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# The Mechanism of Reducing Scale during Magnetic Water Treatment in Heat-Power Devices

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**Abstract**—A model describing the mechanism of the magnetic treatment of the water flow based on the Deryagin–Landau–Ferway–Overbeck theory is refined. The effect of homogeneous generation of new nuclei during the coagulation of critical-size particles in the colloid solution that lost stability is taken into account. This allowed us to approach the qualitative evaluations of efficiency of the scale-proof treatment of the water flow to the actual experimental data.

*Keywords:* scale formation, coagulation, critical nucleus, magnetic treatment, crystallization

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The methods for reducing scale using the magnetic treatment of the water flow are widely used in practice but are still not satisfactorily substantiated theoretically. This explains the topicality of our work since we attempted to describe the experimental results based on the suggested model in it.

The effect of decreasing the aggregate stability of the colloid solution during the magnetic treatment of the water flow described by the Deryagin–Landau–Ferway–Overback theory is known [1, 2]. According to this theory, the Lorentz forces deform a double electric layer of colloid particles and accelerate their coagulation, which coarsens the suspension and correspondingly increases the supersaturation of the solution with respect to it. In this case, the crystallization of dissolved salts transfers onto the surface of suspended particles, which explains the mechanism of the magnetic treatment of the water flow [3].

In this work, we suggested adding model [3] allowing for other known physicochemical effects.

First, we note that supersaturation of the solution and, consequently, the crystallization rate of dissolved salts substantially vary during the coagulation for the particles with radius $r < r_{\rm cr}$, which we conventionally call the subcritical radius. The solution, being unsaturated before the magnetic treatment, becomes supersaturated after it. Therefore, the magnetic effect varies the direction of mass transfer only for the subcritical particles. Since the subcritical particles are those that transform into a stable crystalline form increasing the suspension surface and decreasing the scale on the heat exchanger walls, the main attention should be paid to this suspension fraction.

Second, we should take into account the effect of homogeneous generation of new nuclei during the coagulation of the particles with the subcritical radius in the colloid solution that lost stability. It is known that the particles are continuously generated and dissolved in the solution with a specified supersaturation [4] so that the statistically stable distribution of crystalline nuclei with a certain initial concentration $n_0(r)$, m$^{-3}$, is established (we assume, instantly). In this case, new nuclei (in the magnetic apparatus and out of its limits) have no time to acquire the charge and the hydrate shell, which could prevent their coagulation after birth.

Third, the memory effect of the magnetic treatment should be taken into account. It consists in that according to evaluation [5], the time constant of reduction of the deformed double electric layer substantially exceeds the transit time of the water flow through the magnetic apparatus. Due to this, coagulation processes continue in water after the passage of the magnetic apparatus in the heat-exchange tube itself.

Fourth, the known experiment [6], with which we will compare the results of simulation, showed that when magnetizing the water flow, the sediments on the heat-exchanger wall substantially decreased although the concentration of dissolved salts remained the same. This is caused by the fact that the scale formation has a limited power and occurs in the diffusion region, where the diffusion rate of the salts to the wall surface and to the suspension is substantially lower than the rate of their heterogeneous crystallization. Therefore, let us assume that summary flow $I_\Sigma$, mol/s, of the molecules of the scale-former on the walls of the heat-exchange tube and on the surface of suspended particles is the same both with the magnetic treatment $I_{\Sigma\rm mag}$ and without it $I_{\Sigma 0}$:

$$I_{\Sigma 0} = I_{\Sigma\rm mag}. \quad (1)$$