Study of the Process of the Polymer Flocculants Degradation Used for Coal Processing

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Abstract: Herein there are the results of study of mechanical and chemical degradation of water-soluble flocculants under ultraviolet and ultrasonic irradiation. Experimentally it was found that the rate and degree of these processes can be evaluated by the change in viscosity of the solutions. The definition of this parameter at the stage of preparation and use of flocculant water solutions let you choose such technological mode when degradation of macromolecules is reducing and eliminating. This ensures maintenance of high flocculant activity while coal preparation.

Keywords: flocculant, mechanical and chemical degradation, viscosity

1.Introduction

Preparation, storage, transportation and practical use of polymer flocculant solutions are often associated with rather intense chemical and mechanical effect, which could lead to degradation, i.e. breaking of the main molecular chain or side groups of the macromolecule substance. Despite the fact that this phenomenon is well known, it is rarely taken into account solving specific technological and practical problems. One of the reasons is the difficulty in determining of the depth of the flow process under production conditions. Therefore, the search for a method that makes such a possibility is very urgent task.

2.Work description

As a model, the diluted solution of polymer flocculants based on polyacrylamide anionic grades Magnaflok 525 and 365 (M 525 and M 365) with a molecular weight (MW) 3×10^6 and 7×10^6, respectively, and cationic Magnaflok 1440 (M 1440) with 1×10^6 MM, are widely used in various industries for wastewater treatment.

The viscosity of the polymer solution η, characterizing internal resistance to the flow, due to the molecular mechanism, and which as per Biki theory of viscosity[1] is associated with a molecular weight of the polymer. If to introduce a concept of a critical molecular weight - $MM_{critical}$ associated with the chain length required for formation of a continuous spatial grid (its nodes are formed by overlaps of macromolecules), then the number of primary, secondary and subsequent links increases significantly at $MM > MM_{critical}$. Resistance to a flow increases, thus the force required to move a macromolecule, interlaced with others, becomes considerably greater compared with the effort required for the motion of a chain, which leads to a viscosity increase. Therefore, in the high molecular weight there is a very strong influence of MM on η, which value becomes proportional to the MM[3,4]. It is easy to

assume that the decrease of MM due to degradation should lead to decrease of η.

Preparation of polymer flocculant solutions and their use in the production is characterized by a whole complex of mechanical and chemical effects on macromolecules under the influence of various factors, but the most typical are the chemical and mechanical degradations.

It is known that chemical degradation is possible not only due to strong oxidants introduced into solution, but also by energy of ultraviolet radiation sufficient to break chemical bonds with formation of free radicals, which are usually quick to react with present oxygen[2]. In this case, one of the main factors affecting the photo-degradation process is the number of quantum of the absorbed radiation; and degradation of the flocculant solutions can be explored without fear of the side effects due to trace impurities introduced to the solution with oxidizing agents. Therefore, during the experiment an irradiation treatment of flocculant solutions was carried out by UV rays of mercury-quartz lamp, provided stable reception of the luminous flux of 4200 lumens.

Mechanical degradation generally occurs due to the fact that the applied voltage exceeds the strength of chemical bonds between the atoms of the main chain. The possibility of this process is defined by the ratio of the sum of energies of intermolecular interactions ΣE_{ms} and energy of chemical bonds E_{xc} of the main chain. If $\Sigma E_{ms} > E_{xc}$, chemical bonds will be destructed first. However, the diluted solutions of polymers are characterized by the ratio $\Sigma E_{мс} < E_{xc}$, where macromolecules are more likely sliding along each other, but not breaking [3]. At the same time, the forces generated by stirring of solutions in mixes of various types, their transportation through pipelines and extruding through filters lead to the creation of solutions with great velocity of shear, and that is accompanied by very intensive movement of molecules of the solvent relatively to the less mobile macromolecules, leading to the break of chemical bonds.

Mechanical destruction of solutions was examined by ultrasound of 15 kHz frequency and 55 W/sm^2 intensity, because out of all kinds of mechanical impact the ultrasonic radiation (UR) is the best one for the quantifiable description, and its intensity and frequency are much easier to measure than the shear stress, for example, in the mixing process. [2]

The degree of destruction was estimated by the change in viscosity of the solutions using a Höppler reo-viscometer (made in Germany), which operates on the principle of gravity (motion) of the calibrated on diameter ball under the applied load in a cylindrical measuring vessel filled with liquid. The motion of the ball is from weights having share zone created during measurements.

Magnaflokov solutions M 365, M 525 and M 1440 of 0.1 % (w) concentration were studied. The results of the study are presented on Figures 1, 2 and Table 1. Changes in viscosity were evaluated by the value $\Delta\eta$ (%) using the formula as follows:

$$\Delta\eta = \frac{\eta_0 - \eta_i}{\eta_0} \cdot 100,$$

where η_0 – initial viscosity of the solution before irradiation, сПз (centipoise); η_i – viscosity of the solutionoсть after irradiation, centipoise.

Fig. 1 shows the dependence of viscosity of η polymer flocculants from time of UV irradiation, which is directly dependent on the number of photons absorbed radiation.

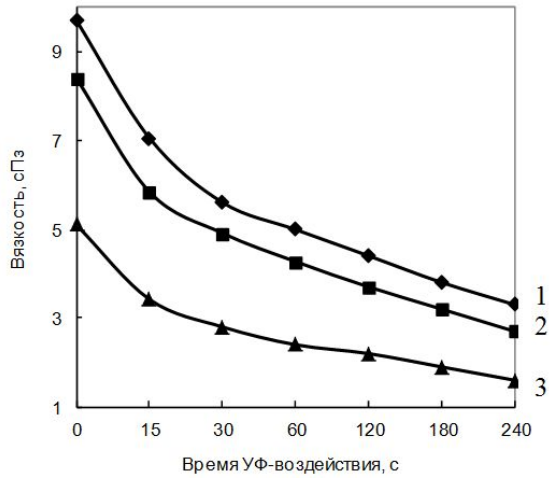

Fig.1: The Influence of the UV Irradiation Time on the Polymer Solutions:
1 – M365; 2 – M525; 3 – M1440

This dependence for all materials is practically the same, but the numerical values of viscosity change $\Delta\eta$ (Table 1) are essentially depend on the MM of the original polymer, which determines the initial solution viscosity η_0 at t = 0. Obviously, that the viscosity drops intensively during the first 60 seconds of irradiation, for example, 365 M $\Delta\eta$ is 51.3%. Later, within the experimentally studied length of time the rate of change of viscosity is significantly reduced and becomes approximately constant. The maximum value of $\Delta\eta$ at t = 240 sec. is observed for M 365 (66.7%), the minimum for M – 1440 (61.7 %).

Table 1: The Change of the Viscosity of the Polymer Flocculant Solutions $\Delta\eta$ at Degradation

Type of Irradiation	Grade of Flocculant	Irradiation Exposure Time, sec.							
		0	15	30	60	120	180	240	360
UV	M365	0	40.9	45.7	51.3	59.0	–	66.7	–
	M525	0	31.7	36.6	43.9	51.2	–	64.6	–
	M1440	0	23.4	38.3	44.7	48.9	–	61.7	–
US	M365	0	–	–	42.2	54.2	59.5	60.7	72.1
	M525	0	–	–	21.6	31.3	42.9	46.2	61.0
	M1440	0	–-	–	34.0	42.6	48.9	55.3	59.6

It should be noted that at different values of the initial viscosity of the polymer solutions with increase of the UV exposure time the leveling of value η happens, and after 60 sec. They become rather close. Another interesting feature was revealed i.e. the Magnaflokov solutions 365, 525 and 1440 reduced their initial viscosity to a 3^d to the same value during a maximum period of exposure (t = 240 sec.), regardless of their molecular weight. Moreover, the higher the molecular weight of polymer, the more actively destruction process goes, that should be considered at developing and implementing of the technology for dissolving of polymers.

Mechanical effects on the flocculant solutions by ultrasound cause mechanical degradation of polymers, that is also which is characterized by a decrease in viscosity (Fig. 2).

Besides, there are some peculiarities as more uniform in time decrease of this parameter for all flocculants except for M

365, for which, for example, after 60 seconds of ultrasonic exposure $\Delta\eta$ was 42.2% (the rest – 1.634%), Table. 1.

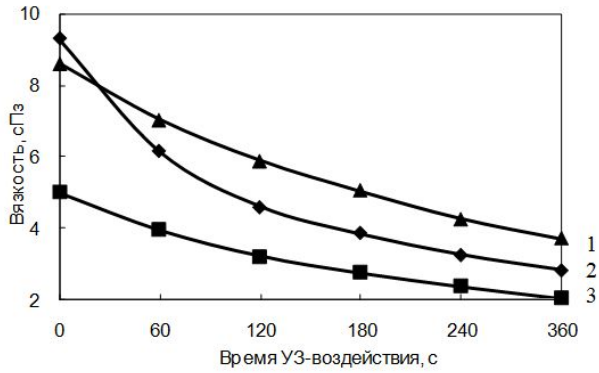

Fig. 2: The influence of the US Exposure on the Viscosity of the Polymer Solutions:
1 – M365;2 – M525; 3 – M1440

3.Conclusions

The experimental results show that:

– the viscosity of the polymer flocculant solutions is fairly reliable, though indirect characteristic, with the help of which you can evaluate the rate and extent of degradation processes;

– the determination of viscosity allows adjusting the depth of degradation process at preparing solutions by selection of the process parameters that allow either eliminate or substantially reduce degradation of macromolecules in order to maintain a high activity of the flocculants at coal preparation.

4.References:

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