MEAN-DIAMETER THEORY

An elementary way of estimating the creep strain occurring in a thick-walled cylinder is to treat it as being thin-walled and to calculate the equivalent shear stress at the mean diameter. This is essentially the same approach as that of Soderberg [5], except that he considered only steady-state or secondary creep and used tension creep data.

The shear stress in a thin-walled cylinder is given by

$$\tau = \frac{p(a+b)}{4(b-a)} = \frac{p}{4}\left(\frac{K+1}{K-1}\right) \tag{12}$$

The shear strain γ in a thin cylinder is half the circumferential strain, and thus, if a single torsion creep test is run at a shear stress given by Eq. (12), the circumferential creep strain at the mean diameter of a thick-walled cylinder will be given approximately by

$$\epsilon_{\theta_m} = \gamma/2 \tag{13}$$

Assuming constancy of volume and zero axial creep, the strain at the outside surface is, therefore,

$$\epsilon_{\theta_b} = \frac{\epsilon_{\theta_m}}{\left(1+\frac{b-a}{a+b}\right)^2} = \frac{\epsilon_{\theta_m}(K+1)^2}{4} \tag{14}$$

Clearly, this theory is a gross oversimplification of the problem. However, Coffin et al. [6] have shown that there is a radius in the cylinder wall where the effective stress or the second stress invariant J_2 remains sensibly constant, and this has been proposed independently by Marriott and Leckie [7]. Consequently, a single creep test such as this effective stress should be adequate to predict the creep of a thick-walled vessel. The mean-diameter formula might consequently be expected to give results of the right order of magnitude; if so, it could provide a simple rule for the use of designers.

STRAIN-HARDENING METHOD ALLOWING FOR EFFECT OF WALL THINNING ON CREEP OF THICK-WALLED CYLINDER

The theories examined earlier have ignored the effect of wall thinning on the creep behavior of a thick-walled cylinder. For bore strains as small as 1 percent in a cylinder of diameter ratio 2, this effect can be considerable. In this section the simple Bailey theory is adapted, using a strain-hardening method to allow for these changes in dimensions.

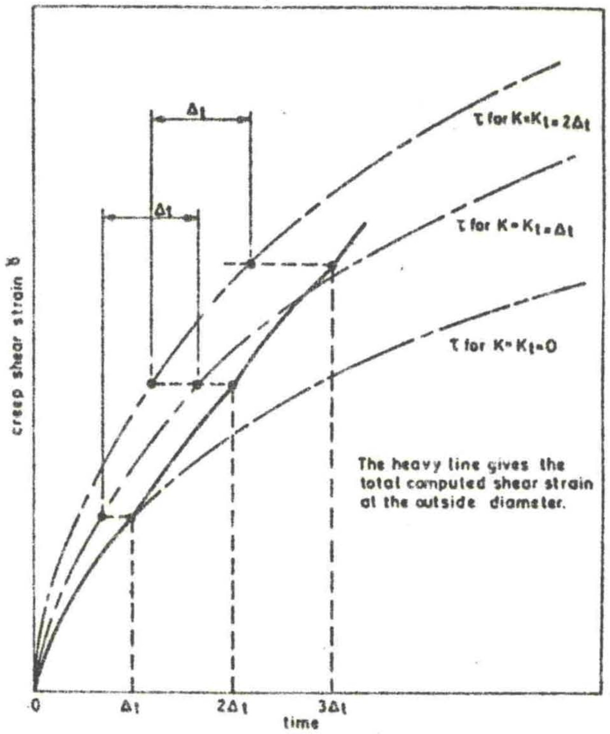

FIG. 2 EXAGGERATED DIAGRAM TO ILLUSTRATE STRAIN-HARDENING METHOD USED TO PREDICT CREEP OF THICK-WALLED CYLINDER

Considering a cylinder with diameter ratio $K' = (b'/a')$, the shear stress at the outer surface is from Eq. (9)

$$\tau = \frac{p}{n\left[(K')^{2/n} - 1\right]} \tag{15}$$

where the dash refers to current dimensions as opposed to original dimensions. Clearly, as the cylinder expands due to creep, because the bore material is strained very much more than the material at the outside surface, the diameter ratio will be gradually reduced. Equation (15), therefore, predicts a continual increase of shear stress at the outer diameter. The technique employed to deal with this varying stress is to consider it as remaining constant for small intervals of time and then increasing stepwise to a new value at the end of each interval. Reference to Fig. 2 will explain the procedure used to predict the creep strain occurring in the cylinder.