The Influence of Natural Rubber (NR) – Butadiene Rubber (BR) and Type of Carbon Black Particle as the Filler on the Mechanical Properties of Track

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Abstract. Track shoe is a driving component in the chain-shaped tank, the main components are made of steel and rubber. Rubber Track Shoe serves to prevent the road damage caused by the chain round tank when operating on the highway. Given its function rubber track shoe should have a high abrasion resistance, heat resistance due to friction (heat build up), tear resistance, and able to withstand the load of the weight of the tank itself.

This research will use natural rubber (NR) and synthetic rubber (BR) as well as variations in filler materials, to produce the formulations which is used in the manufacture of rubber track shoe one of a kind tank AMX 13. The purpose of this formulation design to see the nature of vulcanized rubber produced from each formula, which will meet the technical specifications required Tank AMX 13.

The composition of natural rubber (NR) and BR are used are as follows NR: SBR, 100%: 0, 80%, 20% and also 0: 100%.As filler materials is used Struktol 40 Ms, Coumorone Resin, Ultrasil VN 3, PEG 4000, KH-845-4 (SI), Stearat acid, Zn O, Wax S-RP 3 Rubber, 6 PPD – Santoflex, TMQ-Flektol, Dispergator FL,Minarex Oil, Oricle CBS, Sulfur and also Carbon Black.. In each formula using several kinds of carbon black is N 220, N 330, N 550 and N 660, which has a different particle size. The vulcanized rubber produced from each formula was characterized with tensile strength, elongation, hardness, abrasion resistance, compression set as well as heat build up.

The specification requirement of track shoe for AMX 13 is the hardness shore A 71-73, tensile strength minimum 18 N/mm2, elongation at break 300 %, tear strength minimum 5.7 N/mm2, specific gravity 1.19-1.3 g/cm3 and abrasion resistance maximum 21 DIN mm3. The Characterization of all formula results showed that the formula mixture of natural rubber and BR produced vulcanized rubber properties similar to the technical specifications of the AMX 13,such as the hardness shore A 81 to a formula that uses carbon black N 220, and shore A hardness 74 to formula with carbon black N 660. Thus to obtain hardness, tensile strength, tear strength and abrasion strength is good, then use carbon black with small particle size N 220. However, the smaller particle size of carbon black produced heat build-up is also greater than when using carbon black with a large particle.

Keywords: Track shoe; natural rubber; butadiene rubber; compounding; carbon black

Introduction

Tank is an armored fighting vehicle that moves using a wheel-shaped tires or chains. The main characteristic is a tank protector that usually is a heavy armor, weapon is a large cannon, and high mobility to move smoothly in all fields. Military vehicles such as tanks using a track shoe that is integrated in the structure of the distribution chain to reduce the weight of the tank. Reduction in weight distribution allows the tank to move faster. Vehicle weight is transferred to all parts of the track with a road wheel or wheel group called bogie. Tanks that use track shoe has better mobility than pneumatic tires in rough terrain. The use of track shoe also cause less likely stuck in mud or snow because of track shoe distribute the weight of the vehicle on a large contact area, reducing the ground pressure. In addition to the large contact area, coupled with cleats or grousers enabling far superior traction and produce a much better ability to push or pull large loads where wheeled vehicles may be stuck in the ground. The weakness of the track is a lower speed, much greater mechanical complexity. Besides all of the tracks that use iron often causes a track of the road was badly damaged due to the sharp end of the track. Therefore gluing rubber on the track iron components will make the track move smoother, faster and not noisy on paved surfaces.

Currently, many manufacturers use rubber tracks than steel tracks. Compared with steel tracks, rubber track lighter, make less noise, and produces a maximum of a lower ground pressure and does not damage the pavement. Current track shoe is made of butadiene rubber (BR). Widespread use in the manufacture of components of BR rubber track shoe seems to be based on cost, and the fact that at this time in western countries especially those producing military vehicles require rubber materials that are widely available to the continuity of supply of rubber for use on their combat equipment. The factors that led to western countries manufacture track shoe uses synthetic rubber as compared to natural rubber. Indonesia is the second producer of natural rubber in the world, therefore this research tries to develop a formulation manufacture track shoe with mixing natural rubber (NR) with Butadiene Rubber (BR).

The main objective of this study is to provide a design of compound formulations AMX 13 track shoe with optimal performance. Formulation design is expected to be a standard formula for the manufacture of components of the AMX 13 scale track shoe production of finished goods in the local rubber industry. To improve the performance of track shoe, first of all should be to identify the nature of the required properties and then optimize it.

To improve the performance of track shoe, the properties such .as cutting and chipping resistance, tear and tensile strength, crack growth resistance, abrasion resistance, hysteresis and thermo-mechanical stability should be improved.

The technical specifications of the standard track shoe AMX 13 is as follows:

Table 1. Technical specifications track shoe AMX 13.

Properties	Standard
Hardness Shore A	71 – 73
Tensile Strength N/mm2	Min 18
Elongation at Break (%)	300
Tear Strength N/mm2	Min 5.7
Spesific Gravity g/mm3	1.19 – 1.3
Abrasion resistance DIN mm3	Maks 21
Loadcarrying capacity N/mm2	Min 1.8
Life time, km	Min 600

Other key properties that need to be considered is the heat build up for finished goods like track shoe is very susceptible to heat generation under conditions of dynamic use. Actually, the heat generation is determined by the properties of the polymer, physical and chemical properties of materials and their interaction with the compounding rubber, operating parameters, and environmental conditions. Heat generation of rubber components is more dependent on the physical properties of the rubber and operating variables.

Experimental

Material

Elastomers has nature elastic, flexible, tough and air-proof and water resistant, and can be classified according to their application. Elastomers used in our research were natural rubber (NR), BR (Butadiene Rubber) and a mixture of natural rubber and BR. Struktol 40 MS was used as peptizer, Coumorone resin as tackifier, Ultrasil and carbon black as filler, PEG 4000, Stearic acid, ZnO, wax, 6PPD, TMQ, and minarex oil as additives. CBS was used as accelerator and sulfur as vulcanizing agent.

Sample Preparation

Besides reviewing the material through the literature, trial formulations was also conducted based on the selection of material to obtain the physical properties of the resulting vulcanized were similar to expected technical specifications. Three types of formulas were developed in this research.

Table 2. Three formulas for track shoe.

Material	Formula 1 (phr)	Formula 2 (phr)	Formula 3 (phr)
SIR 20	100	80	---
Koysin KBR 01/ BR 1208	---	20	100
Struktol 40 MS	1,5	1,5	1,5
Coumorone Resin	3	3	3
Ultrasil VN3/ Chemisil	15	15	15
PEG 4000	1,5	1,5	1,5
KH-845-4 (SI)	1	1	1
Stearic Acid (FL-1800RB)	1,5	1,5	1,5
ZnO red seal	4	4	4
WaxS-RP 3 Rubber	3	3	3
6 PPD-Santoflex	2	2	2
TMQ-Flektol	3	3	3
Dispergator FL	3	3	3
Minarex oil	3	3	3
Carbon Black	65	65	65
Oricle CBS	1,5	1,5	1,5
Sulfur	1,7	1,7	1,7

Characterization

Vulcanized rubber testing include: Hardness in accord with ASTM D2240-04E01, Tensile strength with ASTM D430, Elongation at break with ASTM ASTM D 1456-86R01, abrassion resistance with : ASTM D 1630-94R00, Compression set with ASTM D 0395-03 and also heat build up.

Results and Discussion

Hardness

Based on the measurement results shown in the figure below, the trend of hardness that occurs in nature vulcanized natural rubber is the tendency of hardness increases with decreasing particle size, but the hardness are not different significantly.

The addition of carbon black in different types of elastomers are shown in the figure below. It is also not very significant effect on the value of hardness, this is due to the hardness of natural rubber and BR rubber is almost the same.

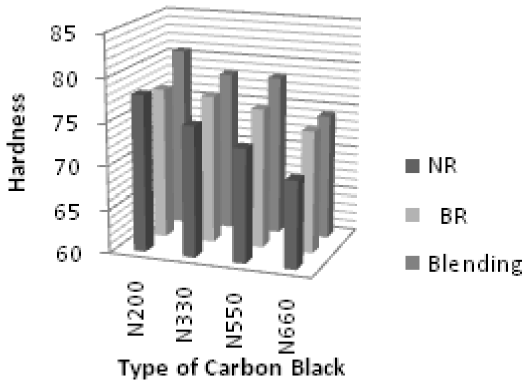

Figure 1. The influence of carbon black types on hardness.

Tensile Strength

The influence of the type of carbon black added to the tensile strength, compression set, tear strength, elongation and modulus can be seen in the figure below.

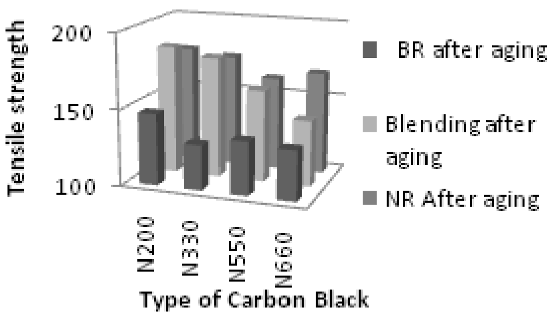

Figure 2. The influence of carbon black and elastomer types on tensile strength.

From the measurement data, it can be seen that the tensile strength will affect the surface activity, where it depends on the diameter of the carbon black particles used. The smaller of particle size, the tensile strength of natural rubber products will be greater. Carbon black has a high surface energy derived from unsaturated polyaromatic structure and its functional groups. This structure makes carbon black particles can adsorb polymer chains strongly. Without carbon black, vulcanized rubber has a tensile strength that only comes from crosslinking by sulfur atoms. However, the presence of fillers such as carbon black, make the tensile strength becomes greater because it is supported by the interaction between the polymer chains with carbon black. Carbon black particle size affects the intensity of the adsorbed polymer chains. This increases the van der Waals interaction between carbon black and polymer chains. The more adsorption occurs, the greater the deformation energy.

Elongation at Break

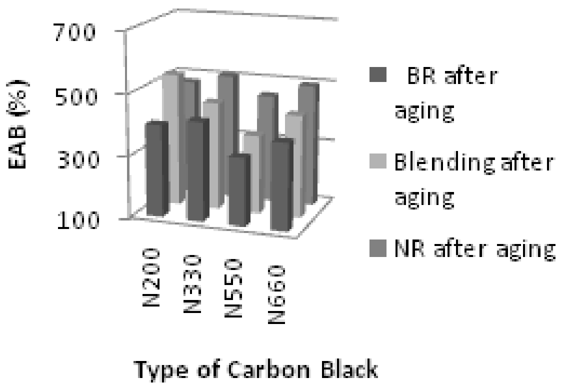

Figure 3. The influence of carbon black and elastomer types on elongation at break.

From the measurement data, the elongation at break is not affected by the size of the carbon black particles used, this is indicated on the elongation at break values that were almost the same, this was because the elongation at break is a function of the structure of the carbon black. However, the addition of carbon black (size and amount of carbon black) into natural rubber gave greater elongation at break compared with BR. This is due to the natural rubber has a higher elasticity compared to BR that give greater elongation at break.

Tear Strength

Tear resistance properties is needed for finished goods track shoe, because the tanks operational experience dynamic loads and operating conditions are heavy enough. Based on the research results, the smaller the particle size, the greater tear resistance. However, the selection of elastomer greatly affect tear resistance. The tear resistance is best obtained for BR comparison to Natural rubber (NR).

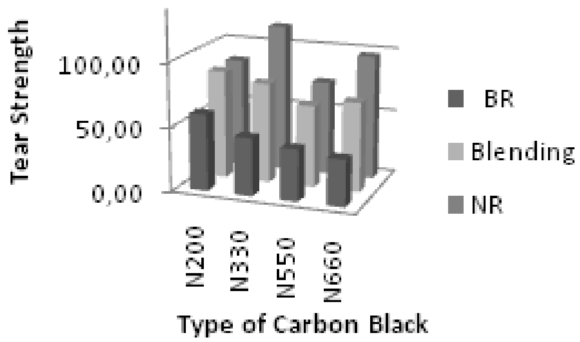

Figure 4. The influence of carbon black and elastomer types on tear strength.

Abrasion Resistance

Abrasion properties of the polymer molecule is the ability to maintain formation of the polymer chain friction, so the better of the abrasion properties made slightly vulcanized rubber that can be erode. The ability of the polymer chains in overcoming friction is greatly influenced by the interaction between the polymer chains with the polymer chains and the polymer chains with the surface of the carbon black. Besides the crosslinking, abrasion vulcanized natural rubber was also influenced by the interaction between the polymer chains to the surface of carbon black through Van der Waals interactions. Smaller particle size on carbon black has an advantage in terms of quantity of surface area. Larger surface area increases the intensity of the Van der Waals interaction of the polymer chains by carbon black. As a result, the smaller the particle size of the carbon black used as filler material, the more powerful the abrasion properties of vulcanized rubber. While the type of rubber used, the best abrasion acquired BR compared with natural rubber, this is likely due to the quality of the natural rubber used is using SIR 20 produces a low abrasion resistance. Abrasion resistance can be improved by changing the types of natural rubber used and the mixing between natural rubber with BR.

Compression Set

The compression set is defined as the ability of the material to return to its original shape after experiencing loading. In use track shoe has pressure, so in order to function properly, track shoe must have good compression set so it can maintain the initial shape when exposed to pressure or deformed shape. From the measurement result, it was obtained that the particle size did not significantly influence the compression set remains despite a downward trend with increasing size of the particles used. The best value compression set was obtained by using rubber BR compared to natural rubber (SIR 20). Therefore, in order to reduce the value of compression set replacing the type of natural rubber used with better quality than the SIR 20, or by mixing natural rubber with BR can be applied.

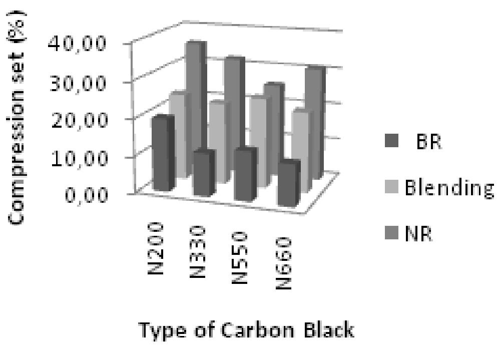

Figure 5. The influence of carbon black and elastomer types on compression set.

Heat Build Up

When an elastomer deformation is repeated with sufficient magnitude and frequency, hence resulting in heat generation and temperature rise of vulcanized rubber. This phenomenon is getting worse, especially for finished goods thick rubber and its use dynamic such as tread rubber as well as track shoe. If the temperature rise is too high, it can cause the inside of the rubber becomes very hot and may explode or known as the blow out. Reinforcing fillers such as carbon black has a considerable effect on the heat generation in the rubber compound. The result is the larger size of the particles, the heat arising become lower. The smaller size of the carbon black forming crosslinking density higher and higher heat generation. While the addition of carbon black with the same size and amount into different elastomers does not significantly affect to the resulting heat build up. Although the results of this study indicated that BR is still a better value than natural rubber (SIR 20).

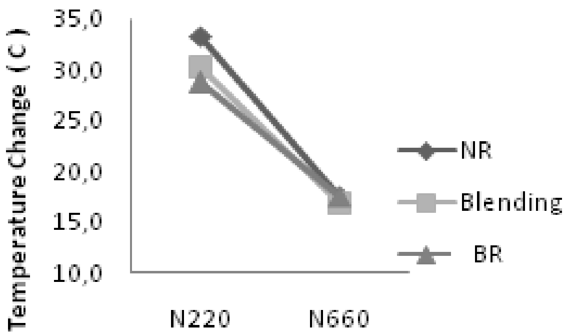

Figure 6. The influence of carbon black and elastomer types on heat build up.

The analysis of these formulas were made and the results were compared to the standard technical specifications AMX 13 rubber track shoe. Here is a summary of the generated test data.

Table 3. Testing result of formulas track shoe.

Natural Rubber SIR 20					
Parameter	N220	N330	N550	N660	Standard
Hardness shore A	78	75	73	70	71 – 73
Tensile Strength N/mm2	17.46	17.06	15.89	16,48	Min 18
Elongation at Break (%)	408	507	452	497	300
Tear Strength N/mm2	8.33	11.32	7.2	9.51	Min 5.7

Spesific Gravity g/mm3	1.17	1.17	1.18	1.18	1.19 – 1.3
Abrasion resistance DIN mm3	111.23	114.36	118.15	159.32	Maks 21
Ozon Resistance	No crack	No crack	No crack	No crack	
Compression set (%)	35.48	31.90	25.41	30.77	
Heat Build Up (ΔT) °C	33.3			17.5	

Elastomer BR					
Parameter	N220	N330	N550	N660	Standard
Hardness shore A	77	77	76	74	71 – 73
Tensile Strength N/mm2	14.41	12.74	13.23	13.04	Min 18
Elongation at Break (%)	400	422	321	383	300
Tear Strength N/mm2	5.86	4.42	3.96	3.57	Min 5.7
Spesific Gravity g/mm3	1.17	1.17	1.18	1.18	1.19 – 1.3
Abrasion resistance DIN mm3	42.26	55.81	51.13	65.02	Maks 21
Ozon Resistance	No crack	No crack	No crack	No crack	
Compression set (%)	19.78	11.61	13.44	11.33	
Heat Build Up (ΔT) °C	28.7			17.5	

Blending Natural Rubber SIR 20 and BR					
Parameter	N220	N330	N550	N660	Standard
Hardness shore A	81	78	78	74	71 – 73
Tensile Strength N/mm2	18.14	17.65	15.69	14.02	Min 18
Elongation at Break (%)	531	450	355	433	300
Tear Strength N/mm2	8.32	7.65	6.25	6.83	Min 5.7
Spesific Gravity g/mm3	1.2	1.2	1.2	1.2	1.19 – 1.3
Abrasion resistance DIN mm3	75.16	88.17	86.9	84.13	Maks 21
Ozon Resistance	No crack	No crack	No crack	No crack	
Compression set (%)	23.56	22.04	24.43	21.79	
Heat Build Up (ΔT) °C	30.2			16.8	

From the data above is shown that the hardness of the three formulas can fulfill the standard for AMX 13 rubber track shoe, but the tensile strength which meet the standard was only the formula of blending of NR and BR with Carbon Black type N 220. While the abrassion for all three formulas cannot be satisfy the standard.

Conclusion

The formulation of natural rubber has a value of tensile strength, elongation at break and tear resistance greater than the synthetic rubber BR but have abrasion resistance and compression set remains smaller than BR synthetic rubber.

To get the properties of tensile strength, elongation and tear resistance, abrasion resistance and good compression set is by mixing natural rubber with synthetic rubber.

To get the properties of tensile strength, elongation and tear resistance, abrasion resistance and a good compression set, used filler with smaller particle size N220, but the smaller particle size, resulting heat arise greater even compared to most of the large particle size. Therefore to obtain the physical properties of vulcanized rubber high without reducing the thermal resistance properties need to be mixing between the filler particle size small and large particles.

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[1] J. L. Bras, E. Papirer. *Rubber Chem. Technol*. **1976**, *52*, 43.
[2] J. W. Meng, et. al., *Introduction of Carbon black*. New York: John Wiley and Sons. **2001**, *9*, 52.
[3] G. Kùhner and M. Voll, in J.B. Donnet, R. C. Bansal, and M. J. Wang, *Carbon black, Science and Technology*. New York: Marcel Dekker, 1993.
[4] S. C. George and S. Thomas. *J. Macromol. Sci*., **2000**, *39*, 175-195.
[5] M. E. James, B. Erman, F. R. Eirich. *The Science and Technology of Rubber 3rd Edition*. Elsevier Academic Press., 2005.
[6] E.M. Dannenberg., Rubber Chem. Technol: Bound rubber and carbon black reinforcement. New York: Elsevier Academic press,1986.
[7] Subhan Salaeh, Charoen Nakason. *Polym. Compos.* **2012**, *33*, 489.
[8] J.J. Han, X. L. Zhang, W. H. Guo, C.F. Wu., *J. Plast. Rubber and Compos. 36(4)*, 149.
[9] J. Anderson, E. A. Dawes, *Microbiol. Rev*. **1990**, *54*, 450.