TABLE III

Variable	Percentage error
Diameter	0.3
Length	0.5
Torque	1.0
Angular rotation (for modulus)	1.3
Angular rotation to failure	1.0
Weight of fibre or composite	1
Density of fibre or composite	1

TABLE IV

Property	Maximum percentage error
Shear modulus	4.0
Shear strength	1.9
Shear strain at failure	1.8
Volume loading	3.0

material property. In particular, note the small percentage error in the shear strain at failure compared with the large coefficient of variation of the measured results.

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Cooling-rate determination in splat-cooling of oxides

The technique of ultra-fast quenching from the melt (splat-cooling) developed by Duwez and co-workers about fifteen years ago has raised much interest in materials science research as shown by the large volume of work carried out in this field and reported in two exhaustive reviews [1, 2]. The very high cooling rates available in the splat-cooling technique (10^5 to $10^{8\circ}$ C sec^{-1}) made possible the preparation of new metastable cristalline and non-cristalline phases, providing a whole range of materials of unknown properties.

The quenching rates attainable by splat-cooling have been determined experimentally by three main methods. The first, due to Predecki *et al.* [3], consists of propelling a molten metallic sample by the "gun" technique on a substrate on which two dissimilar metals have been placed. The splat establishes a contact between the two metals and constitutes the hot junction of a thermocouple, the e.m.f. of which is recorded on an oscilloscope. A second method, due to Matyja *et al.* [4], is based on the study of the microstructure of a rapidly cooled alloy and uses the relationship between secondary dendrite arm spacing and cooling rate. A power relation between these two factors is established at low rates of solidification and may be used, by extrapolation, at higher cooling rates. The third method, proposed by Burden and Jones [5], is based on a method similar to the previous one, but takes into account the $\lambda^n R$ = constant correlation between the interlamellar spacing, λ, of an eutectic structure and its growth rate, R.

These methods have given rise to much controversy [6–9] in which we do not intend to participate here. We shall only consider that the proposed methods give only estimates for the cooling rates rather than precise measurements.

Splat-cooling has been so far almost exclusively applied to metallic systems except for some incursions in the field of oxides by Sarjeant and Roy [10–12]. The method has recently attracted more ceramists [13–17] and it seemed interesting to investigate what cooling rates are achieved during splat-cooling of oxides in comparison with metals and alloys.

The method of Burden and Jones [5] was considered. Experiments were carried out with the system NiO–CaO at the composition of the eutectic point (58% mol NiO). The melting point of mixtures of this composition is about 1720° C [18].

The splat-cooling device used in this study is of

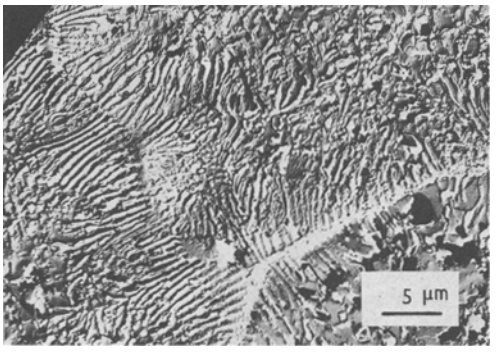

Figure 1 Electron micrograph replica of splat-cooled NiO–CaO eutectic (58 mol % NiO).

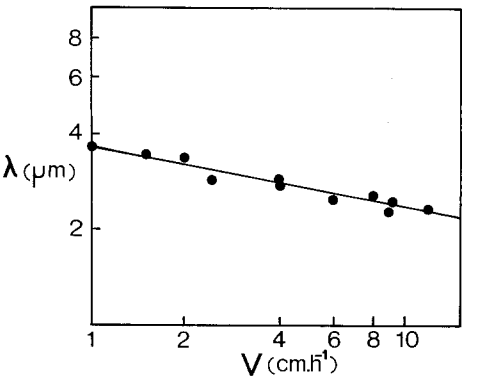

Figure 2 Variation of the interlamellar spacing, d, of the NiO–CaO eutectic (58 mol % NiO) as a function of the growth rate.

the "hammer and anvil" type. It consists of a metallic piston propelled at a high velocity against a water-cooled substrate on which the sample of eutectic composition is melted by concentration of solar energy [14]. The liquid is squeezed between the two metallic bodies into a thin foil, the edges of which break into very thin flakes of thickness 10 to 50 μm. Plastic-carbon replicas of the surface of the foils were made for electron microscopic observation. Replicas of the flake cross-sections were impossible to prepare because of the size and fragility of the samples. Fig. 1 is a replica showing the lamellar morphology of the eutectic structure.

Fig. 2 is a plot of log λ versus log R established for the NiO–CaO eutectic in the course of a unidirectional growth study [18]. It should be pointed out that the $\lambda^5 R$ = constant correlation found for this sytem is quite different from that established by Jackson and Hunt [19] and generally accepted for the solidification of eutectics. The mean interlamellar spacing of 0.65 μm, measured from electron micrographs, yields a value for R of 1.3 cm sec^{-1}. In order to derive the cooling rate, V, from the growth rate, R, of the eutectic structure if we assume that Newtonian rather than ideal cooling conditions apply [3], a heat-transfer coefficient h has to be considered. According to Predecki *et al.* [3] the cooling rate V may then be expressed by

$$V = \frac{h(T_F - T_S)}{\rho \cdot C_p \cdot d} \qquad (1)$$

with

$$h = \frac{\rho \cdot L_F \cdot R}{T_F - T_S} \quad , \qquad (2)$$

expressions in which T_F is the temperature of solidification (temperature of the eutectic), T_S the substrate temperature, ρ the density, C_P the specific heat of the splatted material, d the splat thickness, and L_F the latent heat of fusion of the eutectic.

Combination of Equations 1 and 2 yields

$$V = \frac{L_F \cdot R}{C_p \cdot d} . \qquad (3)$$

If the following values are taken for the eutectic composition: $L_F = 0.956 \times 10^6$ J kg^{-1} (derived from $L_{F_{CaO}} = 18$ kcal mol^{-1} [20] and $L_{F_{NiO}} = 12.1$ kcal mol^{-1} [20] and considering the relative proportions of NiO and CaO in the eutectic), $C_p = 961$ J kg^{-1} °C^{-1} (derived from $C_{P_{CaO}} = 0.25$ cal g^{-1} ° C^{-1} [21] and $C_{P_{NiO}} = 0.2$ cal g^{-1} ° C^{-1} [20] and $d = 50$ μm as a mean value, Equation 3 leads to $V = 2.6 \times 10^5$ ° C sec^{-1}.

This estimate is of the same order of magnitude as the cooling rates achieved with metals in hammer and anvil devices [1, 2] and indicates that the splat-cooling method might find wide application in the field of oxides.

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Stress corrosion cracking of a 6% cobalt/tungsten carbide hard metal

In an experiment to examine the shape of cracks in indented specimens of a tungsten carbide/cobalt hard metal a staining technique was tried [1], and it was found that petal-shaped flakes broke away from the surface around a pyramid identation when a specimen was left exposed to hydrogen fluoride vapour overnight (Fig. 1). The damage around the indentation resembled the flaking and cracking observed in indentation tests on glasses and ceramics where the surface fractures as a result of the propagation of lateral vents generated by tensile stresses during unloading [2, 3]. Under normal conditions flakes do not form during indentation of hard metals, but cracks are found at the corners of indentations (Fig. 2) and these propagate radially during both loading and unloading [4] probably as a result of the growth of median vents initiated

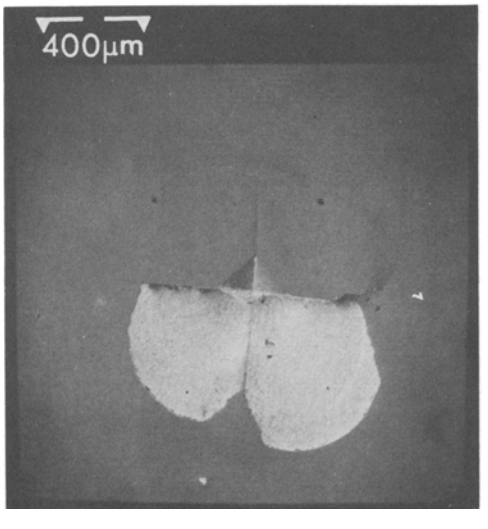

Figure 1 Flakes formed around a pyramid indentation in a 6% Co/WC hard metal, indented with a 981 N load and exposed to HF overnight.

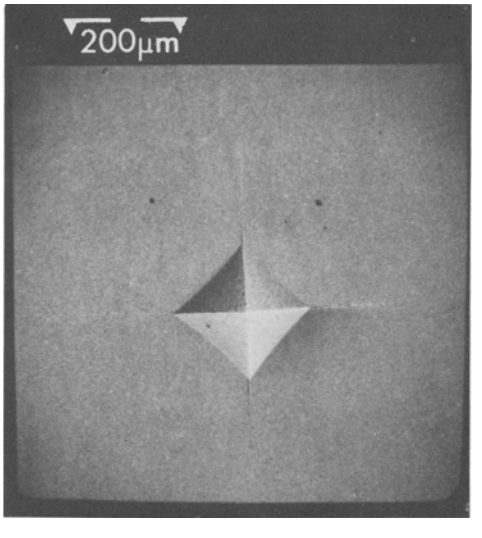

Figure 2 Radial cracks at the corners of a pyramid indentation in a 6% Co/WC hard metal indented with a load of 589 N.