RHEOLOGICAL AND THERMOPHYSICAL HANDBOOK DATA FOR HIGH-VISCOSITY COMPOUNDS (MASTICS)

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The rheological and the thermophysical properties of high-viscosity compounds (mastics) were measured within shearing-rate and temperature ranges most typical of engineering applications.

For corrosion and noise proofing of all-metal conveyances and automobile bodies in car manufacturing and servicing plants, one uses high-viscosity coating compounds of the bitumen-mastic type.

The following grades of mastic are widely used in the industry: No. 579, No. 213, No. 580, BPM, ABK, and since recently also grade D11-A plastisol.

Studies made at the Scientific-Industrial Department of "Lakokraspokrytie" have shown that all these grades of mastic are distinctly non-Newtonian fluids and belong to the class of nonlinear viscoplastic materials.

The development of technological processes and apparatus for such coatings has generated a need for engineering design methods. These methods, which involve the use of formulas applicable to the hydrodynamics of and the heat transfer in non-Newtonian fluids, are largely based on handbook values of rheological and thermophysical properties – values which are also useful for the formulation of such coating compounds.

The following rheological equation describes the mastics listed here most accurately [1]:

$$\tau^{\frac{1}{n}} = \tau_0^{\frac{1}{n}} + (\mu_p \dot{\gamma})^{\frac{1}{n}}.$$

TABLE 1. Rheological Properties

Mastic	Heating temperature, °C	τ_0, N/m²	μ_p, N·sec/m²	n	For the range of shearing rates $\dot{\gamma}$, sec⁻¹
№ 579	20	20	1,6	2,5	10—1000
	40	10	0,7	2,4	
	60	5	0,5	2,3	
№ 213	20	23	3,4	2,5	10—1000
	40	10	1,4	2,4	
	60	2	0,6	2,3	
ABK-2	20	10	1,6	2	1—1000
	40	3,6	0,7	1,9	
	50	1,4	0,5	1,8	
BPM	20	3	2,3	1,5	10—1000
	40	0,5	0,8	1,4	
	60	0,15	0,4	1,3	
BPM	20	3	—	1,1	1—10
	40	0,5	—	1,1	
	60	0,15	—	1,1	
Grade D11-A plastisol	20	10	4,9	1,5	1—1000

Note. The relative error of the measured rheological properties does not exceed 9%.

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TABLE 2. Thermophysical Properties.

Mastic	Heating temperature, °C	γ, kg/m³	λ, W/m·deg	$a \cdot 10^6$, m²/sec	c, kj/kg·deg
№ 579	24	1030	0,173	0,097	1,80
	40	1010	0,139	0,077	1,80
	70	999	0,124	0,075	1,68
№ 213	25	1050	0,153	0,078	1,88
	45	1030	0,113	0,068	1,59
	70	1010	0,108	0,068	1,51
BPM	24	1260	0,204	0,113	1,45
	41	1240	0,179	0,104	1,38
	60	1210	0,145	0,092	1,26
Grade D11-A plastisol	20	1340	0,224	0,143	1,17
	40	1320	0,178	0,117	1,17
	60	1300	0,174	0,102	1,30

Note. The relative error of the measured thermophysical properties does not exceed 5%.

TABLE 3. Mean Nusselt Number for Mastics

Mastic	t, °C	$\frac{1}{Pe}\frac{l}{d}\cdot 10^4$	Nu
№ 579	50	5,55	75
	50	3,6	85
	51	2,85	89
№ 213	45	4,2	70
	46	3,26	77
	50	2,2	99
BPM-1	46	4,76	69
	51	3,5	74
	55	2,68	87

Note. The relative error of the measured Nusselt number does not exceed 10%.

Parameters τ_0, μ_p, n, c, λ, and $a = \lambda/\gamma c$ are handbook properties, rheological and thermophysical, respectively, of these mastics and their values at the appropriate temperatures are listed here.

The rheological properties of these mastics were measured with a capillary rheoviscometer according to the procedure in [2, 3].

The method used for measuring the thermophysical properties of these mastics was based on the solution to the problem of transient heat conduction in systems of organic (coating material) and inorganic (substrate as reference material) layers with boundary conditions of the first and the fourth kind [4, 5].

The heat transfer coefficient was measured with a steady thermal flux and according to the Newton–Riechmann law [3, 6]:

$$dQ = \alpha (t_w - t_f)\, dF.$$

The rheological properties of these mastics are listed in Table 1; their thermophysical properties are listed in Table 2; values of the heat transfer coefficient Nu, as a function of the (1/Pe) (l/d) complex, are shown in Table 3.

NOTATION

τ is the shearing stress;
τ_0 is the ultimate shearing stress;
$\dot{\gamma}$ is the shearing rate;
μ_p is the plastic analog of dynamic viscosity;
n is the non-Newtonian exponent;
c is the specific heat;
a is the thermal diffusivity;
α is the heat transfer coefficient;
t_w is the temperature of the substrate surface;
t_f is the temperature of the test material;
γ is the density;
Pe is the Peclet number;
l is the length of the test specimen;
d is the diameter of the test tube;
Q is the thermal flux;
F is the area of the heat transfer surface;
λ is the thermal conductivity.

LITERATURE CITED

1. V. M. Gorislavets, B. M. Smol'skii, and Z. P. Shul'man, in: Heat and Mass Transfer [in Russian], Vol. 3, Minsk (1968).
2. W. L. Wilkinson, Non-Newtonian Fluids [Russian translation], Mir, Moscow (1964).
3. B. M. Smol'skii, Z. P. Shul'man, and V. M. Gorislavets, Rheodynamics and Heat Transfer in Nonlinear High-Viscosity Materials [in Russian], Nauka i Tekhnika, Minsk (1970).
4. L. N. Novichenok and Z. P. Shul'man, Thermophysical Properties of Polymers [in Russian], Nauka i Tekhnika, Minsk (1971).
5. A. V. Lykov and B. M. Smol'skii (editors), Heat and Mass Transfer in Non-Newtonian Fluids [in Russian], Énergiya, Moscow (1968), p. 217.
6. V. A. Osipova, Experimental Study of Heat Transfer Processes [in Russian], Énergiya, Moscow (1969).