Theory of a Thermal Fluxmeter in a Shear Flow

ZEVTZ ROTEM. The author of this paper has presented an elegant theory for the prediction of behavior of thin film fluxmeters. Comment on the following points would be valuable. The assumption of a steady viscous sublayer has recently been criticized, c.f. [13]. Thus the author's theory may well predict a time-average behavior. Clearly, more experimental evidence is required to settle this point.

One may argue with the author's statement that the effect of variable shear stress in the sublayer will always be a reduction in the rate of heat transfer.

Supplementary Reference


Author's Closure

The author thanks Professor Rotem for his comments. It is clear that the analysis is restricted to a steady sublayer and unsteadiness (or, more seriously, vortical type secondary flows) will need extra consideration. With regard to his second point, one has to restrict the statement on variable shear stress to the usual case of reducing stress as y increases. Finally, Professor Rotem has noted that in the definition of $Nu$ for a wide strip in equation (1) $Nu = \Phi - \Phi_0/K_s T^*$, $\Phi$ and $\Phi_0$ are rates per unit width. Elsewhere $\Phi, \Phi_0$ are total rates. He also pointed out the misprints in the final square root of equation (5) which should read $\sqrt{K_s/K_s}$; also on p. 804, line 4, read $b/t$ for $t/b$.

References


Analysis of the Propagation of Plane Elastic-Plastic Waves at Finite Strain

C. W. BERT and B. E. CUMMINGS. The problem of the development of an adequate mathematical description of the behavior of materials subject to shock waves in the regime where material strength effects are significant is of considerable current interest and importance. However, it is an exceedingly complicated problem due to coupled thermal and mechanical effects. The authors are to be commended for the development of what appears to be a very practical engineering theory appropriate to this problem. It is hoped that, in the future, they will apply their theory to shock waves in specific materials and compare their results with experimentally determined quantities.

The results of experiments at finite strain conducted by Dillon [1] suggest that shear strains can be induced by large temperature changes. This requires, in the free-energy expansion, the use of higher degree terms in the product of the strain invariants and the temperature, as carried out by Dillon [1].

It is interesting to note that the approach used by the present authors does not involve separation of the deformation variables into nondissipative and dissipative types as does the work of Dillon [2]. However, the net results are similar, except that Dillon assumed that all of the plastic work is dissipated in the form of heat, i.e., he neglected the internal energy storage due to lattice distortion.

Another effect, which can be quite significant in the high-stress range involved in this problem, is the effect of stress $\sigma$ upon the thermal expansion coefficient $b_1$, as first reported by Rosenfield and Averbach [3]. Their simple analysis indicated that for uniaxial stresses in the elastic range,

$$\frac{db_1}{d\sigma} = -E \frac{dE}{dT}$$

where $E$ is Young's modulus and $T$ is temperature.

As would be expected, Rosenfield and Averbach found that when the stress was removed, there was no permanent change in $b_1$ when the applied stress was below the elastic limit. However, when the applied stress exceeded the elastic limit, a permanent change in $b_1$ was observed. This is undoubtedly related to the fraction $(1 - \gamma) b_1$ of the plastic work which causes permanent distortion of the crystal lattice (Ref. [2] of original paper). However, this permanent change in $b_1$ increases steeply at first, then levels off, and finally decreases with increasing stress (or strain) [3]. This suggests a third-degree polynomial expression for $b_1$ and for $(1 - \gamma)$ in the plastic range.

Authors' Closure

We wish to thank the discussers for their pertinent comments. It seems to us that the experiment cited by Dillon (reference [1] of the Discussion) must have involved appreciable plastic flow, and that this, rather than higher terms in the free energy expansion, is responsible for the temperature increase. It seems to us unlikely that in torsion appreciable plastic nonlinearity would arise below the elastic limit. However, of course, the present theory could include higher terms in the elastic-free energy expansion. The consideration of elastic and plastic strain components in the paper under discussion constitutes effectively a breakdown into nondissipative and dissipative strain. Because of the measurements by Farren and Taylor cited in the original paper, the work associated with plastic