SYMPOSIA ON IRREVERSIBILITY AND TRANSFER OF PHYSICAL CHARACTERISTICS IN A CONTINUUM

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THE treatment of modern problems like elastic-plastic deformation, creep, fatigue, turbulence, random and multiple component medii involve irreversibility and thermodynamic effects. They have wide applications in all branches of science and technology. This year, the International Union of Theoretical and Applied Mechanics, therefore, sponsored two Symposia on these subjects. They were held in Vienna at the Technical Museum from June 22nd to 29th, 1966. 28 papers were presented. Those who took part in it included: (1) L. I. Sedov (Moscow); (2) C. Truesdell (Baltimore); (3) B. R. Seth (Kharagpur); (4) D. C. Drucker (Providence); (5) A. M. Freudenthal (New York); (6) S. Kaliski (Warszawa); (7) E. H. Lee (Stanford); (8) J. Meixner (Aachen); (9) P. M. Naghdi (Berkeley); (10) W. Nowacki (Warszawa); (11) W. Olszak (Warszawa); (12) W. Prager (La Jolla); (13) M. Reiner (Haifa); (14) Yu. N. Rabotmov (Moscow); (15) R. S. Rivlin (Providence); (16) Yu. P. Lunken (U.S.S.R.); (17) F. N. Frenkiel (U.S.A.); (18) V. N. Nikoleski (U.S.S.R.); (19) B. D. Coleman (Pittsburgh); (20) G. K. Batchelor (Cambridge); (21) M. J. Lighthill (London).

The first symposium on "Irreversible Aspects in Continuum Mechanics" opened with a paper by L. I. Sedov and the second on "Transfer of Physical Characteristics in Moving Fluids" with a paper by B. R. Seth.

L. I. Sedov stressed the need of using generalised variational methods for construction of new models of complicated physio-chemical nature, having finite degrees of freedom. He formulated the basic equation in the form

$$\delta\int L d\tau - \delta W + \delta W^{+} = 0,$$

where $d\tau$ is the element of arbitrary four-dimensional space-time "volume" V bounded by the three-dimensional surface Σ; $L(q_i \nabla_j q_i)$, a generalized Lagrangian function. The variable q_i and their corresponding gradients $\nabla_j q_i$ form a system of determining parameters.

Then we have

$$\delta W^{+} = \int_V Q^i \delta q_i d\tau + \int_\Sigma Q_j{}^i \delta q_i \eta^i d\sigma,$$

and

$$\delta W = \int_\Sigma p_j{}^i \delta q_i \eta^i d\sigma,$$

where η^i are components of the unit vector of the external normal to Σ and $d\sigma$ is an element of the surface Σ.

In most of the other papers, participants discussed particular models bringing into prominence the thermodynamic effects. It was pointed out that Onsager's relations, which hold good only for small deviation from the equilibrium position could not be used in problems like elastic-plastic deformation and creep. It was also stressed that they could not be used in non-linear problems. H. Zieglier gave a recast of these relations by establishing a criterion for the choice of fluxes or forces, and by replacing them by a physically significant maximum principle applicable to non-linear cases.

C. Truesdell showed that the classical thermodynamic theory can be presented in a simple explicit form based on the two axioms of

(1) the balance of energy;

(2) the Clausius-Planck inequality.

Thermodynamic materials can then be defined by constitutive equations, and all classical problems can be readily solved.

B. D. Coleman and M. E. Gurtin showed that one-dimensional wave propagation in non-linear thermodynamic materials with memory, like shock-waves, can be readily treated by generalizing the theories of Hugonoit and Duhem. S. Kaliski showed how generalized Onsager's relations could be used for interaction fields like Cerenkov generation of thermo-waves and thermo-electro-magneto-elasticity, while W. Olzack used the theory of simple materials to discuss medii of a dfferential type.

The first and second laws of thermodynamics figured prominently in the discussions and generated a lot of heat. A number of participants thought that they should be suitably modified for continuum problems. R. S. Rivlin showed how the thermo-mechanical field equations may be obtained from these laws by making some specific assumptions regarding the invariance of generalised co-ordinates under rigid motions.

In a non-equilibrium continuum J. Meixner made out that the concept of entropy should be discarded while J. Kestin showed that in strained solid materials some independent thermodynamic parameters must be identified.

For finite plastic deformations, E.T. Onat also found that state variables are necessary. J. F. Besseling wanted that a distinction be made between thermodynamical systems and those dealing with boundary value problems. He showed that a continuum theory of deformation and flow can be based on the principle of conservation of mass, the two laws of thermodynamics, the concepts of a local thermodynamic state and a local geometric natural reference state, a principle of determinism and on a postulate concerning the production of entropy.

Thermodynamical effects and irreversibility in elastic-plastic problems, creep and rupture were discussed by W. Prager, E. H. Lee, P. M. Naghdi, G. S. Shapiro, B. R. Seth, Ju. N. Rabotnov, Jan Hult, M. Reiner and others. B. R. Seth showed that, contrary to current concepts conditions of state and jump conditions could be obtained from the field equations by treating them as asymptotic solutions at the transition points of the differential system defining the field. He showed how jump conditions for shock waves, yield conditions for elastic-plastic deformation and creep conditions like those of Norton's law could be obtained.

W. Nowacki extended the coupled-stresses theory of thermo-elasticity to that of a homogeneous Cosserat's medium and obtained a generalization of the Galerkin method for the corresponding dynamical system. An accumulating second order effect on strain-hardening aluminum specimens in reversed torsion was pointed out by A. M. Freudenthal and M. Ronay. This should be treated as a transition phenomenon and not explained by a particular type of constitutive equation. M. J. Lighthill discussed the interesting example of a Cosserat's fluid medium having a gas bubble.

The Proceedings of the Symposia will be published by SPRINGER-VERLAG under the Editorial Chairmanship of Prof. Dr. Heinz Parkus of Vienna.

RADIAL PARTICLE PROFILE IN NEGATIVE GLOW NEON PLASMA

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IN a steady-state plasma, where the losses of charge carriers are governed mainly by the diffusion processes, the general particle balance equation can be put as:

$$D_a \nabla^2 n_e + \nu_i n_e = o \tag{1}$$

where D_a = coefficient of ambipolar diffusion; ν_i = rate of collisional ionization referred to an average plasma electron, and n_e = plasma electron density. Here it is assumed that the dominant process of secondary ionization in the plasma volume is due to electron collisions and is therefore dependent on the density n_e. The solution of (1) for the case of a cylindrical plasma, considering only the radial boundary conditions, was shown by Schottky[1] to give a distribution represented by a Bessel function.

$$n_r = n_0 J_0 (br) \tag{2}$$

where $b = (\nu_i/D_a)^{\frac{1}{2}}$ and n_0 = particle density along the tube axis. Schottky's theory was given for the positive column part of the plasma where the motions of the charge carriers are sufficiently randomized. The negative glow plasma in a highly abnormal discharge is mainly generated by an approximately monoenergetic beam of electrons arriving from the cathode fall region. If the energy of the incoming electrons is very high compared with the average energy lost in an ionizing collision, the secondary ionization rate in the negative glow space becomes uniform and independent of the particle density n_e. Such a situation, as pointed out by Persson,[2] leads to a well-behaved laboratory plasma. For a uniform electron beam with energy enough to make the reaching distance[2] $L >> R$ (R = radius of container) and to cause ionization at a constant rate along its length, the charge carriers so produced are lost either by ambipolar diffusion or by volume recombination. Persson[2] has shown that the radial particle profile for the diffusion limited case (neglecting recombination) is parabolic in form.

We have observed the radial density profile in Neon ($p = 260\,\mu$; $i_{dc} = 4 \cdot 5$ mA; $V_{dc} = 1160$ V) by the double-probe method,[3] when both the probes were in the negative glow plasma; the plasma was generated in a cylindrical discharge tube (Pyrex, radius $R = 1 \cdot 3$ cm.). The exploring probe was moved radially from the geometrical position of the wall to the axis of the tube by a micrometer screw movement.