

Effect of Stearic Acid Level on the Physical Properties of Natural Rubber Vulcanisate.

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ABSTRACT

An investigation was carried out comparing seven different natural rubber formulations, in each case stearic acid level used varied from 0.00 pphr to 6.00 pphr. Vulcanizing at a temperature of 165^oC for 5 minutes at a pressure of 300 psi, the various compounded formulations were cured. The physical properties viz: hardness, tensile strength, modulus, compression set, elongation at break and abrasion resistance were evaluated. The results obtained are of the view that hardness and compression set increased with an increase in stearic acid levels. Tensile strength and modulus also show an increase with stearic acid level only up to a level of 4.0 pphr. Above this, there is a noticeable drop in both properties. Abrasion resistance decreases with an increase in stearic acid level up to a level of 3.0 pphr, but above this there is a remarkable increase in abrasion resistance. The various results show that stearic acid has a remarked effect on the physical properties of natural rubber vulcanisate.

(Keywords: stearic acid, hardness, abrasion resistance, compression set, modulus, vulcanisate)

INTRODUCTION

Reports from students undergoing the Student's Industrial Work Experience Scheme (SIWES), (Evwerejeria, 2004), have indicated that technicians and rubber compounders in some rubber products manufacturing companies use stearic acid, a basic compounding additive in quantities higher than the recommended dosage 1.00 – 3.00 pphr. (Ciullo and Hewitt, 1999) stated in the formulation recipe during the process of compounding.

Every recipe contains a number of components, each having a specific function either in the processing vulcanization or end use requirement of the product, (Barlow, 1993). All of the ingredients given are normally in specific amount, based on a total of 100 parts of the rubber or combination of rubber (blend). Each additive used has finite duty to perform either during processing or application of a particular compound.

Hence, stearic acid, in conjunction with a metallic oxide such as zinc oxide, acts as activator. They are used in small proportions usually about (1.00 – 3.00 pphr) and form zinc stearate which promote at vulcanization temperature the action of the accelerators to increase the efficiency of vulcanization or cross-linking. The use of the activator-accelerator system is a standard practice in rubber compounding and vulcanization, (Cheremisinoff, 1993).

Stearic acid, in conjunction with some metallic oxides, notably zinc oxide, form the activating system during sulfur vulcanization, (Hofmann, 1996). The essence of activating the vulcanization process is that sulfur acting on its own is a very slow process; hence the essence of activating the vulcanization process is to increase the efficiency of crosslink formation. The use of stearic acid and zinc oxide as activating system is a standard practice in rubber compounding, (Nagdi, 1992).

The objective of this work, therefore, is to critically examine the effects of stearic acids levels on vulcanisates properties.

EXPERIMENT

Materials

Natural rubber conforming to SNR-10 obtained from Rubber Research Institute of Nigeria, Benin City, Edo State was used in the study. Stearic acid, zinc oxide, CBS, sulfur, trimethyle quinoline (TMQ), and other compounding additives were of commercial grades.

Sample Preparation

Formulations for different stearic acids levels are given in Table 1. Prior to mixing, the natural rubber was premastered.

The natural rubber mixes were carried out on laboratory Farrel two roll mill size 12" x 38"

capacity 1.2 kilogram. Starting temperature was 60°C and the mixing schedule is given in Table 2. Total mixing time was kept to minimum to avoid sticking of the rubber compound to the mill rolls. The rolls were cooled to ensure that milling temperature was not too high to avoid scorching.

After mixing, the compounds having different stearic acid levels were molded in an electrically heated press where vulcanization took place.

Assessment of Vulcanisate Properties

Cure characteristics, such as hardness, tensile strength, modulus, compression set, elongation at break, and abrasion resistance were assessed, according to standard methods (ASTM-D1415, ASTM-D1456, ASTM-D385, BS 903 part A9, BS 903 part A6).

Table 1: Formulation with varying Stearic Acid Levels.

Additives	Parts Per Hundred Rubber (pphr)						
	A	B	C	D	E	F	G
Natural Rubber	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Carbon Black	45.0	45.0	45.0	45.0	45.0	45.0	45.0
Zinc Oxide	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Stearic Acid	0.0	1.0	2.0	3.0	4.0	5.0	6.0
Sulfur	2.0	2.0	2.0	2.0	2.0	2.0	2.0
CBS	0.6	0.6	0.6	0.6	0.6	0.6	0.6
DPG	0.4	0.4	0.4	0.4	0.4	0.4	0.4
TMQ	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Processing Oil	2.0	2.0	2.0	2.0	2.0	2.0	2.0

Table 2: Mixing Schedule.

Operations	Time (mins)
Mastication of rubber	4
Addition of zinc oxide	2
Stearic acid and antidegradants (TMQ)	2
Addition of carbon black + oil	4
Addition of carbon black	3
Sulphur, CBS, DPG	3
Sweep and dumb	2
Total	20

RESULTS AND DISCUSSION

Table 3: Result of Variation of Stearic Acid Level on Vulcanizate Properties.

Sample	Stearic Acid Level	Hardness (IRHD)	Tensile Strength (MPa)	Modulus at 100% Elongation	Compression Set (%)	Elongation at Break (%)	Abrasion Resistance (%)
A	0.00	41.00	9.20	0.98	25.00	844.00	96.60
B	1.00	46.00	10.40	1.13	33.30	821.60	55.80
C	2.00	50.00	12.10	1.65	38.30	632.80	12.50
D	3.00	55.00	13.38	2.08	41.60	541.60	10.80
E	4.00	61.00	14.62	2.49	47.50	487.20	50.00
F	5.00	65.00	8.95	1.83	50.00	389.60	66.40
G	6.00	69.00	7.23	1.56	53.30	362.40	70.80

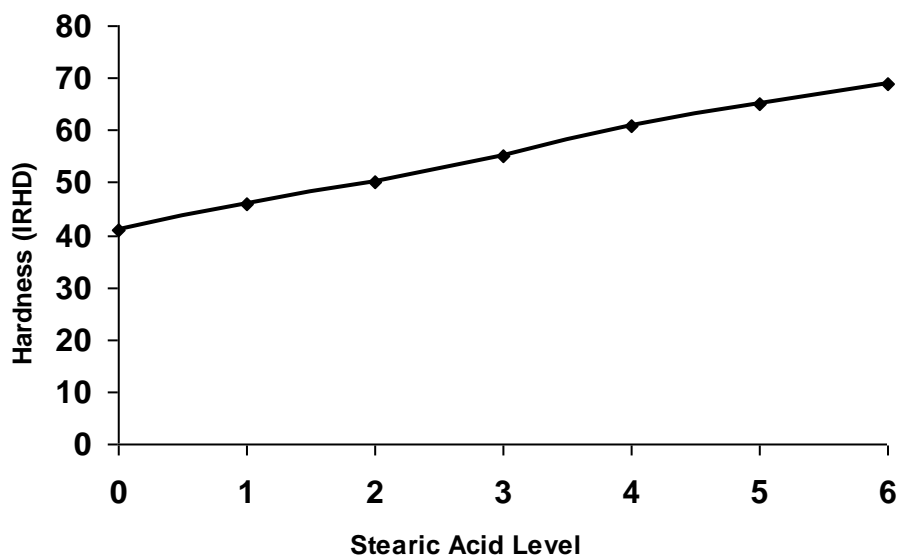


Figure 1: Effect of Stearic Acid Level on Hardness.

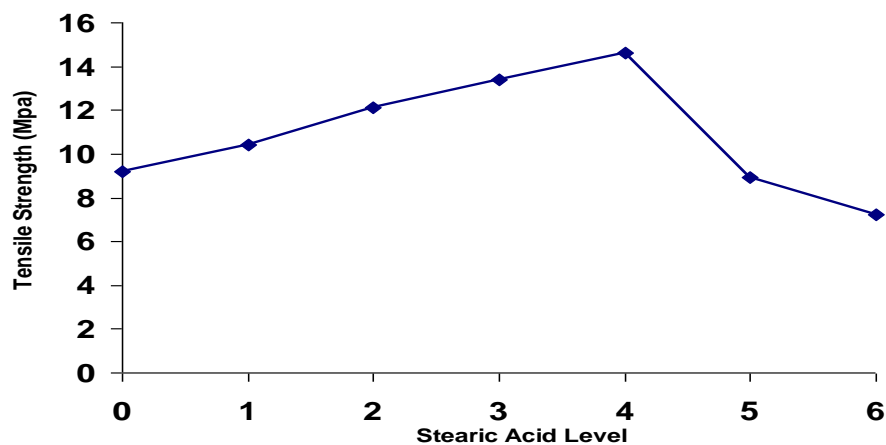


Figure 2: Effect of Stearic Acid Level on Tensile Strength.

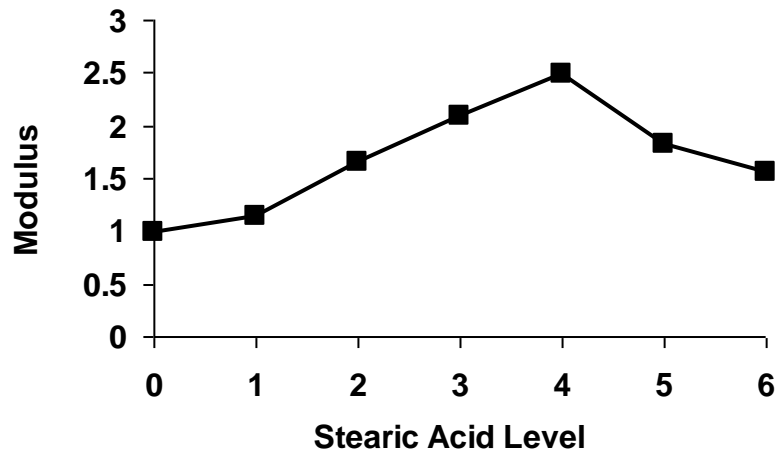


Figure 3: Effect of Stearic Acid Level on Modulus.

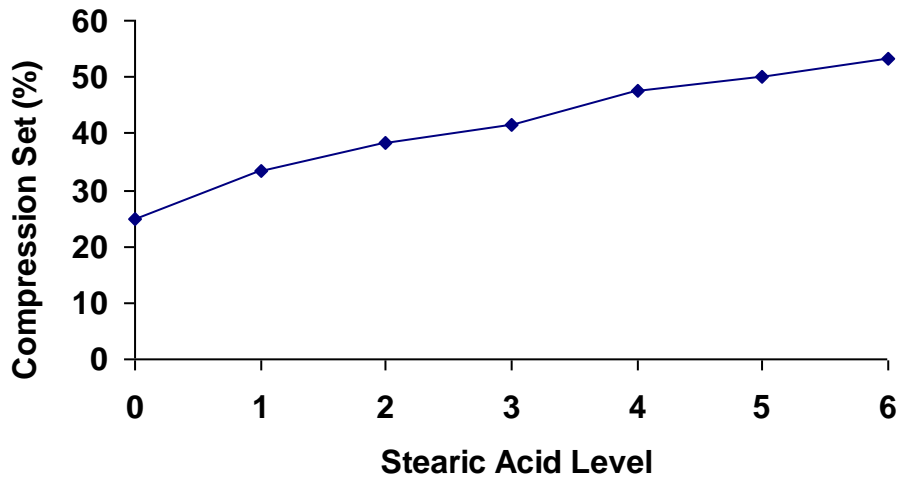


Figure 4: Effect of Stearic Acid Level on Compression Set.

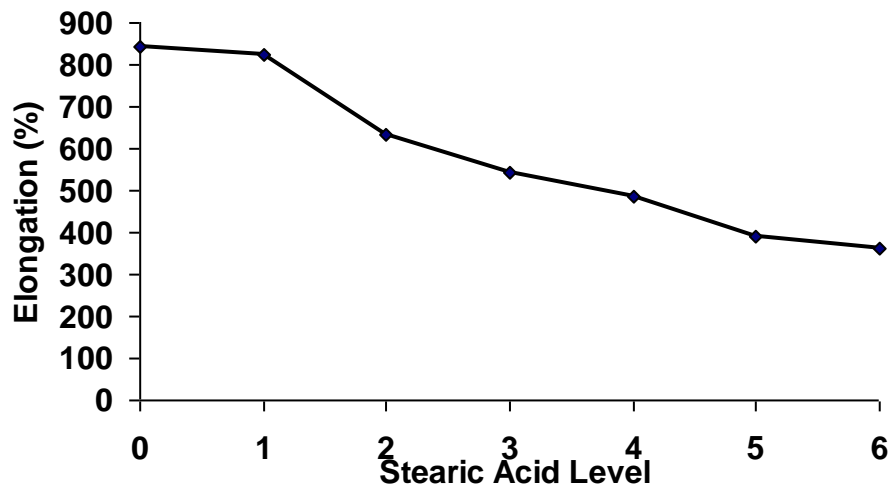


Figure 5: Effect of Stearic Acid Level on Elongation.

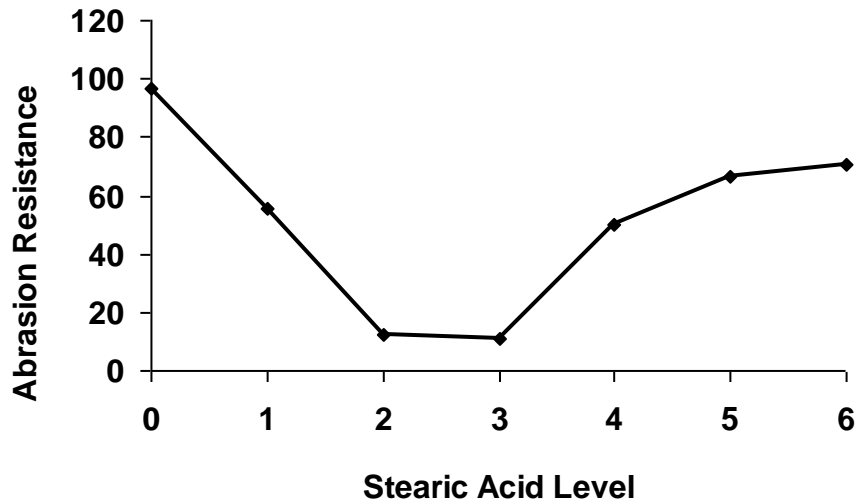


Figure 6: Effect of Stearic Acid Level on Abrasion Resistance.

DISCUSSION

The formulation recipe for the seven variations of stearic acid levels is presented in Table 1, while Table 2 shows the mixing schedule adopted; and Table 3 is a presentation of the various results obtained as a result of the variation of stearic acid level from 0.00 to 6.00 pphr. The result obtained is an indication that stearic acid has varying degree of influence on the physical properties of natural rubber vulcanisates. As part of the activating system stearic acid in conjunction with zinc oxide, during mill processing helps in the dispersion of other compounding ingredients by exerting a plasticization action on the stock compound (Fairclough and Swift, 1993). Also during vulcanization, it helps in activating the vulcanization system, by increasing the efficiency of the penetration and consolidation of the elemental sulfur at the anchoring point of the network (Barnhart, 1982) refer to as internal lubrication effect, (Wang, 1994).

The above statement has equally been proven in this research as indicated in the result obtained, which confirm or conform to some previous workers (Fairclough, 1993; Crowther, 1981). Wang and Kuriakose in their independent works had earlier stated that during vulcanization, most especially using the convectional vulcanization system, stearic acids has a profound effect in the consolidation of network structures by increasing the efficient formation of cross-link density, (Wang, 1994; Kuriakose, 1993). This has also

been confirmed in this work from the analysis and result of the hardness obtained.

As shown in the Table 3 and graphically illustrated in Figure 1, the hardness (IRHD) increases as the stearic acid level increases. Sample A, having zero stearic acid level has a hardness of 41.00 IRHD while sample G with 6.00pphr of stearic acid has 69.00IRHD, the highest hardness of all the samples. This can be explained from the fact that stearic acid has a profound effect in the consolidation of network structures by increasing the efficiency of vulcanization network leading to an increase in crosslink density (Wang, 1994).

Figure 2 shows that the tensile strength of natural rubber vulcanizate increases with an increase in the stearic acid level as a result of consolidation of network structure leading to increase in crosslink density. There was a steady rise in tensile strength from 0.00 pphr stearic acid level up to 4.00 pphr. Above this, (4.00 pphr) there is a drop or decrease in tensile strength.

This resultant decrease in tensile strength and modulus has been reported earlier by Kuriakose and co-workers, in their independent study (*“effect of high temperature vulcanization on the physical properties of pre-cured retread compounds”*), they were of the view that above 4.00 pphr of stearic acid, there is a reversion (over-cure) which is indicated by lower tensile Strength and modulus in cured natural rubber vulcanisates (Kuriakose, 1993).

From the results in Table 3 and the graphical illustration as shown in Figure 5, the elongation at break decreases with increase in stearic acid levels. This shows that sample A has the highest elongation and decreases from B to G as the stearic acid levels increases.

The possible explanation for the decrease in elongation at break is that as the stearic acid level increases, there is a corresponding increase in the efficiency of crosslink density formation (as illustrated in the Hardness level) leading to less elastic material. Note that elongation is extension between benchmarks produced by tensile force (Simpson, 2002).

High level of process aids or stearic acid should however be avoided as excessive rubber breakdown before addition of carbon black leads to poor black dispersion. This is likely to cause a significant deterioration in physical properties (Fairclough, 1993).

The results in Table 3 show that stearic acid is an important component of the activation system in rubber technology, as the various results of the vulcanizate properties indicates an influence as the stearic acid level varies.

For the abrasion resistance, the graphical illustration as represented in Figure 6 shows that there is a rapid decrease in abrasion resistance as the stearic level increases from 0.00 pphr to 2.00 pphr. Above this, there is a significant increase as the stearic acid level increases. This seems confusing, but solace has been found in the work of Wang, P. J. and co-workers, as earlier indicated. He asserted that the use of higher than normal levels of stearic acid in natural rubber based compound has been shown to lead to significant improvement in abrasion resistance particularly after over-cure or reversion (Wang, 1994). As indicated in the results of tensile strength and modulus, Table 3, there is a reversion in sample F and G as shown by poor vulcanisate properties.

Kuriakose, further asserted that whilst a higher level of stearic acid has only a marginal effect on scorch safety, the effect on cure time and most importantly reversion is significant. He asserted that stearic acid has a more beneficial effect on 100% natural rubber and 100% SBR than on blends of these polymers with polybutadiene (Kuriakose, 1993).

CONCLUSION

The results of this study and the analysis made from it shows that stearic acid level of 4.00 pphr gives vulcanisates with optimum physical properties, such as hardness, tensile strength, modulus and abrasion resistance. But above this level up to 6.00 pphr, abrasion resistance, compression set are also favored; but has adverse effect on those properties it favors at lower levels. Hence, it can be concluded that the use of stearic acid level is a compromise between the more desirable vulcanizate properties as may be specified by area of application.

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