Effects of Total Batch of Straining Process on Scorching Time of Rubber Compound

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A B S T R A C T

To protect electrical power installation equipment, especially that in open areas where it is particularly vulnerable to both technical and non-technical disturbances, such as those frequently brought on by lightning surge currents that result in large fault currents, it is crucial to build a grounding installation. A good and trustworthy grounding system is required to flow this significant fault current, both in terms of a low grounding resistance value and the grounding system's design. There are several high voltage transmission towers or electrical power installation tools in open spaces, and they are built on a variety of soil types, including 150 kV transmission towers built on swamp land. The measurements on the shampooing marsh terrain yielded the maximum and minimum values, with the maximum value occurring at a depth of 1 meter and a earth resistance value of 25.70 Ω and the minimum occurring at a depth of 2 meters and a earth resistance value of 12.10 Ω, respectively. Based on the findings of these measurements, a grounding grid construction employing four electrode rods of two distinct types copper-coated iron rods and galvanized iron rods each measuring 3.5 meters in length was designed using the CYMGRD application. Through the CYMGRD application, a different Ground Potential Rise (GPR) is obtained; with the same fault current of 10234.6 Ampere, the GPR value for the copper-coated rod construction is 54.7871 volts as opposed to the galvanized rod construction's 55.0625 volts.

Keywords:

Electrical power, CYMGRD, application, rubber compound

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1. INTRODUCTION

With its distinctive characteristics, rubber has been widely used as the primary raw material for automotive, household and other products. The main characteristic of rubber is its elasticity, which is supported by other physical properties that support the ability and function of a product. The physical properties of rubber are supported by the three-dimensional molecular structure formed in rubber processing (vulcanization). The rubber compound is vulcanized with vulcanizing material and heat to form a three-dimensional network on the molecular structure of the rubber so that the rubber changes properties from thermoplastic to heat stable, with improved elastic properties [1].

Vulcanization is a deliberate and expected process in rubber products so that 3-dimensional cross-links are formed in the molecular structure. However, 3-dimensional cross-linking can occur in rubber compounds that have not been shaped (scorching). Scorching is a premature vulcanization of rubber compounds where 3-dimensional cross-links begin to form, causing the rubber compound to experience a decrease in plastic properties and can no longer be processed (dead compound). Scorching is caused by an increase in temperature and time during the processing of rubber compounds [2].

The process of making rubber products goes through several stages: material mixing, product forming, and the vulcanization process (formation of cross-links) in the final product [3]. One of the final product-forming processes is extrusion technology. The vulcanization process is carried out after the forming process in the extruder machine. In extrusion processing, scorching the rubber compound and using heat to soften the compound and processing time are possible.

One application of rubber extrusion is the process of filtering (straining) rubber compounds to remove contaminants with a strainer machine. In the filtering process with a strainer machine, the rubber compound is softened in a barrel with a rotating screw, and the compound is passed through a filter in the form of a mesh on the strainer head. According to [4], the mesh size of 40 is capable of filtering out relatively small foreign materials, undispersed carbon black particles, and other contaminants. Applying the mesh will reduce the material flow (drag flow) and increase the material's pressure flow/backflow, thereby increasing the mixing effect and the shear heat [5]. The repeated straining process (batch) causes the mesh to wear out more and more. The mesh holes are covered with contaminants, so the straining process is not optimal and allows the process temperature to rise even higher. It increases the risk of scorching the rubber compound due to straining; in the end, the rubber compound will die in the subsequent formation process.

2. Experiment Design

The experiment design used was the 1-factor complete randomized design, namely the total batch of straining process using the same mesh, with batch levels per mesh of 4 to 10. The response variable was the scorching time of the rubber compound resulting from the straining process. The complete randomized design was applied using a random model, where the experimental sample was taken in the current production process, so the inferencing was carried out on the population-straining process [6].

The tools and materials used in this study were the tools and materials in the rubber compound straining process and the rubber compound testing process as a result of straining. The materials used were natural rubber, additives from a compounding process, and mesh-40. The tool used for the straining process was a strainer machine. The tools used for compound testing were thermogun and Mooney viscometer. The natural rubber material and additives used were the same for all experiments. The straining process parameters were at 90°C, and the processing speed was the same for all experiments. The data for the scorch time value for each total batch variation and each repetition were plotted in a complete randomized design standard table in Table 1.

TABLE 1. Data Layout Completely Randomize Design [7]

	Treatment					
	1	**2**	**…**	**i**	**…**	**t**
	Y_{11}	Y_{21}	…	Y_{i1}	…	Y_{t1}
	Y_{12}	Y_{22}	…	Y_{i2}	…	Y_{t2}
	.	.	.	.		.
	.	.	.	.		.
	Y_{1j}	Y_{2j}	…	Y_{ij}	…	Y_{tj}
	.	.	.	.		.
Total	.	.	.	.		.
treatment	Y_{1r1}	Y_{2r2}	…	Y_{iri}	…	Y_{trt}

$$\overline{Y_{i.}} = \frac{Y_{i.}}{r_i} \text{ = ith treatment mean} \tag{1}$$

$$\overline{Y_{..}} = \frac{Y_{..}}{\sum_{i=1}^{t} r_i} \text{ = Mean} \tag{2}$$

Calculation of the analysis of variance included the total square of treatment and the total square of error, with degrees of freedom as a comparison to obtain the average value of the square of treatment and the average of the squares of error. Comparison of the mean square of the treatment with the mean squared error as the Fcount value. The calculation data for the analysis of variance are shown in Table 2.

TABLE 2. Analysis of Variance Completely Randomize Design

Source of Variaton	Sum of Square	Degree of Freedom	Mean Square	F0
Between Treatment	SST	DoFT	$MST = \frac{SST}{DoFT}$	$F0 = \frac{MST}{MSE}$
Error (Within Treatment)	SSE	DoFE	$MSE = \frac{SSE}{DoFE}$	
Total	SSTot			

3. Analysis

A complete randomized design model is formed from treatment and error. As a consequence, analysis of variance for a complete randomized design only includes sources of treatment variability and error. The linear model for a complete randomized design consisting of ttreatment and rireplication as follows [8]:

$$Y_{ij} = \mu + \tau_i + \varepsilon_{ij} \ ; \quad i= 1,2,\ldots,t \ ; j= 1,2,\ldots,r_i \tag{3}$$

In which Yij is the observation on the -i treatment in the -j repetition, was the general mean, was the -i treatment, and was the error component.

The inference analysis was a random model where the diversity came from the distribution of all treatment effects. The effect of the treatment was Γ~N(0,$\sigma 2\boldsymbol{\tau}$), with the following test hypothesis:

$$H_0 : \sigma_\tau^2 = 0 \ ; \ H_1 : \sigma_\tau^2 \rangle 0 \tag{4}$$

4. RESULT AND DISCUSSION

The results of the experiments carried out on the straining process using the same mesh of 4 to 10 batches with different repetitions are shown in Table 3. The number of repetitions was different because it followed the current production process.

TABLE 3. Data of the Scorching Time of Rubber Compound

Repetition	Scorch time (minute)						
	4 batch	5	6	7	8	9	10
1	12,57	12,34	10,51	9,33	8,40	8,10	7,50
2	11,42	11,32	10,20	9,07	8,20	7,60	7,30
3	11,26	11,30	10,00	9,00	8,00	7,30	7,25
4	11,26	11,23	9,80	8,70	7,00	6,50	
5		10,50	9,39	8,10	6,80		
6		10,42	9,11	8,00	6,80		
7		10,12	9,11	7,80			
8		10,00		7,80			

Based on Table 3, the total trial was 42. Thus, it can be assumed that the experimental data were normally distributed. The data from the test results for the scorch time value of rubber compounds were analyzed for their diversity based on the complete randomized design method, with random models and unequal repetitions. The results of the analysis of variance are shown in Table 4.

TABLE 4. Analysis of Variance of the Scorching Time Data of Rubber Compound

Source of Variaton	Sum of Square	Degree of Freedom	Mean Square	F0
Between Treatment	93,17	6	15,53	36,18
Error (Within Treatment)	14,17	33	0,43	
Total	107,33			

Based on the analysis of variance in Table 4, it is known that the Fcount value is 36.18, which means it is greater than the Ftable value at the 5% significance level, which is 2.39. It can be concluded that accepting Hypothesis-1, namely, the diversity is greater than 0, and shows that variations in the total batches with the same mesh in the straining process produce rubber compounds with significantly different scorching times. At least one scorching time value for a specific total batch significantly differs from the scorching time value of other batches.

According to [9], the polymer filtration process by the extrusion method, continuous filtration on the same mesh will cause a buildup of contaminants. It causes the mesh to become clogged, so the material flow is not smooth. This condition allows material backflow, causing the material residence time in the extruder barrel to be longer. The return flow of the rubber compound material and the higher residence time allow the temperature of the rubber compound in the extrusion barrel to be higher. The higher the temperature of the rubber compound in the extrusion barrel, the lower the scorching time of the rubber compound. [10] Because heat can increase the reaction rate, the reaction between the rubber molecules and the additives takes place more quickly [11].

Based on the analysis of variance, which showed a significant difference, a further significant difference test was carried out to determine the variations in the number of batches that resulted in significantly different scorching time values for rubber compounds. The results of the significant difference tests using the Duncan Multiple Range Test (DMRT) method are presented in table 5.

TABLE 5. Duncan Multiple Range Test (DMRT) Result

Treatment (x)	**mean**	**$Mean_i$ + $DMRT_i$**						**P**	**DMRT (5%)**
		8,15	**8,22**	**8,40**	**9,36**	**10,63**	**11,82**		
10 batch	7,35	a						2	0,80
9	7,38	a	b					3	0,84
8	7,53	a	b	c				4	0,87
7	8,48				D			5	0,89
6	9,73					e		6	0,90
5	10,90						f	7	0,91
4	11,63						f		

The results of the DMRT test in Table 5 show that the total batches 4 and 5 produce scorching time values that are not significantly different. Besides that, the total batches of 8, 9, and 10 also resulted in the rubber compound's scorching time value, which was not significantly different. The total batches 6 and 7 resulted in a rubber compound scorching time significantly different from the number of other batches.

Scorching time is the processing lag time before the rubber compound undergoes vulcanization. When the rubber compound has been vulcanized, the compound can no longer be processed, so the longer the scorching time, the better the processing ability of the rubber compound. If the scorching time is too short, the ability of the compound process will be worse. Therefore, when the extrusion process or strainer has undergone vulcanization, this vulcanization process should occur in the curing process. Compounds that have undergone scorch cannot be processed further because the compound is no longer plastic.

Based on the average value of the scorching time of the rubber compound for each treatment variation of the total batches in the straining process, it shows a tendency that the higher the total batches with one mesh, the lower the scorching time of the rubber compound. Based on the test results, the total batches 4 and 5 gave the highest average score of rubber compound time. It can be used as a reference in the rubber compound straining process to determine when the time to replace the mesh is appropriate.

5. CONCLUSION

The rubber compound straining process based on extrusion technology aims to filter out contaminants. Using mesh as a filtering medium has another impact on the condition of the rubber compound material. Using the same mesh for the rubber compound straining process affects the material flow in the straining machine. It affects the rheological condition of the rubber compound material. The greater the total batch of the rubber compound straining process with the same mesh, the impact of the rubber compound scorching time is decreased. The decrease in the scorching time of the rubber compound will cause the risk of scorching the rubber compound for further processing. Replacing the mesh can be done by taking into account the efficiency of the production process and the rheological conditions of the rubber compound.

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7. REFERENCES

[1]. J. E. Mark, B. Erman, F.R. Eirich, "Science and Technology of Rubber 3rd edition", Elsevier Academic press, United State of America, 2005, pp. 321 – 366.

[2]. S. H. Al-Nesrawy, M. Al-Maamori, H. R. Jappor, "Effect of Temperature on Rheological Properties of SBR Compounds Reinforced by Some Industriap Scraps As A Filler, International Journal of Chemical Science, 14 (3), pp. 1285 – 1295, June 2016.

[3]. J. G. Sommer, " Engineered Rubber Product, Introduction to design manufacture and testing" Hanser Publisher, Munich, 2009, pp. 1 - 24

[4]. Exxon Chemical international Asia Ltd, " Butyl Rubber Innertube Technology" in Exxon Chemicals Elastomer Technical Information Manual, Polymer Technology Centre, 1989.

[5]. H. Nishizawa, "Heat Controls and Rubber Flow Behaviour in Screw of Extruder and Injection machine and The Problems Occuring in These Processes", Nippon Gomu Kyokaishi, 88, No. 4, 2015, pp. 136 – 143.

[6]. H. T. Shalabh, "Statistical Analysis of Designed Experiment, 3rd Edition" Springer NewYork, 2009, pp. 113 - 156

[7]. M. lentner and T. Bishop, "Experimental Design and Analysis (Valey Book Company, Blacksburg,1986), pp. 1 - 565

[8]. D. C. Montgomery, "Design and Analysis of Experiment, 8th Edition", John Wiley & Sons, Inc. New jersey, 2013, pp. 65 - 131

[9]. H. F. Giles Jr., J. R. Wagner Jr., E. M. Mount III., "Extrusion: The Definitive Processing Guide and Handbook", William Andrew Publishing, New York, 2005, pp. 13 – 34.

[10]. N. A. Talib, O. Ertunc, T. Turkistanli, E. Aydin, "Experimental and Numerical Study of Rubber Flow in the Extrusion Die of a Weather Strip", Journal of Chemical Engineering of Japan, Vol 52, No. 12, December 2019.

[11]. A. Yuniari, H. E. mayasari, I. Setyorini, "Curing Characteristics, Swelling, and Mechanical Properties of natural Rubber/Nitrile Butadiene Rubber Blends With And Without Compatibilizer", Majalah Karet, Kulit dan Plastik, 33 (2), 2017, pp. 65 – 72.