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APPLICATION OF DESIGNING EXPERIMENTS TO REGULATE THE RATIO OF MATERIALS IN THE FORMULATION OF RUBBER COMPOUNDS

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Mohamma Reza Rabiee Mendejin
Islamic Azad University Central, *Assistant Professor, Faculty Member Islamic Azad University Central Tehran Branch, Teheran, Iran*

Ph. Hojjat Taheri Goudarzi
Islamic Azad University, *Assistant Professor, Faculty Member of Islamic Azad University Boroujerd Branch, Boroujerd, Iran.*
h_taheri47@yahoo.com

Abstract: Nowadays, there are so many invented technics for the betterment of production processes one of the best and the strongest of which is designing of experiments which is an important and effective technic in this field, which starts with specifying an experiment and selection of processes factors.The specifications of " Experiment designing" process is in such a way that it could be applied for both processes of designing and promotion(betterment) of products.In this essay, applying "experiments designing " technic, the effects of carbon black and oil on hardness range of one type of tire rubbery compound has been studied. After performing the experiments, and specifying the effects of the factors (and the amount of its effectiveness) on the response level, the best amount of each factor, for regulating the average effective hardness of the rubbery compound on the assigned target is specified, Comparing the results before and after applying the " Experiment designing" process, will specify its effectiveness.

Keywords: “Design of Experiments “process, rubbery compound, formulation

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1. INTRODUCTION

Test design is the study and investigation coupled with several variables of process. By combining several variables in a study, rather than conducting separate studies for each of them, the number of tests required is significantly reduced and thus a better understanding of the process is obtained (Nourosana, R 1382).

Most of the tests (experiments) include a study of the effect of two or more of the two factors. In general, factor designs are more efficient for these types of experiments (Jamshidian, A 1383).

The existence of numerous papers suggests that this method has been used in many fields (areas). But in the field of improving the properties of rubber compounds using this research, no recorded (documented) research was found.

2. A BRIEF DESCRIPTION OF THE PROCESS

The company in which (where) this research carried out is a tire manufacturing company has received a production technology one size of its product tires from one of large tire manufacturers in the country. Among the transferred technical cases is the formulation of rubber compounds. Rubber compounds have important properties that most important of them are: hardness, modulus, elongation, strength and density, all of which must be within a certain range.

This company has encountered an unusual number of returned tires in spite of the use of rubber compound formulations according to maternal factory documentation that using critical six-point sigma point of failure methodology; the low tread strength of the tire compound and the root cause of defect in the soot and oil ratio in the formulation of the desired compound has been identified; this study is aimed to determine the best soot and oil ratio in the formulation of the desired compound, so that the best hardness is obtained and other properties of the compound do not change. The formulation of this intended compound is set forth in table 1. In this compound, the hardness should be between 60/65 shore A. The best level of hardness that the compound can have is shore A of 62.5. The mean of results from the production of this compound is 60.65 shore A.

Table 1: Formulation of the compound

Material name	Weight (unit)
SMR20	481
BR ARAK	819
Soot N330	780
BeranOil 290	234
ZNO	65
Stearic acid	36
Paraffin wax	13
WING STAY 100	19.5
4020	13
MOZ	15.6
S	26
PVI	6.5

Which, according to Fig. 1, is close to the lower limit of acceptance of 60, and the low hardness causes a defect in the tire's procedure (position). In the implementation process of the study, a test design tool was used to determine the average (mean) of the hardness of the manufactured compound on the target number of shore A 62.5. In this regard, firstly, by selecting soot and oil soils and using the Minitab software 14, a model to determine the number of tests and their performing arrangement with specific levels for agents is obtained. Then, we have performed the experiments (tests) on a laboratory scale using a 3-liter compound machine; a six-inch rod and a laboratory cooking machine. After performing the experiments (tests) on the above scale, using the optimal response level, the soot and oil soils factors (agents) has been determined to adjust the hardness on the target set at 62.5 shore A, and after determining the optimal amounts of soot and oil on a large scale of 130, the industrial batch of compound was produced, with the average hardness of these shore A 62.5 products has been measured. In the end, using the run chart, the hardness of the products was compared before and after the improvement, that considering the increase in hardness and reduced visible dispersion, the effectiveness of the improvement is proven.

3. SELECTING FACTORS (AGENTS) AND DETERMINE THE LEVELS

In determining the properties of rubber compound, the ratio of the raw materials in the formulation plays

a major role. The most important of these materials are: dissolved sulfur / MOZ / SMR20 / PVI / BR / soot / oil; on the other hand, the change in the ratio of these materials may improve one of properties but other properties are subject to undesirable changes. Therefore, the factors necessary for designing the model should be carefully chosen so that the hardness is improved and other physical properties of the compound are maintained within their standard range. So, after examination of the topic, two factors (agents) of soot with 806 and 845 unit and oil with 195 and 260 units were selected.

4. DESIGNING A MODEL FOR PERFORMING TESTS (EXPERIMENTS)

5.

Designed model has two factors: soot and oil, and for each of these factors (agents), two levels are considered for oil: 195 and 260, for soot 806 and 845 units, and the number of replicates in this model was determined 2 times. The mentioned model was designed by MINITAB 14, the output of which is according to table 2.

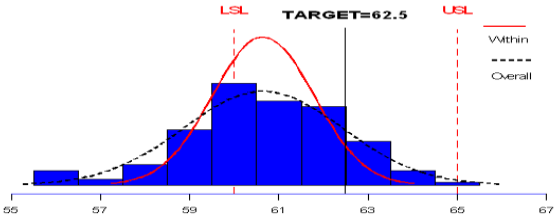

Fig. 1 Distribution of compound hardness before improvement

As outlined in this table, in order to avoid adverse environmental effects, using software, the experiments (tests) order has been selected randomly. In order to accomplish this, eight tests (experiments) should be performed according to the Run Order column of the table in the same order.

Table 2: Model Designed for performing the tests (experiments)

Std order	Run order	Center pt	Blocks	Carbon	oil
8	1	1	1	845	260
2	2	1	1	845	195
7	3	1	1	806	260
3	4	1	1	806	260
1	5	1	1	806	195
4	6	1	1	845	195
4	7	1	1	845	260
5	8	1	1	806	195

6. SELECTING THE ANSWER VARIABLE

According to the presented explanations, the compound hardness is considered as the response variable.

Execution of tests:
Eight designed experiments (tests) were carried out according to the designed model (Table 2) and the results were obtained by Minitab software 14.

7. ANALYSIS OF THE RESULTS OF THE EXPERIMENTS (TESTS)

As shown in figure 2, based on Pareto, both factors (agents) of soot and oil are effective on the hardness of the compound, which oil has a higher and soot has a lower effect, but the effect of the interaction between these two materials has not affected on hardness. In figure 3, the slope of the oil graph is higher, and this fact indicates that its more effect on the hardness, and on the other hand, according to this same figure, with increasing soot content, the hardness increased and with increased amount of oil, its amount has been decreased. Therefore, it can be concluded that the amount of oil is inversely related with the hardness ratio and the amount of soot is directly related with the hardness.

8. DETERMINATION OF OPTIMAL AMOUNTS OF SOOT AND OIL

As stated at the beginning of the article, the hardness of the mentioned compound must be between Shore A 60-65, which is the best target point for optimizing the hardness of the compound to be 62.5 Shore A, which is exactly in the middle of the acceptance range. Using the Optimization Response topic, the statistical tool of tests (experiments) design and with the help of the software Minitab 14 it was attempted to optimize the hardness of the compound mentioned above, that to achieve the hardness of Shore A5 / 62, the soot amount of 828.038 and the oil amount of 196.282 units are obtained (Figure 4).

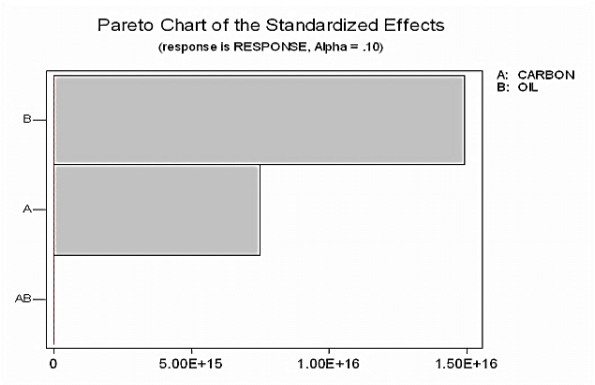

Fig. 2 Pareto chart of soot and oil effects

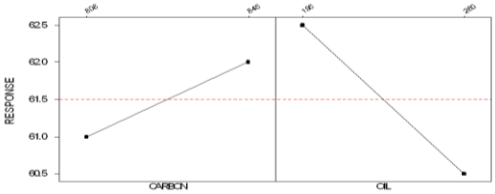

Fig. 3 the main effects of soot and oil

Response Optimization

Parameters

	Goal	Lower	Target	Upper	Weight
Import					
RESPONSE	Target	60	62.5	65	10

Starting Point

CARBON = 806

OIL = 195

Global Solution

CARBON = 827.038

OIL = 196.282

Soot and oil quantities for the purpose of adapting the mean on target

Figure 4 Optimization of soot and oil quantities

9. MONITORING THE EFFECTIVENESS OF THE OBTAINED RESULTS

After determining the optimal amounts of soot and oil, the cases were considered in the corresponding formulation. After examining the results, the average (mean) of the hardness of the products in the large scale Shore A5 62.5790 was obtained which is very close to the predicted value (Figure 5).

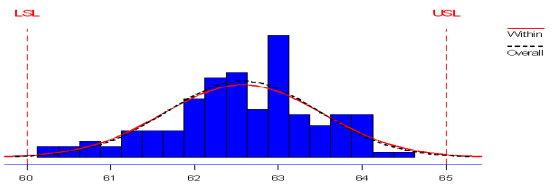

Fig. 5 Distribution of compound hardness after improvement

In order to determine the effectiveness of the resulted improvement, the products chart was prepared before and after the improvement in contrast to each other, as presented in Figure 6, which clearly illustrates the improvement.

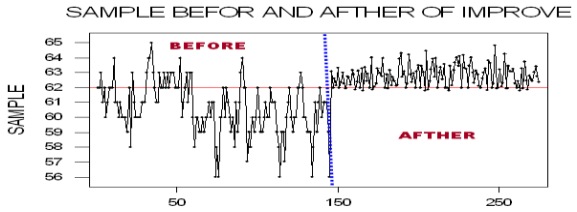

Figure 6 Comparison of the results before and after the improvement in a three-month period

10. CONCLUSION

Considering the transfer of technical knowledge among the tire-producing factories such as the conditions governing the production, the changes in the properties of the raw materials, the equipment, the skill of the manpower, etc., makes the properties of the manufactured compounds do not exactly match the standard documents. For this reason, the formulation used should be modified and revised according to the existing conditions of the manufacturer, which can be done by statistical tools that one of the best of these tools is the design of experiments (tests) that its potential and ability to do this important was considered in the current article.

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