response are listed. In this study factors X1 and X4 were the dominant. According to [12] fiber speed can provoke the tension to move away from its nominal value, which in this paper has a rank of influence 3. In [13] it was reported that, due to specific shape of manufactured composite part the filament winding tension wasn't evenly distributed even though it was held constant during the filament winding process, which led to increase in the percent of voids and decrease in mechanical performance of hybrid composite samples. Risteska et. al. [14] had published that winding speed shows more pronounced influence on mechanical characteristics of NOL ring composite samples in comparison to fiber tension, which is in accordance with results given in Table 4.

Optimized parameter's value used in this research are:

- Fibers tension, level 1 – 20N,

- Winding speed, level 3- 15[m/min],

- Number of layers, negligible,

- Temperature curing, level 2.

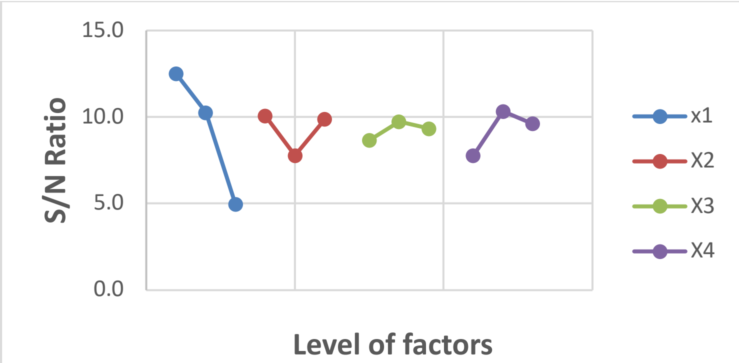

Fig. 2. Plot of factor effects on S/N ratio

3. Conclusion

The experiment conducted with the Taguchi method has demonstrated that the fiber tension is very important. Fiber tension is significant both in voids and mechanical properties. The most advantageous for the voids is tension 20N. Parameter number 1 (X1) – Fiber tension demonstrated the biggest impact on void percent in composite samples

In this experiment, factor X4 (temperature curing) affects variability the most. Temperature curing range between 100-140°C has not significant influence on the voids; but however the optimum temperature curing is 1,5h@120°C. Factors X2 (winding speed), X3 (number of layers), are not so important, but however the optimum winding speed is 15m/min and the optimum number of layers is 10.

Acknowledgment

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