

Adjustment and Interpretation of Coefficients for Coal Tar Viscosity/Temperature Equations

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Abstract

Some viscosity/temperature equations allow to predict the fluidity of the coal tar, but it is often still necessary to fit the coefficients of the equations for the accurate predicting for the individual cases of specific tar density. Matrix table of coal tar viscosity in the range of 35-80 °C was taken from literary sources. The values of coefficients of above-mentioned equations fitted for wide range of coal tar densities allow achieving sufficient accuracy for engineering calculations for nine groups of coal tars. The calculations showed the feasibility of reducing the exponent at temperature in the Cornelissen-Waterman equation with an increase in the density of the tar. It can be assumed that the exponent reflects the degree of condensation of aromatic substances in coal tar. The DIPPR 101 equation coefficients for 62 aromatic compounds of various classes was applied for the analysis of fitted coefficients for coal tar. Alkyl derivatives of naphthalene and phenols are the closest classes of compounds to coal tar by the level of viscosity of substance regardless from temperature. But as to the degree of change in viscosity depending on the temperature (coefficient B), there are no close analogues with coal tar among the considered aromatic compounds. This indicates a unique ability of the components of the coal tar to form and destroy the structural units of the flow under the influence of kinetic energy of heat.

Keywords: Viscosity/temperature curve; Coal tar; Coefficients of equation; Physical meaning; Aromatic substances.

1. Introduction

The optimal operation of a coke oven plant includes, in addition to the coal preparation shop and coke oven shop, the cleaning and recovery of chemical by-products from coke oven operation [1-5].

Reliable viscosity data is of a great value for engineering calculation and comprehension of such a complex multicomponent disperse system as coal tar. Operating with viscosity values gives a possibility to predict the rheological behavior of mixtures even of different nature [6], research viscometry methods are successfully used to understand the processes of oil emulsion breaking [7]. Rheometric measurements have been unified and expressed in SI units of viscosity with the equipping of coking plants laboratories and research institutes by rotary viscometers. At present there is still a need to generalize the available data and predictive formulas for the viscosity of coal tar. Such generalization was performed for coal tar pitch and refined coal tars with content insoluble in toluene particles less than 0.2% [8], coefficients of viscosity/temperature equations were determined, which were related to the content of insoluble in toluene and softening temperature of pitches. However, such data are not applicable to usual commercial coal tar with a toluene insoluble content of at least 5% and above, in addition, the presented equations cover the viscosity range of coal pitches and tars. Therefore, the average absolute relative deviation for tars is within 8.1-11.9% that is out of fair accuracy. Computer programs based on the modified group contribution combined with free volume theory [9-10] have been developed for the prediction of viscosity values, however, these and similar approaches were difficult to apply to such a multicomponent system as coal tar. Coal

tar is represented by such groups as polycyclic aromatic hydrocarbons, phenolic compounds, light aromatic compounds, miscellaneous organics [11]. The content of only a few components in the coal tar exceeds 1%. In addition, to predict the viscosity values it is sometimes necessary to determine such specific data for aromatic and condensed components as acentric factor, critical parameters, etc.

There are several well-known equations of viscosity/temperature dependence, which give occasion to further modification and improvement. One of them is the Walter equation, which still serves as a basis for developing viscosity/temperature models for oils and for oil fractions [12]. Such data can be determined by the Walter equation using the viscosity value at one temperature, mid-boiling point temperature and specific gravity [13]. Obviously, the nature of the flow of coal tar and its derivatives significantly differs from that of petroleum oil, does not obey the Newtonian character of flow and contains solid dispersed substances insoluble in quinoline [14]. The available dependences for petroleum medium are difficult to apply to coal tar even from a methodological point of view. However, the rheology of heavy oils due to the presence of resins and asphaltenes [15] and non-boiling vacuum residue [16] is also complicated, which leads to lower accuracy in predicting viscosity values. Therefore, extra heavy oils require the development of special models [17], what unites them with coal tars. Several viscosity/temperature equations for coal tar are known, the main drawback of these equations is the invariability of the equation's coefficients for tars of different degrees of pyrolysis and content of dispersed substances. This reasons greatly reduces the accuracy of predicting the behavior of the coal tar at different temperatures. It also of great scientific and practical interest interpretation of the physical meaning of the coefficients of viscosity equation and compare them with corresponding values of aromatic compounds. The task of the study was to make more accurate the existing dependencies of the coal tar viscosity on the temperature for narrow ranges of density, to consider the physical meaning of the coefficients and compare them with values for aromatic compounds that are part of coal tar. It is desirable also to select a more common temperature dependence among the individual aromatic compounds and, perhaps, to find a suitable model component.

2. Experimental

Data on the viscosity of coal tars of different densities were obtained from the available nomogram [18], for nine groups of coal tar density (Table 1).

Table 1 Kinematic viscosity of various coal tars in Stokes

Specific gravity	Temperature, °C					
	35	40	50	60	70	80
1.1700	3.2	2.2	1.0	0.55	0.36	0.210
1.1750	4.5	3.0	1.4	0.68	0.40	0.250
1.1800	6.5	4.1	1.7	0.85	0.46	0.283
1.1850	9.3	5.5	2.1	1.07	0.58	0.340
1.1900	13.6	7.8	3.0	1.36	0.70	0.410
1.1975	23.8	13.0	4.9	2.10	1.09	0.615
1.2050	44.0	22.2	8.0	3.60	1.76	0,990
1.2125	85.0	44.0	15.0	6.40	2.98	1.550
1.2200	165.0	80.0	26.0	11.00	5.00	2.580

An adaptability of different viscosity equation was performed for the base matrix (table 1). The influence of the content of dispersed particles insoluble in toluene and quinoline, as well as distributed water droplets was not considered in this work. The coefficients of available viscosity/temperature equations were fitted for the narrow ranges of coal tar density for the next viscosity/ temperature equations [18-21]:

– for kinematic viscosity:

$$lgv = K \cdot lgt + b, \quad (1)$$

where: K, b – constants; v – viscosity, cSt; t – temperature, °C;
– for dynamic viscosity:

$$\lg(\mu \cdot 10^4) = B - A \cdot lgt, \quad (2)$$

where: A, B – constants; t – temperature, °C; μ – viscosity, Pa-s;
– Walther equation:

$$\lg \lg(v + 0.8) = K - K_1 \cdot \lg \cdot T, \quad (3)$$

where: K, K_1 – constants; v – viscosity, cSt; T – temperature, K;
– Cornelissen-Waterman equation:

$$\lg \eta = A \cdot T^{-x} + B, \quad (4)$$

where: A, B, x – constants; η – viscosity, cPs; T – temperature, K;
– DIPPR 101 equation:

$$Y = \exp\left(A + \frac{B}{T} + C \cdot \ln(T) + DT^E\right), \quad (5)$$

where: A, B, C, D, E – parameters; Y – viscosity, Pa-s; T – temperature, K.

The coefficients for the equations were selected by trial-and-error method to the highest degree of the coincidence of the calculated and experimental curve on the graph. The quantitative fitting criterion was minimum value of the absolute deviation of experimental and selected coefficient values. Average absolute relative deviation (AARD, %) was calculated according to the formula:

$$AARD (\%) = \left(\frac{100}{N}\right) \sum \left| \frac{\mu_{corr} - \mu_{exp}}{\mu_{corr}} \right|, \quad (6)$$

where: μ_{corr} – calculated viscosity data; μ_{exp} – viscosity data from the Table 1; N – number of viscosity/temperature data points ($N=6$).

The results of the selection were evaluated by comparing the obtained coefficient values for coal tar with the available data on the temperature dependence of the viscosity of coal tar and individual aromatic substances. As for the DIPPR 101 equation data for 62 aromatic compounds of various classes were analyzed [21].

3. Results and discussion

The results of the coefficients fitting and AARD are presented in Table 2 for the logarithmic viscosity equations (1)-(3), Table 3 represents the coefficients and AARD for more exquisite equations (4)-(5). Temperature range and coal tar density are in general agreement with usual working environment of coking plant.

Authors of equation (1) have classified coal tar on three groups according to specific gravity: 1.16÷1.17; 1.18÷1.19; 1.20÷1.22. Proposed coefficients values coincide with corresponding specific gravities in Table 2. Practical experience in applying viscosity data from equation (1) with proposed coefficients has shown the excess calculated values over experimental ones with only exceptions for upper limit of above-mentioned density intervals. As for the rest cases, the fitted coefficients enable applying equation (1) with sufficient accuracy for engineering calculations (5%). The coefficient K determines the grade of viscosity change depending on the temperature and reflects the flatness of the curve on the viscosity/temperature graph. The higher the absolute value of the coefficient, the more curved is the viscosity/temperature line and the greater is the slope of the straight line in logarithmic coordinates lgv - lgt . The sensitivity of coal tar viscosity to temperature varies with its nature, there is a close correlation linear relationship between the coefficient of K and the density of the coal tar ($R^2=0.951$). With a conditional decrease in the coal tar temperature to 1°C, the logarithm of the viscosity will be equal to the value of the coefficient b , which represents the initial level of viscosity beyond the temperature dependence. For less dense low-pyrolyzed coal tars, the values of the coefficient b are lower, there exists also its linear dependence on the tar specific gravity with the coefficient of determination $R^2=0.982$.

Table 2. Coefficients of equations (1)-(3) for different densities of coal tars in the temperature range 35-80°C

Specific gravity	Equation (1)			Equation (2)			Equation (3)		
	<i>K</i>	<i>B</i>	AARD (%)	<i>B</i>	<i>A</i>	AARD (%)	<i>K</i>	<i>K_I</i>	AARD (%)
1.1700	-3.36	5.69	6.4	8.44	3.2	3.7	12.350	4.800	5.1
1.1750	-3.57	6.19	2.5	8.90	3.4	4.9	12.500	4.850	4.0
1.1800	-3.92	6.89	2.6	9.43	3.65	4.8	12.642	4.900	3.7
1.1850	-4.03	7.19	1.9	9.84	3.83	4.8	13.013	5.039	5.2
1.1900	-4.29	7.75	3.3	10.44	4.1	4.5	13.128	5.075	4.6
1.1975	-4.31	7.99	3.6	11.00	4.3	3.9	12.643	4.868	5.5
1.2050	-4.40	8.38	3.8	11.35	4.38	4.7	12.656	4.859	12.7
1.2125	-4.73	9.20	3.5	12.2	4.71	5.0	11.805	4.505	7.6
1.2200	-5.00	9.91	3.2	12.63	4.83	4.3	11.575	4.400	10.6

Table 3. Coefficients of equations (4)-(5) for different densities of coal tars in the temperature range 35-80°C

Specific gravity	Equation (4)				Equation (5)			
	<i>A</i> ×10 ⁻¹²	<i>B</i>	<i>x</i>	AARD (%)	<i>A</i>	<i>B</i>	<i>C</i>	AARD (%)
1.1700	6.50	0.230	-5.000	3.3	-63.000	8501.3	6.000	5.7
1.1750	6.71	0.251	-4.997	4.6	-64.900	9150	6.025	4.9
1.1800	7.00	0.255	-4.996	6.5	-66.800	9799	6.050	6.2
1.1850	7.35	0.257	-4.996	6.1	-69.100	10270	6.241	8.4
1.1900	7.61	0.250	-4.990	6.4	-71.330	10740	6.429	7.4
1.1975	7.90	0.240	-4.980	1.5	-82.950	11570	8.080	7.9
1.2050	8.66	0.219	-4.980	7.6	-89.400	11978	9.000	8.5
1.2125	8.515	0.490	-4.976	1.9	-103.31	13000	11.000	8.5
1.2200	8.705	0.550	-4.969	5.6	-117.201	14000	13.000	9.1

Similar logarithmic equation (2) was originally derived by Gurevich [18] with unique value for *A*=8.4996 and *B*=2.9326. It could be assumed that the equation (2) is only applicable to a coal tar of a certain pyrolysis degree. Coefficient fitting shows that equation (2) was derived for fairly low-pyrolyzed tars with a specific gravity of about 1.17. As for the rest coal tars the AARD does not fall below 21%, the greatest discrepancies observed for tars with a specific gravity of 1.19-1.22. The fitted coefficient values of equation (2), Table 2, meets the requirements for the accuracy of engineering calculations. By analogy with equation (1), constant *A* is linearly dependent on the tar density with the determination coefficient *R*²=0.975, and constant *B* – with the determination coefficient *R*²=0.993. The physical meanings of constants *A* and *B* of equation (2) are the same as for constants *K* and *b* of equation (1).

Viscosity data for individual aromatic substances [22] were processed using the equation (2) while getting following fitted coefficients (Table 4).

Table 4. Viscosity parameters of equation (2) for some aromatic substances

Formula	Substance	Molecular weight	Viscosity at 80°C, cPs [22]	Temperature range, °C	Coefficients		AARD (%)
					<i>B</i>	<i>A</i>	
C ₆ H ₆	Benzene	78	0.318	30÷80	1.43	0.47	3.5
C ₁₂ H ₁₈	Hexylbenzene	162	0.712	30÷80	2.03	0.6	3.0
C ₁₆ H ₂₆	Decylbenzene	218	1.275	30÷80	2.96	0.98	3.7
C ₁₂ H ₁₂	Naphthalene	156	0.89	80÷152	6.02	2.63	6.5

As the molecular weight of aromatic substances raises, the values of coefficients *B* and *A* increase. Moreover, for condensed aromatics with approximately the same molecular weight, the value of the coefficients of equation (2) is significantly higher than for alkyl derivatives of benzene. As the molecular weight of the tar increases, the number and length of alkyl derivatives of aromatic substances decrease and their degree of condensation increases. Thus,

coefficients B and A of equation (2) are related to the degree of condensation and branching of aromatics, which is corresponded with viscosity of tars with different grade of pyrolysis.

Double logarithmic equation (3) was developed by Walther with specified coefficients values $K=13.80$; $K_1=5.33$ for coal tar. According to Franck & Wegener's research [18], the coefficients are correlated to the properties of the tested material, as the difference in values for two different viscosities is reduced by double logarithm. Individual aromatic tar components have close values of these coefficients, the lowest values are quinoline ($K=7.3$; $K_1=3.0$) and the highest – 3.5xylenol ($K=15.1$; $K_1=6.0$) [18]. But viscosity mixing rules are not applicable since most of aromatic coal tar components have melting points far higher than investigated temperature range 35-80 °C. It is rational to correlate the obtained constants with the density, molecular weight, degree of pyrolysis, the content of dispersed particles, etc. For petroleum oil liquids constant K in the Walter equation is related to the boiling point of the fraction [12]. For coal tar this relationship is not applicable, because the distillation of coal tar produces non-boiling residue ($\approx 55\%$). In accordance with [23], the K_1 coefficient correlates with the content of coal tar particles insoluble in toluene. For coal tar distillates a tendency of increasing the value of K and K_1 coefficients with the growth of the molecular weight of the coal tar fractions was established [18].

Fitting coefficients for equation (3) made it possible to establish that the values of Walther coefficients were obviously obtained for coal tar with a specific gravity of about 1.1975. Besides, K and K_1 in Table 2 have close correlation linear relationship ($R^2=0.9895$) that confirms the correctness of the approach to the equation coefficients fitting to the data in Table 1.

The obtained K and K_1 correlation on the tar specific gravity have a complex character with a maximum about 1.185. Perhaps this is associated with the content of naphthalene in the coal tar, that increases with growing degree of pyrolysis. For light coal tars the growing of molecular weight has a decisive influence. With further increase in tar density the naphthalene content also increases for which the coefficient values are lower ($K=9.5$; $K_1=4.0$), and with naphthalene addition tar viscosity is reduced [20]. Moreover, the concentration and influence of dispersed particles insoluble in toluene and quinoline also increase, which may have an even greater impact on the coefficient values. But for a narrow density group of coal tars it is probably possible to assume fixed values of the coefficients.

The Cornelissen-Waterman equation (4) is valid over a wide temperature range, that allows viscosities assessment of the coal tar and coal tar pitch at the same time. The constant x depends on the type of materials, for coal tar $x=5$ [23], in order to increase the accuracy of equation (4) values of constant x was also varied. The results of coefficients fitting (Table 3) show that coefficient A increases proportionally with growing of tar density (coefficient of determination 0.95), and the absolute value of the exponent x also increases linearly ($R^2=0.96$). As the degree of pyrolysis of the tar increases, the value of the coefficient x decreases, that can be observed for a similar coefficient in Mehrotra's correlation equations [24]:

$$\lg(\mu + 0.8) = 100 \cdot (0.01T)^{B_m}, \quad (7)$$

$$B_m = B_{m0} + B_{m1} \cdot \lg(MW), \quad (8)$$

where: μ – dynamic viscosity, mPa·sec; T – temperature; MW – molecular weight; K , B_m , B_{m0} , B_{m1} – parameters.

Table 5 presents values of the coefficients B_{m0} and B_{m1} for different classes of hydrocarbons with the approximate molecular weight of coal tar. As follows from a comparison of formula (4) and (7), Mehrotra's correlation equation (7) for the dynamic viscosity of hydrocarbons has the same arrangement as the Cornelissen-Waterman formula. The temperature indices B_m and x have the same sign and direction, as well as close numerical values of these coefficients. It can be assumed that the decrease in the coefficient x with increasing degree of pyrolysis reflects a growth in the degree of condensation of aromatic rings in coal tar substances.

Table 5. Literature and calculated data of the coefficients of equation (8) [24] for substances with a molecular weight of 230

	B_{m0}	B_{m1}	MW	B_m
Nonfused aromatics	-9.692	2.261	230	-4.352
Fused ring aromatics	-9.309	2.185	230	-4.149

The values of constant B in Cornelissen-Waterman formula, as in the above logarithmic expressions (1)-(3) increase with growing density of coal tar, and control the "initial" level of viscosity of coal tar, regardless of the temperature.

It is of interest to compare the viscosity/temperature dependences for coal tar with data for individual classes of aromatic substances. The form of this dependence may be polynomial with established coefficients for the viscosity values of individual substances, for example, viscosity/temperature dependence developed by the Design Institute for Physical Properties, known as the DIPPR 101 equation (5). Since equation (5) contains only three coefficients (A, B, C) for the most considered aromatic compounds, the coefficient fitting was carried out also for these three coefficients. Results are presented in Table 3.

As the density of the coal tar increases, the absolute value of the coefficient A decreases, with an inflection point in the region of specific gravity ≈ 1.19 . This rise in viscosity level can be attributed to an increase in the molecular weight in this case. As the molecular weight of a molecule increases, the number of meshing and moving assemblies per molecule increases. It is likely that the inflection point correlates with the formation of a fluctuation mesh formed by associates of segments or knots of interlacing [25]. In this point viscosity level of coal tar with high molecular weight increases dramatically.

The role of A and B coefficients of equation (5) are similar to coefficients a and b that are used to describe the two-parameter temperature dependence of viscosity in analogous equation [26]:

$$\ln \mu = a + b/T, \tag{9}$$

where: μ - viscosity; T - temperature; a, b - coefficients.

In this equation the values of coefficient b increase proportionally to molecular weight [26], and the values of the coefficient B in Table 3 also increase with specific gravity. Two coefficients B and C in equation (5) determine the degree of viscosity change as a function of temperature, and are parameters of the susceptibility of tar viscosity to temperature changes.

As the coal tar density increases, the values of coefficient C increase in inverse dependence on the values of coefficient A. A similar direction of change in individual aromatic compounds is observed for alkyl derivatives of benzene, alkyl derivatives of naphthalene and for aromatic condensed substances with melting point less than 110°C but with less close correlation dependence (Table 6).

Table 6. Determination coefficients of logarithmic dependences of the coefficients of equation (5) on molecular weights of individual aromatic substances

Classes of substances	Coefficients of equation (5)		
	A= f(ln(MW))	B=f(ln(MW))	C= f(ln(MW))
Alkyl derivatives of benzene	0.94	0.95	0.94
Alkyl derivatives of naphthalene	0.95	0.95	0.94
Condensed aromatic compounds	0.82	0.96	0.81
Nitrogen-containing (pyrrole and pyridine derivatives)	0.91	0.98	0.90
Nitrogen-containing (quinoline derivatives)	0.95	0.90	0.96
Phenol and homologues	0.08	0.02	0.09
Sulfur compounds	0.19	0.00004	0.17
Coal tar	0.95*	1.00*	0.90*

*function of specific gravity

The coefficients A, B, C of equation (5) are not correlated with their molecular weight for polar heteroaromatic compounds, perhaps because of more complex viscosity dependence with changes in the dipole moment of molecules, tendency to form intermolecular structures.

Figs. 1 and 2 show a comparison of the ranges of coefficients A and B values of equation (5) for coal tar and various aromatic substances. As follows from Fig.1 alkyl derivatives of naphthalene and to lesser extent phenols are the closest classes of aromatic compounds to coal tar by the level of viscosity regardless of temperature (coefficient A in equation (5)). However, as for the degree of change in viscosity/temperature dependence (coefficient B in

equation (5)), there are no close analogues with coal tar among the considered aromatic compounds (Fig.2).

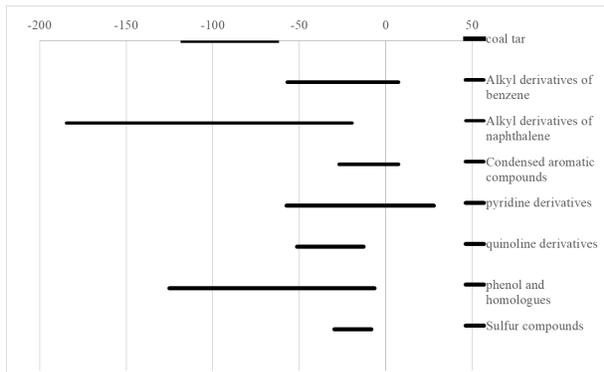


Figure 1. Values of the coefficient A in equation (5) for aromatic substances and coal tar

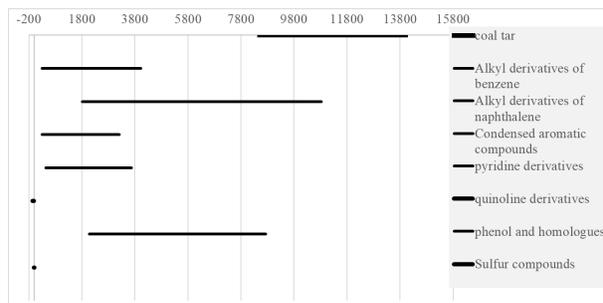


Figure 2. Values of the coefficient B in equation (5) for aromatic substances and coal tar

This indicates a unique dependence of the coal tar components to the formation and destruction of structural units of the flow under the influence of kinetic energy of heat exposure. Apparently, this is due to the different polarity and polarizability of the coal tar aromatic components, which form many intermolecular bonds of varying strength, which consistently weaken as the temperature increases.

The values of the C coefficient in equation (5) increase with pyrolysis degree of coal tar. Fig. 3 shows a close linear relationship between the coefficients A and C in equation (5). One might say that the coefficient of determination of analyzed relation is equal to 0.99 for aromatic compounds, and disjointedly for coal tar $R^2=0.99$ (Fig. 3). The same relationship character was also observed for the coefficients of various chemical substances in proper viscosity/temperature dependences.

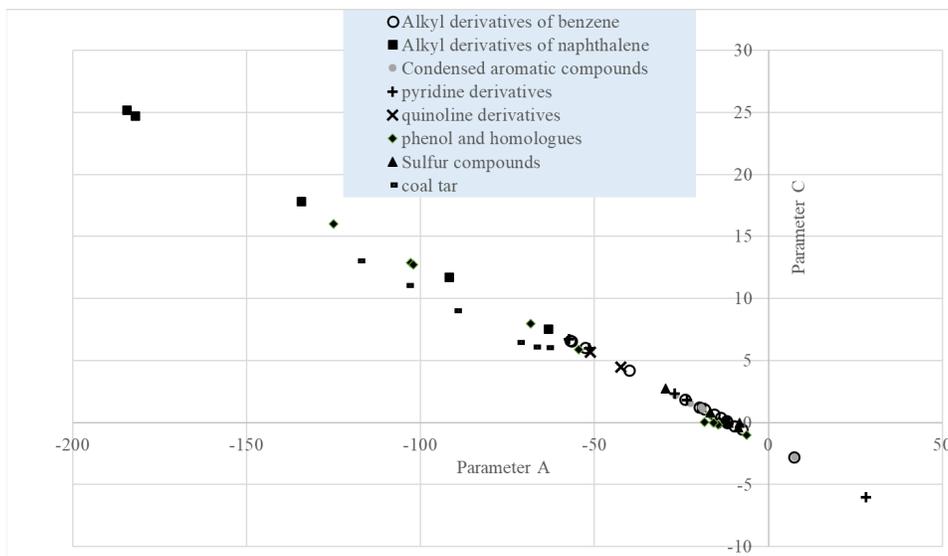


Figure 3. Dependence of parameters A and C of equation (5) for different classes of aromatics and coal tar

For the equation (5), the physical meaning of coefficient C can be taken as similar to coefficient B, and the degree of viscosity/ temperature change can be estimated by coefficient B, taking into account the increase of the degree of viscosity/ temperature change with a decrease of coefficient A. The direction of change of constants of equation (5) for linear alkyl homologues with increase of molecular weight is the same as for coal tar, the level of values for benzene homologues is significantly lower.

Comparison of the data in Table 1 and the obtained coefficients of equations (1)-(5) with the measured viscosity of coal tars in Ukraine shows good correlation with light coal tars. Measured viscosity of high-pyrolyzed coal tars ($\approx 200\div 400$ cPs, 50 °C) is at least one order of magnitude lower than the data in Table 1. The fitting of model coefficients shows an increase in AADR as the density of tar increases, indicating that the intermolecular interactions of the system are becoming more complex. Apparently, the viscosity of heavy coal tars is more individual than that of light tars. Therefore, the temperature dependence of the viscosity of heavy tars requires fitting the parameters of the available equations in a particular case. Such deviations, in addition, should be analyzed taking into account the content and composition of disperse inclusions (water and particles insoluble in toluene and quinoline).

4. Conclusion

New values of the coefficients of the equations have been obtained for the considered viscosity/temperature dependences of the coal tar, which allowed to clarify their applicability limits and improve the accuracy of viscosity values in the range of specific gravity 1.17-1.22.

It was shown that the coefficients of the equations were related to the degree of condensation and branching of aromatics, and the degree index in the Cornelissen-Waterman reflected the increasing degree of condensation of aromatics in a similar relationship.

Coal tar with a high degree of pyrolysis has the lowest predictability of the viscosity level and its temperature dependence. The highest values of AARD for the considered equations most often refer to coal tar samples with a specific gravity above 1.19. Temperature dependence of viscosity of heavy tars is more individual and requires selection of parameters of available models in a particular case. Comparison of Table 1 data and obtained coefficients of various equations with experimental viscosity data for coal tar in Ukraine shows that the measured values correlate well with the calculation results only for coal tars with low density.

The fundamental applicability of the DIPPR 101 equation is shown for representation of temperature dependence for coal tar with different degrees of pyrolysis. The coefficient A indicates the viscosity level of the substance regardless of the temperature; by the value of the coefficient A, alkyl derivatives of naphthalene and phenols are the closest classes of compounds. However, according to the degree of change in viscosity depending on the temperature (coefficient B), coal tar has not close analogues among the considered classes of aromatic compounds. This indicates a unique ability of the components of the coal tar to form and destroy the structural units of the flow under the influence of kinetic energy of heat. Apparently, this is due to the different polarity and polarizability of the numerous aromatic substances of coal tar, which form many intermolecular bonds of varying strength, which consistently weaken as the temperature increases.

Symbols

ν	kinematic viscosity, cSt;
η	dynamic viscosity, cP;
μ	dynamic viscosity, Pa-s;
t	temperature, °C;
T	temperature, K;
K, b	constants of equation (1);
A, B	constants of equation (2);
K, K_1	constants of equation (3);
A, B, x	constants of equation (4);
A, B, C, D, E	constants of equation (5);
B_m, B_{m0}, B_{m1}	parameters of equation (7)-(8);
a, b	coefficients of equation (9);
AARD	average absolute relative deviation, %;
R^2	coefficient of determination;
N	number of viscosity/temperature data points;
μ_1, μ_2	calculated and experimental viscosity data in proper units of measurement;
MW	molecular weight;
DIPPR	Design Institute for Physical Properties.

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