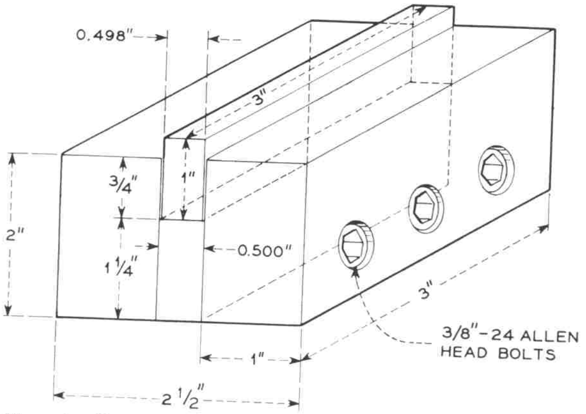

FIG. 3. Compression device for approximating plane strain deformation.

equally applicable in the present case of plane strain compression.

Table 2 indicates that the M values vary by as much as a factor or two. Hence, the theoretical results may be readily tested.

EXPERIMENTAL

A special compression die, somewhat similar to that described by Wever and Schmid,(9) was constructed for quantitative testing of the theory. As illustrated in Fig. 3, the die consists of a hardened steel plunger fitted in the slot of a three-piece assembly, which is secured by bolts to facilitate specimen removal after the test. The specimen, carefully machined to the slot width, is placed between the plunger and the platen. The ensemble is then attached to a Baldwin hydraulic testing machine for compression testing.

This test setup has several advantages in controlling the deformation process. First, the fixed slot width insures negligible lateral spread of the crystal during compression. Secondly, the present setup permits highly accurate orientation alignment even for very small crystals. Finally, this method allows a continuous recording of load versus deflection, an important feature for quantitative stress comparisons. In the present setup, however, there is no constraint on $d\varepsilon_{yz}$ and $d\varepsilon_{zx}$.

The single crystal specimens with orientations listed in Table 2 were machined from large grains which were solidified slowly from the melt. Two fine grained (dia. ~0.04 mm) polycrystalline samples were also tested. Orientation of the single crystals was controlled to about one degree in the finished crystals. Typical dimensions are 0.4 in. long by 0.5 in. wide 0.1 in. thick. After machining, the specimens were etched in *aqua-regia* and then electropolished in a solution of CrO_3 and H_3PO_4 to allow slip line observations as well as to reduce friction. Teflon strips 5 mils thick were used as lubricant. Breakdown of these strips (usually in the periphery region in the elongation direction) occurred between twenty and forty per cent thickness reduction depending on the flow characteristics of the sample. Loading rate was equivalent to about 0·01 in/min.

RESULTS AND DISCUSSION

Figure 4 shows typical curves of true compression stress (load divided by instantaneous area) versus true strain (log [initial height/instantaneous height]). The break in the curves is due to temporary unloading to insert new teflon strips. The lower flow stress upon reloading is the result of reduced friction. There is little doubt that the stress measurements were complicated by friction, see Appendix II. However, the friction ought not to vary widely from crystal to crystal. Unloading curves such as those in Fig. 4 indicate that the extra friction stress (above that of a freshly lubricated surface) amounts to about 20%, mainly as a result of some teflon breakdown. Finally, the stress levels reached in the present study are comparable to those under tension (where friction is absent) of a 78% Ni–22% Fe alloy as studied by Vidoz *et al.*(10)

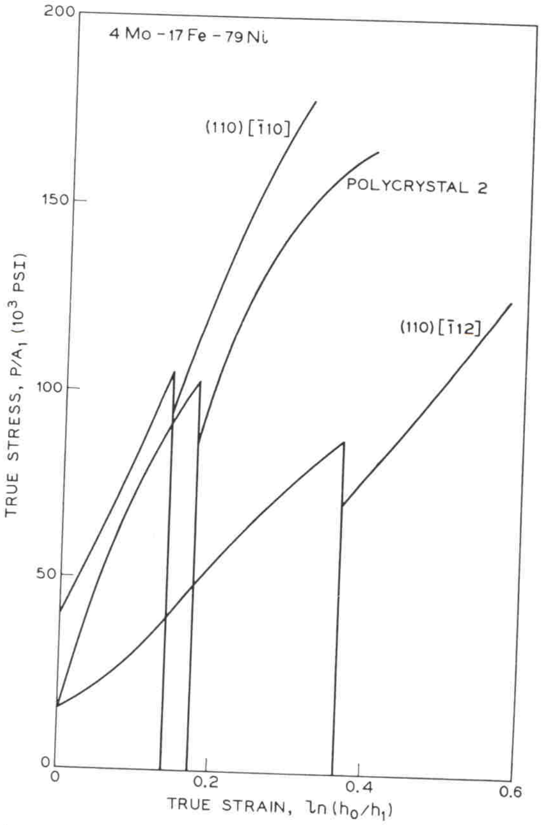

FIG. 4. True compression stress–true thickness strain curves for three samples. 4–79 Mo-Permalloy. Break in curves due to unloading to renew teflon lubricant.

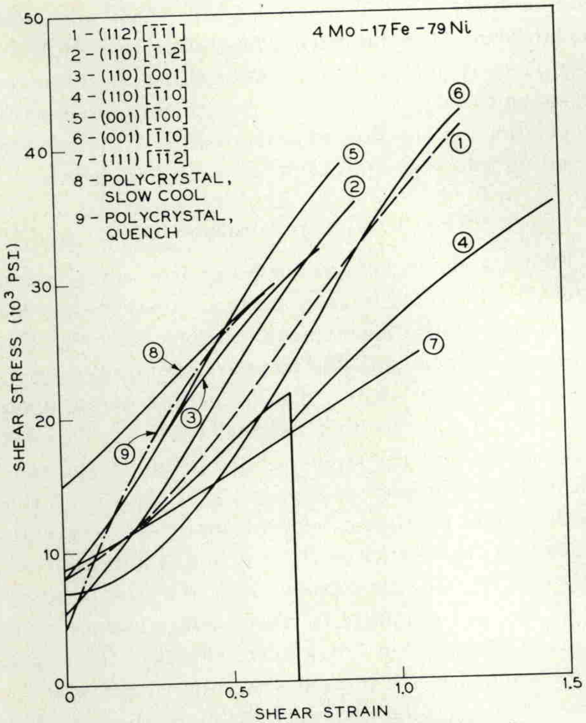

FIG. 5. Resolved shear stress–resolved shear strain curves of all samples tested. 4–79 Mo-Permalloy.

Thus, the relative stress levels among samples, for a given moderate reduction, are thought to reflect mainly the orientation difference as analyzed.

It may be observed in Fig. 4 that the strength of the $(110)[\bar{1}10]$ crystal exceeds that of the $(110)[\bar{1}12]$ crystal by a factor of about 2. This is in qualitative agreement with their difference in M values. For a more quantitative comparison, all curves should be plotted on a resolved shear stress (τ)–resolved shear strain (γ) basis. This is shown in Fig. 5 for all samples, with calculations based on the formulas $\tau = \sigma/M$, $\gamma = M\varepsilon$. If the Bishop and Hill theory is correct, all curves should fall into one.

The majority of the curves do not in fact fall into a band with maximum deviation of ± 20 % from the average. This scatter is within the range of expectations when frictional variation and other inherent errors are considered. Some remarks, however, may be made with several of the samples. First, at large strains crystals 4 and 7 seem to harden less than the average. Examination of crystal 4, which is a $(110)[\bar{1}10]$ orientation, reveals the presence of large deformation bands, Fig. 6. This deviation from homogeneous deformation is expected to result in softening, effectively lowering the M value.$^{(6)}$ On the other hand, for this orientation in aluminum, Hosford$^{(7)}$ has found only slight asterism in the Laue spots. In addition, the τ–γ curve does not deviate from those of the other orientations. Such observations suggest that deformation banding may be absent in aluminum of the $(110)[\bar{1}10]$ orientation. Accordingly, we deformed such a crystal in our apparatus. As Fig. 7 shows, deformation banding was indeed absent. Except for a few long slip lines which appeared very early in the test, only a clothlike mixture of fine slip was found distributed uniformly throughout the surface.

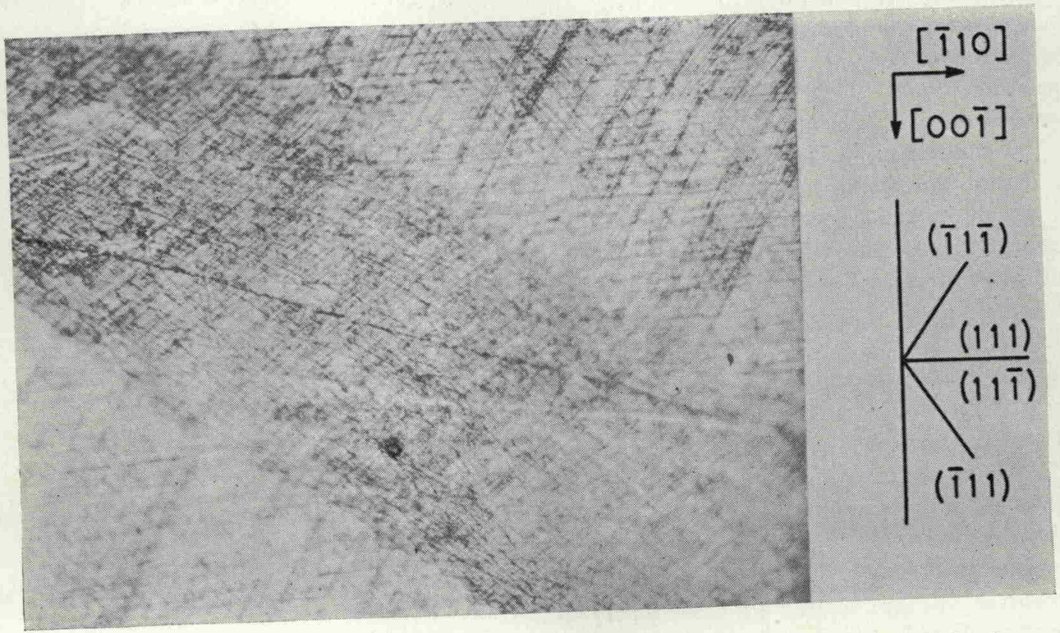

FIG. 6. Slip traces on top surface of $(110)[\bar{1}10]$ Permalloy crystal after 21.7 % thickness reduction, showing presence of deformation bands. The $[\bar{1}10]$ direction is nearly horizontal. Slip plane traces are noted in margin. × 280