Effect of Filler on Heat Build-up of Rubber

Sanae Rukkur[1,]*, Charoenyut Dechwayukul[1] Wiriya Thongruang[1] and Orasa Patarapaiboolchai[2]

[1] Department of Mechanical Engineering, Faculty of Engineering, Prince of Songkhla University, Songkhla, Thailand 90110
[2] Department of Polymer Science, Faculty of Science, Prince of Songkhla University, Songkhla, Thailand 90110
* Corresponding Author: E-mail: rsanae@gmail.com. Tel: 074 287 035, Fax: 074 212 893,

Abstract

The research is about added filler to reduce heat build-up in a solid tire. This study is using two different fillers, Carbon Black and Silica; 40:10 phr, compared with four different brands of solid tire manufactured in Thailand. It is found that proportion of filler reduces hysteresis loop and Young's modulus, whereas compressive properties are the same.

***Keywords**:* Filler, Natural Rubber, Heat Build-up

1. Introduction

Rubber is the major material to use in vehicle tires as solid tires. It must be mixed with fillers to have more suitable to production. Most popular fillers in tire industry are carbon, silica, etc. The chemical composition is very important to increase heat build-up in solid tire [3]. A good formulation of fillers has been established that there is a good correlation between the heat build-up resistance and the hysteresis in solid tire. Since, the explosive durability is determined by heat build-up which is governed by fillers formulation [1][2].

This research aims to guide to reduce heat build-up in a solid tire, improve and develop the quality and reduce the explosion of solid tire.

2. Materials, instruments and the experiment

2.1 Materials

Rubber block STR 5L is used in this research; the Carbon Black and Silica are used as filler to increase the tire strength. And also, the chemical substances are used; Sulphur, Silane, Catalyst (6PPD, TMQ, CBS, DPG), Zinc oxide and Stearic acid accelerator and activator, as shown in Table 1.

Table 1. Tire compound formula for this research

Compound	Amount (phr)
NR(STR 5L)	100
N-330	40
Silica (VN3)	10
Silane	0.2
Oil	5
Sulphur	1.4
Activator	10
Age-resistors	1
Accelerators	3.3

The set of tested tire is shown in table 2. Tire A, B, C and D are commercial solid tire manufactured in Thailand. Tire E is a formulated tire in this study.

Table 2. Type of solid tires.

Tire	Name
Tire A	A
Tire B	B
Tire C	C
Tire D	D
Formulated tire	E

2.2. Experimental equipment

1) Internal mixer
2) Two roll mill
3) Hot press
4) Mooney Disk Rheometer (MDR)
5) Universal Testing Machine (UTM, Instron Model 8872)
6) BF Goodrich Flexometer (MODEL II)
7) Durometer Shore A

2.3 Experimental method

2.3.1 The mixture of rubber and filler

Formulated Tire prepared by adding STR-4L and fillers such as Carbon Black 40 phr and Silica 10 phr, then the Silane coupling agent is used to improve surface. The Formulated tire is mixed with Carbon Black in internal mixer with master batch mixing. After that, the two roll mill is used to mix additional substances respectively. At this time, it is necessary to complete mixing within 40 minutes. Sulphur should be added in the last 5 minutes.

2.3.2 Cure characteristic test

The cure time 90% (tc90, min) of rubber compound is obtained by Moving Disc Rheometer (MDR) following ASTM D2240. Then rubber compound is made as test specimens by hot press at 150 °C for one period of time same as vulcanization.

2.3.3 Standard measurement

- Hysteresis Loop test

Measuring the change of mechanical energy to thermal energy in a solid tire with Universal Testing Machine (UTM, Instron Model 8872) under ASTM D 575-91

- Rubber hardness test

Measuring the hardness with Durometer Shore A, testing at three different positions and average the values, under ASTM D2240 standard.

- Uniaxial compression test

Compression test with Universal Testing Machine (UTM, Instron Model 8872), under ASTM D575-91 standard.

- Heat build-up test

Testing with BF Goodrich Flexometer (MODEL II) under ASTM D623 standard, generated compressive force at circumference of tire for 25 minutes with constant frequency 30 Hz, static force 245 N and with deformed distance 4.45 mm.

3. Experimental results

3.1 Hysteresis Loop testing result

Referring to Hysteresis Loop test, with UTM (Universal Testing Machine) under ASTM standard, the result is shown in Fig. 1.

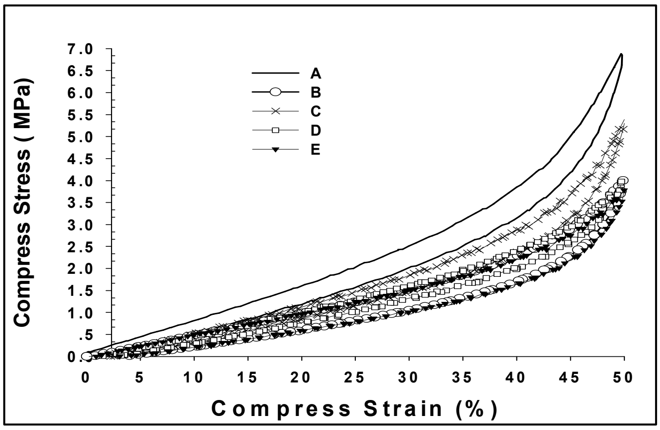

Fig. 1. Comparison of Hysteresis Loop

The Hysteresis loop was calculated from an area of the stress–strain loop. As seen, tire E has lower hysteresis loop than tire A, B, C and D. Hysteresis loop's area describes energy lost that convert to heat build-up apparently is shown comparatively in Fig. 2.

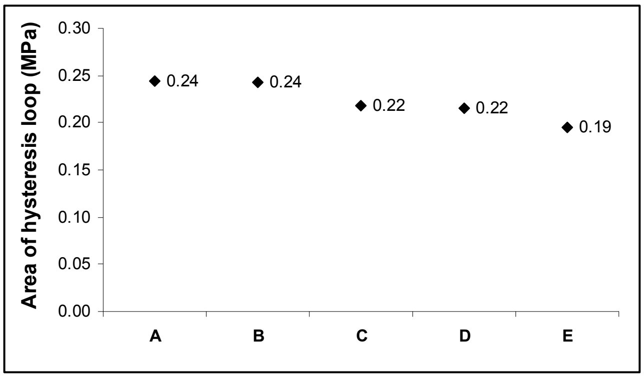

Fig. 2. Energy lost in Hysteresis Loop

3.2 Uniaxial compression testing result

The compressive strain is shown in Fig. 3. At the 50% compressive strain, tire E has the lowest stress of 3.8 MPa while the highest stress of 5.6 MPa is belonging to tire A. As seen, property of compressive resistance agrees with tire hardness.

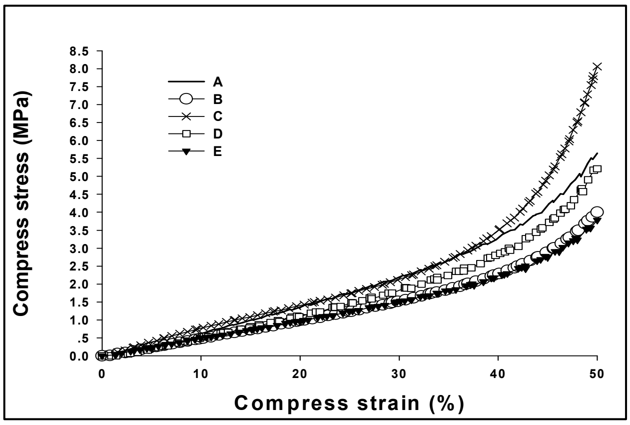

Fig. 3. Compressive properties

The result of Young's modulus of solid tire is shown in Fig. 4. The modulus of 0.076 MPa is lowest belonging to tire E, whereas tire A has the highest Young's modulus of 0.113 MPa. These agree with hysteresis loop result which means that higher Young's modulus create hysteresis loop.

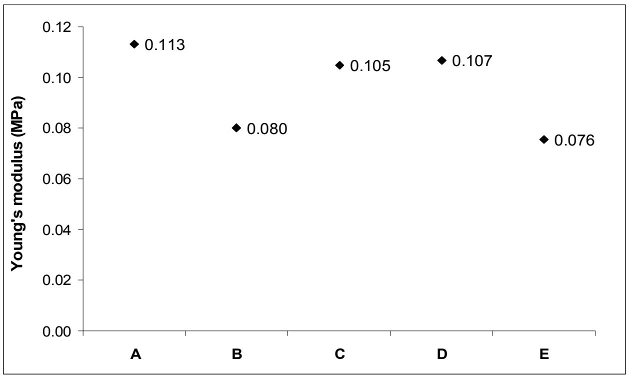

Fig. 4. Comparison of Young's modulus.

3.3 Hardness testing result

Refer to result of Hardness test with Durometer Shore A under ASTM D2240 standard, as shown in Fig. 5. It is found that tire E has lower hardness Shore A than other tires because oil 5 phr is added in tire E.

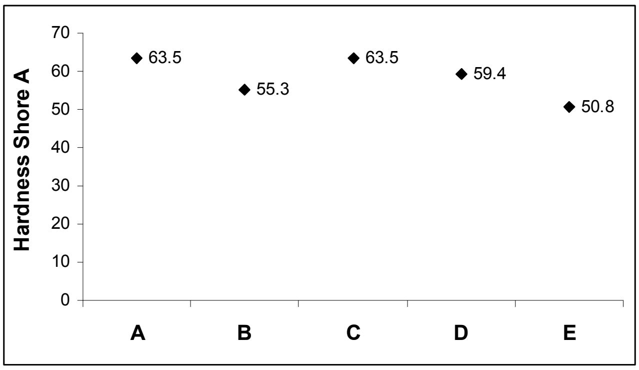

Fig. 5. Hardness of solid tires.

3.4 Heat build-up testing result

Refer to heat build-up with BF Goodrich Flexometer (MODEL II) under ASTM D623 standard, it is found that tire D has the lowest heat build-up 17 °C; tire D, C and B has higher value respectively. Tire E which it has the highest heat build-up at 24.7 °C, it might affected by thermal properties, for example the low thermal conductivity of tire, however this study did not focus on this point. Fig. 6 shows the comparison of heat build-up that occurs in solid tires.

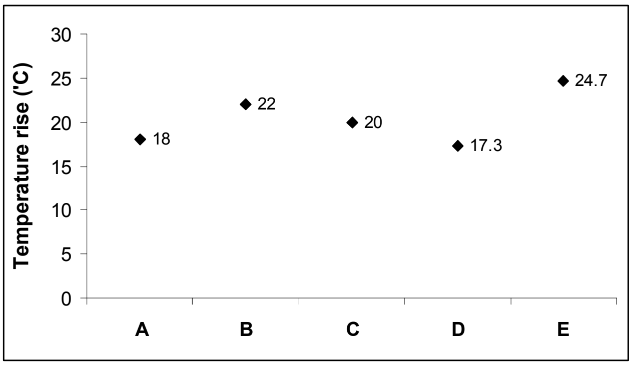

Fig. 6. Heat build-up of different solid tires

4. Conclusion

The fillers, Carbon Black and Silica 40:10 phr affect lower Hysteresis loop, heat build-up and Young's modulus. The compressive properties are same with different solid tire that manufactured in Thailand. It is found that oil caused lower hardness and higher heat build-up, which might affected by thermal properties; for example the low thermal conductivity of tire. However, in continuation of this research, we are going to study thermal properties augmentation.

5. Acknowledgement

The authors would like to thank Research and Development Prince of Songkhla University and Graduate School with financial support for this research.

6. References

[1] เจริญยุทธ และคณะ, สัญญาเลขที่ R D G 4750037, รายงานฉบับสมบูรณ์ โครงการ "ผลของความสม่ำเสมอของรูปทรงต่อการสั่นสะเทือนของล้อรถแบบยางตัน",สำนักงานกองทุนสนับสนุนการวิจัย ฝ่ายอุตสาหกรรม, พฤษภาคม 2550

[2] เจริญยุทธ และคณะ, สัญญาเลขที่ RDG 5050026, รายงานความก้าวหน้า โครงการ "พัฒนามาตรฐานการทดสอบและข้อกำหนดความทนทานของล้อยางตัน", สำนักงานกองทุนสนับสนุนการวิจัย ฝ่ายอุตสาหกรรม, ธันวาคม, 2550

[3] ชลดา และคณะ, สัญญาเลขที่ RDG 4650057, รายงานความก้าวหน้า โครงการ "การปรับปรุงความทนทานและการขับขี่ที่สะดวกสบายของยางรถล้อตัน", สำนักงานกองทุนสนับสนุนการวิจัย, ตุลาคม, 2547

[4] บุญธรรม และคณะ, รายงานวิจัย เรื่อง "ความสัมพันธ์ระหว่างความกระเด้งตัวกับความร้อนสะสมของยางวัลคาไนซ์", ทุนอุดหนุนการวิจัยจากงบประมาณแผ่นดิน, 2538

[5] A.N. Gent and M. Hindi, "Heat build-up and blow-out of rubber blocks", Institute of

polymer science, The University of Akron Akron, Ohio 44325, May,1988

[6] พงษ์ธร แซ่อุย, สารเคมียาง, กรุงเทพฯ, ศูนย์เทคโนโลยีโลหะและวัสดุแห่งชาติ (เอ็มเทค), 2548

[7] วราภรณ์ ขจรไชยกุล, ยางธรรมชาติ: การผลิตและการใช้งาน (Natural Rubber : Production Application), กรุงเทพฯ, สำนักงานกองทุนสนับสนุนการวิจัย (สกว.), 2549

[8] Hashim A.S. and Kohjiya S., "Preparation and properties of deoxidized natural rubber network crosslinked by ring opening reaction", Polymer Gels and Networks Volume 2, Issues 3 -4, 1994, 219-221

[9] Yu H., Zeng Z., Lu G. and Wang Q., "Processing characteristics and thermal stabilities of gel and sol of epoxidized natural rubber", European Polymer Joumal Volume 44, Issue2, 2008, 453-464

[10] Park D. M., et. al., "Heat generation of filled rubber vulcanizates and its relationship with vulcanizate network structures", European Polymer Journal, 36, 2000, 2429-2436