Eng. & Tech. Journal, Vol.31, No.2, 2013

The Effect of Rubber filled with Carbon Black in Design of Truck Tiressidewall Ricipe

Dr.Hussain J.M. Al-Alkawi
Electromechanical Engineering Department, University of Technology/Baghdad.
Dr.Dhafir S. Al-Fattal
Machines & Equipments Engineering Department, University of Technology/Baghdad.
Email: alfattal40@yahoo.com
Nabel K. Abd-Ali
Engineering College, University of Al-Qadisiya/ Al-Qadisiya

Received on: 25/1/2012 & Accepted on: 15/8/2012

ABSTRACT

One of the main requirements of the truck tire sidewall are flexing resistance, tensile strength and tear resistance, as well as resistance to weather conditions experienced by tires during use, which include exposure to sunlight and ultraviolet radiation. Therefore, the requirements and changing circumstances led to develop the design parts of tires, and sidewall is more susceptible to these conditions, where it will be studying the properties of truck tire sidewall produced by Al- Dewaniya Tires Factory- Iraq, according to the specifications designed by Italian Perilli Co. since about 20 years ago, which prompted to development the mechanical and physical properties of those components.

The present work aim to design stocks with high specifications, through the study of the impact of the substantial material (rubber) in truck tire sidewall recipe. Natural rubber, Standard Vietnam Rubber (SVR5) and synthetic rubber, Styrene-Butadiene-Rubber(SBR1502),also the introduction of a new type of synthetic rubber is Poly Butadiene (BR_{cis}), filled with carbon black (N550) as a reinforcement agent with fixed loading percentage (51pphr),as well as other components such as accelerators, anti-oxidants, anti-ozonants and vulcanizing agent. Through laboratory testing found that stocks containing ($NR/SBR/BR_{cis}$) blending with (40/60/-), (40/50/10) and (40/40/20) as a percentage loading has given good results in many tests including tensile, tear, compression, hardness and fatigue crack growth resistance.

Keywords: sidewall, fatigue crack growth, rubber, carbonblack, truck tires.

https://doi.org/10.30684/etj.31.2A.1
2412-0758/University of Technology-Iraq, Baghdad, Iraq

تأثير المطاط المقوى بأسود الكاربون في تصميم عجنة الجدار الجانبي لاطارات الشاحنات

الخلاصة

ان من اهم متطلبات الجدار الجانبي للاطارات هي مقاومة الانثناء، مقاومة الشد ومقاومة التمزق،بالاضافة الى مقاومة الظروف الجوية التي تتعرض لها الاطارات اثناء الاستخدام، والتي تشمل التعرض لضوء الشمس والاشعة فوق البنفسجية. لذا فان المتطلبات والظروف المتغيرة قادت الى تطوير تصميم اجزاء الاطارات، ومن تلك الاجزاء الجدار الجانبي للاطار والذي يكون اكثر عرضة لتلك الظروف، حيث تم هنا دراسة خصائص الجدار الجانبي لاطار الشاحنات الكبيرة المنتج من قبل مصنع اطارات الديوانية-العراق، وفق مواصفات مصممة من قِبل شركة بيريلي الايطالية منذ حوالي ٢٠ سنة مضت، وهو ما دفع لتطوير الخصائص الميكانيكية والفيزيائية لتلك المكونات.

يهدف العمل الحالي الى تصميم عجنات بمواصفات عالية، من خلال دراسة تاثير المادة الاساس (المطاط) في عجنة الجدار الجانبية لاطارات الشاحنات.المطاط الطبيعي، المطاط القياسي الفيتنامي (SVR5) والمطاط الصناعي، مطاط الستايرين بيوتادين (SBR1502)، ايضاً ادخال نوع جديد من المطاط الصناعي هو البولي بيوتادين (BR_{cis})، بإستخدام اسود الكاربون (N550) كعامل تسليح وبنسبةتحميل ثابتة(51pphr)، بالاضافة الى المكونات الاخرى للعجنات مثل المعجلات، مانع الاكسدة ومانع تاثير الاوزون ,وعامل الفلكنة. من خلال الفحص المختبري وجد ان العجنات التي تحتوي($NR/SBR/BR_{cis}$) وبنسبة(--/40/60)، (40/50/10) و(40/40/20)كنسب تحميل قد اعطت نتائج جيدة في فحوصات عديدة منها الشد، التمزق الانضغاطية، الصلابة ومقاومة نمو شق الكلال.

INTRODUCTION

In most applications for rubber products there are no alternative materials except other rubbers. It has very high deformability. It consists of very high molecular mass molecules that can be crosslinked together to form a network. If the crosslink density is not too high the material will retain a memory of its original unstressed state and will return to its original dimensions when external forces are removed. This ability to recover its original dimensions leads to many applications.

The tire sidewall as shown in figures. (1) and (2) is the outer surface of the tire between the bead and the tread, and its function is to protect the tire casing against weathering. It provides a physical link between the wheel and the tire tread in transmitting power and braking forces to the tire tread [**1, 2**].

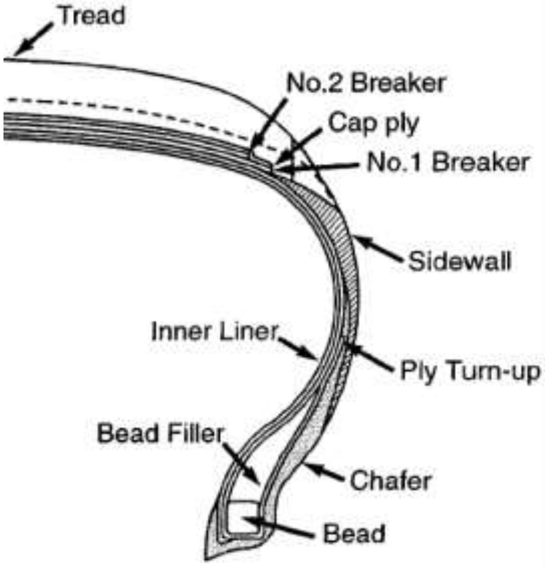


Figure (1): Structure of a Tyre.[2]

Figure(2): Section inTruck Tyre.

Rubbers are used in many industrial applications, they are often submitted to cyclic loading conditions inducing first, a stress-softening and second, a fatigue failure recognizable by the appearance of a crack and its fatal propagation [**3**].

The mechanical properties of rubbers derive from the molecular chains that are assembled into a cross linked network. When unstressed, the molecular segments between crosslinks are randomly coiled. When a tensile stress is applied, deformation is principally achieved by localized motions of the molecular segments that take on new shapes, in which they are stretched out in the direction of the tensile axis [**4**].

Several studies tried to develop new polymers for tire sidewall applications which offer a polymeric protection system against ozone attack and flex fatigue while eliminating the need for chemical protectants, and discussed in detail the molecular parameters of the new polymer which is tailored to have increased functionality, specifically for sidewalls[**5**].

In other studies, various antidegradants and their blends had been evaluated in tire sidewall to improve flex fatigue property for longer lasting tires. The tire compounders continue their efforts to improve tire performance by developing better fatigue resistant and dynamic ozone crack resistant rubber compounds using various antidegradants and elastomers[**6**].

The fatigue cracks initiation and propagation were studied in natural and synthetic rubbers in service conditions. A finite element simulation of stresses and strains was presented in order to get a better explanation of the experimental results[**7**].Improving tire sidewall properties was devoted, and rubber composition was comprised. Weight ratio of rubber blend (pphr) contributed to high flexibility of tire sidewall [**8**].

The blending of NR/BR was studied by reactive processing for tire sidewall applications and showed that the NR/BR blend compound formulations contain a set of stabilizers added to prevent degradation mainly due to oxygen, ozone, and heat[**9**].

Fatigue life prediction was the key technology to assure the safety and reliability of mechanical rubber.Mechanical properties of natural rubber and fatigue life (constant amplitude stresses) were carried out experimentally for Dumb-bell specimens at room temperature and 40^0C, and the properties were compared under different conditions [**10**].The mechanical properties andcut growth by using De Mattia machinewere also discussed to understand the performance of a model sidewall compound [**11**].

The present work usesseveral percentage of (NR/SBR/BR_{cis}) blending to develop new recipes with specific properties for truck tire sidewall.

EXPERIMANTAL WORK

The sidewall component of a tire is an important part and amount up to 20 percent of the whole tire by weight. Based on tire structure and its practical use, sidewall properties should be relevant to Dewaniya Tires Factory conditions(according to PerilliCo.) with several requirements such as flex life, tensile strength, tear strength, compressivestrength, crack-growth resistance, and glossy surface.

In the present work, mechanical properties and flex fatigue under some influential conditions, such as exposure tosunlight were correlated with the rubber properties to understand the performance of a model sidewall compound .The selection of the formulations has been done on the basis of common tire sidewall formulations, experimental history and scientific research.Details of the formulations, including the polymers compounding areshownin table (1).

Table (1): Polymers Loading (pphr)*.

Materials	**Stock No.**													
	1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
NR(SVR20)	30	70	50	40	40	40	40	30	25	20	20	10	10	50
SBR1502	70	30	50	60	50	40	30	50	50	60	50	60	50	0
BR_{CIS}	0	0	0	0	10	20	30	20	25	20	30	30	40	50

* part per hundred of rubber.

** Standard Perilli Recipe.

Materials

In this study, Natural Rubber (NR),Styrene Butadiene Rubber (SBR) and Polybutadiene Rubber (BR_{cis}) were used to investigate the effect of blends in different percentages on the characteristics and mechanical properties of rubber compounds. The carbon black grade used was FEF N550 supplied by Cabot-Columbian-Philips,Italy.The materials that which are used in this study to prepare the rubber compounds are:

1. Elastomers: Natural Rubber (SVR5), Synthetic Rubber (SBR, BR_{cis}).
2. Fillers:Carbon Black FEF N550,with 51 pphr.
3. Antioxidants:TMQ, with 1 pphr.

4. Antiozonants: IPPD with 1.75 pphr and paraffin wax with 3 pphr.
5. Accelerators: CBS with 0.5 pphr.
6. Activators: Zink oxide with 4 pphr, Stearic acid with 2 pphr.
7. Softening Aids : Dutrex Oil, with 8.5 pphr.
8. Vulcanizing Agents: Sulfur, with 2 pphr.

The mixing conditions and procedure were made at a temperature of 70±5 °C(158±9 F), mixing speed (slow roll) 24 rpm and roll ratio of slow to fast roll (1to1.4)[**12,13**].Mixing mill size and capacity arelistedin table (2).

Table (2): Mixing Mill Size and Capacity.

Roll Size (Dia.×Length) Inch	**Approx. Batch weight (Kg)**	**Drive (HP)**
10 × 20	4.50	15 - 20

After rubber compounds are properly mixed and shaped into blanks for molding, they must be vulcanized by one of many processes. Sulfur was the most common used with rubber compounds in tyres industry.The compression molding technique which was used in the present work is also the most common type of molding used in the rubber industry. Several types of dies were used with different conditions such as temperature, pressure and curing time according to tests requirements. The variety conditions for vulcanization processes were applied bya hydraulic press.

Mechanical and Physical Tests

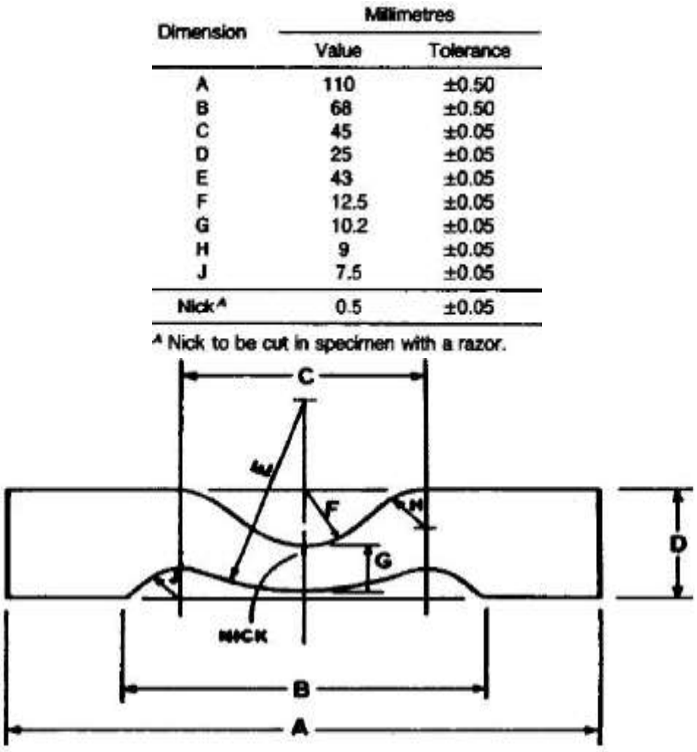
Tensile Test: Thistest method cover procedures used to evaluate the tensile (tension) properties of vulcanized rubbers.Measurements for tensile stress at a given elongation, tensile strength, yield point, and ultimate elongation are made on specimens that have not been pre-stressed,and based on the original cross-sectional area of a uniform cross-section of the specimen.The applied force is measured with the requisite accuracy duringthe extension of the specimen to rupture[14,15].

Test method for Dumbbell shape specimen was used and the test was controlled at room temperature (23-25°C) and at loading rate 500 mm/min with uniform thickness.The machine used was Monsanto T10 Tensometerand according to ASTM D412.

Tear Test: Tear resistance in rubber may be described as the resistance to growth of a nick or cut when tension is applied to the tear specimen[4,15].

A tearing strain (and stress) is applied to a test specimen by means of a tensile testing machine operated without interruption at a constant rate until the specimen is completely torn. This test method measures the force per unit thickness required to rupture, initiate, or propagate a tear through a sheet of rubber in the form of one of several test piece geometries.The testing machine shall conform to the requirements as specified in Test Method D 412. The rate of jaw separation shall be 500 mm/min

(20in./min.) according to ASTM D624,Type B. Figure.(3) shows the configuration and dimensions of tear specimen.



Dimension	Millimetres	
	Value	Tolerance
A	110	±0.50
B	68	±0.50
C	45	±0.05
D	25	±0.05
E	43	±0.05
F	12.5	±0.05
G	10.2	±0.05
H	9	±0.05
J	7.5	±0.05
Nick[A]	0.5	±0.05

[A] Nick to be cut in specimen with a razor.

Figure (3): Tear Specimen, Type B, according to ASTM D 624[16].

The tear strength (T_s) is calculated from the expression in equation (1):

$$Ts = \frac{F}{a} \qquad \ldots\ldots (1)$$

Where F: the maximum for ce,a: the cross sectional area of each test piece.

Compression Set: Compression set testwas intended to measure the ability of rubber compounds to retain elastic properties after prolonged action of compressive stresses[**17**].The actual stressing service may involve the maintenance of a definite deflection, constant application of a known force, or rapidly repeated deformation and recovery resulting from intermittent compressive forces. All vulcanized test specimens to be tested are stored at least 24 hr. but not more than 60 days. The standard test specimen is a cylindrical disk cut or molded with specific dimensions according to (ASTM D395 and B.S.903, PT.A.6).

After the rest period of 30 min., the final thickness at the center of the specimenis measured andthe compression set is calculatedas a percentage of the original thickness as expressed in equation (2) [18,19]:

$$C_A = [(t_o - t_i)/t_o] \times 100 \qquad \text{......(2)}$$

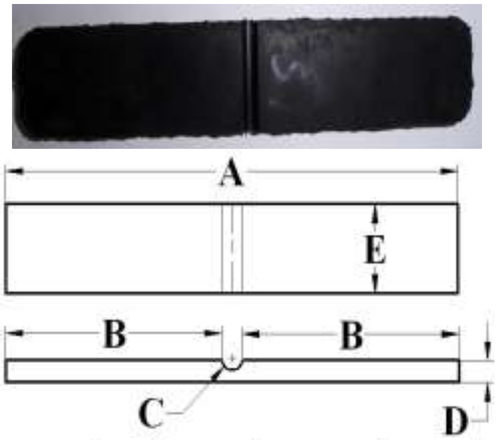
where :$C_A$is the compression set, t_o is the original thickness and $t_i$isthe final thickness.

Hardness Test: The hardness testis based on the measurement of the indentation of a rigid ball into the rubber test-piece under specified conditions using dead-load instruments. The usual test is conducted on flat test-pieces (8-10mm) thick, at least (9-10mm) from the edge [**20**].The Wallace Dead Load Hardness Tester is a precision instrument which measures the hardness of rubber to a laboratory degree of accuracy [**21**].This test is conducted on rubber in according with ASTM D1415[22].

Fatigue (Cut Growth)Test: The most important fatigue failure is called flex cracking, the cause of this failure is twofold; stress breaking of rubber chains and cross-links and, more important, oxidation accelerated by heat buildup in flexing[23].This test method covers the determination of crack growth of vulcanized rubber when subjected to repeated bending strain or flexing. It is particularly applicable to tests of synthetic rubber compounds which resist the initiation of cracking due to flexing when tested byASTM D813 andmethod B of Test Methods D430[24,25].The DeMattia flexing machine and Flexing Specimenare shown infigs.(4) and (5)respectively.

The final failure consider at (Grade 10) where the length of the largest crack is greater than 15.00 mm. This indicates to failure of the specimen for bending under thermal effect ($T=60\pm2^{o}C$).

Figure (4): De Mattia Flexing Machine Test. (Made in England)



	A	B	C	D	E
mm	150	75	2.39 ± 0.03	6.35 ± 0.13	25
(in.)	(6)	(3)	(0.094 ± 0.001)	(0.250 ± 0.005)	(1)

Figure (5): Flexing Test Specimen according to ASTM D 813[25].

RESULTS AND DISCUSTION

Tensile Test: Table (3) shows the tensileproperties for 13 stocks with the base rubber stock (Perilli recipe). The best tensile strength is found with the stocks from 2 to 6.

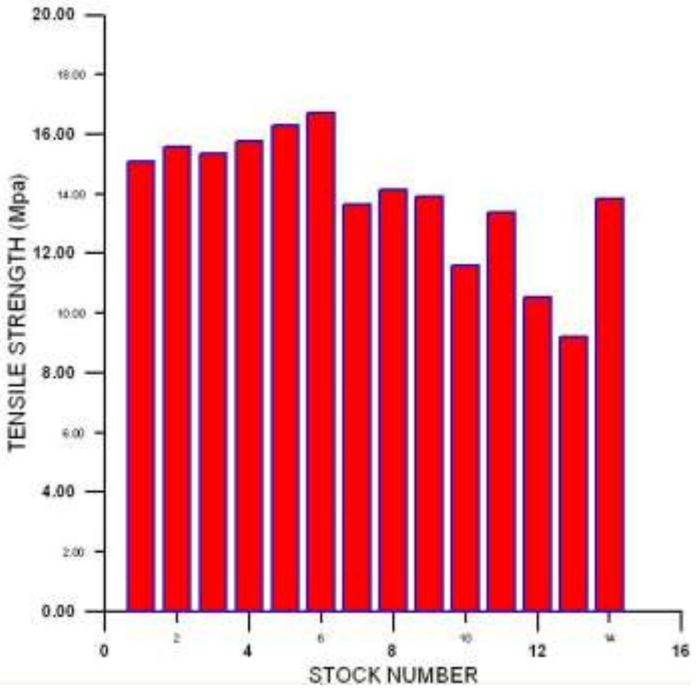
Table (3): TensileProperties of Recipes.

Stock No.	Tensile strength (MPa)	Modulus at 300%(MPa)	Elongation at Break (%)	Tensile strength Improvement (%)
1	15.10	9.56	408.30	0
2	15.60	12.18	390	3.31
3	15.34	10.31	438	1.59
4	15.76	9.16	430.6	4.37
5	16.32	9.80	408	8.08
6	16.72	9.40	403	10.72
7	13.64	10.18	408.30	-9.67
8	14.13	11.44	474.50	-6.42
9	13.93	10.10	419	-7.75
10	11.60	10.41	336.30	-23.18
11	13.40	9.06	433.60	-11.26
12	10.55	8.90	350.30	-30.13
13	9.20	10.18	249	-39.07
14	13.84	13.10	320.50	-8.34

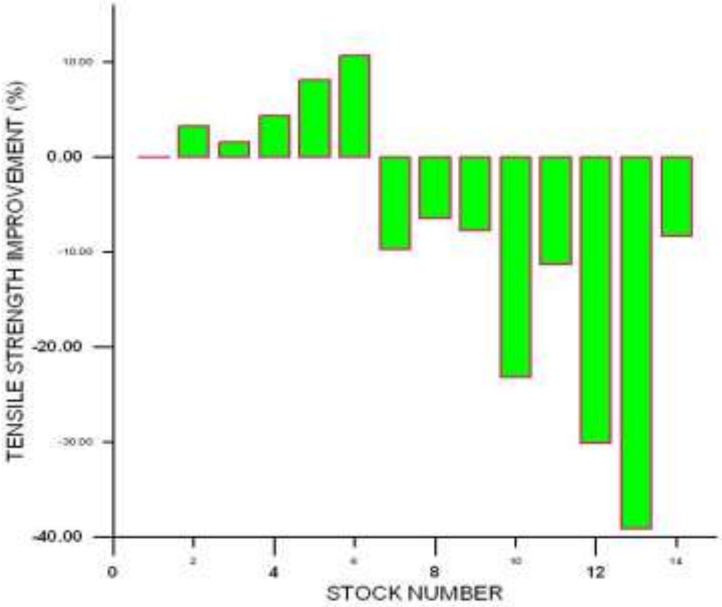
It is clear that the tensile strength of stocks 4,5 and 6 is better than the other stocks and in comparison with stock 1 (standard Perilli recipe) the tensile strength improvement percentages(TSI%)are 4.37,8.08 and 10.72 forstocks 4, 5 and 6 respectively, as shown in figure(6-a) and (6-b). The above improvement may be due to the increase of NR percentage from 30 to 40 pphr in stock 4. The tensile strength increases as a consequence ofstereoregularity of NR which makes it susceptible to crystallization upon straining. The crystalline domains of NR restrict the free ends of flexible segments in rubber chains (act as sulfur crosslinking) then this imparts the green strength and gives vulcanized rubber high cut growth resistance at severe deformation even without reinforcement, while SBR is amorphous and uncrystallized upon straining[26-28].

In addition, the improvement in tensile properties seems clearly in stocks 5 and 6. The incorporation of developed polymer (BR_{cis}) may be the reason of this improvement. Where properties of special interest, high green strength, tack, can be compounded with fillers and other polymers, can form block copolymers for specialty applications, high tensile strength owing to strain-induced crystallization[28].

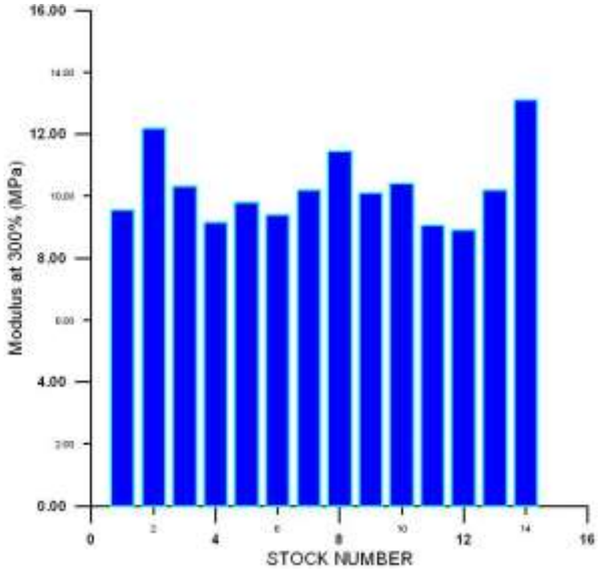
$BR_{cis}$is used in tyres since it shows low hysteresis combined with good wear characteristics [4]. When blended with other synthetic rubbers suchas SBR, it combines BR properties with millability and extrudability[26,30].All this may make BR_{cis} suitable for the crescent shape that is required for sidewall with excellent hold together with other tire components.



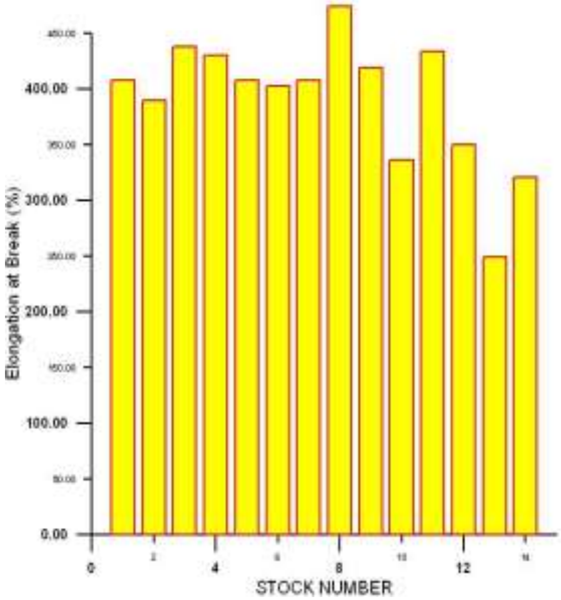
a)Tensile Strength



b)Tensile Strength Improvement (TSI%)



c)Modules at 300%



d)Elongation at Break(%)

Figure (6): Representation of Data for Tensile Test.

Figure (6-c) and firegu (6-d) represent modulus and elongation vs. stock number respectively. Stock 3 and 11 have good elongation, but stock 8 was the best in comparison with the Pirelli stock. Also, moderate values for stocks 4, 5 and

6areacceptablefor optimum properties. Figure (7) shows test specimen after failure during tensile test.

Figure (7): Tensile Specimens after Failure.

Table (4) shows the recipes that have unique tensile strengthand good improvements, namely stocks 4,5, and 6, in addition to Perilli stockafter exposure to sunlight for 72hr., under static stress, and these stocks remain the best in comparison with the standard stock.Stocks5 and 6 improved dramatically.

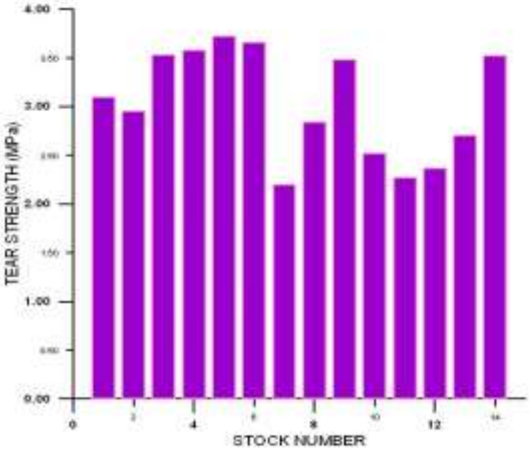
Table (4):Tensile Properties Exposure to Sunlight.

No	Tensile Strength(MPa)	Modulus at 300% (MPa)	Elongation at Break (%)	Tensile Strength Improvement(%)
1	9.44	7.73	387	0
4	10.21	7.86	410	8.16
5	12.47	8.33	398	32.09
6	13.68	8.67	381	44.92

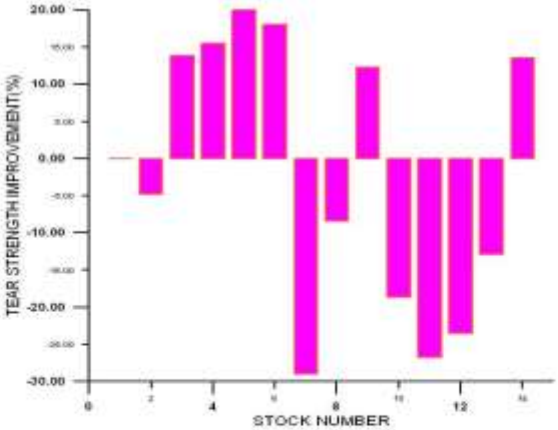
Tear Test: Table (5) shows the tear strength for 13 stocks with the base rubber stock (stock 1). The tear resistance of rubber vulcanized in stock 3, 4,5,6,9 and 14 are found to be considerable where NR blend with SBR or with SBR/BR$_{cis}$, but stocks4,5 and 6were the bestas shown in fig.(8-a).The highest values in the Tear Strength Improvement percentages are 15.48,20 and 18.06 for stock 4, 5, and 6 respectively as shown in figure (8-b).

Table (5): Tear Strength of Recipes.

No.	**Tear St. (MPa)**	**Improvement. %**	**No.**	**Tear St. (MPa)**	**Improvement. %**
1	3.10	0	8	2.84	-8.39
2	2.95	-4.84	9	3.48	12.26
3	3.53	13.87	10	2.52	-18.71
4	3.58	15.48	11	2.27	-26.77
5	3.72	20	12	2.37	-23.55
6	3.66	18.06	13	2.70	-12.90
7	2.20	-29.03	14	3.52	13.55



a) Tear Strength.



b) Tear Strength Improvement

Figure (8): Representation of Data for Tear Test.

R. Zhang[29]referred to high degree of stereo-regularity in structure ,strain-induced crystallization, high gum tensile strength, and hot tear resistance asproperties of cis-1,4-Polyisoprene.

Tear specimens after failure are shown in figure (9).A jagged tear path is observed where the applied force is concentrated at the base of the nick[**20**].

Figure (9): Tear Specimens after Failure.

Table (6) showsthe recipes that have unique tear strength and good improvements in comparison to Stock 1, after exposure to sunlight. Stock 5 showsnoticeable improvement.

Table (6): Tear Strength after Exposure to Sunlight.

Stock No.	Tear Strength (MPa)	Improvement(%)
1	2.87	0
4	2.77	-3.48
5	3.13	9.06
6	2.95	2.79

Compression Set: The compression specimens were compressed by calibrated spring loading with 814 lb-in for 24hr. at room temperature.The results are reported in table (7).

Table (7): Compression Set (C_A) under Constant Load.

Compression Set	Stock No.													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
C_A	3.8	3.71	3.92	3.80	3.91	3.83	3.9	4.8	4.13	4.51	4.10	3.96	4.45	3.93

A small Compression Set value refers to the ability of the specimen to maintain original thickness, therefore, stocks 4,5 and 6 have good results, but stock 2 is the best.This due tothehigh percentage of NR (70%), where the resilience of NR is very high, with values exceeding 90% in well-cured gum Vulcanizates[4].

Hardness Test: The hardness values for all recipes vary from56 to 64 as shown in table (8). Stocks 4,5 and 6 have the lowest values.These results are compatiblewith the results of Mohd et al results[**30**],where an increase in tensile strengthis accompaniedby a decrease in hardness value.

Table (8): Hardness (IRHD)*.

Property	**Stock No.**													
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
IRHD	61	60	60	59	58	56	62	61	61	62	60	63	64	61

* International Rubber Hardness Degrees (IRHD)

The hardness of the standard stock is acceptable and within the range of Pirelli limits for hardness, and stocks 12 and 13 have the highest values, 63 and 64 respectively.These two stocks have NR with only 10pphr.

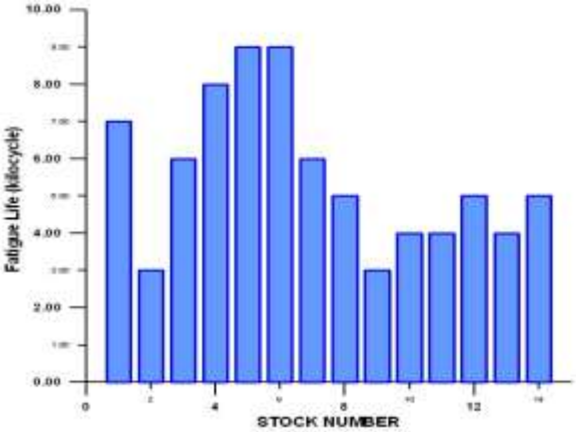
Fatigue (Cut Growth) Test: The test specimenswere conditioned at least 12 hr.at the test temperature.Four specimens from each stockwere tested and the average was reported. And test simultaneously with each set of specimens a set ofcontrol specimens such as Perilli Recipe, as criterion, and results reported in table (9).

Table (9): FailureLife ofFatigue Test Specimens.

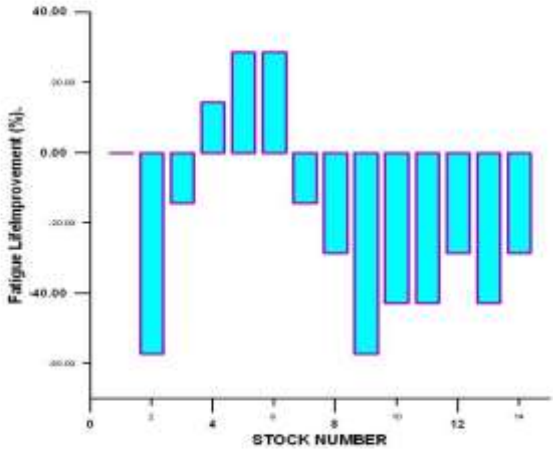
No	**Fatigue Life (kilocycle)**	**Improvement. (%)**	**No**	**Fatigue Life (kilocycle)**	**Improvement. (%)**	**No**	**Fatigue Life (kilocycle)**	**Improvement. (%)**
1	7	0	6	9	28.67	11	4	-42.85
2	3	-57.1	7	6	-14.3	12	5	-28.67
3	6	-14.3	8	5	-28.67	13	4	-42.85
4	8	14.33	9	3	-57.1	14	5	-28.6
5	9	28.67	10	4	-42.85			

In a tyre, sidewalls are the most strained elements and are susceptible to flex cracking and ozone cracking. The flex-cracking behaviour of NR is better than SBR at higher strains and therefore, sidewalls of radial tyresincorporate substantial proportions of NR [**3**].The test specimens must be conditioned for at least 12 hr. at the test temperature and the first record was at first minute (300 cycle), and reported data each thousand cycles, where the rate of test was 5 Hz (300cycle/min)[25, 32].

The fatigue life of stocks 4, 5 and 6 are the bestand even better than stock 1 (Perilli recipe) and the fatigue life Improvement percentages are 14.33, 28.67 and 28.67 for these stocks respectively as shown in figure (10-a) and (10-b).The above improvement may be related to the increase in NR percentage and the use of BR_{cis}.



a) Fatigue Life vs. Stock Number.



b) Fatigue Life Improvement vs. Stock Number.

Figure (10): Fatigue Life Data for All Recipes.

The crystalline domains of NR imparts the green strength and gives vulcanized rubber high cut growth resistance at sever deformation even without reinforcement, and BR_{cis} used in blend with NR and SBR to achieve techno-economic benefits, and improves flex cracking and fatigue resistance[20,26-28].

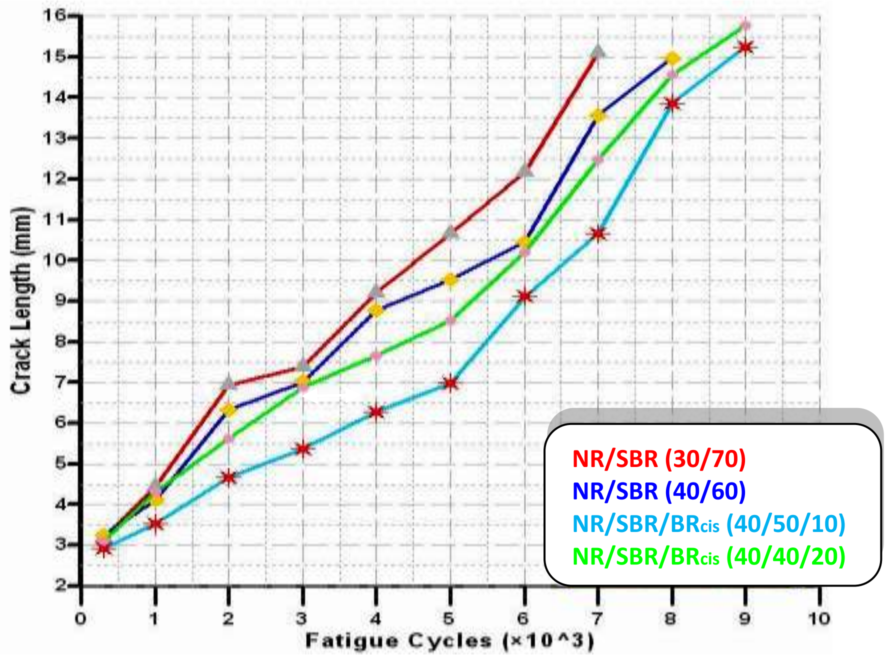


Figure (11): Crack Length vs. Fatigue Cycles.

Figure (11) shows the results of continued cycling to generate more than 15 mm of crack length, i.e. crack length-number of fatigue cycle plot. This approach is compatible with several studies[33,34].High cut growth rate for standard recipe (stock 1) in comparison with other recipes can observe in this figure.Table (10), shows the results of fatigue test for stressed stocks 1, 4,5 and 6 after exposure to sunlightfor 72hr. Stocks 4 and 5 show the same improvement, but stock 6 is the best.

Table (10):Fatigue Life for Specimens Exposure to Sunlight.

Stock No	Fatigue Life (kilocycle)	Improvement(%)
1	3	0
4	5	66.67
5	5	66.67
6	6	100

CONCLUSIONS

From the observations and results obtained, the following conclusions can be drawn:

1. Increase in NR loading and uses of BRcis in sidewall recipes was the reason behind the improvements in tensile and tear strength, also (40/40/20) percentage for (NR/SBR/BR_{cis}) blending was the best.
2. Compression set increases with the increase of SBR and decrease of NR. The use of BR_{cis} with different percentages in NR/SBR blendshows acceptable results.
3. Hardness decreased with increasing of NR, also in cause of using BR_{cis}.
4. Distinguishedresults in fatigue test were in (40/50/10) and (40/40/20) for (NR/SBR/BR_{cis}) blending.
5. Exposure to sunlight causesdegradation in mechanical properties, but new selected recipes showed better mechanical properties and fatigue life than the Perilli recipe.
6. As a optimum properties, the recipes that have(NR/SBR/BR_{cis}) blending with percentage (40/60/0), (40/50/10) and (40/40/20)fortruck tire sidewall Compound were the better in comparison with standardPerilli recipe.

REFERENCES

[1]. Seidelt, S,M.Mu¨ller-Hagedorn and H. Bockhorn,"Description of Tire Pyrolysis by Thermal Degradation Behaviour of Main Components",Institut for TechnischeChemie andPolymerchemie, University of Karlsruhe (TH), Germany, (2005).

[2]. Andrew J Tinker and Kevin P Jones, "Blends of Natural Rubber Novel Techniques for Blending with Specialty Polymers", 1st Ed. Chapman& Hall,UK,(1998).

[3]. Mathias Brieu, J.Diani, C.Mignot and C.Moriceau, "Response of a Carbon Black Filled SBR under Large Strain Cyclic Uniaxial Tension", International Journal of Fatigue 32, doi:10.1016/ijfatigue.2010.06.002. Elsevier LTD,(2010).

[4]. Sadhan K. De and Jim R. White, Rubber Technologist’s Handbook, Rapra Technology Limited, U K, (2001).

[5]. Flowers, D.D. ,J.V.Fusco, L.J.Gursky, D.G.Young, "New Tire Black Sidewall Composition",Publication: Rubber World, Tire Industry Research,(1991). http://www.thefreelibrary.com/New+tire+black+sidewall+composition.-a011245818

[6]. Lin, Chung-Yuan,"Improving Flex Fatigue and Dynamic Ozone Crack Resistance Through Antidegradants", Publication: Rubber World,(2000). http://www.thefreelibrary.com/Improving+flex+fatigue+and+dynamic+ozone+crack+resistance+through...-a078792187

[7]. Legorju-jago and C. Bathias, K. "Fatigue Initiation and Propagation in Natural and Synthetic Rubbers, Department of Mechanical Engineering",Paris, France,(2002).

[8]. Huynh Tan Phat,Tran Le Hai, Nguyen Thi Hue and NguyenV.Tri,"Research in

Rubber Composition for Improving Tire Sidewall Properties", Faculty of Applied Science and Rubber Research Institute of Vietnam, (2005).

[9]. Sahakaro, K., Datta, R. N., Baaij, J. and Noordermeer, "Blending of NR/BR/EPDM by Reactive Processing for Tire Sidewall Applications", Journal of Applied Polymer Science, 103: 2555–2563. doi: 10.1002/app.25101,(2007).

[10]. Alalkawi, H.J. Z. K. Hantoosh and R.H. Majid,"The Tensile and Fatigue Properties of Vulcanized Natural Rubber under Ambient Temperatures", Diyala Journal of Eng.Sc. Vol.3, No.2, pp16-24, Iraq, (2010).

[11]. Brindha, M.; Mahapatra, D.,"Effect of Reinforcing Fillers on the DeMattia Cut Growth and Dynamic Properties of a Model Sidewall Compound",Publication: RubberWorld, Tire Industry Research, (2010). http://www.thefreelibrary.com/Effect+of+reinforcing+fillers+on+the+DeMattia +cut+growth+and+dynamic...-a0223749696

[12].Maurice Morton, Rubber Technology, Institute of Polymer Science, University of Akron, Ohio,(1973).

[13]. Wallace Tow Roll Mill ApparatusManual, B.S 903,(1976).

[14]. ASTM D412, Vulcanized Rubber and Thermoplastic Elastomers-Tension,Annual Book of ASTM Standards, Vol. 09.01,(2003).

[15].Roger Brown , "Physical Testing of Rubber", 4th Ed. ,Springer Science-i-Business Media, Inc., USA, (2006).

[16]. ASTM D 624, "Tear Strength of Conventional Vulcanized Rubber",Annual Book of ASTM Standards, Vol. 09.01,(2001).

[17]. N. S. Thamer,"Mechanical Properties of composite using Natural Rubber with Epoxy Resin", Master Thesis, Al-Nehrin University, Iraq,(2007).

[18]. ASTM D395,"Rubber Property-Compression Set",Annual Book of ASTM Standards, Vol. 09.01,(2003).

[19]. Wallace Compression Set ApparatusManual, Constant Stress, B.S 903, Pt A.6., (1978).

[20]. Matthan, R.K. Rubber Engineering, Indian Rubber Institute, Tata McGraw-Hill Publishing Co. Ltd., New Delhi, (1998).

[21]. Wallace Dead Load Hardness TesterManual,ISO/R.48,1968& B.S.903A26,(1969).

[22]. ASTMD1415, "Rubber Property-International Hardness", Annual Book of ASTM Standards, Vol. 09.01,(1999).

[23]. James E. Mark, BurakErman and Frederick R. Eirich, Science and Technology of Rubber, 3rdEd., Academic Press, Elsevier,(2005).

[24]. ASTM D430, "Rubber Deterioration-Dynamic Fatigue",Annual Book of ASTM Standards, Vol. 09.01,(2000).

[25]. ASTM D813, "Rubber Deterioration-Crack Growth", Annual Book of ASTM Standards, Vol. 09.01,(2000).

[26]. Charles A. Harper, Handbook of Plastics Elastomers and Composites, 4thEd., McGraw-Hill Handbooks;(www.digitalengineeringlibrary.com),(2004).

[27]. Alan N. Gent, "Engineering with Rubber- How to Design Rubber Components", 2nd Ed., Hanser Publishers, Munich,(2001).

[28]. Shaw and W.J.MacKnight, M.T. " Introduction to Polymer Viscoelasticity", Published by John Wiley & Sons, Inc., Hoboken, New Jersey,3rdEd.,(2005).

[29]. MARK, J. EPolymer Data Handbook, Oxford University Press, (1999).

[30]. Klaus Friedrich, StoykoFakirov and ZhongZhang,"Polymer CompositesFrom Nano- to Macro-Scale", Springer Science and Business Media Inc.,(2005).

[31].MohdBijarimi,H. Zulkafli and M.D. Beg,"Mechanical Properties of IndustrialTyre RubberCompounds",Journal of Applied Sciences 10(13):1345-348,Malaysia,(2010)

[32]. You-Ping Wu, Wei Zhao, Li-Qun Zhang, Improvement of Flex-Fatigue Life of Carbon-Black Filled Styrene-Butadiene Rubber by Addition of Nanodispersed Clay,Beijing University of Chemical Technology,China, (2006).

[33]. Schuble, P.M. E.E.Gdoutos and I.M. Daniel, "Fatigue Characterization of Tire Rubber",Robert McCormick School of Engineering and Applied Science, Northwestern University, Evanston IL 60208, (2002).

[34]. Mars and A. Fatemi, W. "Fatigue Crack Nucleation and Growth in Filled Natural Rubber", Blackwell Publishing Ltd, Fat.Fra. Eng. Mat. Str.,USA,(2003).