EFFECT OF ADDING NATURAL RUBBER TO INNER TIRES USING THE PRESSURE METHOD

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***Abstract*—The inner tire significantly determines the effectiveness and efficiency of a commercial transportation vehicle. The inner tire is expected to have high durability against friction with the outer tire and a high tensile strength to prevent it from bursting under heavy loads. To address this issue, the process of adding natural rubber material to the inner tire is carried out using the pressure method with two variables. Firstly, a single layer of inner tire and a single layer of natural rubber are attached to the outer side of the inner tire. Secondly, the inner tire is sandwiched between two layers of natural rubber placed on the outer and inner sides of the inner tire. Then, a pressure process is applied, followed by FTIR, tensile brake, hardness, and adhesion testing, aimed at obtaining data to understand the impact of adding natural rubber to the inner tire using the pressure method. This data serves as a reference for inner tire production to improve product quality. After conducting the research process, the FTIR testing revealed the presence of several constituent materials in the inner tire component, including natural rubber, IIR, and BIIR. For the tensile brake test, the obtained strength values were 20.4 Kgf for specimen one, 23.8 Kgf for specimen two, and 31.05 Kgf for specimen three. Furthermore, the hardness test yielded results of 52° for specimen one, 48° for specimen two, and 44° for specimen three. In the adhesion testing, the adhesion strength was found to be 2.5 Kgf for specimen one, 3.7 Kgf for specimen two, 1.8 Kgf for specimen 3.1, and 3.1 Kgf for specimen 3.2. These findings provide valuable insights into the effects of adding natural rubber to the inner tire using the pressure method and can serve as a reference for improving inner tire quality.**

Keywords—natural rubber, tensilebrake, hardness.

I. INTRODUCTION

The National Transportation Safety Committee (KNKT) states that 80% of passenger transport accidents occur due to inner tire bursts in vehicles. This finding applies to both public and private vehicles. KNKT Chairman Soerjanto Tjahyono explained that the cause of inner tire bursts is speeding on the highway, leading to fatigue in the corner areas and resulting in tears in the inner tire. In 2019, there were a total of 337 traffic accidents, and 80% of them, which amounts to 265 cases, were caused by inner tire bursts. Therefore, inner tires play a crucial role in the effectiveness and efficiency of transportation vehicles, especially in the commercial sector. Several manufacturers continue to innovate to create inner tires with high durability and strong tensile strength because the primary function of inner tires in both two-wheel and four-wheel or more vehicles is to bear the load and withstand friction [1].

Natural rubber is a renewable polymer material that exhibits good physical properties and is widely used in various industries. Products made from natural rubber include vehicle tires, mining equipment, medical equipment, and petrochemical equipment [2]. Natural rubber is derived from the latex of rubber trees. Latex contains 25-40% raw rubber material and 60-75% serum consisting of water and dissolved substances. Raw rubber material consists of 90-95% pure rubber, 2-3% protein, 1-2% fatty acids, 0.2% sugar, and 0.5% various salts of Na, K, Mg, Cn, Cu, Mn, and Fe. The advantages of natural rubber over synthetic rubber include good elasticity, high wear resistance, resistance to heat, high crack resistance, greater strength, and impact resistance [3]. Therefore, it is essential to treat inner tires specially by adding natural rubber material to improve their physical strength.

The addition of natural rubber to inner tires can be accomplished through various methods, one of which is the pressure method. The initial step in this method involves cleaning the inner tire, followed by a roughening process. Subsequently, it is coated with natural rubber, and finally, the layer is pressed using a tire press tool and heated to allow the natural rubber and the inner tire to fuse together.

Therefore, a research process will be conducted where the inner tire will be enhanced with natural rubber components using the pressure method. Subsequently, it will be heated to ensure the fusion of these two components. Following that, a testing process will be carried out to determine the impact of adding natural rubber components to the inner tire using the pressure method.

II. STUDY LITERATURE

A. Natural Rubber Specification

Natural rubber is a crucial component required for this research. In most cases, natural rubber is in the form of seeds and is specifically used as a filler in synthetic rubber using a two-roll mill machine. However, in this study, to homogenize natural rubber with the inner tire using the pressure method, the natural rubber used is ANR 40050150. Here is the specification table for ANR 40050150 natural rubber.

Table 1 Natural Rubber Specification

Material Specification			
Specification	*Test Method*	*Test Result*	*Unit*
Specific Gravity	ASTM D-297	1,5	g/cm^3
Hardness	ASTM D-2240	40 +/-5	Shore A
Tensile strength	ASTM D-412	5	Mpa
Elongation	ASTM D-412	250	%
Tear Strenght	ASTM D-624	20	Kgf/cm
Compression Set	ASTM D-395	40	%

Tabel 1 provides the specification of natural rubber, with the following results *specification grafity* with ASTM D-297 method get result 1,5 g/cm^3. *Hardness test specification* with ASTM D-2240 methode method get result 40 +/-5°. *Tensile strength specification* with ASTM D-412 methode get result 5 Mpa. *Elongation specification* with ASTM D-412 methode

U. S. Saputri and M. A. S. Yudono (eds.), *Proceedings of the International Conference on Consumer Technology and Engineering Innovation (ICONTENTION 2023)*, Advances in Engineering Research 233,
https://doi.org/10.2991/978-94-6463-406-8_14

get result 250%. *Tear strength* specification with ASTM D-624 methode get result 20 Kgf/cm. *Compression set* specification with ASTM D-395 methode get result 40%.

B. Inner Tire

Inner tires with the Swallow brand and made of butyl rubber (IIR) are cut into sheet form, which will then be coated with natural rubber. Subsequently, a homogenization process is carried out using the pressure method.

Table 2 Inner Tire Specification

Test Type		Inner Tube
Tensile Test	Termination Extension	Min. 500%
	Tensile strength of the inner tube	Min. 11,8 MPa (120 Kgf/cm^2)
	Strong tensile connection	Min. 8,3 Mpa (85 Kgf/cm^2)
Elongation Test		Max. 25%
Obsolescence Test	Tensile strength decrease	Max. 10%

In table 2 it is known that the specifications of the inner tube material have a value of elongation at break min. 500%, inner tire tensile strength min. 11.8 MPa, tensile strength min. 8.3 MPa, elongation test max. 25%, and hardness testing according to SNI 06-1542-2006 standard with a value of 50 +/- 5 degree

C. Pressing Process Time

The tire patching process typically takes a relatively short amount of time, depending on the level of damage to the tire. The more severe the damage to the tire, the more time it will require for the repair. Additionally, the type of tire also plays a role. In general, if a tire has a puncture from a nail or similar object, the time needed for the pressing process until the tire patch adheres perfectly is 15 minutes [4]

D. Pressing temperature

Based on the evidence from the test results at a temperature of 70°C, it can be observed that the patching results fall into the category of perfection. This is evident from the seamless integration of the tire patch material with the tire, both on the top and on the sidewall of the tire [5].

III. Methodology

A. Research Procedure

To achieve the expected research outcomes, this study involves several experimental stages that will be carried out until the results in the form of natural rubber composites as potential candidates for strengthening the inner tire are obtained. The steps are as follows.:

1. Prepare all tools and materials.
2. Conduct compression between natural rubber and inner tire
3. Shape the pressed specimens according to the testing specimen specifications
4. Perform testing
5. Analysis
6. Conclusion

B. Research Variables

The variables used in this research are the ratios of natural rubber to the inner tire, as outlined in the table below:

Table 3 Variable

No. Specimen	Natural Rubber		Inner Tube	Unit
1	**0**	**:**	**1**	**layer**
2	**1**	**:**	**1**	**layer**
3	**2**	**:**	**1**	**layer**

In specimen one, there is only one layer, which is the inner tire itself. In specimen two, there are two layers, namely natural rubber and the inner tire, where natural rubber is on the outer side. In specimen three, there are three layers, consisting of two layers of natural rubber and one inner tire layer, with the inner tire layer in the middle of the natural rubber layers. Then, each specimen has two variables to test the reliability of the obtained data. Subsequently, the data results are averaged, and graphs are created to visualize the differences.

C. How to Work with Specimens

The procedure for creating a tensile test specimen of inner tire coated with natural rubber using manual equipment, with its working process explained as follows:

1. Abrade the surface of the inner tire and natural rubber before the pressing process.
2. Place the inner tire and natural rubber specimen on the press machine.
3. Then, rotate the lever of the press machine to apply pressure to the specimen.
4. Turn on the flame, which serves as the heat source for the press machine.
5. Periodically check the temperature using a thermometer to ensure it remains stable within the range of 70°C to 90°C for 15 minutes.

D. Test Type

This research will involve four types of tests on the inner tire coated with natural rubber to determine the influence of adding the natural rubber layer to the inner tire:

1. FTIR Test : detailed specimens of inner tire sections measuring 30 mm in length, 30 mm in width, and 1 mm in thickness.
2. Tensile Test : In the tensile testing in this research, ASTM D 638-02 standard is used, as shown in the figure below:

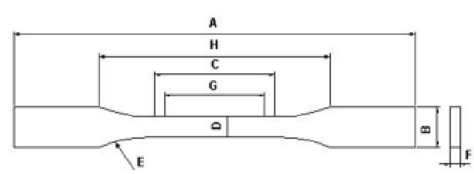

Figure 1 Dimension Tensile Test Specimen

Keterangan gambar:

A.	LO (Langth Overral)	= 165 mm
B.	WO (Width Overral)	= 19 mm
C.	L (Length of narrow section)	= 57 mm
D.	WC (width of narrow section)	= 13 mm
E.	R (Radius of fillet)	= 76 mm
F.	T (Thickness)	= 3 mm

G. G (Gage length) = 50 mm

H. D (Distance between grips) = 115 mm

3. Hardness Testing: The hardness testing method employed is SHG (*Shore Hardness Degress*).
4. Adhesion Testing: In the adhesion testing, ASTM D413 standard is utilized with specimen specifications as follows:

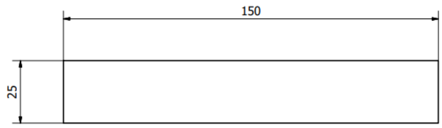

Figure 2 Dimension Adhesion Test Specimen

Long : 150 mm
Wide : 25 mm

IV. Results

The following are the results of the FTIR test, tensile strength, hardness, to find out the effect of adding natural rubber material to the inner tube using the pressure method.

A. FTIR Result Test

FTIR testing serves to determine the functional groups of the compounds that make up the tire by directing infrared light, which will subsequently produce a peak diagram as shown in the diagram below.

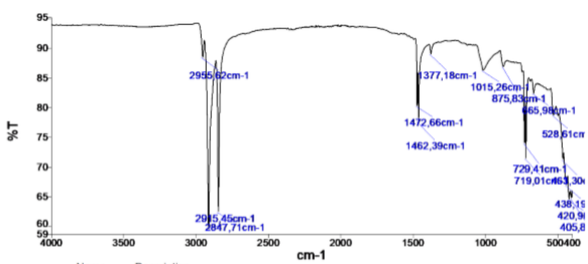

Figure 3 FTIR Result Test

Table 4 Peak Max FTIR Result Test

No. Peak	X (cm^{-1})	Y (%T)	Gugus Funsi	Vibrasi	Material
1	2915,45	59,54	C-H	*Streching*	*Natural rubber*
2	1472,66	80,39	C=O	*Bending*	IIR
3	729,41	7415	C=H	*Streching*	BIIR

the results of FTIR testing on the inner tire of the car were obtained, with a specimen dimension of 25mm x 25mm x 1mm. In this study, only strong category peaks were sought. In the first peak, the wavenumber value was 2915.45 cm-1, and this peak indicated the presence of a functional group in the form of C-H bonds in organic molecules. For this wavenumber, the fundamental vibration type is symmetrical stretching, and the range of 3000-2800 cm-1 indicates the presence of natural rubber material [6]. In the second peak, the wavenumber value was 1472.66 cm-1, and this peak revealed the presence of a functional group in the form of C=O bonds (carbonyl group), indicating the material to be IIR (butyl rubber). Furthermore, in the third peak, the wavenumber value was 729.41 cm-1, and this peak indicated the presence of a functional group in the form of carbon-hydrogen bonds, specifically C≡H (alkyne), with the fundamental vibration type being stretching vibration. The wavenumber in the third peak suggests the presence of BIIR (bromobutyl rubber) material [6].

B. Tensile Brake Result Test

The results of tests conducted at PT. Bando Indonesia with the ASTM D 638-02 specimen standard using a Shimadzu machine (Cap. 10Kn) as a tensile test tool obtained the following result:

Table 5 Tensile Brake Result Test

No.	Sample	wide (mm)	long (mm)	TB (Kgf)	EB (%)
1	SP 1	1,61	12,78	20,4	-
2	SP 2	3,83	12,18	23,8	560,5
3	SP 3	5,83	12,81	31,05	620

Tensile strength is the amount of load required to stretch a test specimen until it breaks, expressed in kg/mm² of the cross-sectional area of the test specimen before stretching [7]. Table 5 presents the results of tensile testing, where specimen one consisted of a single layer of pure inner tire rubber with a thickness of 1.61 mm and a length of 12.78 mm. It exhibited a tensile force of 20.4 Kgf, and the elongation at break was zero because it snapped immediately upon being pulled. Specimen two consisted of a single layer of pure inner tire rubber and an outer layer of natural rubber attached to the outside of the inner tire, with a thickness of 3.83 mm and a length of 12.18 mm. It exhibited a tensile force of 23.8 Kgf, and the elongation at break was 560.5%. Specimen three consisted of one layer of inner tire rubber and two layers of natural rubber, with the inner tire layer sandwiched between the two natural rubber layers. It had a thickness of 5.83 mm and a length of 12.81 mm. This specimen showed a tensile force of 31.05 Kgf, and the elongation at break was 620%."

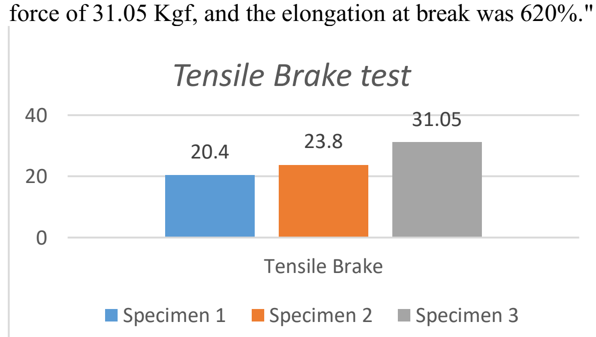

Figure 4 Tensile Brake Diagram

In the tensile testing, the lowest value was obtained in specimen one with a composition of natural rubber to inner tire rubber at 0:1, resulting in a tensile strength of 20.4 Kgf. Subsequently, specimen two with a composition of natural rubber to inner tire rubber at 1:1 exhibited a tensile strength of 23.8 Kgf, and the highest tensile strength was observed in specimen three with a composition of natural rubber to inner tire rubber at 2:1, measuring 31.05 Kgf. As for the elongation at break results, the highest value was recorded in specimen two at 560.5%, followed by specimen three at 620%.

C. Hardness result test

The results of the hardness test conducted at PT. Bando Indonesia with ASTM D 638-02 specimen standards obtained the following results:

Table 6 Hardness Result Test

No.	Sample	Tebal (mm)	Panjang (mm)	Hardness (°)
1	SP 1	1,61	12,78	52
2	SP 2	3,83	12,18	48
3	SP 3	5,83	12,81	45

Hardness testing is conducted to determine the hardness of rubber vulcanizate with a specific compressive strength [8]. The hardness of rubber vulcanizate varies depending on the amount of filler materials and plasticizers used in the compound [9]. Table 6 presents the results of hardness testing, where Specimen one, with a thickness of 1.61 mm and a length of 12.78 mm, exhibited a material hardness of 52°. Specimen two, with a thickness of 3.83 mm and a length of 12.18 mm, showed a material hardness of 48°. Specimen three, with a thickness of 5.83 mm and a length of 12.81 mm, displayed a material hardness of 45°.

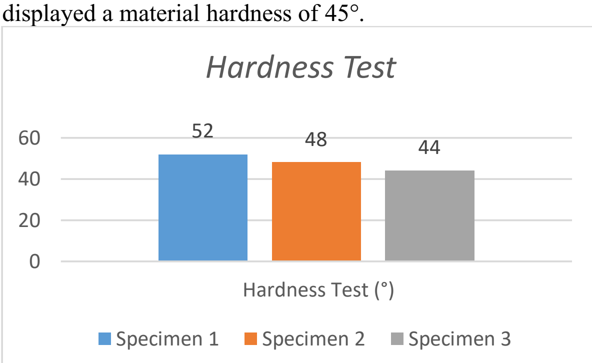

Figure 5 Hardness Test Diagram

In hardness testing, the highest value was obtained in specimen one with a composition of natural rubber to inner tire rubber at 0:1, resulting in a hardness value of 52°. Subsequently, specimen two with a composition of natural rubber to inner tire rubber at 1:1 exhibited a hardness value of 48°, and the lowest hardness value was observed in specimen three with a composition of natural rubber to inner tire rubber at 2:1, measuring 45°. Therefore, according to the SNI 06-1542-2006 standard, the allowed hardness value for inner tires is 50 +/- 5 degrees. In specimens 1, 2, and 3, the hardness values are still within the tolerance range.

D. Adhesion result test

The Adhesion testing conducted at PT. Bando Indonesia according to ASTM D-413 standard consists of 3 specimens. The first specimen is a product from the factory, so its adhesive strength is standardized according to SNI. The second specimen is a combination of natural rubber sheets and inner tire rubber bonded using the pressure method, with the natural rubber positioned on the outside of the inner tire. The third specimen comprises three layers: the first layer of natural rubber and the second layer of inner tire rubber are bonded through a pressure process, and conversely, the second layer of inner tire rubber is bonded to the third layer of natural rubber using a pressure process. Below are the graphs depicting the results of the adhesion testing for each specimen.

Table 7 Hardness Result Test

Sample name	Specimen 1-3	Methode Name	Test Adhesion
Waktu	15 / 08 / 2023	Test Date	15 / 08 / 2023
Speed	50 mm/min		
Sample name		*Peak Max* 3 Kgf	
Specimen 1		2.5 (14mm)	
Specimen 2		3.7 (17mm)	
Specimen 3.1		1.8 (32mm)	
Specimen 3.2		3.1 (90mm)	

Table 7 presents the results of adhesion testing. In specimen 1, the maximum peak occurred at a stroke point of 14 mm, with an adhesive strength reaching 2.5 Kgf. Adhesion testing on specimen 2 showed the maximum peak occurring at a stroke point of 17 mm, with an adhesive strength of 3.7 Kgf. Adhesion testing on specimen 3 was conducted twice. The first test was between the first layer of natural rubber and the second layer of inner tire rubber, with the maximum peak occurring at a stroke point of 32 mm and an adhesive strength of 1.8 Kgf. The second test was between the second layer of inner tire rubber and the third layer of natural rubber, with the maximum peak occurring at a stroke point of 90 mm and an adhesive strength of 3.1 Kgf. Therefore, the adhesion testing results show that the adhesive strength of specimen 2 and specimen 3.2 is higher than that of specimen 1 (the reference specimen).

V. Discussion

If the tensile strength value increases, it indicates that the rubber compound becomes more elastic. The increase in tensile strength is due to the increased incorporation of fillers into the polymer matrix, where at the same time, there is an interaction between the filler and the polymer matrix [10]. Loading natural rubber with fillers can enhance mechanical properties such as tensile strength and modulus because of the reinforcing effect resulting from the interaction between the filler and the polymer [11]. Thus, the tensile strength generated by specimens 2 and 3 is higher than that of specimen 1 (the reference specimen).

Hardness testing is conducted to determine the hardness of rubber under specific compressive strength [12]. The hardness of rubber vulcanizate varies depending on the amount of filler materials and plasticizers used in the compound [13]. Natural rubber reinforced with carbon black and calcium carbonate fillers can increase the hardness of butyl rubber [14]. Specimens 2 and 3 have lower hardness values than specimen 1, but they still fall within the tolerance range defined by the SNI 06-1542-2006 standard. This indicates that materials in specimens 2 and 3 are not brittle, making them less prone to break or rupture when operating in high-temperature environments.

Natural rubber is an essential component added to rubber composite materials used in inner tire production. This is because natural rubber possesses unique properties and characteristics not found in other materials, such as flexibility, high deformation resistance, and wear resistance. Natural rubber consists of long and flexible polyisoprene polymer chains. The hydrophilic (-OH) groups present in the polymer structure can lead to hydrogen bonding between natural rubber molecules, resulting in sticky properties [15].

The adhesive properties formed in natural rubber added to the inner tire using the pressure method depend on the type of treatment, such as heat treatment, the duration of treatment, and whether surface roughening processes are applied to natural rubber and the inner tire. These processes aim to create surface interlocking of the material, thereby enhancing the adhesive strength of the material. The adhesion testing results show that the adhesive strength of specimens 2 and 3.2 is higher than that of specimen 1 (the reference specimen). However, specimen 3.1 exhibits lower adhesive strength than specimen 1 due to the overheating caused by double heating processes, which reduce the material's rigidity.

VI. Conclusion

The addition of natural rubber to the inner tire using the pressure method in this study, following tensile testing, hardness testing, and adhesion testing, can be summarized as follows:

1. There is an overall improvement in performance. This improvement is attributed to the use of natural rubber as a crucial component added to the inner tire composition. Natural rubber possesses unique properties not found in other inner tire materials, and as a result, there are positive effects observed in various aspects of performance. In terms of tensile strength, there is an increase, making the tire more capable of withstanding heavy loads and pressures, especially in the case of transport vehicles such as trucks and buses.
2. Regarding hardness testing, there is a slight decrease in hardness, but it still falls within the allowable tolerance limits. This indicates that the inner tire is not prone to cracking or damage, even under high-temperature environmental conditions.
3. Furthermore, there is an enhancement in the adhesive strength between the inner tire and the natural rubber. This improved adhesion ensures that the natural rubber layer adheres well to the inner tire, reducing the likelihood of detachment or separation.
4. In summary, the addition of natural rubber to the inner tire using the pressure method results in overall performance improvements, including increased tensile strength, acceptable hardness levels, and improved adhesion between the inner tire and the natural rubber layer, preventing separation issues.

References

[1] PT.Dunlop Tyres, "yang Harus dilakukan saat pecah ban" Minggu 19 April 2020, www.dunlop.co.id/berita-detail/89/Ini yang Harus Dilakukan Saat Pecah Ban, 08.47

[2] Singh, G., Mahajan, A., & Kumar, M. (2015). Comparative study of tyre rubber and v-belt rubber:composition and mechanical properties. Journal of Mechanical and Civil Engineering (IOSR-JMCE),12(5), 60-65

[3] Nabil, H., Ismail, H. and A. R. Azura, (2013). Compounding, mechanical and morphological properties of carbonblackfiller natural rubber/recycled ethylenepropylene-diene-monomer blends, Polymer Testing, 32: 385-393.

[4] Bagas AG., 2023, "*Pengaruh Variasi Waktu Pemanasan Terhadap Kekuatan Ban dalam Motor"*, Sukabumi: Universitas Nusa Putra

[5] I Made Arsana, Tahun 2019, "Analisis hasil penambalan ban pada alat penambal ban dengan pengontrol suhu otomatis", Jurnal Program Studi Teknik Mesin, Unesa.

[6] Julie C, Suganthi M., Comparative Study of Butyl Rubber (IIR) and Bromobutyl Rubber (BIIR) based on FTIR, Dielectric and Thermal Studies

[7] Basseri, A. (2005). *Teori dan Praktek Barang Jadi Karet.* Balai Penelitian dan Teknologi Karet. Bogor.

[8] Wahyudi, T. (2005). Teknologi Barang Jadi Karet. Bogor: Balai Penelitian Teknologi karet Bogor.

[9] Thomas, J. (2003). Desain Kompon. Bogor: Balai Penelitian Teknologi Karet Bogor.

[10] Rosszainily, I.R.A., Salim, M.A., Mansor, M.R., Akop, M.Z., Putra, A., Musthafah, M.T., Hassan, M.Z., Rahman, M.N.A and Sudin, M.N. (2016). Effect of Carbon Black fillers on Tensile Stress of Unvulcanized Natural Rubber. Journal of Mechanical Engineering and Sciences (JMES). 10(2): 2043-2052.

[11] Rajkumar. K., Prem. R., Thavamani. P., Jeyanthi. P., and Pazhanisamy. P. (2013). Dispersion Studies of Nanosilica in NBR Based Polymer Nanocomposite. *Rasayan J. Chem*, 6(2): 122-133.

[12] Wahyudi, T. (2005). Teknologi Barang Jadi Karet. Bogor: Balai Penelitian Teknologi karet Bogor.

[13] Thomas, J. (2003). Desain Kompon. Bogor: Balai Penelitian Teknologi Karet Bogor.

[14] Bao, C.A., Kamaruddin, S., Yeow, T.K., Ing, K., Han, B.T.J., and Ying, C.S. (2016). The Effect of Oil Palm Fiber/Eggshell Powder Loading on The Mechanical Properties of Natural Rubber Composites. *ARPN Journal of Engineering and Applied Sciences*. 11(1): 128-134

[15] Suryawan, D. 2002. Pedoman Praktek Pengolahan Lateks Pekat, Kursus Teknologi Barang Jadi Dari Lateks. Balai Penelitian Teknologi Karet : Bogor.