EFFECTS OF A MAGNETIC FIELD ON HEAVY OIL RESIDUES AT HIGH TEMPERATURES

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UDC 621.318:66.042.947

Results are presented on the effects of electromagnetic fields on heavy oil residues.

There are many papers on the use of physical fields to influence liquid systems. The liquids may be divided into two classes: magnetic and nonmagnetic. The magnetic liquid is made by dispersing ferromagnetic particles in an ordinary (nonmagnetic) liquid [1]. A monograph [2] presents original results on the effects of magnetic fields on the rheological, physical, and thermal characteristics of these media, as well as on equipment employing magnetic rheological effects. A nonmagnetic liquid is one whose magnetic susceptibility is low. Nevertheless, magnetic fields may have important effects in such cases [3-6].

We have measured the effects of magnetic fields on heavy oil residues at high temperatures.

This was necessary because deposits (coking) may be formed in heat-transfer equipment in oil refineries.

Deposition occurs in heat exchangers, reboilers, ovens, tubes, and compressors in systems for distilling petroleum, alkylation, and cracking over wide parameter ranges for liquids with boiling points up to 311°K at flow temperatures of 408-755°K with metal surfaces at 477-803°K [7], with the deposition most pronounced in tubular ovens in slow-coking systems. There are several ways of reducing the coking in these tube coils, which include chemical ones (the introduction of solvents) and hydrodynamic ones (increased turbulence in the flow). Here we examine the use of magnetic fields for these purposes.

The coking can be represented as follows [8]. Heavy oil residues constitute microheterogeneous colloidal systems, in which there is a dispersed phase (asphaltenes, carbenes, carboids, mechanical impurities, and inorganic salts) and a dispersion medium (oil or tar). The high degree of dispersal results in excess surface energy, which makes the system thermodynamically unstable. If the stabilizing action of the dispersion medium is inadequate, the particles of the dispersed phase tend to associate and the system loses kinetic stability. High temperatures cause partial destruction of the macromolecular alkanes and the production of light hydrocarbons (the viscosity is reduced), which accelerates the deposition of the carboids and carbenes. The premature deposition of these leads to coking in furnace coils. The condensation of the dispersed phase is [9] favored by organometallic components resulting from traces of metals (for example, as the salts of organic acids such as naphthenic ones). The latter act as stabilizers in colloidal systems and form stable micelles. A double electrical layer is formed round the core of a micelle. The dispersed phase thus acquires an electric charge [10].

Also, the C—H and C—C bonds are broken at high temperatures (553-773°K), which gives rise to paramagnetic centers; the radicals are stable, because they cannot recombine as they are not mobile in the solid matrix. This means that the solid phase acquires paramagnetic properties.

The particles are thus paramagnetic and can interact with magnetic fields [11]; this colloidal system from the secondary processing of petroleum can thus be influenced by Lorentz forces acting on the particles, which can accentuate the convection currents and thus prevent the deposition of coke particles, with the aggregation displaced to the volume of the solvent or dispersion medium.

All-Union Research Institute for Collecting, Preparing, and Transporting Oil and Oil Products, Ufa. Translated from Inzhenerno-Fizicheskii Zhurnal, Vol. 51, No. 6, pp. 990-993, December, 1986. Original article submitted October 25, 1985.

 0022-6841/86/5106-1452 $12.50

TABLE 1. Results of Effects of a Magnetic Field on Cracking Residues

Oven temp., °K	Field, Oe	Amount of coke from material	
		field treated	initial
523	355	0,40940	0,84004
		0,44815	0,64795
		0,19455	0,49275
		0,63230	0,77245
		0,40100	0,58460
		0,57135	1,38180
		0,61630	0,7667
		0,51308*	0,68408*
653	410	0,51810	0,59685
		0,37470	0,54245
		0,36355	0,68780
		0,48000	0,65400
		0,45490	1,127
		0,57855	0,61275
		0,46160*	0,61877*

Note: The figures with asterisks represent the mean amount of coke deposited.

TABLE 2. Deposit Compositions

Cracking residue	Components, %						
	paraffinic-naphthenic	light aromatic	medium aromatic	heavy aromatic	tars I	tars II	asphaltenes
Field treated	15,54	4,56	4,82	38,8	4,23	9,51	22,54
Untreated	11,62	3,33	5,08	38,87	4,63	11,35	25,12

We built a laboratory system in which the liquid moved under the magnetic field and as a result of the heating. The model liquid was provided by cracking residue and was driven by a plunger pump through a brass tube in a heated oven having removable indicating heat exchangers. An electromagnet was installed in front of the oven. The conditions were kept unchanged throughout the series. The bulk flow speed was on average 3.6 m/sec, with the volume pumped during an experiment of $4 \cdot 10^{-3}$ m^3. The series differed in oven temperature and field strength. Before the start and after the end, the heat exchangers were carefully weighed with laboratory balances. The indicators were thin-walled brass tubes (weight clean not more than 60 g). The oven was switched off at the end of the experiment and the indicator was allowed to cool for a set time before being removed and placed in a stand above a filter in the vertical position, which allowed the liquid to flow from the walls. The indicator was kept in that position for 20 h at room temperature, after which it was weighed. The weight change gave the amount of coke formed. Table 1 gives the results.

The data show that there is less deposition from material treated by the field.

The data were processed to exclude gross errors and evaluate the significance of the mean amounts of deposit from the initial material and after treatment with the field. The 0.95 significance level was used in identifying differences (Table 1).

The deposits were submitted to chromatographic analysis, with the internal cavity washed with solvent (toluene). Table 2 gives the analyses.

The soluble phase from magnetized raw material contained a considerable amount of carbenes and carboids. The weight of the undissolved coke residue was larger in the indicator handling the initial material.

The effects of a field can also be used to accelerate the production of coke in slow-cooking equipments.

The laboratory equipment simulating a so-called no-flow system provided for the liquid flow to intersect a magnetic field in a high-temperature reactor. The liquid was heavy fuel oil 40. The reactors were steel vessels set up in pairs in an oven, where the liquid was kept at 753-773°K for eight hours. The paired reactors provided identical thermal conditions for the simultaneous flows of liquid, one of which was treated with the magnetic field. The amount of coke was determined from the weight change. The field strength varied from 100 to 1000 Oe. From the magnetized raw material the yield of coke increased by comparison with the untreated liquid (up to 40% in individual runs).

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CRITICAL AMPLITUDES OF PURE SUBSTANCES

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UDC 536.44

Consequences of theoretical models for the critical amplitudes A, B, Γ, D are considered and calculated values of critical amplitudes for pure substances are presented for the range $Z_{cr} = p_{cr}v_{cr}/RT_{cr} = 0.22$-$0.29$, as obtained by the proposed expressions.

Near the critical point the behavior of thermodynamic functions of pure substances on the fundamental curves is defined by asymptotic exponential functions:

$$C_v/(RZ_{cr}) = A|t|^{-\alpha} \quad \text{on the critical isochor;}$$

$$\Delta\rho = B(-t)^{\beta} \quad \text{on the boundary curve;}$$

$$\left(\frac{\partial\omega}{\partial\pi}\right)_{\tau} = \Gamma|t|^{-\gamma} \quad \text{on the critical isochor;}$$

$$|\Delta p| = D|\Delta\rho|^{\delta} \quad \text{on the critical isotherm.}$$

Here $\tau = t + 1 = T/T_{cr}$, $\pi = \Delta p + 1 = p/p_{cr}$, $\omega = \Delta\rho + 1 = \rho/\rho_{cr}$, $Z_{cr} = p_{cr}v_{cr}/(RT_{cr})$.

The modern theory of critical phenomena predicts that the critical exponents α, β, γ, δ do not depend on the nature of the substance, but are universal constants [1]:

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Translated from Inzhenerno-Fizicheskii Zhurnal, Vol. 51, No. 6, pp. 994-998, December, 1986. Original article submitted February 2, 1986.

0022-6841/86/5106-1454$12.50