RHEOLOGICAL INVESTIGATIONS OF A PLASTICIZED POWDER CHARGE

1. BEHAVIOR OF A PLASTICIZED POWDER CHARGE UNDER SHEARING CONDITIONS

A. G. Kostornov and A. I. Raichenko

Institute of Materials Science, Academy of Sciences of the UkrSSR
Translated from Poroshkovaya Metallurgiya, No. 5, pp. 9-15, May, 1966
Original article submitted September 30, 1965

To develop an efficient technology of extruding powders with a plasticizer admixture and their subsequent heat treatment we need know the transformations that occur in the object at all stages of its processing. For a proper understanding of the irregularities of extrusion we need know the characteristics of the behavior of the powder charge in the presence of shearing stress because the latter is one of the most important factors involved during extrusion of the charge. In this report we will elucidate the problem: a plasticized powder charge is a body of some kind (according to the rheological classification).

The object of investigation was a charge with the following mass composition: 77% nickel carbonyl powder, 3% starch, 20% water. The kinetics of the development of shear in a plasticized powder charge under the effect of a constant shearing stress increasing from experiment to experiment was investigated on an instrument with a parallel shifting plate having an indicator for reading the displacements [1].

The basic units of the instrument are: plates (50 x 20 mm) between which is placed a specimen of the mixture, a socket for installing the lower plate and a position regulator of a thread from which a load is suspended. The surfaces of the plates abutting the mixture have grooving directed opposite to the direction of the deforming forces (Fig. 1). On the upper plate is installed a rod with an area for attaching a lever which transmits the readings of the values of deformation to the indicator in a ratio of 1 : 5 (the scale division of the indicator is 2 &mu;m). The socket has a screw for fastening the lower plate and a vertical motion arresting device for the upper plate to prevent it from breaking away. The thread position regulator is intended for horizontally positioning the thread tightened by a load during possible changes of thickness of the investigated specimen.

The investigated plasticized mixture was placed between the plates so that the teeth of the latter were completely buried in the mixture without causing its compaction when pressing in. For this purpose we used a special sectional mold which simultaneously formed the side faces of the specimens flush with the edges of the plates. The height of the layer of the mixture was determined by the difference of the thickness of the specimen together with the plates and the thickness of the composite plates.

The sides of the specimen were covered with vaseline to avoid drying of the mixture during the experiment. After this preparation the plates, together with the specimen between them were placed in the receptacle of the instrument and fastened, and to the upper plate we connected the suspension for loads approximately balancing the pressure of the indicator spring. Then we applied the first load, below which deformation was not noted, and simultaneously started a stop-watch.

The readings on the indicator were noted every 1, 5, 10, 15, 20, 30, 45, 60, 120, 180, 300, 450, 600, 750, and 900 sec. Then unloading was done in the same order for 180 sec. The next experiment of this series consisted of loading with a somewhat larger load. Successive loadings and unloadings were continued until failure of the specimen. The results of the experiments are shown in Fig. 2.

Shear was calculated by the formula

$$\varepsilon' = \frac{\varepsilon}{A},$$  (1)
where $\varepsilon$ is the displacement of the upper plate determined from the indicator; $A$ is the height of the layer of the mixture.

A study of the experimental data permits noting the following characteristics of the kinetics of shear of the charge. At the very start of loading, shear practically instantaneously (more exactly, with the speed of sound) reached a certain value, after which it increased with an ever decreasing speed. At small shearing stresses "saturation" occurred, i.e., after reaching a certain value deformation remained constant in time. At larger shearing stresses deformation increased during the entire experiment, at a low rate in the last stages. In a number of experiments the specimens were brought to fracture; if the load was removed before fracture, then in all cases, regardless of the applied load, deformation disappeared almost instantaneously. No permanent set was observed in a single experiment. All this indicates that under the conditions of the described experiments the charge behaved as an elastic (Hooke's) body. However, the behavior of the specimen under a load in time after reaching instantaneous elastic deformation $\varepsilon_0$ is not quite ordinary (see Fig. 2).

One of the peculiarities of the behavior of the specimen was disruption of "continuity"; in it on both grooved surfaces appeared cracks (see Fig. 1), the number of which increased with time. This phenomenon can be understood if we apply to our object the criterion of one of the hypotheses of strength.

The investigation showed that the disruption of continuity of the specimen can be explained by the hypothesis of the "maximum normal stress" (see, for example, [2]).

Actually, let us examine in greater detail the stress state in which the body is found during the experiment. If we consider that the specimen is in no way limited on the sides, i.e., in a direction parallel to the teeth of the plates and no stresses are acting, then it is natural to consider it to be in a plane stressed state characterized by the following stress tensor:

$$\mathbf{\sigma} = \begin{bmatrix} 0 & \tau & 0 \\ \tau & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix}$$

(2)

where $\tau$ is the shearing stress imparting strain to the body.

Let us examine on an area of what orientation a normal tensile stress acquires a maximal value. This can most graphically be established by means of Mohr's circle (Fig. 3). In a state of simple shear the stressed state is characterized by Mohr's circle, the center of which coincides with the origin of the coordinates. The maximum shearing stress $\tau$ and a zero normal stress correspond to point A. A maximum normal tensile stress, equal in magnitude to the shearing stress, corresponds to point B, the minimum (i.e., compressive) normal stress, also equal (in absolute magnitude) to $\tau$, corresponds to point B'. For a coordinate system turned relative to that for which the stress tensor (2) was drawn, to a position in which there are no shearing stresses (tensor (2)) will change thus:

$$\mathbf{\sigma} = \begin{bmatrix} -\tau & 0 & 0 \\ 0 & \tau & 0 \\ 0 & 0 & 0 \end{bmatrix}$$

(3)

The angle of this turn should be equal to $\theta = \pi/4$ clockwise, as is apparent from Fig. 4. Thus, in a coordinate system $x_1$-$x_2$ the maximum tensile stress is directed along the $x_2$ axis, i.e., fractures can be expected along the planes whose track in Fig. 4 is parallel to the $x_1$ axis. This occurred in the experiment. The places at which cracks will form cannot of course be indicated beforehand. Apparently the formation of cracks begins where there are maximum stress concentrations for one reason or another (for example, at the edges of the teeth of the plates).

Let us now examine the problem of how the elastic deformability of a specimen depends on the number of cracks oriented as shown in Fig. 1.