MODELS OF DISLOCATIONS FOR CLASSROOM ***

R. Prasad

Department of Applied Mechanics, Indian Institute of Technology, Hauz Khas, New Delhi 110 016, India; *rajesh@am.iitd.ernet.in*

ABSTRACT

Three-dimensional models for dislocation studies in crystal structures are suggested, which can be made by students to improve understanding of the concepts.

Keywords: *dislocation models; teaching strategies*

INTRODUCTION ***

Crystal structures and associated defects are important concepts taught in introductory courses in materials science to engineering undergraduates[1]. Presentations of these concepts require three-dimensional visualization. Thus two-dimensional figures used in textbooks or drawn on blackboards are often inadequate in imparting a clear view of crystals or defects. To overcome this problem most teaching laboratories in material science present students with three-dimensional models. These models are often successful in showing concepts related to periodicity, coordination number, close packing etc. However, in the

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view of this author, in most cases, the models for dislocations in crystal, are not adequate. In the present work a simple method for making attractive models for dislocations in crystal structure is suggested.

MODEL MAKING

The models are built by using 'atoms' and 'bonds' supplied by *Cochranes of Oxford* [2]. Atoms are just little plastic spheres from which emerge six arms (along the six nearest neighbours in a simple cubic lattice). Bonds are plastic tubes, which are used to join atoms. By joining sufficient number of atoms with help of bonds a three-dimensional simple cubic lattice can be easily constructed. By suitable alteration in the joining scheme different kinds of dislocations can be introduced in the structure. At present we have made following models with different dislocation configurations.

EDGE DISLOCATION

If one half of one of the planes from the lattice is removed one gets a model for an edge dislocation, Fig. 1. Students can easily follow a Burgers circuit around the dislocation to determine that Burgers vector is perpendicular to the dislocation line. Such a circuit can be shown by using atoms of different colour to identify the circuit.
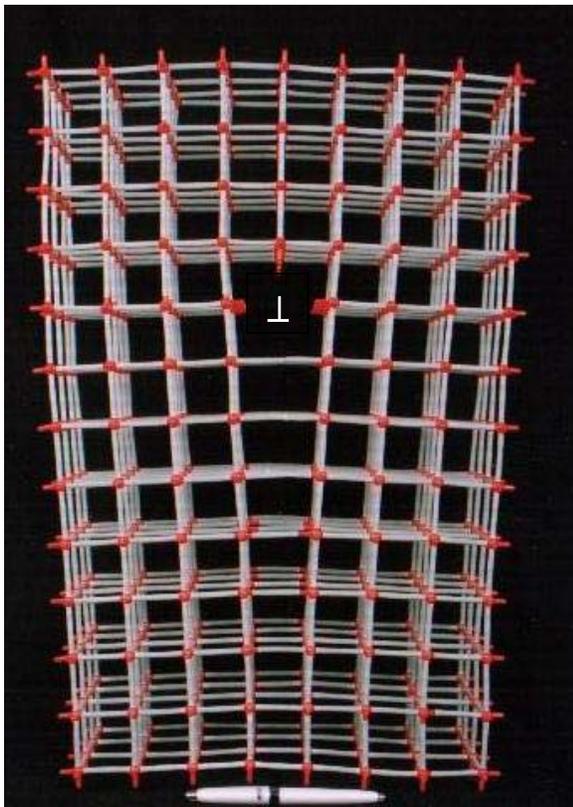
Fig. 2(a)

Fig. 2(b)

Fig. 2 (a) and (b). Two views of a model of a right-handed screw dislocation. The dashed lines indicates the approximate location of the dislocation line (525 atoms, 45cm × 20cm × 15cm)

Fig. 1.   A model of an edge dislocation. The dislocation symbol ⊥ identifies its approximate location. (432 atoms, 55cm × 38cm × 15 cm)

SCREW DISLOCATION

Screw dislocation presents greater difficulty in visualization than edge dislocation. The model shown in Fig. 2 is thus very useful in showing the spiral ramp configuration of atomic planes around a screw dislocation. Burgers circuit can also be easily constructed to demonstrate that the Burgers vector is parallel to the dislocation line.
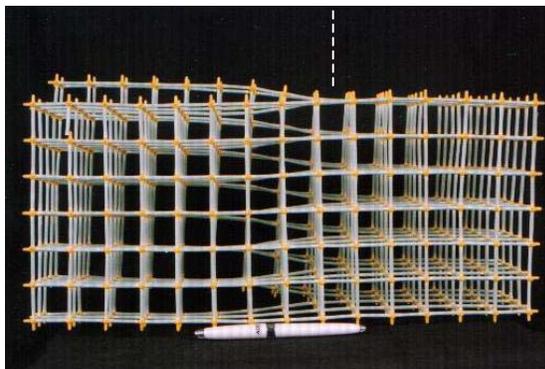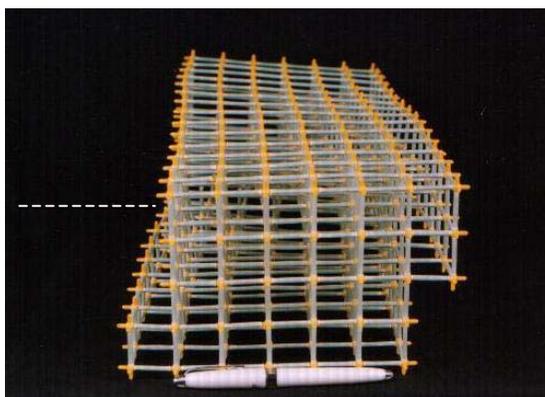
MIXED DISLOCATION

The concept of mixed dislocation often causes greater difficulty for students. The model shown in Fig. 3 has been constructed in a way that the mixed dislocation line consists of two pure segments meeting at 90° inside the crystal. One of the segments is edge and the other is screw. In Fig. 3 the dislocation enters the front face *ABCD* at *L* as an edge dislocation, takes a 90° turn inside the crystal and comes out of the left face as a screw dislocation. To bring this out clearly a schematic of the model is shown in Fig. 4. Same letters in Figs. 3 and 4 represent identical locations in the model and the schematic. Thus Fig. 3 is the front view of the schematic model shown in Fig. 4. *PQRS* is the slip plane on which lies the dislocation line
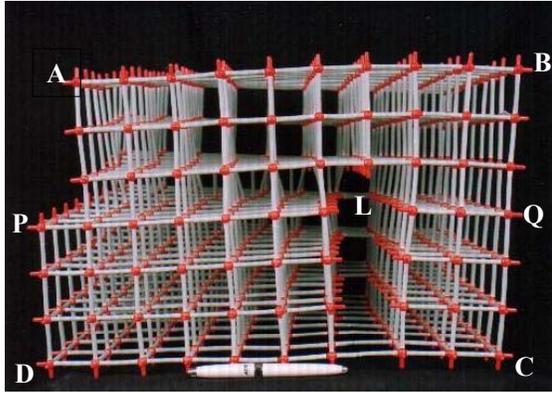
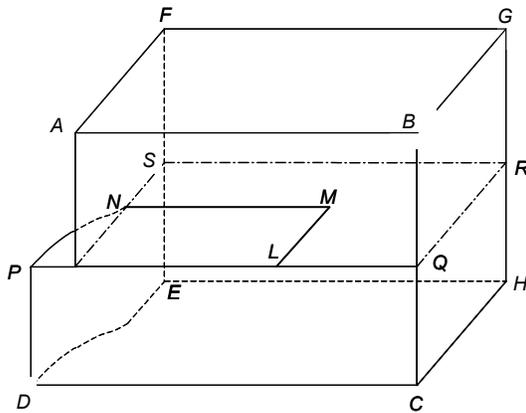Fig. 3. A model of a mixed dislocation. (720 atoms, 45cm × 39 cm × 30 cm)

Fig. 4. A schematic of the model shown in Fig. 3.

Fig. 5. The same model as in Figs. 3 and 4, but viewed from behind. The same letter corresponds to identical locations in the three figures.

LMN. The orientation of the Burgers vector *b* is also shown. The segment *LM* is an edge and the segment *MN* is a screw dislocation.

This model can be used to illustrate the principle that a dislocation line cannot end abruptly inside a crystal. When a student looks at face *ABCD* of the model (Figs. 3 and 4) he sees that an edge dislocation enters the crystal at *L*. When he turns the model over to look at the opposite face *EFGH*, where he expects the dislocation to come out, he finds none, Fig. 5. This may give him a feeling that the dislocation entering the face *ABCD* has abruptly ended within the crystal. A further examination of the model then reveals that a screw dislocation also enters into the crystal at *N* on face *ADEF*. Again this dislocation does not come out of the opposite face *BCHG*. One then finds that the
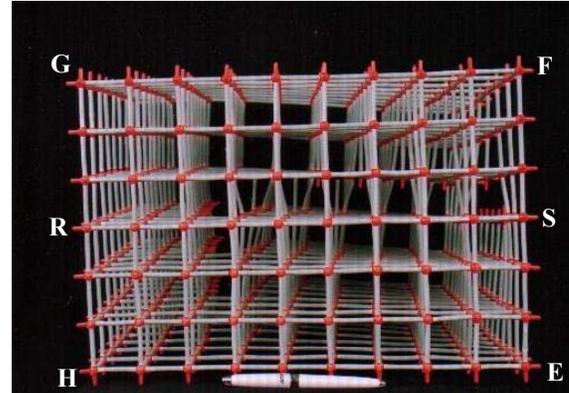
two segments *LM* and *MN* actually meet at *M*. Thus *LMN* should be considered as a single mixed dislocation entering the crystal at *L*, abruptly changing its direction and character at *M* and finally coming out at *N*. So there is no abrupt end of the dislocation line inside the crystal, only an abrupt change in its direction and character.

The model can also be used to illustrate another principle of dislocation theory. The Burgers vector of the dislocation does not change even when a dislocation changes its direction[3]. Students can make Burgers circuit around the dislocation on both the front *ABCD* and the left *ADEF* faces and find that it is the same.

PRISMATIC DISLOCATION LOOP

This configuration is obtained by inserting an extra layer of 9 atoms (3×3) in the middle of the model, Fig. 6. The square boundary of this layer is an edge dislocation with Burgers vector perpendicular to the layer surface. This model shows that dislocation lines may form a loop inside a crystal. This model shows a prismatic dislocation loop due to a layer of interstitials. A similar model showing a prismatic dislocation loop due to a layer of vacancies has also been constructed.

The viewing direction of Fig. 6 lies in the plane of the loop. It thus shows the loop in edge-on
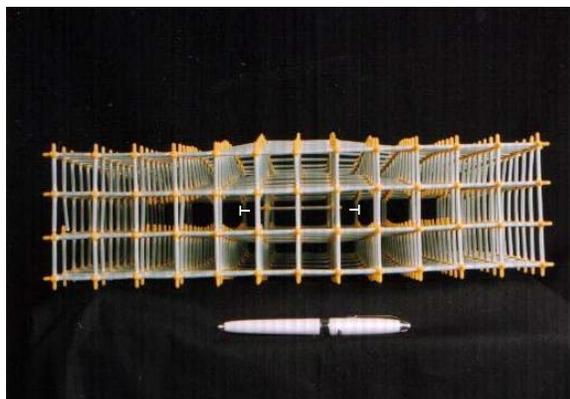
Fig. 6.   A model of a prismatic dislocation loop. The viewing direction lies in the plane of the loop. The visible segment is one side of the square loop between the two dislocation symbols. (685 atoms, 38 cm × 38 cm × 12 cm)
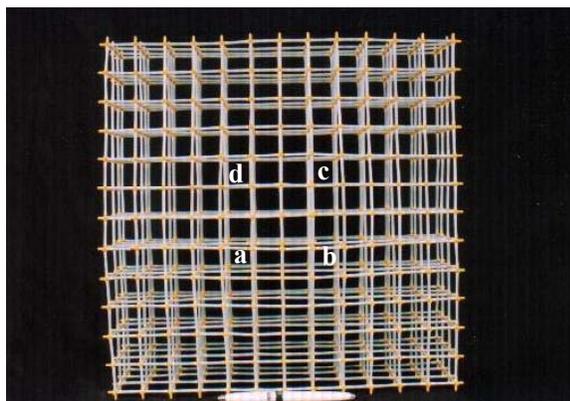

Fig. 7.   Same model as in Fig. 6 but viewed in a direction normal to the loop. The loop is not revealed in this orientation. It lies directly below the square of nine atoms (whose corners are identified as a, b, c and d) in the centre of the figure.

position with only one side of the square visible between the dislocation symbols marked on the figure. This is deliberate, as a view along normal to the plane of the loop, Fig. 7, does not show the loop due to perfect alignment of atoms within the loop and outside it in this direction. The loop lies directly below the square marked *abcd*. Thus although it is common to show a loop in schematic diagrams in this orientation, a three-dimensional model like this one will not reveal the presence of the loop. This fact emphasizes the need for working with three-dimensional models to get a good feel of the dislocation geometry.

LOW ANGLE SYMMETRIC TILT BOUNDARY

This model, Fig. 8, clearly shows a low angle symmetric tilt boundary as a series of parallel edge dislocations. Students can measure the distance d between the successive dislocations, Burgers vector b and the tilt angle θ of the model and thus verify the formula[3]

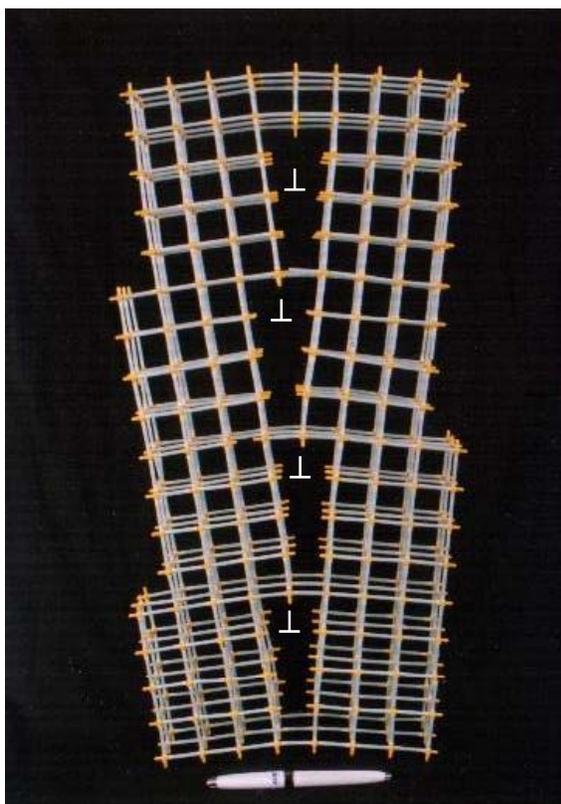$$\frac{b}{2d} = \sin\frac{\theta}{2}.$$

Fig. 8. A model of a symmetric tilt boundary. The dislocations are approximately located at the symbols ⊥. The symmetric tilt boundary is the vertical plane passing through these locations. (477 atoms, 55 cm × 30 cm × 8 cm)

CONCLUSIONS

It is expected that these models will help students understand difficult concepts related to dislocations. Nowadays there are several teaching aids based on interactive computer graphics available on CD-ROMs and the Web[4].

In our opinion, solid three-dimensional models often offer better visualization than computer graphics. The models presented here have been tested in an introductory course on materials science for undergraduate engineering students. The response of the students have been favourable and enthusiastic.

Another teaching idea can be to give students atoms and bonds and let them construct the models for themselves. This will probably lead to better understanding than simply observing the models constructed by someone else. In fact, all the models presented here has been constructed by the students, although not in classroom but outside it.

Only five models are discussed here. Other models can also be made. For example, like the symmetric tilt boundary consisting of parallel edge dislocations shown here, model for a twist boundary comprising of parallel screw dislocations can also be made. Similarly, a dislocation loop which is not prismatic and hence changes its character along the loop can also be constructed.

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