FLOW OF A DYE SLURRY IN A CYLINDRICAL TUBE

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A dye slurry has a marked viscosity anomaly. The flow curves are found to be invariant with respect to channel size. The concentration dependence of the viscosity is deduced for aqueous slurries.

Automation and mechanization in dye production involve various problems with slurries and suspensions flowing in pipes [1].

Nothing has been published on the rheology of dye slurries, which hinders the design and general use of automatic filtering, transport, and drying plant.

Azo dyes are important ones that occur as slurries at various stages in production. As a typical one we chose Acid Bordeaux (AB, red) in the form of aqueous slurries.

Azo-dye slurries often have particle sizes from 1 to 5 μ, although single particles and clumps up to 30 μ occur. We used AB slurries containing 9.4, 26, 30, and 40 wt.% dry material, which had fairly high concentrations of fine particles, so there was little tendency for them to separate.

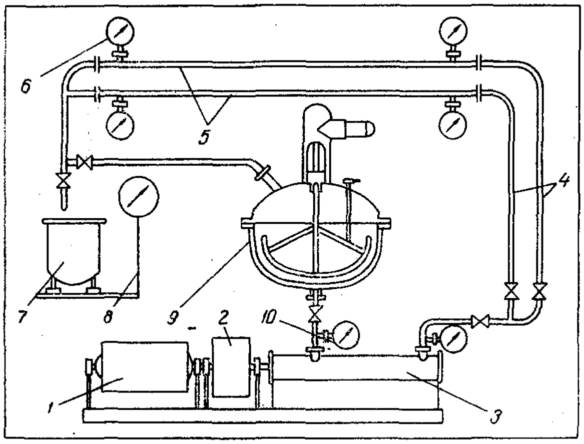

Fig. 1

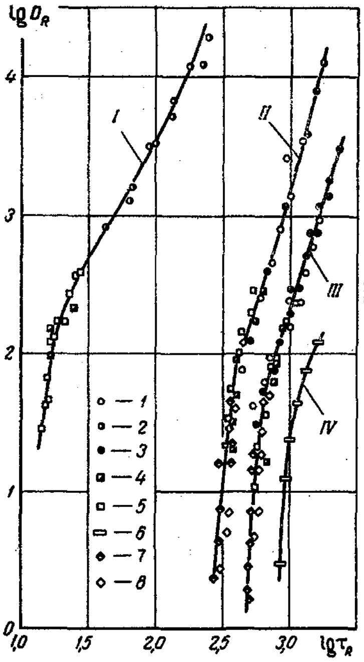

Fig. 2

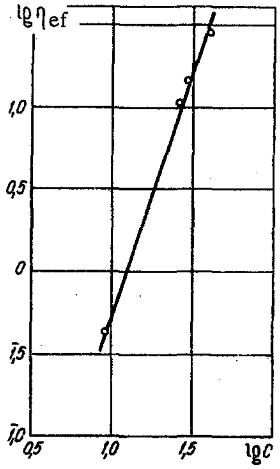

Fig. 3

Fig. 1. Apparatus for examining slurry flow in pipes.

Fig. 2. Invariant flow curves for AB dye slurries with contents of dry material if: I) 9.4%; II) 26%; III) 30%; IV) 40% (see Table 1 for 1-8). D_R in sec^{-1}, τ_R in dyne/cm^2.

Fig. 3. Effective viscosity (poise) as a function of dry material content C (%) for dye slurries.

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TABLE 1. Characteristics of the Capillaries and Pipes

No	Material	R, cm	L, cm	$\frac{L}{R}$	Symbol*
1	Glass	0,0324	4,93	152,1	1
2	"	0,0328	9,90	302,0	1
3	"	0,0360	60,41	1675,0	2
4	"	0,0360	50,15	1394	2
5	"	0,0360	37,70	1048	2
6	"	0,360	27,25	757	2
7	"	0,0405	3,97	98,0	3
8	"	0,0408	9,07	222,3	3
9	"	0,0850	39,40	463	3
10	Steel	1,35	220,3	162,4	4
11	"	1,35	432,5	320,3	5
12	PVC	1,90	81,0	42,6	6
13	"	1,90	135,4	71,3	6
14	Steel	2,50	220,5	88,1	7
15	"	2,50	432,7	172,2	8

* The symbols are as in Fig. 2.

The slurries were passed through a No. 0.1 sieve before viscometry.

We used a constant-pressure capillary viscometer [2-4] and an apparatus for studying the flow of slurries in pipes.

The viscometer had a 215 cm^3 pressure vessel and a set of glass capillaries, whose parameters (Nos. 1-9) are given in Table 1.

Figure 1 shows the apparatus for research on slurries in tubes.

The slurry from vessel 9 (volume 100 liters) with an anchor stirrer is fed by the single-bladed pump 3 to the system of pipes 4 (total length 21 m) to the measuring vessel 7 on the weighing machine 8; the pump is driven via the planetary reduction gear 2 from the dc motor 1. The pipe has measuring instruments (pressure gauge 6 and vacuum gauge 10) and the standard monitoring sections 5 can be changed. The lower part of Table 1 gives the parameters of these monitor tubes.

The pressure drops in the rectilinear parts of the tubes were measured in the apparatus to an error of ±0.3% by means of precision manometers; the flow rate was measured gravimetrically, and the average values taken over three to five measurements were used for the calculation. The experiments were carried out at room temperature.

The source vessel 9 has an anchor stirrer used in preparing the slurries in the vessel at the appropriate concentration by adding water to a highly concentrated slurry.

A stirrer is essential to homogenize the initial slurry and also the more dilute ones, especially after prolonged standing.

The reproducibility was satisfactory, as the coefficient of variation for the pressure differences was only ±5% in parallel experiments.

Figure 2 shows the principal results, where the ordinate is the shear velocity gradient D_R at the wall and the abscissa is the tangential shear stress τ_R at the wall.

The results are as follows: 1) thixotropic equilibrium is established so rapidly under the conditions used here that the length has no effect on the flow conditions; 2) the results are invariant not only with respect to length but also with respect to tube diameter.

It is of practical importance that the pipes and capillaries give consistent flow parameters, so viscometer results can be used in calculation on pumping of azo-dye slurries through pipes.

Figure 2 shows that AB slurries show a very pronounced viscosity anomaly.

Figure 3 shows the concentration dependence of the effective viscosity for a shear velocity gradient of 40 sec^{-1}. However, most of the curves in Fig. 2 may be taken as parallel to a first approximation, so the results of Fig. 3 apply for gradients other than 40 sec^{-1} to the same degree of approximation.

Linear interpolation and extrapolation allow one to get practical viscosity estimates up to concentrations of 45%.

$$\eta_{ef} = 0{,}000521\, C^{3.0101}.$$

The following equation has been derived from Fig. 3 for the effective viscosity η_{ef} as a function of dry matter content C for Acid Bordeaux.

The results for this dye are typical also for slurries of other azo dyes if they are sufficiently finely divided and the particles are roughly isometric.

LITERATURE CITED

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