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Model of deformed crystalline structure

L. M. Polyakov

Physicotechnical Institute, The Ukrainian SSR, Academy of Sciences, Kharkov

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When plastic deformation of crystalline solids is investigated, it is useful to have models that simulate the formation and motion of the different structural defects. This is usually done with two-dimensional ball bearing or bubble models. The ball bearing model consists of a single layer of ball bearings of the same diameter, located between two parallel transparent plates. The packing symmetry of the model is modified by shaking, and the resulting local change in density simulates the structural defects in the medium. In this type of model, the defects are fixed irregularities that appear as a result of uncontrolled interaction between the ball bearings. Bragg's model[1] consists of inflated bubbles held in position by surface tension, and clusters of such bubbles simulate the crystal structure of real solids. Bubble models are more satisfactory because they involve attractive forces between bubbles, due to surface tension, and repulsion forces due to the excess pressure in each bubble. A disadvantage of both models is the uncontrollable change in shape, size, and position of the defects. Both models are difficult to make.

The relatively simple two-dimensional model proposed here is an improvement on both the conventional ball bearing and the bubble models. It produces mobile structural defects, and the interaction which involves both attractive and repulsive forces can be controlled. The model (Fig. 1) consists of steel ball bearings 1 held in a stretched rubber ring 2 and placed between transparent plates 3. Six screws 5 with plungers 6 are arranged on a rigid ring 4 and are used to produce the loading on the model. Displacement of any one of the plungers deforms the rubber ring and displaces the ball bearings. This is opposed by the reaction due to the rubber ring which simulates elastic bonding forces between the ball bearings. Departures from symmetry simulate the development of dislocations, vacancies, pores, slip processes, formation of boundaries between grains, and other phenomena that are typical of deformed crystalline structures. Slip is produced by displacing ball bearings in one row relative to a neighboring row. Unequal displacement of ball bearings along a row simulates dislocational breaking of symmetry. Grain boundaries appear as a broken line along which there is an appreciable linear variation in density. When the land is removed, there is a partial re-establishment of density due to the compressive reaction of the rubber ring. The points of intersection of shearing displacements are occupied by clusters of defects which do not disappear when the load is removed. Rapid application of a force to a plunger leads to a discontinuous shift of the ball bearings and even to a rearrangement in the region adjacent to the plunger. By using ball bearings of two different diameters, it is possible to observe distortions that are characteristic of the influence of impurities (the smaller ball bearings can move in the voids between the larger ball bearings). The possibilities of the model can be extended by using groups of ball bearings of different color.

Figure 2 shows a similar model in which steel ball bearings are replaced by rings made from a photoelastic material. When the plungers are pushed-in in the radial direction, the rings are displaced and elastically deformed, so that one can observe in transmitted polarized light the characteristic dark and bright regions representing the stresses on the contacts and their distribution within the medium. The rubber (black) rings simu-

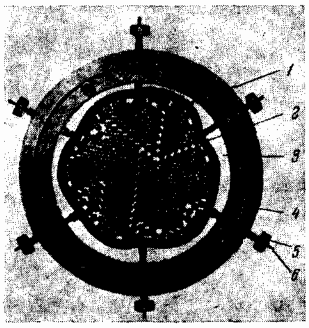

FIG. 1. Ball bearing model of a crystalline structure.

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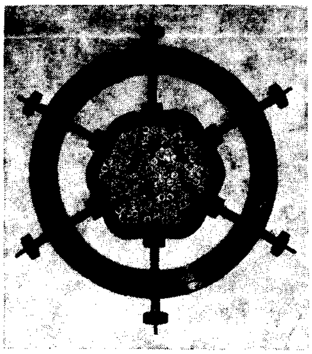

FIG. 2. Ring model of a crystalline structure.

late the rearrangement and healing of the medium under load. This model can be used to illustrate processes occurring during the deformation of a dispersive medium under load. The elastic bonding forces between the ball bearings (rings) can then be varied by varying the size of the rubber ring, and the external forces can be measured by measuring the deformation of springs mounted between the plungers and the screws.

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