Jl. Rubb. Res. Inst. Sri Lanka (1985) 64, 1-6

EFFECT OF MOISTURE ON THE PROCESSABILITY AND PHYSICAL PROPERTIES OF NATURAL RUBBER

by

M. C. S. PERERA AND T. A. S. SIRIWARDENA

ABSTRACT

The natural rubber absorbs moisture when exposed to high humidities. The presence of moisture is found to reduce the mastication efficiency of rubbers resulting in stocks with high Mooney viscosities. The green strength and the die swell increases as a result. It has also been found that this affects the milling efficiency resulting in heterodisperse stocks. These effects could be eliminated by further milling. The presence of moisture, however, affects directly, the Mooney scorch time of conventional mixes, the tensile strength, resilience and heat build-up.

INTRODUCTION

The producers take great care in producing natural rubber (NR) with low moisture content and ensure that the final raw rubber has a moisture content of below 0.8%. However, natural rubber is known to absorb water during storage and transport when it either comes in contact with water or exposed to atmosphere of high humidity. Witby (1918) and De Varies (1920) have shown that the amount of water absorbed by rubber depends upon humidity and temperature of the atmosphere in which it was stored. Pure rubber, however, takes up only a minute amount of water (Shatsberg, 1963 ; Black et *al.*, 1948). The presence of hydrophilic impurities such as proteins and inorganic salts can enhance the absorption of water in natural rubber. It has been shown by Van Rossen et *al.*, (1918), and Witby (1918) that the amount of such hydrophilic impurities determines the equilibrium water uptake. It has also been shown that by washing the rubber reduces the amount of water soluble constituents in the rubber and the amount of water absorbed. The uptake of water by rubber can affect their properties and hence influence their service performance. An analysis of the effect of absorbed moisture on the processability of natural rubber is presented in this paper.

EXPERIMENTAL

The ribbed smoked sheets (RSS) of thickness 3 mm and a volatile matter content of 66% were exposed to 100% relative humidity in a desiccator containing water. Samples were withdrawn at different intervals and the properties such as volatile matter content and the Mooney viscosity (ML 1+4, 100°C) of the samples were measured using standard methods for technically specified rubbers after homogenising in a two roll mill.

Rubber samples (200g) were milled in a two roll mill at an initial temperature of 30°C and a set nip distance. Samples of 10 g were withdrawn at intervals and the Mooney viscosity (ML1+4, 100°C) was determined to study the mill breakdown. Vulcanizing chemicals were incorporated into rubber in a two roll mill either keeping the milling time constant (10 Min) or until the desired compound mooney (ML 1+4, 100°C) was achieved. The green strength of the rubber compound with ZnO/stearic acid was measured on sheets moulded with vegetable oil paper placed between the compound and the plates and pressed at 100°C for 10 minutes. Dumb—bells were cut from these sheets and after removing the paper immediately before testing, load elongation data at 23°C was obtained on an Instron Tensile Tester using a cross—head speed of 500 mm/min.

The Mooney scorch at 121°C was determined in a conventional mix and an EV formulation given in Table 1. The extrusion were done in a Hot Feed Extruder manufactured by David Bridge Co., U.K., and the die swell percentage determined using usual methods. Tensile strength, resilience and heat build-up determined by ASTM methods.

Table 1. *Vulcanizing systems*

	Conventional mix	EV mix
Natural rubber ...	100.0	100.0
Zinc oxide	5.0	5.0
Stearic acid ...	2.0	2.0
CBS	0.6	—
TMTD	—	40
	3.5	—

CBS—N-cyclohexyl 2-benzothiazole sulphenamide
TMTD—Tetramethylthiuram disulphide

RESULTS AND DISCUSSION

The Mooney viscosity drop, with milling in an open two roll mill is shown in Table 2. This indicates that the efficiency of mill breakdown drops with increasing water content in rubber. Nadarajah *et al.*, (1987) has recently made a similar observation when rubber is masticated in an internal mixer. Since it has been shown by Mullins and Watson (1959) that hot and cold mastication is a shear dependent process the water can act as a lubricant and reduce the mastication efficiency. Bristow et *al.*, (1983) reported that slipping is a feature of compounded rather than raw rubber and the effect tend to be highly specific to certain chemicals. The fact that it is an effect of slippage is further evident from the higher smooth band formation time when the moisture content is higher as shown in Table 2. Rupture of rubber in an open mill or in an internal mixer (mastication), has also been related to the tearing strength of the rubber which is shown to be dependent on the Mooney viscosity (Kadir and Thomas, 1984). The higher the viscosity the higher is its tearing strength. Thus, when the mill breakdown is slower due to slippage, the rubber with higher moisture content always has a higher tearing strength (higher Mooney) than the rubber with low moisture. This will further reduce the rupture or mastication of rubber. It is also known that in rubber vulcanizates, the absorbed water reduces its modulus and that the elastic effects are important in the behaviour of materials in the nip of a mill or internal mixer (Bristow et *al.*, 1983). Therefore, reduction in elastic effects (if happening in raw rubber) due to the presence of water could be expected to cause the rubber to behave differently on the mill.

Table 2. *Effect of mill breakdown on initial moisture content*

Initial moisture content (%)	Change in Mooney units	Smooth bond formation time (secs)
0.66	33	126
1.08	29	143
2.81	20	171
3.53	13	186
4.86	06	223

The relationship of the initial moisture content and compound Mooney viscosity with the green strength is shown in Table 3. It is found that the green strength depend on compound Mooney and not on initial or compound moisture content . The Mooney scorch time of ACS—1 formulation was found to be lower when more moisture is present in the rubber. Such a difference is not found in efficient vulcanization (EV) system based on low S as shown in Table 4. This is due to the susceptibility of sulphenemide accelerated vulcanization to moisture effects (Smith 1974).

Table 3. *Effect of on green strength and die swell initial moisture content and compound Mooney*

Initial moisture content	Compound Mooney viscosity	Green strength (MNM^2)	Die swell (%)
0.66	41	8.63	36.8
0.66	52	7.82	33.1
1.08	63	9.15	41.3
1.08	51	8.59	37.0
2.07	71	10.56	42.7
2.07	63	9.11	41.4
2.07	51	10,56	36.9

Table 4. *Effect of scorch time on initial and compound moisture content*

Moisture content (%)		Scorch time	
Initial	Compound	ACS-MIX	EV MIX
0.66	0.22	8.5	4.5
1.08	0.61	7.5	4.5
2.07	0.97	5.0	4.7

The relationship between die swell with initial moisture content and the compound Mooney is also given in Table 3. It is clear that differences in die swell values are due to the differences in compound Mooney but not initial moisture content. Similar dependence of die swell on compound Mooney viscosity has been observed earlier by Cotton (1979), Bristow et *al*., (1983) and Ong (1984). The rubbers with higher moisture contents were found to be difficult to extrude and therefore smooth extrudates were not obtained. In the flow through an extruder die, extensional as well as shear flow are involved. But there is a critical rate of extension below which the rubber flows rather than tears. This critical rate is higher the lower the viscosity of rubber (Bristow et *al*, 1983) .Thus smooth extrudates can only be obtained by extruding low viscosity rubber at low rates.

Due to the poor mastication efficiency in rubbers with high moisture the dispersion of the chemicals were poor and as a result these samples had to be milled more to obtain mix homogenity. When this is achieved all samples had similar compound mooney values. The properties of these compounds (but different compound moisture content) are shown in Table 5. The tensile strength and resilience drop with increase in moisture content while the heat build-up increases. The effect of proteinaceous matter as a reinforcing filler is well known (Knight and Tan, 1975) and the moisture acts to deactivate the protein filler (Derham, 1972). Increase in moisture thus lead to decrease in reinforcement. The reduce reinforcement reduce the tensile strength and resilience while the heat build-up is increased.

Table 5. *Vulcanizing systems*

Moisture content of the compound (%)	Tensile strength (MN M ^{2})	Resilience at 25°C (%)	Heat build up (Temp rise °C)
0.22	27.1	65.0	10.0
0.61	25,2	63.8	10.8
0.97	23.3	62.8	11.4

CONCLUSIONS

Natural rubber even when dried to moisture contents below 0.8% continues to absorb a considerable amount of water when exposed to high atmospheric humidities. Increase water content in the rubber reduces the mastication efficiency resulting in compounds with higher Mooney viscosities. This is due to slippage of rubber on the mill as well as the higher tearing energy. As a result of the higher Mooney viscosities, the properties such as green strength and die swell were found to be affected. The scorch time of the rubbers when sulphenemide accelerators are used is however affected directly by the water present in the rubber. The moisture also affect the reinforcement nature of the protein filler, thus, reducing the tensile strength, resilience and increase heat build-up in stocks of same compound Mooney viscosity.

REFERENCES

BAKER, H. C. and GREENSMITH, (1966), The Processing and vulcanisate properties of commercial grades of natural rubber ; Part 1. Effect of compound viscosities, *Trans*, **42**, T 194.

BLACK J., JORIS, G. C. and TAYLOR H. S. (1948), The solubility of water in hydrocarbons, *J. Chem. Phys.*, **16** (5), 537.

BRISTOW, G. M., FULLER, K. N. G and THOMAS, A. G., (1983), Parameters indicative of the processability of rubbers, *NR Technol.*, **14** (4), 69.

COTTON, G. R., (1979), Influence of C-black on processability of rubber stocks II extrustion strinkage, *Rubb. Chem. Technol.*, **52**, 187.

DERHAM, C. J., (1972), Effect of moisture on the creep and stress relaxation of natural and synthetic general purpose rubbers, *Proc. Int. Rubb. Conf.. Brighton*, F 1-1.

DE VARIES (1920), *Estate Rubber*, 602.

KADIR A and THOMAS A. G., (1984), Tearing of unvulcanised natural rubber, *J. Appl. Polym. Sci* **22**, 1623.

KNIGHT, G. T., and TAN, A. S., (1975), Dyanamic and related properties of natural rubber, *Proc Int. Rubb. Conf., Kuala Lumpur.*

MULLINS, L and WATSON, W. F., (1959), Mastication IX; Shear dependence of degradation on hot mastication, *J. Appl. Polym, Sci.*, **1**, 245.

NADARAJAH, M., WEERABANSA, M. T., DE SILVA, G. A., SENARATNA, S. AND PERERA, D. C. R., (1987), *Proc. of Rubber Conf.* '87, U.K.

ONG, E. L., LIM. C. L. and SUBRAMANIUM, A., (1984), Effect of storage hardening on the processability of NR, *Proc. Int. Rubb. Conf., Colombo*, 97.

SHATZBERG, P. (1963) Absorption of water by rubber, *J. Phys. Chem.*, **67**, 776.

SMITH, J. F. (1974), Natural rubber compounding for engineering applications, *Proc. Rubb. in Engng. Conf., Kuala Lumpur*, Print 5.

VAN ROSSEM, VAN DE LEUR and DEKKER, (1918) Kolliodchem. *Beihefte*, **10**, 43.

WITBY, (1918), *J. Soc. Chem. Ind.*, **37**, 278.

WITBY, (1918), *India World*, **59**, 141.