32

Improvement in Durability of Rubber Compound with Eco-Friendly Chemicals in the Global Economy

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Introduction

One of the biggest environmental issues is global warming. Greenhouse gas emissions from the use of synthetic plastics are negligible. Recycling is the process of turning waste materials into new goods in order to reduce the need for "conventional" garbage disposal, prevent the waste of potentially useful materials, consume less energy, and reduce air and water pollution. Numerous types of glass, paper, metal, plastic, textiles, and electronics are recyclable materials. Additionally, a number of other materials are regularly recycled, often on an industrial scale. Recycling tires is also widespread. Over the past ten years, there has been a growing interest in rubber recycling. The environmental impact of discarded tires and rubber products has been the driving force behind this. The collection and recovery of used tires has increased from 60% to 80% since the Romanian government approved a policy on the management of used tires in 2004. Rubber can be made for playground safety by mixing discarded tires with asphalt to create road surfaces. Tensile strength and the impact on physical properties were examined for four different low PCA oil types and the one standard high PCA oil. The ideal substitute aids for the rubber business may be these LPCA oils. As seen by the current upward trend, the creation of novel LPCA-based materials has been a major source of inspiration for materials scientists.

Although natural rubber (NR) has several desirable properties, such as high tensile strength and extensibility, superior resistance to fracture formation, and low heat accumulation, it is never used in its original form without first being vulcanised. Before other chemical components are added, NR must undergo sufficient mastication to

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reduce its molecular weight because an excessive molecular weight would prevent the new substances from dispersing. The effect of molecular weight reduction through this procedure on tensile properties and microstructure is of great relevance for understanding the final features of vulcanizates, since mastication is usually necessary. In his research on butyl rubber, Flory first investigated the connection between molecular weight and rubber characteristics. He found that tensile strength is directly correlated with the weight fraction of the active network structure. It is essential to comprehend tensile strength since it is a measure of a compound's strength. Tensile strength gives information about how an object will react to tensile stresses, regardless of whether it is designed to break quickly or stay intact. Drive belts, rubber tie-downs, and bungee cords are among the applications where tensile strength is essential. Because of their tendency to break readily, some elastomeric materials, like silicone, have poor tensile strength and are therefore inappropriate for dynamic sealing applications.

As molecular weight increased, so did tensile strength. But as the molecular weight hit 500,000, the tensile strength tended to remain steady. The study examined the strain-induced crystallisation and stress-strain characteristics of NR vulcanizates with varying molecular weights. It found that because high molecular weight rubbers have homogeneous network structures, they can produce higher levels of stress at a given strain and better strain-induced crystallisation ability. But there was no indication of a network structure. The effects of various parameters, including temperature, deformation rate, filler content, and crosslink density, on the final properties, crystallisation behaviour, and microstructure of NR have been thoroughly studied and covered in the report up to this point. However, little is known about how the molecular weight influences strain-induced crystallisation and the network structure. Therefore, it is still intriguing to look into the mechanical characteristics and network structure modifications further in order to confirm the impact of molecular weight.

It is widely acknowledged that mastication reduces molecular weight, which impacts NR viscosity. The impact of mastication duration on the microstructure and physical characteristics of uncross linked NR has been documented previously. Regretfully, the deformation-induced crystallisation behaviour of NR following vulcanisation and the contributions of mastication duration to the network structure was not covered. Therefore, the purpose of this work was to demonstrate how the microstructure and ultimate properties of the NR vulcanizes are affected by the molecular weight reduction caused by mastication. Before the other compounding ingredients were added, the NR was first masticated for a variety of lengths of time. The moving die rheometer was used to examine the processing characteristics of NR. The crosslinked NR's tensile characteristics, strain-induced crystallisation, and network structure were examined using the tensile test, small angle X-ray scattering (SAXS), and wide angle X-ray diffraction (WAXD), respectively.

To improve the compounds' processability, highly aromatic oils are either added to purchase rubbers or mixed into the rubber compound during the manufacturing process. Along with other qualities like durability and wear resistance, the tread rubber compound also shows enhanced performance characteristics, especially in wet grip. Because of their high concentrations of PAHs, several highly aromatic oils are categorised as carcinogenic; eight of these substances are particularly known to cause cancer. However, the EU does not classify completed rubber products—such as synthetic rubber and tyre compounds made with aromatic oils—as hazardous materials. After being vulcanised at the factory and sold to consumers, the tyre is safe to use whether it is being handled physically, used on the road or nearing the end of its useful life. Numerous investigations have confirmed that because aromatic oils are deeply incorporated into the mass of tires, they cannot be liberated in their original chemical state under normal test settings.

Materials and Methods

An analysis will be conducted on one HPCA oil and three low PCA oils to assess their tensile strength, after that the most appropriate option will be chosen. Different require materials are given in table 1.

Table 1

Ingredients	Compound 1	Compound 2	Compound 3	Compound 4
RMA4	27 phr	27	27	27
BR	35	35	35	35
sSBR HPCA	52	--	--	--
sSBR LPCA -3	--	52	52	52
N339	60	60	60	60
Oils No-1	5	--	--	--
Oils No-2	--	5	--	--
Oils No-3	--	--	5	--
Oils No-4	--	--	--	5
ZnO(WS)	2.25	2.25	2.25	2.25
St Acid	0.5	0.5	0.5	0.5
6PPD	1.9	1.9	1.9	1.9
MC Wax	2.4	2.4	2.4	2.4
MS 40	1	1	1	1
S(108)	2.2	2.2	2.2	2.2
TBBS	1.2	1.2	1.2	1.2
DCBS	0.6	0.6	0.6	0.6
PVI	0.15	0.15	0.15	0.15
Batch weight	191.2	191.2	191.2	191.2

R:- regular oil, low PCA oil No 2,3,4, RMA : NR sheet BR - butadiene rubber,

SSBR styrene 40%, Vinyl content 46% having low PCA oil

- **Sample Preparation**: Compression moulding was used to cure the green rubber compounds in accordance with ASTM D3182 requirements in a hydraulic curing press that was electrically heated. The compounds were cured by moulding under the following conditions: 141°C for 45 minutes for the stress-strain study and 141°C for an hour for the evaluation of rebound resilience and abrasion loss.

Compound Mixing

With the formulae listed in Table No-1, the rubber compound was mixed in three separate phases using a two-wing rotor laboratory Banbury mixer (Stewart Bolling, USA): master batch, remill, and final batch. The temperature control unit (TCU) was set to 90°C and the rotor speed was set to 60 rpm for the master batch mixing. The master batch was released when the power integrator (PI) showed that 0.32 kWh had been reached. It was noted that the master batches were dropped at a temperature of 140 to 150°C. The master batches were then run through a two-roll mill in the lab. After eight hours of maturation, the master batches underwent further blending. The rotor speed was set to 30 rpm and the TCU was kept at 60°C for the last batch mixing. An accelerator, a scorch inhibitor, and sulphur were added to the previously made master batch. When the PI reading reached 0.12 kWh, the batch was released. It was discovered that the batches were dropped at a temperature between 95 and 105°C. Additionally, a laboratory two-roll mill was used to process the final batches using the recipe listed in Table 1.

Tensile Strength

The extension that remains after a specimen has been stretched and given time to relax is known as tensile strength. The percentage of the original length that is used to represent Tensile Set. The stress-strain chart does not display tensile set results. Following the tensile strength test, this measurement can be taken. Tensile set is the amount of extension left after stretching, whereas elasticity is a material's mechanical ability to return to its former shape. (ASTM D638). The load at break is divided by the initial minimum cross-sectional area to determine the tensile strength. Three important figures are informed of the outcome, which is expressed in mega pascals (MPa).

A tensometer is used to measure tensile strength. The purpose of a tensometer is to measure the amount of force required to deform and fracture a specimen, in this example a die-cut dumbbell shape, by applying a tensional or compressive force to it. The amount of force needed to stretch the specimen to distortion and eventually break is usually shown on a stress-strain curve.

Tensile Strength = (load at break) /(original width) (original thickness)

Unaged Physical Properties @ 160^{0}C/20min

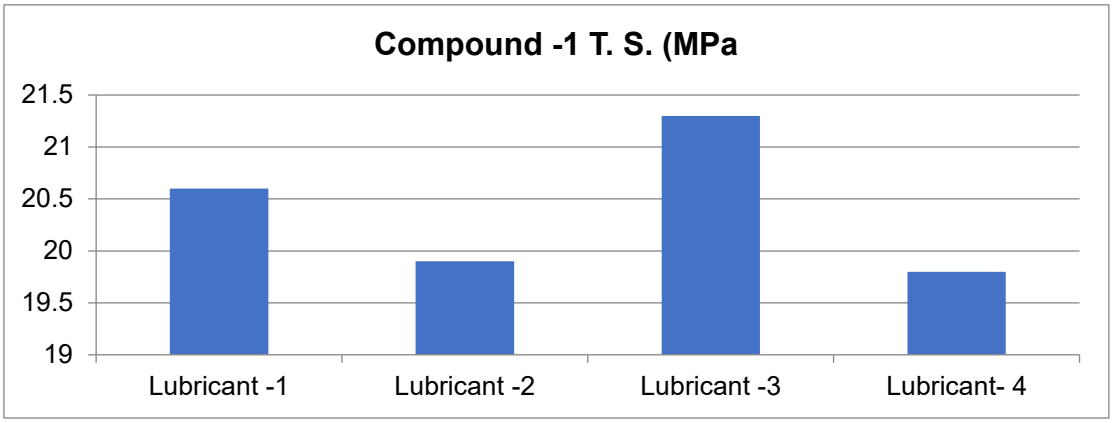

Figure 1

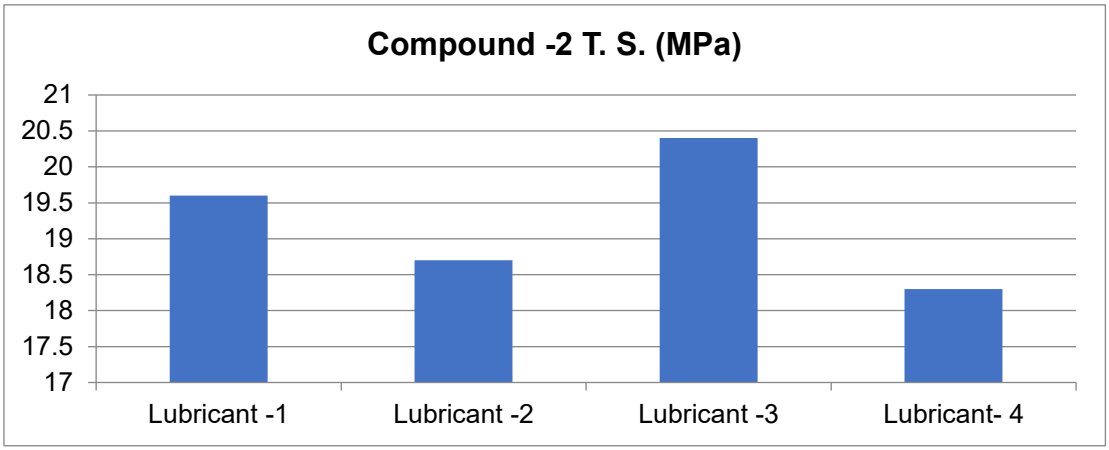

Figure 2

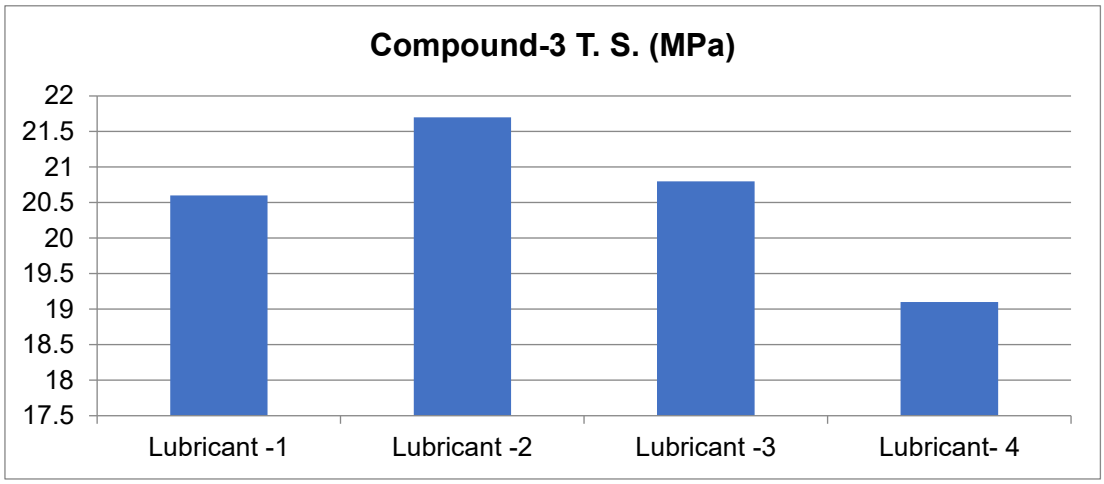

Figure 3

Aged Physical Properties (Molding @105^{0}C/3Day)

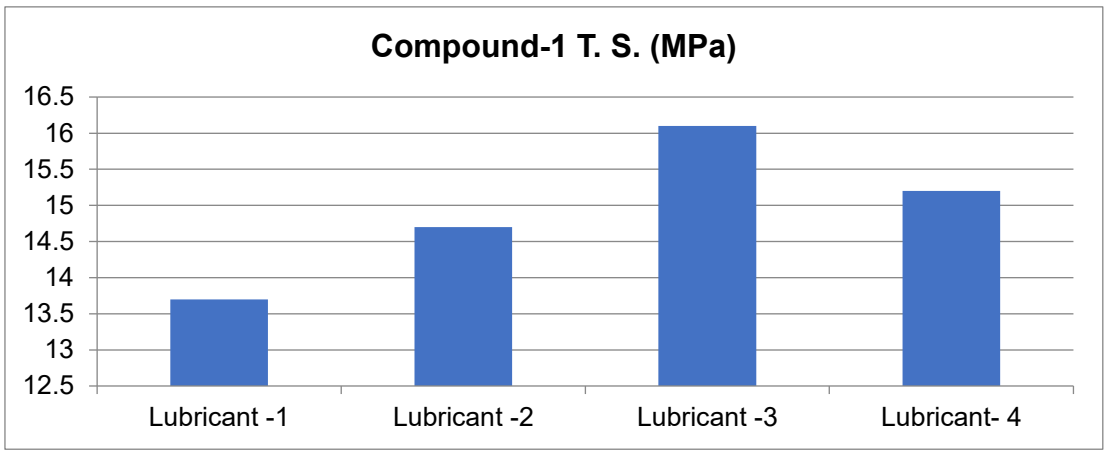

Figure 4

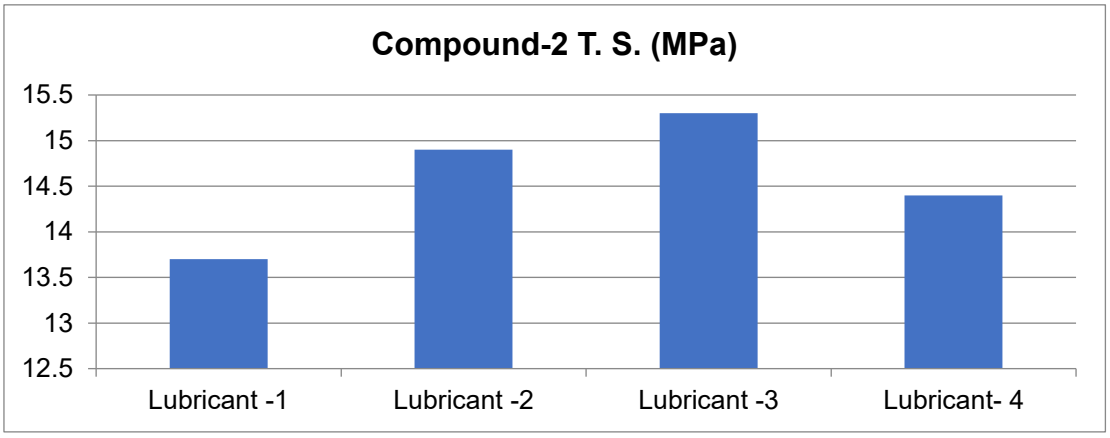

Figure 5

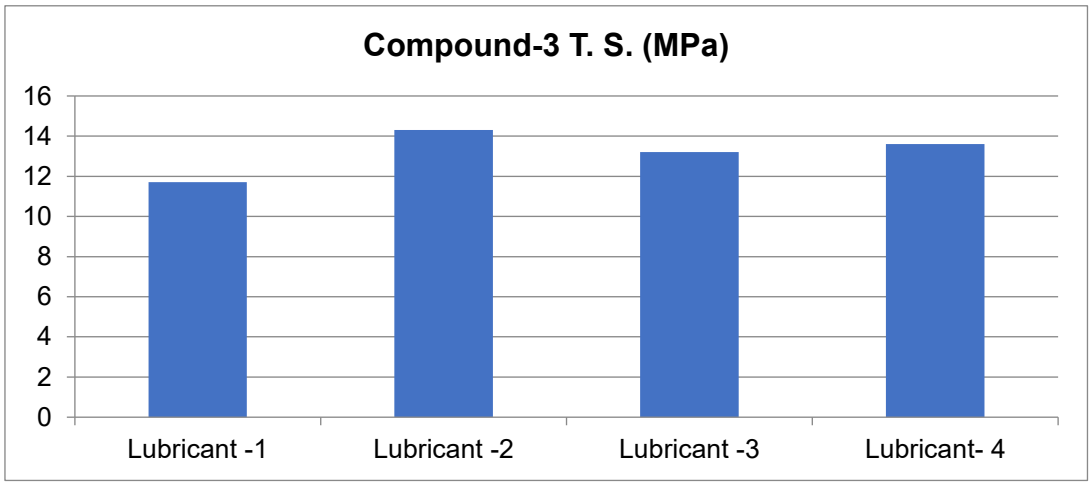

Figure 6

Conclusion

A little decline in tensile strength was noted for the compounds containing LPCA oil when taking into account the stress-strain characteristics of the unaged samples. The inclusion of LPCA oil had no effect on the aged samples' stress-strain characteristics. Some of the most important properties of rubber compounds are significantly impacted by LPCA oil, and as the amount of LPCA oil increased, so did the degradation of those features. The economic cost of the finished product rises as a result of the usage of LPCA oils because they are more expensive than HPCA.

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