complete analysis. Good quantitative agreement between calculated and observed waveforms was achieved. The dislocation density was calculated on the basis of a model in which they were nucleated in numbers increasing linearly with the maximum stress in the precursor and expanded as circular loops with velocity given by Gilman's relation. Calculations based on regenerative multiplication of dislocations could not be brought into agreement with observation using credible values for the initial density of mobile dislocations, thus adding additional support to the earlier inferences that heterogeneous nucleation was occurring.

In a series of experiments mentioned previously, Pope and Stevens [73P1] and Pope and Johnson [75P1] impacted beryllium monocrystals on planes cut at varying angles to the c axis to produce coupled longitudinal and transverse plastic waves. The theory of such waves has been developed by Johnson [72J1, 74J1] and Luzin [75L1]. Application of Johnson's theory to the problem of plane wave propagation in rotated c-cut beryllium crystals indicates that a plastic disturbance comprising two waves can be expected. As with the purely elastic case, the faster of these waves is primarily longitudinal while the slower is primarily transverse. Some of the general features of the theoretical predictions are present in the observations but the differences are pronounced enough to suggest that some deformation mechanism besides dislocation motion was operative. They have suggested that this mechanism may have been twinning, but have not examined this issue directly.

Kim and Clifton [79K1] have recently conducted an investigation of aluminum alloy 6061-T6 in which combined longitudinal and transverse waves were produced by inclined impact and measured by interferometric means. These preliminary results are most encouraging in that they demonstrate both the feasibility of the experiment and the sensitivity with which it can probe shear phenomena.

Twinning. In the case of iron, Johnson and Rohde [71J2] were led to consider the influence of twinning on observed compression waveforms. The motivation for this was provided, in part, by the fact that twins were known to form in this material when it was subjected to shock compression and, in part, by difficulty in explaining measured wave profiles on the basis of dislocation mechanics alone. A theory of twinning deformation analogous to that used for slip was constructed and specific formulae for the growth rate of the twins were postulated. With a suitable choice of parameters, calculated waveforms were in good agreement with observations. Experimental evidence indicated that twins were formed at a critical resolved shear stress of 0.075 GPa and grew at a rate depending on the excess of the applied stress over this threshold. The shear stress was limited in magnitude to 0.3 GPa by the onset of dislocation motion.

Christman et al. [72C3] have observed twinning in α-titanium (hcp) samples recovered after shock compression to 4.0 and 12.5 GPa, but no attempt was made to explain the observed wave profiles on the basis of a theory incorporating microscopic deformation models.

It is unfortunate that, in spite of the success of the early work of Johnson and Rohde, there seems to have been no further attempt to incorporate twinning into theories of wave profiles arising from shock compression. There is reason to believe that twinning is an important dynamic deformation mechanism that must be included in any realistic model of materials in which it occurs. Resolution of questions concerning yield mechanisms would be facilitated by examination of samples carefully recovered from shock experiments (see section 3.6).

The research on plastic wave propagation that has been reviewed seems to support the hypothesis that, for many materials, yielding and plastic flow arise as consequences of the motion of dislocations. The considerations leading to the representation (3.9) of the material behavior have been quite elementary, involving only the most loosely defined average microscopic behavior of the dislocations. Observations of collective motion of dislocations producing heterogeneous deformation fields are common (see sections 3.4 and 3.6). Such deformations are associated with correspondingly nonuniform temperature fields and the coupling between this heating and the deformation process itself opens the way for the occurrence of deformation processes quite different from those that have been discussed.

From the continuum-mechanical viewpoint, the equations derived on the basis of the microscopic models must be regarded as extremely successful. Continuum theories of plasticity have been a subject of active research for many years. Results of practical utility have been obtained, but no truly satisfying theory has emerged. In recent years research into the microscopic aspects of deformation has spawned a number of dynamic theories of plasticity which, while still evolving, show the way to progress in this area. Specific applications of this work to the problem at hand have been discussed by Clifton [74C1] and Davison et al. [77D1].

3.3.5. Strength and rigidity of shock-compressed solids

The introduction of waves of either compression or decompression into material already in a shock-compressed state permits evaluation of the properties of this compressed material. Al'tshuler et al. [60A2] and, more recently, Holt and Grover [71H4], and others have shown how knowledge of the elastic moduli of a compressed substance can be exploited in determining its equation of state. Studies of variations in the shear strength of a solid, as conducted, for example, by Dremin and Kanel' [76D3] and Lipkin and Asay [77L2, 78A5] are also of interest and knowledge of these values is necessary for assessing the validity of the hydrodynamic approximation, for solving the practical problem of attenuation of stress pulses and for interpretation of spall studies and recovery observations.

The earliest experimental investigation of elastic-plastic decompression from high pressures was conducted by Al'tshuler et al. [60A2] and continuations of this work have been reported by Novikov and Sinitsyna [70N1] and Al'tshuler et al. [71A3]. In this latest work it is reported that iron is able to sustain a shear stress of about 0.5 GPa at a pressure of 111 GPa, and this value increases to about 1.4 GPa at a pressure of 185 GPa (iron is in the ε phase at these pressures). The corresponding value for copper is about 0.8 GPa at a pressure of 122 GPa. Interpretation of the observations for iron is complicated by the occurrence of the $\alpha \rightarrow \varepsilon$ phase transformation and Simonov and Chekin [75S1] have recently reevaluated the data in light of this complication and have arrived at even larger values for the yield strength. The data for copper are not subject to this uncertainty and also exhibit a large (over fivefold) increase in shear strength over its low-pressure value. Al'tshuler et al. have also evaluated the increase in the elastic moduli of copper as it is compressed.

Both the elastic moduli and shear strength observed in material that has been compressed by a strong shock reflect the effects of an increase due to the compression and a decrease due to the associated heating. When the material is shock compressed into the melt region its properties will, of course, be those of a fluid and both the shear strength and the shear modulus will vanish. These effects are discussed by Al'tshuler et al. [71A3] and are quite apparent in the work of McMillan et al. [71M1] and Asay and Hayes [75A3]. As pointed out by the latter investigators, observation of a loss of rigidity may be the only way of accurately determining the point at which shock-induced melting occurs.

Other investigations include early work by Curran [63C1] who observed a very strong elastic