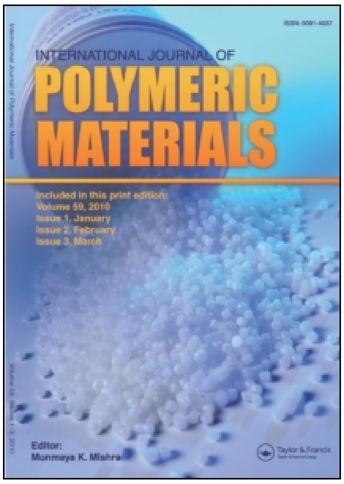

International Journal of Polymeric Materials
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713647664

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Ildong Shin[a]; Janos Szamosi[a]; Singa Tobing[b]
[a] Department of Chemistry, Western Illinois University, Macomb, Illinois [b] Department of Chemical Engineering, Lehigh University, Bethlehem, Pennsylvania

To cite this Article Shin, Ildong , Szamosi, Janos and Tobing, Singa(1991) 'Two-Level Factorial Study of the Rheology and Foaming of Bromobutyl Rubber Solutions', International Journal of Polymeric Materials, 15: 2, 103 — 106
To link to this Article: DOI: 10.1080/00914039108031527
URL: http://dx.doi.org/10.1080/00914039108031527

Intern. J. Polymeric Mater., 1991, Vol. 15, pp. 103–106
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Printed in the United Kingdom

Two-Level Factorial Study of the Rheology and Foaming of Bromobutyl Rubber Solutions

ILDONG SHIN and JANOS SZAMOSI†

Department of Chemistry, Western Illinois University, Macomb, Illinois 61455

SINGA TOBING

Department of Chemical Engineering, Lehigh University, Bethlehem, Pennsylvania 18015

(Received August 10, 1990; in final form August 20, 1990)

The rheology and foaming properties of BIIR coating slurries were studied. Two-level three-factorial analyses showed that solids content had the main influence on apparent viscosity, and foaming was less persistent at higher concentration of hydrated silica. Bentonite, on the other hand, had no statistically significant contribution.

KEY WORDS: Bromobutyl rubber, rheology, factorial study.

INTRODUCTION

Development and characterization of flexible coating materials have been the focus of our research efforts in recent years.[2–5] There has been an increase in the demand for protective clothing worn by workers in hazardous chemical environment. The latter can be accomplished by using coatings with high permeation resistance.[6–8] In order to be mechanically and chemically compatible with rubber gloves and boots, the coating material must be, obviously, elastomeric as well. The simplest way to apply the protective layers onto the substrate is to prepare a coating slurry and dip the substrate repeatedly in it until the necessary thickness builds up.[9] The decision was made early on to study a polar elastomer, NBR (nitrile butadiene rubber), and an apolar one, BIIR (bromobutyl rubber), since these two *together* may impart most of the required properties.

BIIR is brominated isobutylene-isoprene copolymer. The interaction between bromine and double bonds increases cure reactivity and also leads to better

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† To whom correspondence should be addressed: Union Camp R&D, P.O. Box 3301, Princeton, NJ 08543.

compatibility with unsaturated elastomers. BIIR is resistant to air, ozone, acids, alkalis, and solvents, which makes it an excellent candidate for protective coating.

This paper describes our findings concerning the rheology and foaming of high-filler-content toluene solutions of BIIR.

EXPERIMENTAL

The formulations contained BIIR, hydrated silica, Zno, stearic acid, antioxidants, plasticizers, vulcanizing agents, accelerators and bentonite (exact composition and brand names are proprietary). A Farrell 6″ × 13″ two-roll mill was used to compound the ingredients. A Ligthnin 30 air-driven mixer with a ribbon-type impeller was employed to prepare toluene solutions. Apparent viscosity was measured with a Brookfield DV-II instrument at room temperature. Foam stability was determined as the elapsed time for the total disappearance of surface foams.

RESULTS

In order to determine the effects of the three main factors, hydrated silica, bentonite and solids content, on apparent viscosity and foaming, two-level three-factorial experimental design studies were performed (Table I). The silica levels were 30 and 60 phr, bentonite 0 and 1%, and solids content 15 and 20%. These values also represent their practical boundaries as for this application.

A SAS ANOVA[10] analysis was carried out to determine the significance of the factors (Table II).

TABLE I
Apparent viscosity and foam persistence

Silica (phr)	Bentonite (%)	Solids (%)	Viscosity (cP)	Foaming (min)
30	0	15	320	60
30	0	20	1160	50
30	1	15	360	70
30	1	20	1320	50
60	0	15	360	25
60	0	20	1920	22
60	1	15	400	25
60	1	20	2480	23

TABLE II
SAS ANOVA evaluation of the effects

	R-square	p (Silica)	p (Bentonite)	p (solids)
Viscosity	0.89	0.12	0.47	0.006
Foaming	0.96	0.001	0.51	0.08

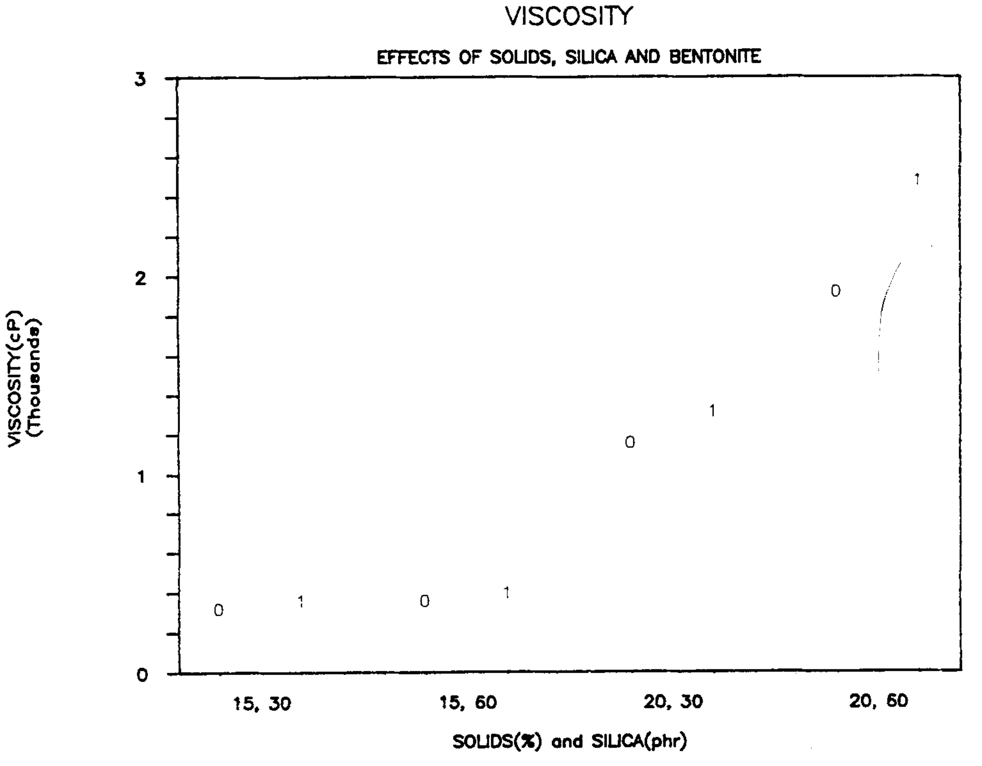

FIGURE 1 Effects of solids content, hydrated silica and bentonite on apparent viscosity. Solids (%) and silica (phr) are on the x-axis; bentonite (%) is shown by its numerical values on the graph.

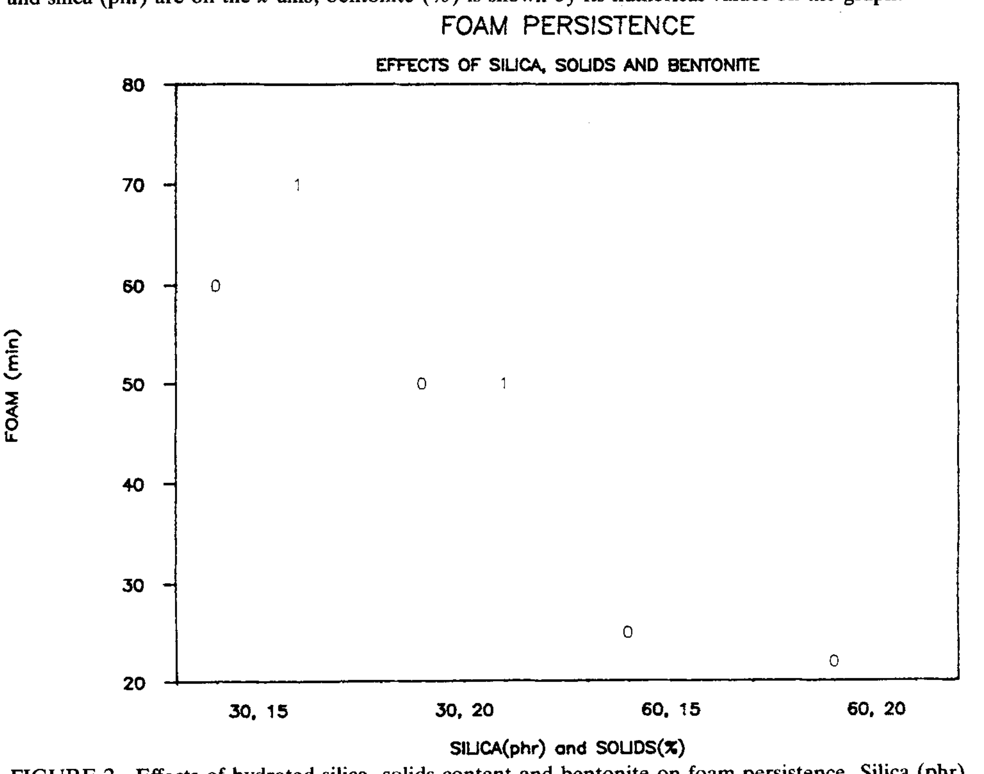

FIGURE 2 Effects of hydrated silica, solids content and bentonite on foam persistence. Silica (phr) and solids (%) are on the x-axis; bentonite (%) is shown by its numerical values on the graph.

In each case, the reasonably high R-square value indicates good fit to the model. The p values (below 0.05 significant, above 0.05 insignificant) show that viscosity was largely governed by solids content, foaming on the other hand was mainly controlled by silica. Bentonite was found to have negligible contribution to both effects.

Plotting the results for viscosity (Figure 1), it is clear that viscosity increases with solids. Silica has an effect only at high solids, and there is a viscosity increase due to bentonite when both solids and silica are high. Foam persistence (Figure 2) is reduced quite effectively by increasing the silica content; at high silica, solids content seems to play some role as well.

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