PHOTOELASTIC INVESTIGATION OF CERTAIN FACTORS INFLUENCING DISKING IN CORES DURING DRILLING

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The breakup of a core into disks during drilling has been used for many years to estimate the state of stress of the solid rock [1-4]. In general, the fracture of disking of a core during core drilling depends on many interrelated factors: a) the type of stress state (uniaxial, plane, or three-dimensional, ratio of components of principal stresses); b) spatial-geometrical factors (borehole diameter, ratio of diameters of borehole and core, shape of face of drilled slot, orientation of boreholes relative to directions of principal stresses in the solid rock); c) deformation-strength factors (elasticity modulus and Poisson ratio of rock, compressive, tensile, and shear strength indices and their anisotropy); d) structural factors (jointing, stratification, and presence of inclusions); e) technological factors (method of drilling, drilling conditions).

An analysis of present methods of estimating the state of stress of the rock by means of core disking reveals that the influence of these factors on core disking has not yet been definitively assessed, and the technological methods and empirical approaches do not take account of the influence of many of them, and cannot be used with equal degrees of reliability in different geological and spatial-stress states of the solid rock.

In this article we give the results of an investigation (based on the optical polarization method) of the stress distribution at the end of a drilled borehole or at the faces of drilled slots of various shapes, for various core lengths, and for various orientations of the borehole axis relative to the direction of the principal stresses, with the aim of assessing the significance of these factors and the possibilities of taking account of them in estimating the state of stress of the rock from a disked core.

The investigations were made on plane models of the optically sensitive material ED-6M. The model (Fig. 1) consists of a plate 1, 260 mm in diameter and 10 mm thick, with a slot 2 in the center simulating a longitudinal diametral section of a borehole with a core. Preliminary experimental work and comparison with three-dimensional models for investigation of the range of problems envisaged by us revealed that it is well-founded and permissible to model the borehole by a slot. To satisfy the boundary condition for the size of our model, we chose a slot of the following dimensions: \( d_{bh} = 30 \text{ mm}, \ d_{cor} = 20 \text{ mm}; l_{cor} = 10 \text{ mm}, l_{bh} = 60 \text{ mm}, \ l_{bh}/d_{cor} = 3. \)

The plate 1 was fixed into a square frame 3 with a circular hole under the model, and the whole assembly was placed in a pneumatic-hydraulic loading device 4, which was capable of creating a plane state of stress with different components. By making the model in this way, by using a single model and rotating it in the frame relative to the applied loads, we were able to investigate the influence of changes in the orientation of the borehole axis relative to the direction of the principal stresses \( \alpha \). The models were investigated at room temperature by photographing the isochromes and isoclines and interpreting the interference pattern by the method of fringes; on this basis we determined the maximum tangential stresses or the stress concentration coefficient (the ratio of the stress at a test point to the external applied pressure acting in the same direction).

We made models of three types of slot face - spherical, planar, and acute-angled (see Fig. 1), for various core lengths \( l_{cor} \), various ratios between the stresses applied to the model, \( \lambda = a/p \), and various orientations of the borehole axis relative to the applied stresses \( \alpha \). The figures in Fig. 1 denote the arbitrary points at which we will consider the stresses at the slot face.

The influence of the length of the core was investigated for all three shapes of slot face with \( \alpha = 0 \) and \( p = 0 \). An analysis of the results (Fig. 2) revealed that, irrespective of the shape of the face, as \( l_{cor} \) increases.
the stress concentration coefficient at the face changes differently at points 1-3.

At the moment of formation of the slot, with \( l_{\text{cor}} = 0 \) the stress concentration coefficients at points 2 and 3 are equal and average 70% and 40% respectively relative to the concentration coefficient at point 1. As \( l_{\text{cor}} \) is increased to \( d_{\text{cor}}/3 \), the stress concentration coefficient at point 1 remains almost constant, but that at point 2 increases on the average to 80-85% and that at point 3 to 90-95% relative to point 1. Further increase in \( l_{\text{cor}} \) causes no further change in the concentration coefficient at the borehole face. As \( l_{\text{cor}} \) increases, the end of the core is relieved of load; relief is complete when \( l_{\text{cor}} = d_{\text{cor}}/3 \).

The change found in the stress concentration at the slot face as its length increases to \( d_{\text{cor}}/3 \) enables us to explain the formation of disks of various thicknesses in the same rocks with the same strength properties. Since the region of greatest concentration is a source of cracking and fracture, the process of separation of the core into disks during drilling will occur at a core length such that the stresses at the slot face are greater than the strength of the core rock at this point. The most favorable site for this is in the region of point 3. Thus an increase in \( l_{\text{cor}} \) and a corresponding increase in the stress concentration coefficient has the result that a higher stress level in the rocks will correspond to a lower thickness of the disks, and vice versa.

The influence of the shape of the slot face on the stress concentration at the face was investigated with \( l_{\text{cor}} = d_{\text{cor}}/3, \alpha = 90^\circ, \) and \( \lambda = 0 \). The results revealed that the shape of the slot face influences both the magnitude of the stress concentration and the position of its maximum. For a spherical face, the maximum stress concentration lies between points 1 and 2; for a plane face, it shifts to point 1, and for an acute-angled face, to point 3. On comparing the concentration coefficients for different slot face shapes, we remark that the smallest concentration coefficient is observed with a spherical face; it increases slightly (by 10%) for a plane face, and more markedly (by 35%) for an acute-angled one.

Thus from the viewpoint of core disking, the best face shape is acute-angled, followed by plane and then spherical.

The influence of the ratio \( \lambda \) of the loads applied to the model on the stress concentration at the slot face was investigated for all three face shapes with \( l_{\text{cor}} = d_{\text{cor}}/3 \) and \( \alpha = 0 \). Increase of \( \lambda \) for any face shape leads to an increase in the stress concentration at the face. For example, Fig. 3 shows the dependence of the stress concentration coefficient at point 3 on \( \lambda \). Variation of \( \lambda \) also influences the position of maximum concentration on the face: for a spherical face and \( \lambda \geq 1 \) the stress concentration maximum lies at point 1, but when \( \lambda < 1 \) it lies at point 2; for a plane face and any value of \( \lambda \) the stress concentration maximum lies at point 1; and for an acute-angled face, it lies at point 3 when \( \lambda > 1 \) and at point 1 when \( \lambda \leq 1 \). Thus an increase in the axial stresses (an increase in \( p \)) can reduce the stress concentration at the face and thus prevent disking of the core. Note that an increase in the axial load leads to a smaller change in the stress concentration at the face at points 2 and 3 when \( l_{\text{cor}} \) changes from 0 to \( d_{\text{cor}}/3 \). When \( p \gg q \), these changes are scarcely observed at all with increasing \( l_{\text{cor}} \).