

A new technique to gauge the vulcanization kinetics of natural rubber latex using viscosity measurements and the use of the above method to study effects of variation of activator content on vulcanization of NR latex

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Abstract

A series of compounded natural rubber (NR) latex samples were prepared with varying amounts of activator contents. Viscosity changes of these samples were monitored with time at two different temperatures (i.e. 30°C and 80°C). These temperatures were selected to cover room temperature and a typical vulcanizing temperature for natural rubber latex based products. Unique pattern of viscosity changes can be observed during the process of vulcanization. There is a possibility of developing viscosity measurement as a way of studying kinetics of vulcanization of NR latex. This can be treated as a method analog to Rheological studies of sulphur vulcanization of dry NR. The variation of activator content showed a significant effect on the viscosity change.

Keywords: activator, latex, NR, viscosity measurements, vulcanization

1.Introduction

Sulphur vulcanization can be accelerated many-folds by the addition of effective activator systems comprising of combination of Zinc oxide (metallic oxides) and stearic acid, with a suitable accelerator or accelerator combination [1]. This can be kinetically studied by using rheology of compounded dry NR.

Viscosity is an important property of latex that depends on various factors associated with NR latex. It is inversely proportional to the mechanical and chemical stability. If the viscosity of the latex is high, this results the low mechanical and chemical stability. Latex with poor chemical stability will produce a compound showing steadily increasing viscosity on storage leading to pre-mature gelation. Further, Latex viscosity is influenced by the particle size and total solid content [2].

In this research, it has been attempted to prove a relationship between the change viscosity of compounded latex and vulcanization kinetics of NR latex. The main aims of this project were to find out how the viscosity changes during the vulcanization process and how the amount of activators of constant particle size and the temperature affect the viscosity during the vulcanization process.

2. Materials and Methods

2.1. Determination of viscosity

Viscosity of latex is usually measured in a viscometer. Here in this experiment Rheo-Win viscometer was used. This instrument consists of a rotating metal cylinder in a cavity that contains the latex sample, initially unvulcanized, but compounded. From the software program accompanied with the viscometer, the viscosity of the sample was measured against time and plotted on graph (Fig 1 to 6).

2.2. Materials used

The properties of the low ammonia latex sample used are as follows:

Total Solids Content % (w/w)	– 60.0
Dry Rubber Content % (w/w)	– 57.8
Volatile Fatty Acids number	– 0.014
Mechanical Stability Time(s)	– 1200
NH ₃ % (w/w)	– 0.2%

2.3. Latex compounding

By using above properties, vulcanization formula given in the Table 1 was selected [3].

2.4. Test procedure

Vulcanizing ingredients were taken as in the formula. However, amount of ZnO in each case was changed as follows (Table 2). They were mixed and the viscosity was measured at room temperature (30°C) and 80°C.

3. Results and Discussion

According to the Figure 1 fluctuation in viscosity was observed up to 40min at 30°C and thereafter the viscosity became constant. There was a small broad peak, which may have been due to some external actor between 10min to 14min. Fluctuation in viscosity was observed at 80°C up to the 40th minute as shown in Fig 2. However, a large peak was observed between 30min to 40min and then, a plateau was observed. From these observations, it can be conclude, the initial viscosity fluctuation was due to the reduction of chemical stability due to incorporation of ZnO [4]. The large peak appears in between 30min and 40 min is due to vulcanization reaction, which occurs usually around 40min at a temperature of 80°C. Further, it is well known that NR latex become stable after vulcanization. The plateau observed after the peak represent the vulcanization reaction is due to the enhanced stability of latex after vulcanization. Fig 3 and 4 represent viscosity curves of samples, which did not have ZnO at 30°C and 80°C, respectively. There was no peak at 80°C (Fig 4). So that may indicates there was no reaction occurred. But at 30°C there is a peak after 30min, which may have occurred due to an external cause as in the Figure 1 such as temperature fluctuation. Further, there are no significant fluctuation observed in viscosity curves showing that the fluctuation observed in ZnO added samples are due to reduction of chemical stability impart by ZnO. Apart from that single peak there are no significant peaks (Fig 3). This gives evidence to the fact that there is no immediate reaction in the absence of the activator due to higher activation energy at relatively low temperatures such as 30°C and 80°C [3].

When the amount of ZnO increases up to 1.0g, at 30°C, one can observe that reduction of chemical stability caused by the introduction of a large amount of ZnO from the fluctuations of viscosity values during the entire period of time (up to 60 min) (Fig 5). However, lack of the prominent peak followed by a plateau shows that vulcanization reaction has not started during 60 min period. In contrast, at 80°C (Fig 6), a peak followed by a plateau was observed. The shape of the peak observed is very similar to that of the Figure 2 (The sample with 0.5g ZnO at 80°C). This shows that the vulcanization reaction taken place is similar to that of the sample containing 0.5g of ZnO at 80°C. However, the width of the

peak has reduced significantly showing a lesser reaction time for the sample with 1.0g of ZnO.

As in the case of the Figure 3.5, when the amount of ZnO increases up to 2.0g, at 30°C a series of large fluctuations were observed within 60min interval (Fig 7). Further, the heights of the peaks were larger than that of Figure 5. This shows that increase of amount of ZnO added has further reduced the chemical stability of latex. Further, as in the earlier cases, at 30°C, there was no evidence for the vulcanization reaction. In contrast, at 80°C (Figure 8), a viscosity curve that is somewhat similar to that of the Figure 6 (1.0g of ZnO at 80°C) was observed. The main difference between two curves is that the peak before the plateau of the Figure 8 is very much smaller compared to that of the Figure 6. This could be attributed to the fact that higher amount of activator content may have reduced the activation energy of the reaction reducing the effect on viscosity. However, it is still evident that the vulcanization reaction has occurred at 80°C at a time similar to in all three cases.

4. Conclusion

All the above facts provide evidence to show that there is a characteristic peak followed by a plateau in a viscosity curve plotted against time during the process of vulcanization due to the changes occurring in a compounded NR latex sample. Hence, this viscosity technique could be used to gauge the vulcanization kinetics of NR latex. A similar study was carried out using varying concentrations of accelerator will be published separately. Further studies are in progress to perfect the technique as a standard test method. The variation of activator content showed a significant effect on the viscosity change.

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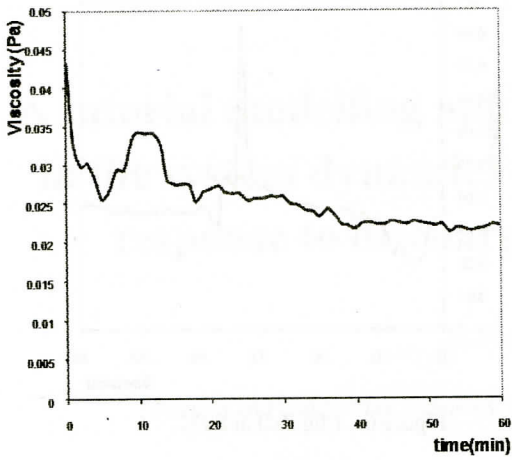


Figure 1: 0.5g ZnO at 30°C

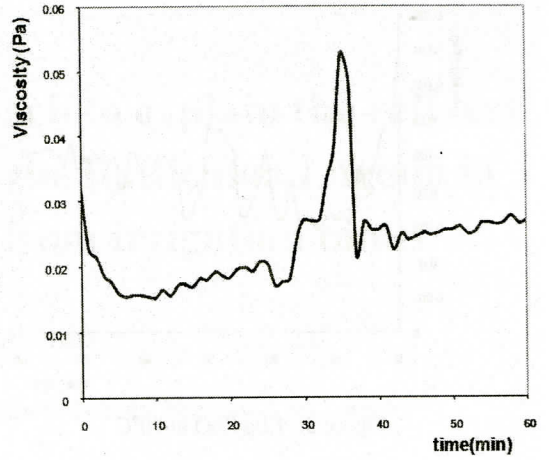


Figure 2: 0.5g ZnO at 80°C

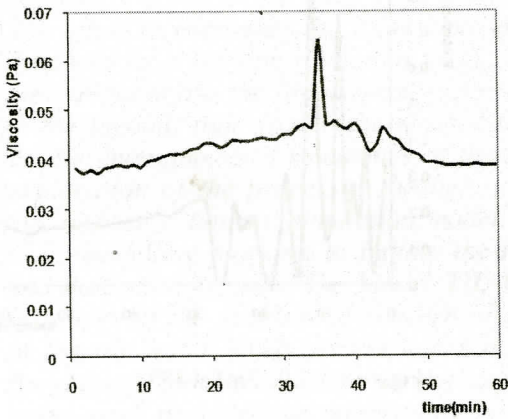


Figure 3: Sample not containing ZnO at 30°C

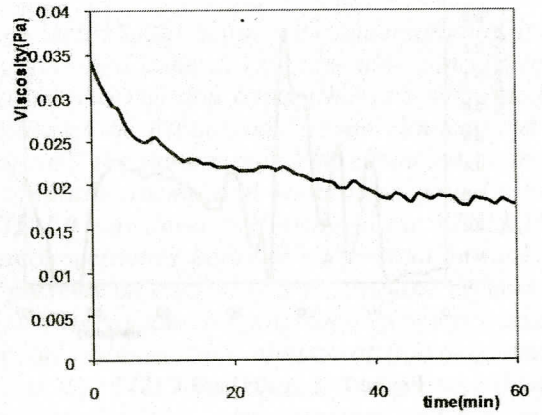


Figure 4: Sample not containing ZnO at 80°C

Table 1: Vulcanization formula (^a the amount of ZnO varied as given in the Table 2)

	Wet (Parts by weight)
60% Ammonia preserved latex	167
20% Surfactant	1
50% S dispersion	2
50% ZnO dispersion (activator)	X ^a
50% ZDC dispersion (accelerator)	2

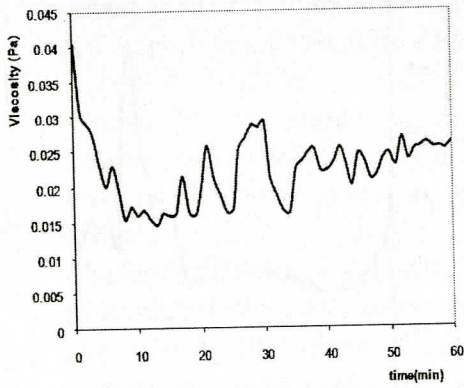


Figure 5: 1.0g ZnO at 30°C

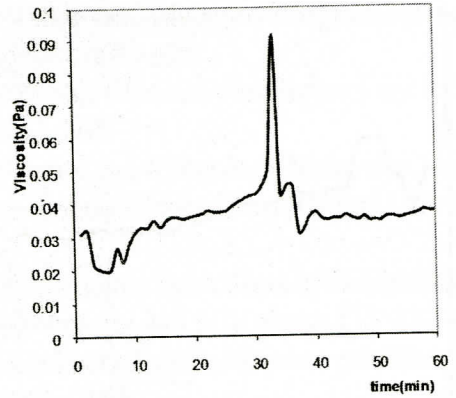


Figure 6: 1.0g ZnO at 80°C

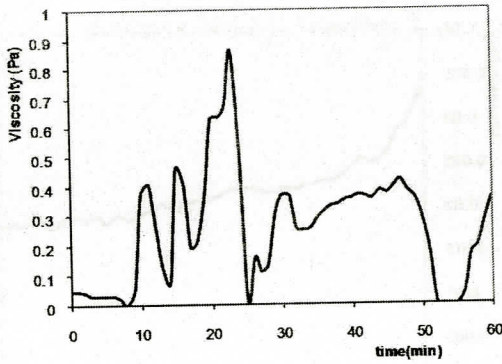


Figure 7: 2.0g ZnO at 30° C

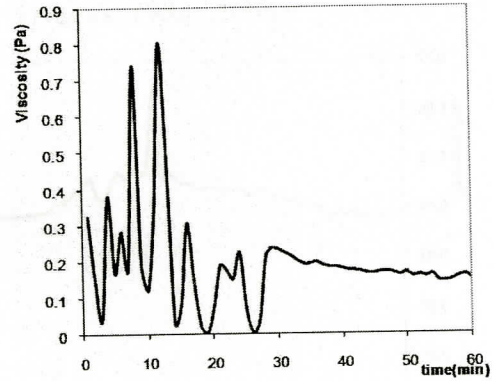


Figure 8: 2.0g ZnO at 80°C

Table 2: Amount of ZnO used

Experiment	Amount of ZnO/g
1	0
2	0.5
3	1.0
4	2.0