SHEAR RATE DEPENDENCE OF THE THERMAL CONDUCTIVITY IN NON-NEWTONIAN LIQUIDS

E. M. Khabakhpasheva, Yu. S. Chirkov, and Yu. V. Kostylev

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The thermal conductivities of solutions of sodium carboxymethylcellulose (CMC), DNA, and albumin (myosin) have been measured at rest and at various shear rates.

It is the current view that in solving problems of heat transfer in non-Newtonian liquids, the shear rate dependence of the thermal conductivity, as well as viscosity, should be taken into account. Various forms of the law of variation of thermal conductivity have been proposed [1, 2]. However, in our opinion the question of whether the thermal conductivity of non-Newtonian liquids does depend on the shear rate and whether this variation should be taken into account in thermal calculations is a debatable one.

There are no experimental facts to confirm the assumption that the thermal conductivity depends appreciably on shear rate. Nor are there any physical models on the basis of which important changes in thermal conductivity might be predicted. There are indirect data indicating that if the thermal conductivity does vary in motion, then the variation is only slight. Thus, experiments on laminar flow heat transfer are consistent with the results of calculations using the thermal conductivities obtained for the steady liquid. As a rule, however, heat-transfer experiments are not accurate enough to serve as a basis for definitive conclusions.

We have investigated the thermal conductivities of a series of non-Newtonian liquids both at rest and in motion. Motion at shear rates from 0 to 500 $\sec^{-1}$ was created in the annular gap between two coaxial cylinders. For liquids with considerable viscosity, the heat release due to dissipation of mechanical energy was taken into account, but for the liquids investigated, the corresponding correction did not exceed 2%. The error in measuring the thermal conductivity was about 5%.

The operation of the instrument was first tested on water and water-glycerin solutions (Fig. 1). We then measured the thermal conductivities of solutions of sodium carboxymethylcellulose (CMC) at various concentrations and weak solutions of DNA and albumin (myosin).

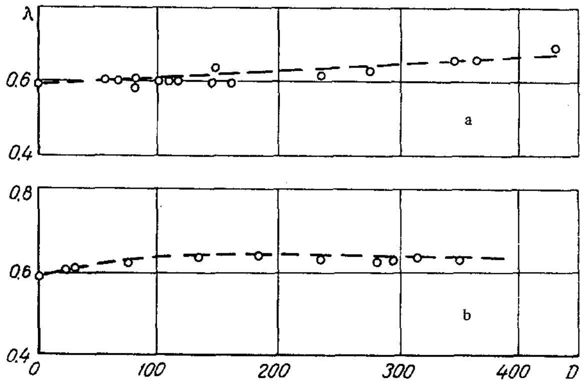

Fig. 2. Thermal conductivity of a 1.25% aqueous solution of Na CMC (a) and a 3% aqueous solution of Na CMC (b). λ in W/m · deg, D in $\sec^{-1}$

Some of the results are presented in Figs. 2 and 3. In a number of cases we detected a slight increase in thermal conductivity, somewhat exceeding the experimental error (1.25% CMC solution, 0.3% albumin solution). For some liquids (3% CMC solution), these variations are typical only of very low shear rates, beyond which a further increase has no effect on thermal conductivity. The same results were obtained for increasing and decreasing shear rates.

Thus, for the liquids investigated, the shear rate dependence of the thermal conductivity, if it exists at all, is so slight that its effect on the heat-transfer process can be neglected. Nonetheless, a more detailed study of this effect may be of interest in connection with the investigation of structure and transport phenomena in solutions of high-molecular-weight compounds.

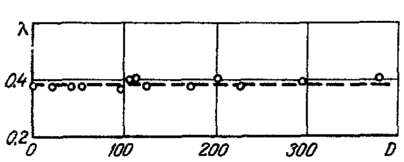

Fig. 1. Thermal conductivity of a 50% water-glycerin solution. λ in W/m · deg, D in $\sec^{-1}$.

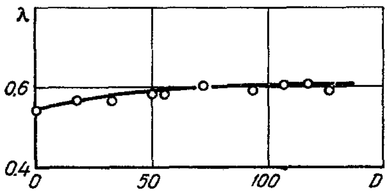

Fig. 3. Thermal conductivity of a 0.02% aqueous solution of DNA. λ in W/m · deg, D in $\sec^{-1}$.

NOTATION

λ is the thermal conductivity; D is the shear rate.

REFERENCES

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Institute of Thermophysics,
Siberian Division AS USSR,
Novosibirsk