4.1.1. *Dislocation nucleation*

The observations of the pressure-induced dislocations at 40 kilobars in tungsten at the particle/matrix interface regions is surprising in that the values of maximum shear stress $\tau_{\max}$ attainable in both the cases of thoria and hafnium carbide particles, $G/225$ and $G/325$, respectively, are still much below the nucleation stress for dislocation generation. In view of the discrepancy between the stress at which dislocations are observed experimentally and the theoretically predicted magnitude of the stress to nucleate dislocations (Cottrell 1964), the assumption made in the present calculations that the particle is spherical with a smooth surface requires further examination. Real particles would be expected to exhibit sharp steps at their interfaces and are seldom truly spherical. Hence, the stresses in the region containing a sharp step or angularity could be increased in such a way that these areas would become preferred sites for dislocation nucleation.

In the case of a small indentor (10^{-4} cm diameter) on a free surface (Friedel 1963)—e.g. silicon carbide particles dropped onto a crystal surface—a contact pressure of $10^{-3}\,G$ is sufficient to punch in dislocation loops. This observation can be explained only if it is assumed that the indentor possesses atomistically sharp steps. The appropriate stress concentration of $2(D/2b)^{1/2}$ (where D is the particle diameter and b is the Burgers vector of the dislocation) corresponds to a stress concentration factor of about 100 for a 1 micron particle and the stress at the edge of such an indentor becomes of the order of $10^{-1}\,G$, as required for dislocation generation. From the calculated magnitude of the shear-stresses induced by differential compression, as shown in table 2, it is apparent that the experimentally observed dislocations could be explained if irregularities in the shapes of the particles or sharp steps on their surfaces acted as stress raisers.

The generation of dislocations on pressurization could also be influenced by the existence of residual stresses around the interface of the inclusion and matrix, such as frequently arise from differential thermal contraction effects during cooling from the annealing temperature. The recent literature contains a number of observations (Leslie 1961, Patel 1962, Kayano 1967 a, b) of particles under applied shear stress acting as dislocation sources; particularly good examples of punched-in dislocations are those formed around FeO particles in iron deformed 2% in tension reported by Kayano, who concluded that residual stresses around the inclusion resulting from cooling must assist dislocation generation during subsequent tensile deformation. Thus, in systems in which thermal stresses of appropriate sign are induced, the existence of residual stresses should similarly assist the generation of dislocations during pressurization and consequently influence the magnitude of the critical pressure observed.

The development of pressure-induced dislocations around thoria or hafnium carbide particles in tungsten (as also for helium bubbles in copper, which will be discussed in detail later) is noticeably dependent on the size