Optimization of Compression Molding Process for NR/EPDM Elastomeric Material

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ABSTRACT – Natural Rubber/Ethylene Propylene Diene Monomer (NR/EPDM) elastomeric is gaining popularity in the growing automotive industry owing to the fact in terms of sustainability. With extensive studies and increasing number of applications for future advancement, the need for accurate and reliable guide in processing this type of elastomer has increased enormously. The present work, deals with the study of compression molding parameters (i.e. temperature, pressure, heating time and pressure time) and its effects against NR/EPDM elastomeric mechanical properties aim on establishing optimized setup of processing parameters. The optimization are achieve through Response Surface Methodology (RSM), Box-Behnken approach as the design of experiment. Adequacy of models is analyzed statistically using analysis of variance (ANOVA) in determination of significant input variables and possible interactions.

1. INTRODUCTION

Natural Rubber/Ethylene Propylene Diene Monomer (NR/EPDM) consists of Natural Rubber (NR) and Ethylene Propylene Diene Monomer (EPDM) which was blended together in order to enhance certain properties. NR have a high strength and good dynamic properties [1] while EPDM has a better chemical resistance and weathering oxidation [2]. The blending between Natural Rubber and Ethylene Propylene Diene Monomer has given upward push to their heat and ozone resistance.

Compression molding is one of the process to make rubber material product in which offers high production rates, accurate repeatability and produced an end product [3]. Generally, compression molding process has been a surprising development in automotive and appliance applications until now. It is a forming process where the material is placed in the mold that had been heated at certain temperature and then is pressed to form the product that looks exactly like the shape of the mold. Just like making waffles. However, the compression molding process is slower and expensive [4].

In the compression molding process, the parameter plays an important role in production of rubber product, subsequently the control of process parameters is fundamental. There are four parameters that influence the mechanical properties in compression molding which are temperature, pressure, heating time and pressure time [5]. The differences between the thermal linear growth of rubber and mold will affect the shrinkage of the mold cured rubber product while the poor vulcanization process will result of porosity. In addition, product that manufactured by NR/EPDM usually causes ozone cracking on the surface of the product and directly reduce the shelf life of that product. Therefore, this study concentrated on optimization of compression parameter for NR/EPDM in order to have a longer shelf life in term of strength and good hydrogel network in term of crosslink density.

Design of experiment (DOE) method is applied in this research and carried out according to the box Behnkan design tools of Response Surface Methodology (RSM) using Design-Expert 8 P (DX8P) software for selected factors. With RSM method, the cost for this project can be reduced and the experiment becomes faster and effective [6].

2. METHODOLOGY

2.1 *Experimental Parameters*

From the previous study, there are four parameters that have been selected for this project. Parameters that have been selected are temperature, pressure, heating time and pressure time. The highest and lowest value for each parameter was determined based on the previous study in order to be inserted in RSM method.

Table 1 Processing parameters data for NR/EPDM elastomeric

Parameter	**Value**	
	Highest	**Lowest**
Temperature	180 C	140 C
Pressure	14.7 MPa	10 MPa
Heating time	12 min	4 min
Pressure time	5 min	4 min

2.2 *Response Surface Methodology (Box Behnken Approach*)

RSM is used for the approximation of both experimental and numerical responses. RSM helps to determine the parameter setting for the research that can give best setting. Table 2 shows complete result of the processing parameter in RSM method for NR/EPDM by Compression molding.

3. RESULT AND DISCUSSION

The processing parameters that are given by RSM method was used in the experiment to get the analysis of the output response is crosslink density (swelling test).

Table 2 The experimental result for crosslink density.

	Factor 1	Factor 2	Factor 3	Factor 4	Response 1
Run	A: Temp	B: Press	C: Heat time	D: Press time	Crosslink Density
UOM	°C	MPa	mm	min	g/cm³
1	160	12.35	12	5	2.72E-007
2	140	12.35	8	5	3.98E-007
3	160	14.7	4	4.5	6.06E-007
4	160	12.35	8	4.5	5.51E-007
5	160	14.7	8	5	6.49E-007
6	160	12.35	4	5	6.74E-007
7	160	12.35	8	4.5	9.15E-007
8	140	12.35	4	4.5	7.45E-007
9	160	14.7	12	4.5	4.22E-007
10	160	12.35	8	4.5	6.36E-007
11	180	12.35	4	4.5	5.54E-007
12	160	10	12	4.5	5.82E-007
13	160	14.7	8	4	6.28E-007
14	180	12.35	8	5	4.48E-007
15	160	10	8	4	6.32E-007
16	180	10	8	4.5	4.45E-007
17	180	12.35	8	4	3.05E-007
18	160	12.35	8	4.5	6.95E-007
19	140	12.35	8	4	6.73E-007
20	140	14.7	8	4.5	6.99E-007
21	160	12.35	4	4	6.28E-007
22	180	14.7	8	4.5	7.75E-007
23	140	12.35	12	4.5	5.73E-007
24	160	12.35	12	4	6.12E-007
25	160	12.35	8	4.5	5.06E-007
26	160	10	8	5	5.13E-007
27	160	10	4	4.5	6.81E-007
28	180	12.35	12	4.5	4.25E-007
29	140	10	8	4.5	4.89E-007

3.1 ANOVAAnalysis of Crosslink Density

Analysis of variance table [Partial sum of squares - Type III						
	Sum of		Mean	F	p-value	
Source	Squares	df	Square	Value	Prob > F	
Model	2.810E-013	4	7.024E-014	3.65	0.0185	significant
A-Temperature	*1.692E-013*	*1*	*1.692E-013*	*8.79*	*0.0067*	
B-Pressure	*1.564E-015*	*1*	*1.564E-015*	*0.081*	*0.7781*	
C-Heat.time	*5.360E-014*	*1*	*5.360E-014*	*2.78*	*0.1082*	
D-Press.time	*5.658E-014*	*1*	*5.658E-014*	*2.94*	*0.0994*	
Residual	4.621E-013	24	1.925E-014			
Lack of Fit	*3.597E-013*	*20*	*1.798E-014*	*0.70*	*0.7375*	*not significant*
Pure Error	*1.024E-013*	*4*	*2.561E-014*			
Cor Total	7.430E-013	28				

Figure 1 ANOVA of crosslink density

Based on the experimental results in Table 2, a quadratic model was developed. Further reveals the model is significant, with p-value of 0.0185 indicating there were effects of factors on the response. The result is supported by Lack of Fit test with p-value of 0.7375, indicating that the model fits the data well. The most significant terms affecting the crosslink density in the design space is temperature (A) while the other are insignificant.

3.2 3D Interaction Effects of Crosslink Density

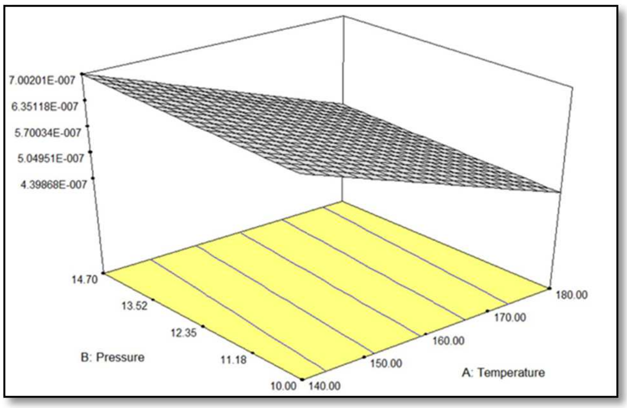

Figure 2 3D surface graph of crosslink density vs temperature (A) vs heating time (B)

Figure 1 shows the 3D interaction graph for crosslink density that revealing the linear interactions between factors and crosslink density in the design space. This graph also reveal that crosslink density value is significantly affected by the temperature and there's only slightly a change in the crosslink density during the changes of the pressure.

3. CONCLUSION

Table above clearly shows the complexities involved in the crosslink density for NR/EPDM elastomeric by compression molding process. In this research, the effect of design parameters that include temperature, pressure, heating time and pressure time have been critically investigated towards establishing an optimized predictive model by RSM.

Response	With increase in Process Parameter			
	Temperature	Pressure	Heating time	Pressure time
Crosslink Density	Increase	Slight increase	Increase	Slight decrease

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