358 19

Rheological Behavior of Natural Rubber Latex in the Presence of Surface-Active Agents

N. R. PEETHAMBARAN, BABY KURIAKOSE, MANJARI RAJAN,* and A. P. KURIAKOSE,† *The Rubber Board, Kottayam-686009, India*

Synopsis

The rheological behavior of centrifuged and creamed natural rubber latex concentrates and the effect of surface-active agents such as casein, polyvinyl alcohol (PVA), sodium alginate, and sodium carboxymethylcellulose (NaCMC) were studied at different shear rates and temperatures. The study showed that creamed latex, prepared using tamarind seed powder, is more sensitive to shear rate and temperature than centrifuged latex. The pseudoplasticity and viscosity of the latices can be increased by the addition of surface-active agents, and the effect varies with the type of surface-active agents. The behavior of the latices toward temperature is also affected by the addition of surface-active agents, and maximum effect is observed for polyvinyl alcohol and least for sodium alginate.

INTRODUCTION

Natural rubber latex is a pseudoplastic fluid, and even at rest the rubber particles in it are in random movement. But when sheared, the rubber particles are progressively aligned and offer less resistance to flow.[1] So the apparent viscosity of the latex decreases on increasing shear rate and continues until the flow curve becomes linear. The viscosity of latex also depends on its total solids content and temperature.[2,3] Due to the non-Newtonian behavior, a single viscosity measurement of latex at a particular temperature is not enough to understand its flow behavior. For many of the latex goods manufacturing process, the flow behavior of latex is critical.[4,5] A latex compound with low viscosity and some thixotropic nature is good for dipping operations. The count of a latex thread is largely influenced by its viscosity[6,7] in elastic thread manufacture.

The basic raw material for a latex compound may be either centrifuged or creamed latex. During compounding various surface-active agents are added to modify the flow behavior of latex to suit the manufacturing process adopted.[8,9] A few items under this category are casein, polyvinyl alcohol (PVA), sodium alginate, and sodium carboxymethylcellulose (NaCMC). Even though these chemicals have a profound influence on viscosity, no systematic study has been reported on the rheological behavior of centrifuged and creamed latex and the effects of these surface-active agents on their flow properties under different shear rates and temperature. In the present investigation we have studied the effects of surface-active agents on the viscosity of centrifuged and creamed natural rubber latex concentrates under different shear rates and temperature.

* Vikram Sarabhai Space Centre, Trivandrum, India.
† Cochin University of Science & Technology, Cochin-22, India.

Journal of Applied Polymer Science, Vol. 41, 975–983 (1990)
 CCC 0021-8995/90/5-60975-09$04.00

TABLE I
Formulation of Gum Latex Compound

Items	Parts by weight (pbw)
60% centrifuged/creamed NR latex	167.00
10% potassium hydroxide solution	0.50
50% sulfur dispersion	3.00
50% ZDC dispersion	1.00
50% zinc oxide dispersion	0.50
50% antioxidant SP emulsion	1.00

Maturation: 24 h at 25°C.

EXPERIMENTAL

A 60% centrifuged natural rubber latex sample conforming to BIS : 5430: 1981 obtained from M/s Padinjarekara Agencies, Kottayam, and 60% creamed latex prepared at the Rubber Board using tamarind seed powder as creaming agent were used for this study. The other compounding ingredients used in the preparation of latex compound were obtained locally. The insoluble compounding ingredients were prepared into a dispersion and the immiscible liquid antioxidant into an emulsion. The surface-active agents such as casein, PVA, sodium alginate, and NaCMC were prepared as 5% solution in water before being added to the latex compound. A typical latex compound, as given in Table I, was used to investigate the effect of surface-active agents on the flow behavior. The dosage of surface-active agent was fixed as 0.5 phr (parts per hundred rubber) based on preliminary experiments.

The flow behavior of the raw latices and that of the latex compounds containing surface-active agents were studied using a viscometer, Rheomat-30 supplied by M/s Contraves Switzerland. As the study is to investigate the effect of shear rate as well as temperature, the concentric cylinder with a B cup is used for making the viscosity measurements. The study was made at three different temperatures, 25, 35, and 45°C, which are the normal range of temperature for latex goods manufacture.

RESULTS AND DISCUSSION

The following properties of non-Newtonian fluids are governed by the basic equation,[10]

TABLE II
Effect of Temperature on Non-Newtonian Behavior of Raw Latices

Sample	Pseudoplasticity index (n)			Viscosity index (κ)			Yield stress (Pa)		
	25°C	35°C	45°C	25°C	35°C	45°C	25°C	35°C	45°C
Centrifuged latex (60%)	0.702	0.722	0.805	0.268	0.1819	0.1460	—	—	—
Creamed latex[a] (60%)	0.520	0.625	0.660	0.912	0.427	0.2820	1.22	0.81	0.81

[a] Pre[illegible] using tamarind seed powder as creaming agent.

$$\rho = \kappa \gamma^{n} \quad (1)$$

where

ρ = shear stress (Pa)

κ = viscosity index

γ = shear rate (s^{-1})

n = pseudoplasticity index

By plotting log ρ vs. log γ the values of κ and n can be determined. Then the apparent viscosity (η) was calculated using

$$\eta = \kappa \gamma^{n-1} \quad (2)$$

Rheological Behavior of Raw Latices

The effects of shear rate and temperature on viscosity of centrifuged and creamed latices are given in Figures 1 and 2. From Figure 1, it is evident that the viscosity of creamed latex is higher than that of centrifuged latex both at

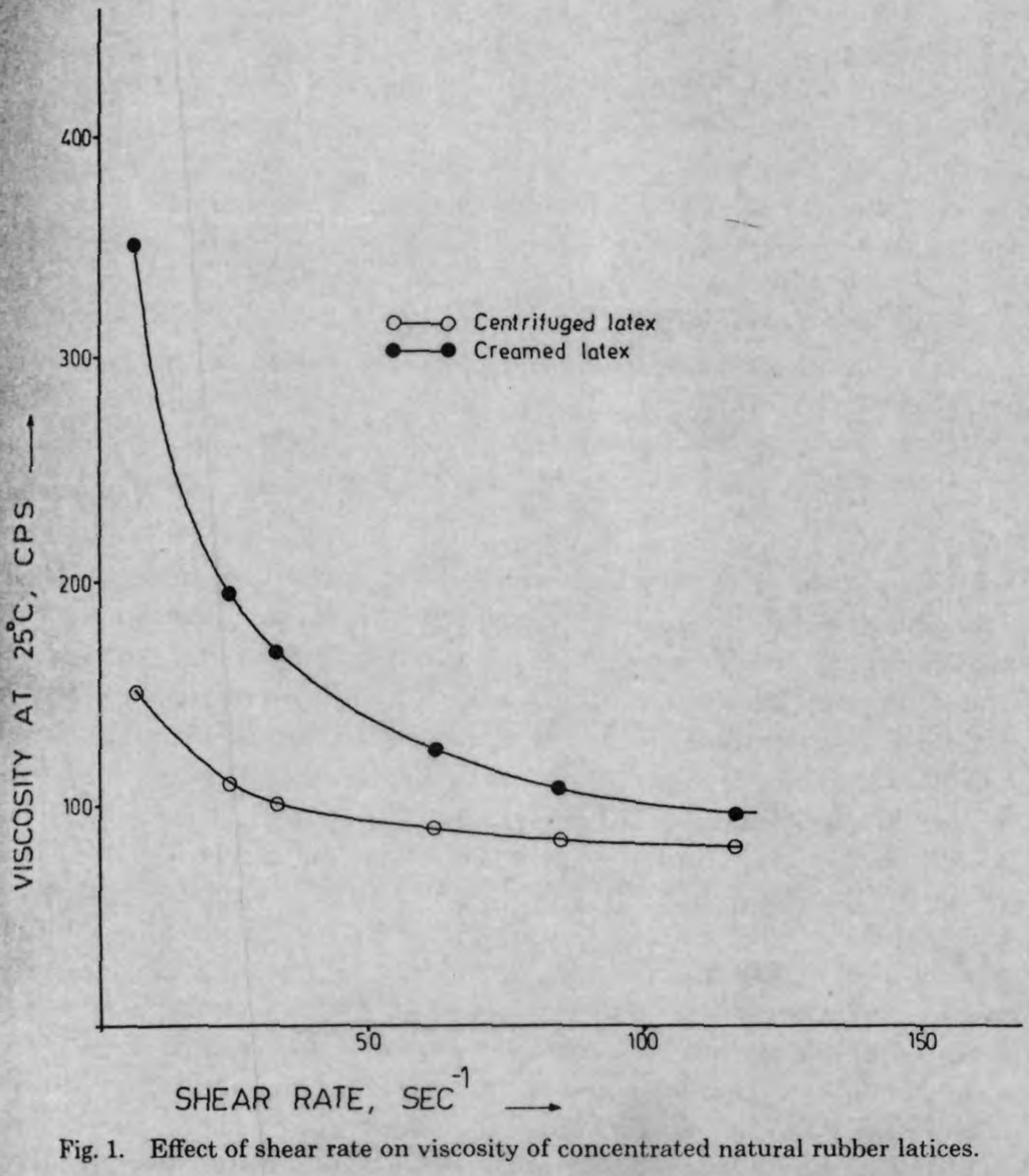

Fig. 1. Effect of shear rate on viscosity of concentrated natural rubber latices.

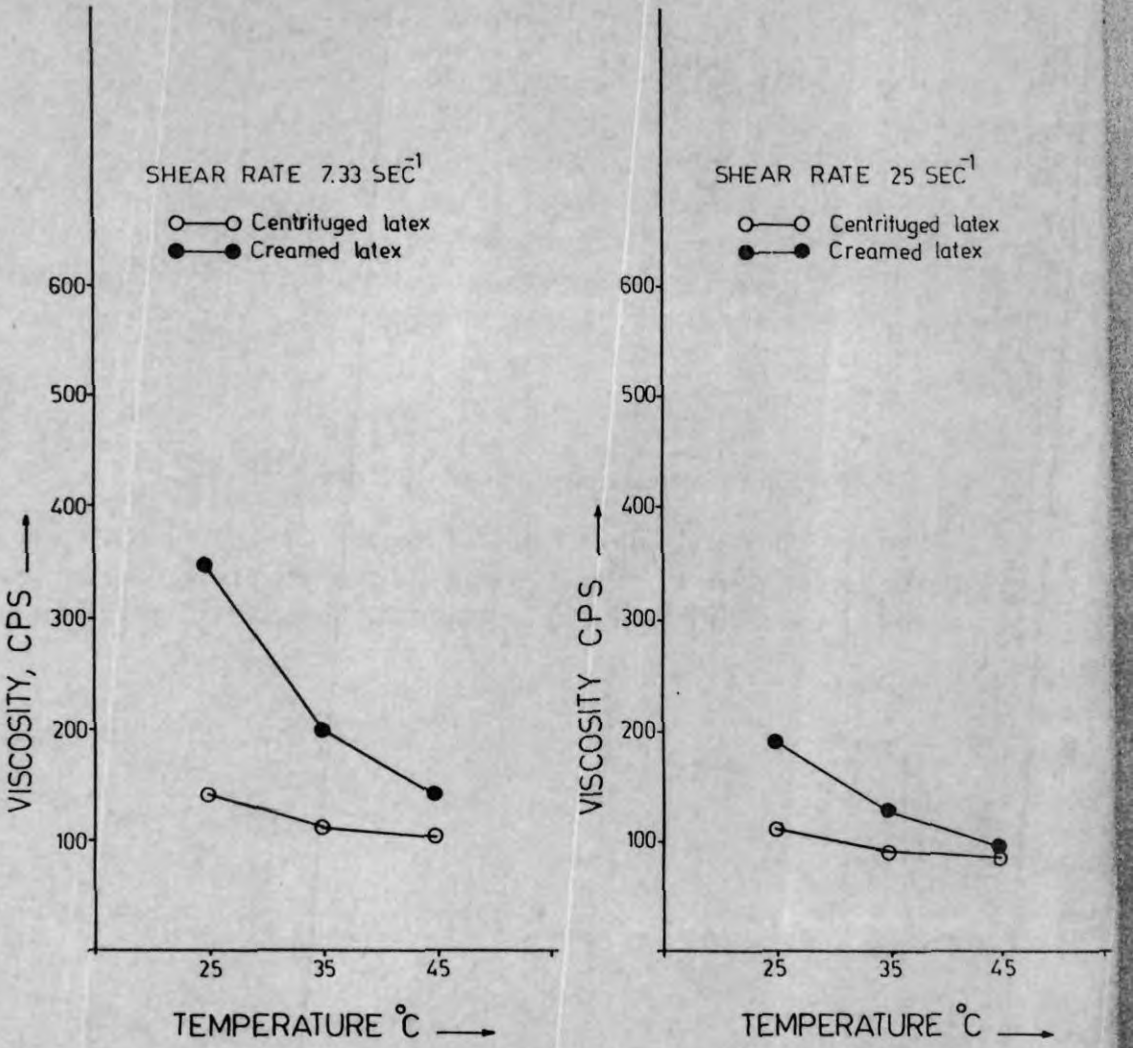

Fig. 2. Effect of temperature on viscosity of concentrated natural rubber latices.

low and high shear rates. In both cases, viscosity decreases with shear rate, which indicated the pseudoplastic behavior. The higher viscosity of creamed latex may be due to the adsorption of the creaming agent on rubber particles, which induces the formation of clusters of particles of different sizes.[6] However, the difference between the viscosities of the centrifuged and creamed latex narrows down as the shear rate is increased. As the shear rate is increased, the adsorbed layer of creaming agent gets displaced and causes the viscosity to be reduced sharply in the shear rate region of 10–50 s^{-1}. It can be seen from Figure 2 that as the temperature is increased there is a marked drop in the viscosity of creamed latex compared to that occurring in the centrifuged latex, and this effect is more predominant in the 25–35°C than in the 35–45°C temperature range, both at low and high shear rates. This property of creamed latex may be due to the restricting effect of the creaming agent on Brownian movement of latex particles and its effect on temperature. Concerning pseudoplasticity, i creamed latex is more pseudoplastic than centrifuged latex as indicated by the lower values of n given in Table II. Creamed latex also exhibited yield stress. The pseudoplasticity decreases with rise in temperature, and the viscosity index showed a sharp drop both for centrifuged and creamed latices.

Rheological Behavior of Latex Compounds in the Presence of Surface-Active Agents

The effect of shear rate and temperature on the viscosity of centrifuged latex compound in the presence of various surface-active agents are shown in Figs. 3 and 4, respectively. Among the surface-active agents, NaCMC offers the highest viscosity at low and high shear rates. Polyvinyl alcohol (PVA) offers a higher viscosity than casein at low shear rates, but as the shear rate increases (60–100 s^{-1}) PVA offers a lower viscosity than casein (Fig. 3). This may be due to the easier displacement of the adsorbed layer of PVA from the surface

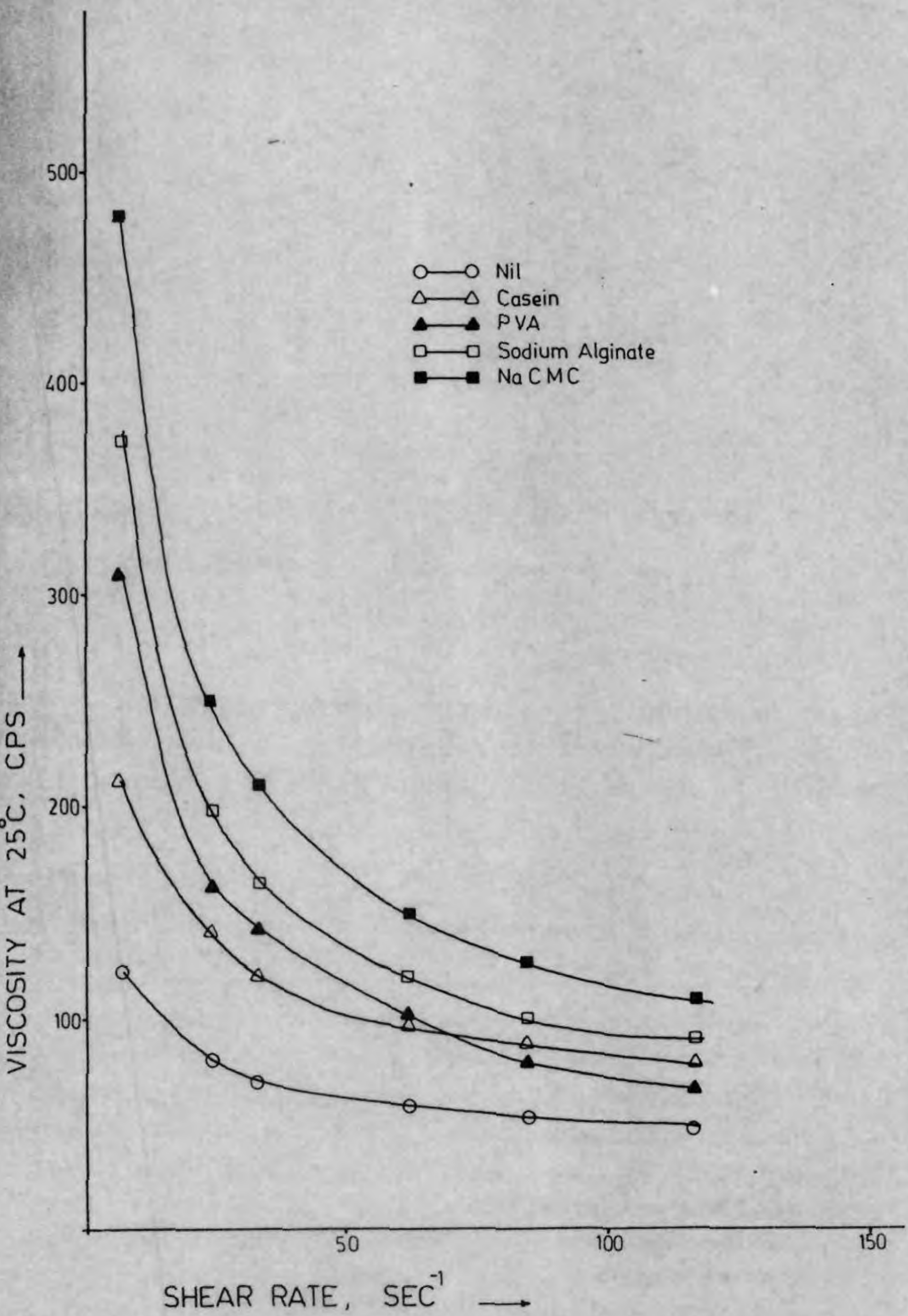

Fig. 3. Effect of shear rate on viscosity of centrifuged natural rubber latex compound containing surface-active agents.

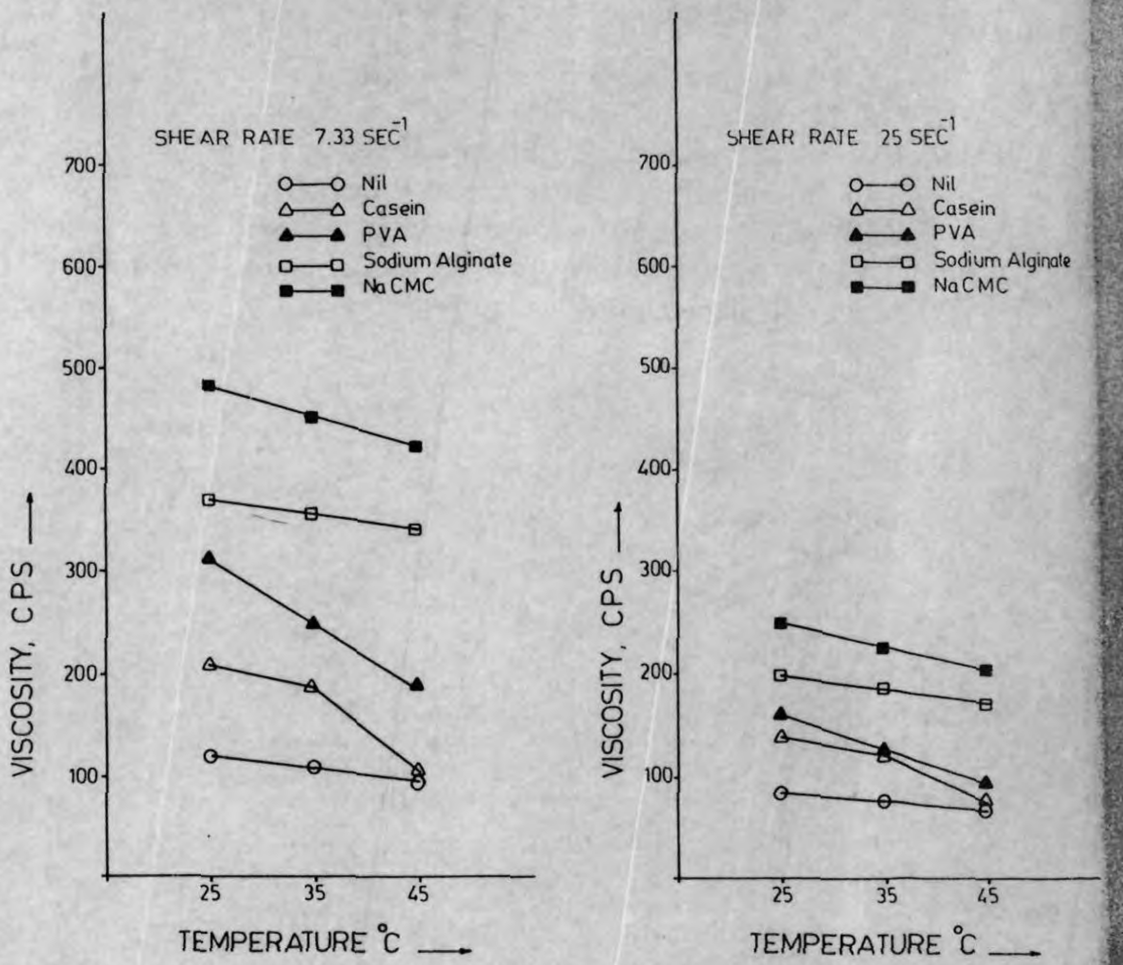

Fig. 4. Effect of temperature on viscosity of centrifuged natural rubber latex compound containing surface-active agents.

of the rubber particles at higher shear rates than that of casein. Disturbance on the adsorbed layer causes the particles to slide past each other resulting in reduction of viscosity. Figure 4 depicts the effect of temperature on the viscosity

TABLE III
Effect of Temperature on the Non-Newtonian Behavior of Centrifuged Latex Compound Containing Surface-Active Agents

Sample	Pseudoplasticity index (n)			Viscosity index (κ)			Yield stress (Pa)		
	25°C	35°C	45°C	25°C	35°C	45°C	25°C	35°C	45°C
Centrifuged latex compound	0.658	0.704	0.760	0.239	0.199	0.1410	—	—	—
Centrifuged latex compound + 0.5 phr casein	0.640	0.660	0.720	0.436	0.363	0.186	—	—	—
Centrifuged latex compound + 0.5 phr PVA	0.460	0.500	0.540	0.9120	0.6607	0.5475	1.20	1.20	0.81
Centrifuged latex compound + 0.5 phr sodium alginate	0.470	0.468	0.456	1.072	1.023	1.00	1.20	1.20	1.20
Centrifuged latex compound + 0.5 phr NaCMC	0.460	0.420	0.422	1.430	1.413	1.318	1.60	1.20	1.20

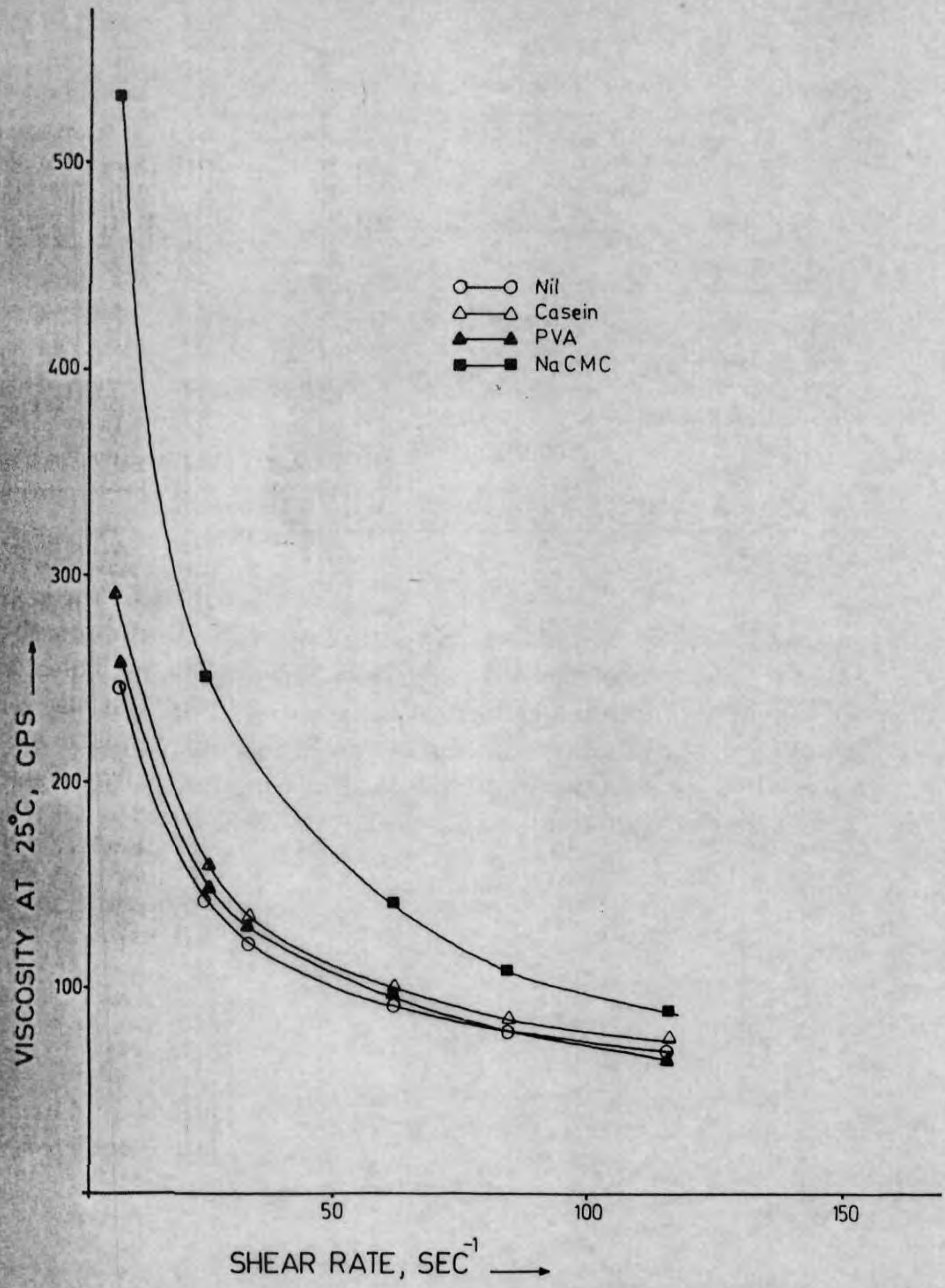

Fig. 5. Effect of shear rate on viscosity of creamed natural rubber latex compound containing surface-active agents.

of centrifuged natural latex compound containing the surface-active agents. It may be noted that even though sodium alginate increased the viscosity of centrifuged latex, it has not affected the general behavior of centrifuged latex toward temperature (Fig. 4). But all other surface-active agents have an effect on the behavior of centrifuged latex toward temperature. Among these, PVA imparts the highest sensitivity to temperature for the viscosity of the latex compound. But at low and high shear rates, the decrease in viscosity of the compound containing PVA is substantial with increase in temperature. This may be attributed to the high sensitivity of PVA solution to temperature. But casein offers a peculiar behavior toward temperature. In the lower temperature

TABLE IV
Effect of Temperature on Non-Newtonian Behavior of Creamed Latex Compound Containing Surface-Active Agents

	Pseudoplasticity index (n)			Viscosity index (κ)			Yield stress (Pa)		
Sample	25°C	35°C	45°C	25°C	35°C	45°C	25°C	35°C	[illegible]
Creamed latex compound	0.550	0.716	0.795	0.589	0.214	0.102	0.81	0.81	[illegible]
Creamed latex compound + 0.5 phr casein	0.500	0.520	0.580	0.794	0.631	0.372	—	—	[illegible]
Creamed latex compound + 0.5 phr PVA	0.530	0.540	0.630	0.631	0.389	0.257	1.22	0.81	[illegible]
Creamed latex compound + 0.5 phr NaCMC	0.375	0.404	0.415	1.905	1.413	1.259	2.4	1.62	[illegible]

range (25–35°C) the reduction in viscosity of the centrifuged latex is at [illegible] same rate as that of the untreated one. But at higher temperature range [illegible] 45°C) there is marked reduction in viscosity. This may be attributed to [illegible] behavior of the alkaline solution of casein toward temperature. It may also [illegible] noted that the pseudoplastic behavior of centrifuged latex was little affec[illegible] by the addition of casein, and it exhibit no yield stress, as seen from Table [illegible]

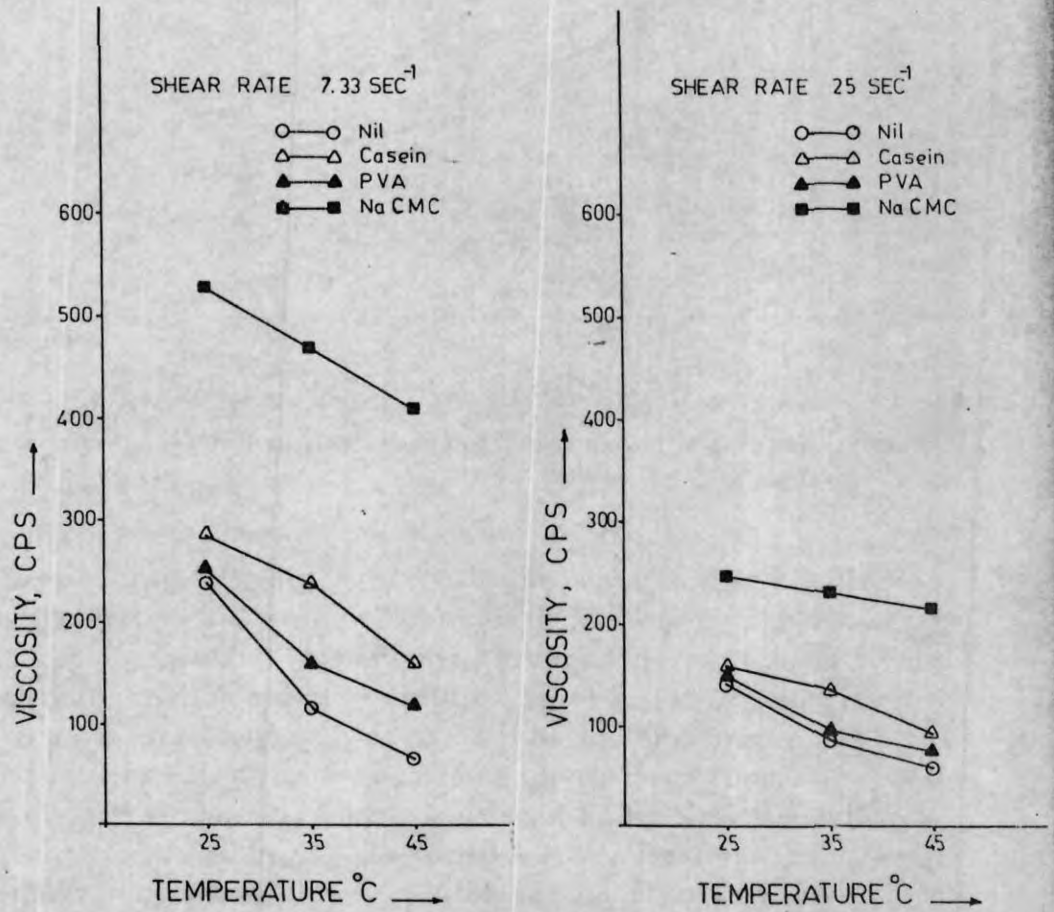

Fig. 6. Effect o[illegible] [illegible]perature on viscosity of creamed natural rubber latex compound contai[illegible] surface-active ag[illegible]

NaCMC offers the maximum pseudoplasticity and yield stress to the centrifuged latex compound. It can also be noted from Table III that the pseudoplastic behavior of latex compounds containing sodium alginate and NaCMC increased with increase in temperature.

The effect of NaCMC on the viscosity and shear rate of creamed latex compound is similar to that in centrifuged latex, and the latex compound becomes highly pseudoplastic (Fig. 5). The effect of PVA and casein on the viscosity of creamed latex is less marked even though these surface-active agents enhance the pseudoplastic behavior (Table IV). This may be due to the interaction of these chemicals with the surface-active agent already present on the latex particles. It may be noted that the addition of casein removes the yield stress already present in the creamed latex compound. The temperature behavior of surface-active agents in the creamed latex is almost similar to that in centrifuged latex compound (Fig. 6).

The authors are grateful to Mr. C. M. George, Project Officer, Rubber Board, Kottayam-686009, for his permission to undertake this work. The authors also express their gratitude to Mr. K. S. Gopalakrishnan, Deputy Director (TC), for his suggestions and encouragement.

References

1. W. L. Wilkinson, *Non-Newtonian Fluids,* Pergamon, London, 1960, pp. 1–9.
2. E. Rhodes and H. Fairfield Smith, *J. RRIM,* **9**, 171 (1939).
3. H. Fairfield Smith, *J. RRIM,* **11**, 44 (1941).
4. E. V. Madge, *Trans. Inst. Rubber Ind.,* **10**, 393 (1933–34).
5. A. D. T. Gorton and P. E. Swinyard, *NR Technol.,* **10**(4), 73 (1979).
6. D. C. Blackley, *High Polymer Latices,* Applied Science, London, 1966, Vol. 2, pp. 97–200.
7. K. O. Calvert, *Polymer Latices,* Applied Science, London, 1982, p. 187.
8. W. D. Schoeder and G. L. Brown, *Rubber Age,* **69**, 433 (1951).
9. G. L. Brown and B. S. Garrett, *J. Appl. Polym. Sci.,* 283 (1959).
10. J. A. Brydson, *Flow Properties of Polymer Melts,* The Plastics and Rubber Institute, 1981, pp. 1-17.

Received May 10, 1989
Accepted June 6, 1989