Researches of structural-mechanical properties of coal tailings as disperse systems

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ABSTRACT: In clause ways of optimization of physic mechanical properties preforming fuel are considered at adhesion-chemical technology preforming coal tailings and breazes. Researches of structural and mechanical properties of coal tailings as disperse systems by means of the methods, defining deformation properties are given: durability – limit tension on shift; elasticity module; relaxation characteristics; after-effects, etc.

1 INTRODUCTION

Fields which are presented by storages coal tailings occupy the huge space that leads to alienation of agricultural grounds and notable deterioration of an ecological situation of territories. But quantity of useful combustible components, in such storages of tailings, about 20-75% which can be overworked in fuel make. In this case the actual industrial and social problem of consumption in additional firm fuel and decrease in an environmental pressure of regions where underground mining of coal fields is conducted is solved.

As effective processing of energy resources and reduction to technical requirements it is offered to technology of a preforming adhesive and chemical (Gayday 2006).

2 FORMULATING THE PROBLEM

Justification of physic mechanical parameters of preforming composite fuel requires research of structural and mechanical properties of coal tailings as disperse systems. Researches were conducted by means of methods of measurement of structural and mechanical properties of disperse systems. Coal tailings (fraction of 0-1 mm) as the disperse breeds including a disperse phase and the disperse environment, represent the system based on physical and chemical interaction of its components.

Existence of structure gives to system peculiar mechanical properties. These properties – elasticity, durability, plasticity, viscosity – depend on the chemical nature of the substances forming this system; decide by molecular forces of adhesion between structure elements, their interaction on the dispersive environment and extent of development of structure in all volume of system. Therefore the improvement of structural and mechanical properties necessary for process of their preforming demands research (Pahalok 1952).

For an assessment of the characteristic of mechanical properties of the structured disperse systems, the most rational methods are determination of their deformation properties: durability – limit tension on shift; elasticity module; relaxation characteristics; after-effects, etc. (Remesnikov 1955).

3 MAIN PART

In many cases for an assessment of the structured disperse system it is possible to be limited to determination of the simplest and almost important size – the mechanical durability of structure that is limit tension of shift P at small speeds of deformation.

Methods of measurement of structural and mechanical properties of disperse systems (Remesnikov 1955, Lurye & Boytsova & Ravich 1957, Lurye 1956, Volarovich 1954, Pertsov 1999, Almazov & Pavlotskiy 1971) can be divided into three groups:

1) Methods of extraction of working part of the device from studied system. Here the method of extraction of the cylinder treats with sharp cutting according to Volarovich-Tolstoy (previously such cylinder – the screw – has to be completely filled or screwed in studied system);

2) Methods of penetration of a tip (indenter) of the correct geometrical form and giving the prints similar each other (a cone, a pyramid), in almost boundless volume of studied system. These methods allow to investigate in detail process of a plastic current of system at a set tension and speeds of deformation and to receive curve currents; this is rheological characteristics of the structured plastic and viscous systems.

Determined by the greatest immersion of a tip (a cone, a pyramid) the limit tension of shift characterizes the plastic durability of system corresponding to the top limit of fluidity.

3) Shift methods in studied system at preservation of constancy of a surface of contact of an indenter with system, this is at preservation of constancy of tension of shift given to system. The method of tangential shift of the plate placed in system on Veylera-Rehbinder belongs to methods of this group, and also a method of a twisting of the cylinder shipped in system (Shvedov's method). Valuable feature of these methods is opportunity to define absolute values of all elastic-plastic characteristics of the structured systems.

Method of immersion of a cone

The method of immersion of a cone is allocated with the simplicity, and also strict validity of calculation, and gives the chance to make measurements at small deformations of shift, i.e. small gradients of speed with transition in a limit to an assessment of static limit stress of shift or limit pressure which for the majority of plastic and viscous systems can characterize durability of their structure. This method is described and presented in works (Remesnikov 1955, Lurye & Boytsova & Ravich 1957, Almazov & Pavlotskiy 1971).

This method consists in definition of dynamics of immersion of a cone in studied system under the influence of constant loading of *F*, as gives the conditional rheological characteristic – a current curve which expresses dependence of speed of immersion dh/dt on tension of the shift *P* which is continuously decreasing in process of immersion owing to increase in the area of contact of a cone with system. Respectively the speed of immersion of $V = dh/dt$ while it doesn't become almost equal to zero at the greatest immersion of h_m decreases also. The limit tension of shift of P_m, that is greatest of all static tension, possible in this system, is equal to the smallest value of the operating tension of P_i, corresponds to an equilibration of external force *F* plastic durability of structure.

The size of P_m is calculated on limit immersion of a cone to h_m caused by this loading of *F*, assuming that at cone immersion in system the current of a layer of system along a lateral surface of a cone takes place. This condition is carried out in rather plastic systems therefore tension of shift *P* causing this current, is defined by a projection of force of *F* operating on a cone to *l* forming a cone carried to unit of area of contact of a cone with system *S*:

$$P = \frac{F}{S} = \frac{F \cdot \cos\frac{\alpha}{2}}{\pi r l}; \quad (1)$$

$$r = h \cdot tg\frac{\alpha}{2}; \quad (2)$$

$$l = \frac{h}{\cos\frac{\alpha}{2}}; \quad (3)$$

$$P = K_\alpha \cdot \frac{F}{h^2}; \quad (4)$$

where $K_\alpha = \frac{1}{\pi}\cos^2\frac{\alpha}{2} \cdot ctg\frac{\alpha}{2}$ - the constant of a cone depending only on a corner α at its top (in axial section), and, therefore

$$P_m = K_\alpha \frac{F}{h_m^2} \quad (5)$$

In some disperse systems with stronger and fragile structure the current isn't possible, and at introduction of a cone plastic deformation a compression takes place. In such systems the limit pressure of P_l which pays off division of force operating on a cone of *F*, into a horizontal projection of S_m is defined by a method of immersion of a cone

$$P_l = \frac{F}{S_m} = \frac{F}{S_m \cdot \sin\frac{\alpha}{2}} = \frac{F \cdot \cos\frac{\alpha}{2}}{\pi h_m^2 \cdot tg\frac{\alpha}{2} \cdot \sin\frac{\alpha}{2}}; \quad (6)$$

$$P_l = K'_\alpha \frac{F}{h_m^2}, \quad (7)$$

where $K'_\alpha = \frac{1}{\pi}ctg^2\frac{\alpha}{2}$ - cone constant; h_m - the greatest immersion of a cone.

Application of this or that formula is defined by invariance of results, this is independence of the calculated limit tension of shift of P_m or limit pressure of P_l from a cone corner α or F loadings.

a) b)

Figure 1. – Device penetrometer LP (a – laboratory, b– industrial).

In figure 1 the general view of the device penetrometer is presented to LP on which measurements of dynamics of durability of structure of system "coal – binding" were made.

Penetrometr – the device for measurement of a consistence of semi-fluid materials by determination of depth of penetration of a test body of the standard sizes and weight on the tested environment. Measures penetration number – an indicator characterizing rheological properties of substances which is equal to depth of immersion of a working body penetrometer in terms of the tenth shares of millimeter. For example, if the working body penetrometer plunged on 20 mm, the number of a penetration will be equal 200.

Usually penetrometer it is applied in the form of freely sliding plunger with the working body fixed on it in the form of a needle or a cone. Before measurement the edge of a working body is brought closely to a surface of the studied environment, and then the plunger is released and starts plunging on environment under own weight. Penetration depth in a definite time (penetration number) is fixed, at a certain temperature and in advance chosen mass of assembly a plunger a working body.

Depending on binding on the example of coal tailing of brand A dependence of an indicator of a penetration in time for disperse system (Figure 2) is presented.

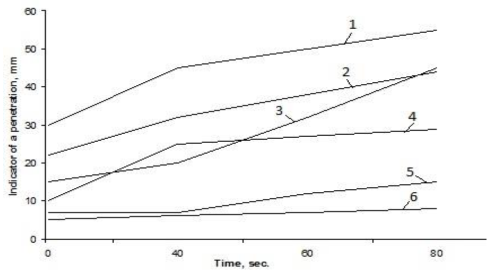

Figure 2. – Dependence of an indicator of a penetration in time for systems of coal tailings with the various binding

1 – cement; 2 – plaster; 3 – physical solute; 4 – liquid glass;

5 – lignin; 6 – not extinguished lime.

Method of tangential shift of a plate

One of the most sensitive methods of determination of durability of structure – the limit tension of shift of P_t in the structured disperse systems – is the method of tangential shift of a plate.

The principle of this method offered by S.Y. Veyler and P.A. Rehbinder, consists in definition of the effort necessary for shift of a plate, shipped in studied system.

Rectangular or round very thin metal plate (50-100 micrometers) is shipped by thickness in investigate substance and suspended on a rigid thread to a quartz or glass spring. Rectangular a ditch with the examinee substance it is strengthened on a special little table. The electric motor with a reducer smoothly lowers or lifts a little table with a constant speed. Shift of a plate and stretching of a spring count by means of the horizontal microscope supplied with an preforming micrometer.

Shift tension in this method is calculated on stretching of a spring and the corresponding this stretching of a spring to effort of *F* and a lateral surface of a plate of *S*

$$P = \frac{F}{2S} \tag{8}$$

The limit tension of shift characterizing durability of structure of system of P_m, corresponds to the greatest effort of F_m (in the absence of system sliding along a plate surface), respectively $P_m = \frac{F_m}{2S}$.

This method allows defining not only the limit tension of shift, but also the elasticity module, effective viscosity, to investigate relaxation process, and also to remove full deformation curves at different speeds of deformation. The method possesses big sensitivity, and is applicable in a wide interval of durability of structure, from weak structure systems to strongly-shaped systems with high-strength structure (Pertsov 1999).

Method of a twisting of the cylinder (Volarovich 1954).

The principle of a method is based on definition of elastic and plastic characteristics of the structured systems on a twisting of the cylinder suspended on an elastic thread and shipped in this system. The twisting device has an exact head in which the elastic thread is fixed. On a thread the corrugated cylinder which is completely shipped in studied system is suspended. At turn of a twisting head to a certain corner α torque it is transferred through a thread to the cylinder and causes shift deformations in the concentric layers of system surrounding the cylinder. The cylinder thus to twirl on some corner β to balance between elasticity of the twirled thread and resistance of the deformed system. The difference $\alpha - \beta$ gives a corner of twisting of a thread ω, *F* corresponding to a certain effort, established on preliminary graduation of a thread [9-17].

Let's consider balance between force of elasticity of the twirled thread and elastic reaction of the deformed layers of system. Let's divide system into concentric layers height to h equal to height of the cylinder, the radius of *r* and *dr* thickness. The layer adjacent to walls of a vessel, remains in rest; the layer which has been directly connected with the cylinder, twirl together with it on a corner β; all intermediate layers experience shift deformations relatively each other [18-25].

The moments of all forces applied to a surface are equal, from where there is a module of elasticity of system

$$E = \frac{K}{4\pi h}\left(\frac{1}{r^2} - \frac{1}{r_l^2}\right) \cdot \frac{\beta}{\omega}, \tag{9}$$

где $r_l = r + dr$.

At such definition of the module of elasticity of system if diameter of the internal cylinder is insignificant in comparison with its height, influence of a bottom of the cylinder can be neglected or it can be considered by special experiences.

The experiment description in laboratory (when using SNS-2).

In a glass the examinee solute is filled in. At glass rotation solute entrains the cylinder which was in it measuring and all suspended system until the moment of a twisting of a thread doesn't become equal to a torque developed by a static stress of shift of solute on the cylinder. Static limit stress is determined by the maximum corner of a twisting of a thread.

4 CONCLUSIONS

Thus, on the basis of researches of physic mechanical properties of disperse coal tailings, it is possible to draw conclusions:

- to number of the major factors defining structural and rheological properties of disperse systems of coal tailings, belong: force of adhesion in contacts between particles; coordination number (this is number of the contacts falling on one particle), depending on increase in concentration of a disperse phase in the dispersive environment, its dispersion and distributions of particles by the size.
- coal tailings as disperse breeds, represent the system of a firm and liquid phase based on physical and chemical interaction of its components. Therefore improvement of physic mechanical properties, disperse coal tailings has to be based on physical and chemical influence on them. With dependence of P=17,853Ln(t)+30,816 the disperse system coal tailings possesses the best physic mechanical characteristics at physic mechanical influence by cement.

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