Reserarch Institute of Rubber Industry, Sofia (Bulgaria)

Drag reduction in polymer mixtures

E. Dschagarowa and T. Bochossian

With 9 figures and 1 table

(Received January 17, 1978)

Notation

\( D \) diameter of capillary
\( DR \) drag reduction
\( DR_{\text{add}} \) additive drag reduction
\( ADR \) excess drag reduction, \( ADR = DR - DR_{\text{add}} \)
\( DR_{\text{mixture}} \) theoretical drag reduction of the mixture
\( DR_{\text{mixture}}^* \) actually measured drag reduction of the mixture
\( DR_{IR} \) drag reduction of an IR molecule in a separate IR solution
\( DR_{IR}^* \) drag reduction of an IR molecule in the presence of molecules of another polymer in the solution
\( DR_{PIB} \) drag reduction of a PIB molecule in a separate PIB solution
\( DR_{PIB}^* \) drag reduction of a PIB molecule in the presence of molecules of another polymer in the solution
\( L \) length of the capillary
\( \dot{V} \) flow rate
\( c \) concentration
\( n \) number of IR molecules
\( p \) number of PIB molecules
\( \tau_w \) wall shear stress

Abbreviations

CMC carboxymethylcellulose
IR isoprene rubber
PAA polyacrylic acid
PAM polyacrylamide
PEI polyethylenimine
PEO polyethylene oxide
PIB polyisobutylene
PS polystyrene

1. Introduction

A large number of investigations have been published on drag reduction of individual polymers dissolved in water or in organic low-molecular liquids. Several works on drag reduction in very diluted solutions of mixtures of two polymers were published only in the recent 2 – 3 years. Positive and negative deviations from the additive straight line have been observed in drag reduction of binary diluted polymer solutions of PEO, PAM and CMC in water (1). For the mixture of PEO and CMC (1 : 1), and PAM and CMC (1 : 1) percentage drag reduction of the binary polymer system is higher (positive deviation) than the sum of percentage drag reduction caused by each of the polymers when present alone in a solution at the same concentration as in the mixture. Reverse results (negative deviations) are obtained for the PEO-PAM (1 : 1) mixture (1).

Drag reduction has been studied in aqueous solutions of PEI and the PEO, PAM and PAA polymers. PEI in aqueous solutions forms large aggregates by hydrogen bonds. It has been observed (2) that PEI interacts to an insignificant degree with non-ionic linear polymers, but forms large aggregates with anionic drag reducing polymers. These aggregates contain considerably larger rotating units than those in the aggregates of the PEI itself. Drag reduction ability of the complexes is considerably smaller than that of the linear polymer itself.

Some data known from (1) show that binary solutions of two PEO of \( 2 \cdot 10^5 \) and \( 4 \cdot 10^6 \) molecular weight respectively, exhibit a roughly additive effect on drag reduction.

Polymer mixtures in organic solvents have been studied for the present only in toluene. In one case these are mixtures of two different molecular weight fractions of one and the same polymer — PIB (3). In the other case this is a mixture of two polymers, one of which, PIB, exhibits a sufficiently high effect, while the other, PS, shows no drag reduction even at Reynolds numbers up to about 50000 (3, 4). A nearly additive change of drag reduction is observed in a mixture of two PIB fractions of different molecular weight both at total concentrations
equal to the optimum concentration and at ones higher than it. When the mixture consists of two polymers (PIB and PS), one of which does not show drag reduction, then the effect deviates from additivity in a positive sense.

To explain the regularities of turbulent drag reduction in solutions of polymer binary mixtures, investigations have been carried out on this effect in mixtures of two polymers which were sufficiently different in their chemical nature and each of them exhibited a definite drag reduction under the experimental conditions. It is also of interest to study the effect of the molecular weight of one of the components on drag reduction of the mixture.

2. Experimental

Drag reduction measurements were made in diluted toluene solutions of mixtures of two polymers: polyisobutylene [Oppanol B 200, Oppanol B 150 (BASF) and PIB P 200 N (USSR) with molecular weight 4.32 \times 10^6, 2.81 \times 10^6, and 2.57 \times 10^6 respectively] and 1,4-cis-isoprene rubber SKI-3 (USSR) with molecular weight $2 \times 10^5$. Each of the polymer components had a definite drag reduction under the experimental conditions. In one group of experiments total concentration of both polymers in the solution was higher than the optimum concentration of PIB which exhibited a higher drag reduction. In another group of experiments total concentration was equal to the optimum concentration (table 1).

The measurements were made by means of a precise glass capillary with $D = 3 \text{ mm}$ and $L : D = 350 \text{ mm}$. Flow pressure of the solutions was measured at two points of the capillary: the first point was at a distance of $200 D$ from the capillary inlet and the second at $100 D$ from the first one and at $54D$ from the outlet of the capillary (5).

The procedure of preparation of solutions, experimental equipment set-up and the method of calculating drag reduction have been previously described in detail (4). Under these experimental conditions a maximum flow rate of $7 \text{ cm}^3/\text{s}$ was attained corresponding to a Reynolds number of 4400 (both were calculated with regard to toluene).

3. Results and discussion

It is known that high molecular PIB is an effective drag reducing additive. The second component in the mixture, isoprene rubber,