Cure characteristics and tensile properties of natural rubber vulcanizates modified by tapioca starch

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ABSTRACT – This study focusing on cure characteristics as well as tensile properties of natural rubber (NR) vulcanizates modified with tapioca starch as biodegradability agent. The samples were prepared by melt compounding via a Haake internal mixer. The tapioca starch was varied from 0, 5, 10, 20, 40, and 60 phr in the formulation. Increasing tapioca starch loading was observed to accelerate the curing process meanwhile increases the crosslinks density which depicted by M_H-M_L value. Furthermore, the additional of tapioca starch up to 20 phr increased the elongation of break of the vulcanizate.

1. INTRODUCTION

Over the past few years, the effects of different types of fillers on Natural Rubber compounds have been studied, in search of improvements on their physical and mechanical properties. Recently, the use of fillers from organic nature has been object of interest due to their low cost, light weight, environmentally friendly nature, and because of enhances the mechanical properties of the filled materials [1,2]. Several cellulosic materials such as nut shells, bamboo, ground wood waste, cereal straw and white rice husk have been used as fillers for plastics [3,4] and elastomers [5-6].

Starch is one of the substances most widely found in nature. It is a biopolymer consisting of amylose and amylopectin, present in most plants and in considerable amounts. There are some investigations concerning the reinforcement of elastomers with tapioca starch [7], but only a few report of this material on the physical properties of the elastomers. Thus, the aims of this contribution to assess the potential utilization of tapioca starch in natural rubber formulations, studying the effects of starch content on the rheological and mechanical behaviour of NR composites.

2. METHODOLOGY

2.1 Materials

Composites prepared based on 100 phr of Natural Rubber (NR) SMR-20 and different proportions of Tapioca Starch (TS) at 5, 10, 20, 40 and 60 phr. The NR was obtained from Malaysian Rubber Board and the TS was obtained from a local company. Curing additives for all formulations based on 100 parts of rubber were: 2.5 phr of sulphur (S), 5 phr of Zinc oxide (ZnO), 2 phr of stearic acid, 1 phr of Tetramethyl Thiuram Disulphate (TMTD) and 1 phr of 6PPD. The rubber compound (Figure 1) was prepared using a Haake internal mixer working at 60°C and a rotor speed of 60 rpm for 7 minutes according to ASTM D-3182.

2.2 Testing

The processability of NR compound was the evaluated with cure characteristic assessment in accordance to ASTM D2084 using an oscillating rotorless rheometer model U-CAN Dynatex UR2010 (U-CAN Incorporation, Taiwan). Samples of the respective compounds were tested at 160°C, 4.5 kg cm^{-2} of compression pressure, 1.7 Hz of swing frequency, and 1° swing amplitude within 5 min of curing time. The maximum curing time (t_{c90}), scorch time (t_{s2}), minimum torque (M_L), and the maximum torque (M_H) were determined in this assessment. The torque different (M_H-M_L) were calculated for further analysis of the compound processability. The compounds were subsequently molded with the compression machine 160°C and 150 kgf using hot press model GT7014-A from GoTech (Figure 2).

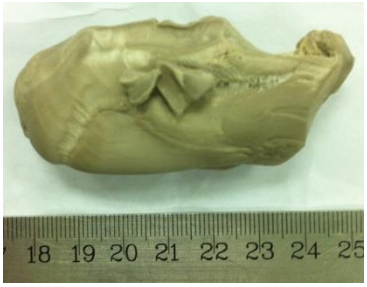

Figure 1 Rubber compound.

Figure 2 Rubber sheet.

3. RESULTS AND DISCUSSION

3.1 Cure characteristics

Table 1 shows the required time for 90% curing (t_{c90}), the maximum torque (M_H), minimum torque (M_L) and the scorch time (t_{s2}) of the samples. Increasing tapioca starch, shows increasing trend of M_L represents a positive relation of compound viscosity due to solid starch increases compound viscosity. Trends of M_H and crosslink density also increased when increasing in the dosages of starch. This is because solid starch limits the mobility of rubber chains. However, decreasing trends of t_{s2} and t_{c90} shows the compounds become more scorch and shorter in cure time. It may relate to the impurities of starch that accelerate cure and also relates to higher crosslink density.

3.2 Mechanical properties

The experimental data are tabulated in Table 2. The results clearly show that the elongation at break (EB) and modulus at 100, 300 and 500 % of elongation (M100, M300 and M500) increase with an increase in tapioca starch. NR compound with tapioca starch experience a slightly higher result and improvement across all tensile properties. For instance, the EB drastically increased up to 2050 % improvement when 20 phr tapioca starch was added. However, a reduction in TS was encountered for NR compound with higher tapioca starch content due to agglomeration and aggregation of platelets that enables pre-mature failure.

Table 1 Curing parameters of NR/TS.

Sample	M_H dNm)	M_L (dNm)	t_{s2} (min)	t_{c90} (min)	M_H-M_L (dNm)
NR-TS0	26.09	7.92	1.14	1.43	18.17
NR-TS5	26.47	8.25	1.11	1.41	18.22
NR-TS10	28.25	8.36	1.10	1.40	19.89
NR-TS20	32.12	8.83	1.07	1.46	23.29
NR-TS40	33.06	9.43	1.03	1.36	23.63
NR-TS60	35.02	9.47	1.02	1.36	25.55

Table 2 Tensile properties of NR/TS.

Sample	M_{100} (MPa)	M_{300} (MPa)	M_{500} (MPa)	TS (MPa)	ε_r (%)
NR-TS0	5.07	11.38	17.31	17.62	1700
NR-TS5	5.72	11.42	17.62	16.49	1750
NR-TS10	6.00	12.08	17.85	15.58	1800
NR-TS20	6.12	12.44	18.26	14.33	2050
NR-TS40	7.10	12.91	19.52	12.94	1600
NR-TS60	8.05	13.33	20.31	8.60	1450

4. CONCLUSIONS

The curing characteristics and mechanical properties of NR compound were examined as a function of tapioca starch loading. The scorch time, t_{s2} and cure time, t_{c90} decrease with increasing tapioca starch. Tensile modulus increase with increasing tapioca starch in NR compund. However, tensile strength decreases with increasing tapioca starch.

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