this behaviour ceases and lumps are simply knocked out of the surface [6, 7]. The same kind of transition can occur if there is an increase in chip-tool friction and this is suggested by the movement of a second operating point along the arrow Y: this accords with the evidence that the initiation of cracking and hence the production of discontinuous chips can be delayed by improved lubrication [8], i.e. by the maintenance of low chip-tool friction. Arrow Z suggests a transition from fracture mode to adiabatic shear and this has been observed [9] in tests in which high strength steel specimens were cut at varying speeds. At low cutting rates the chip was discontinuous and ragged, the machined surface rough and uneven and gave every indication of having been produced by some mechanism involving fracture. As the cutting speed was increased so cutting became smoother; the operating point moving in the direction of arrow Z. In excess of a speed of about 200 mm sec^{-1}, examination of the chip showed it to have the strong segmental form characteristic of the cyclical process of adiabatic shearing, and this corresponds to crossing the surface ABCD. In other materials increasing the cutting speed can bring about a transition from plastic to adiabatic shearing shown by arrow W. In low carbon ferrous materials this transition appears not to occur until superfast machining speeds are approached [10], i.e. greater than 3000 m min^{-1}; however, in material exhibiting limited strain-hardening and poor thermal conductivity, e.g. titanium, the onset of adiabatic shear will occur at much lower speeds; Recht [11] suggests as low as 300 mm min^{-1}.

It must be borne in mind that Fig. 2 is essentially diagrammatic having been drawn to illustrate four possible changes in chip formation, and it is for this reason that the axes have not been calibrated. Nevertheless it does suggest the form that such a diagram might take, although in practice other variables such as tool rake angle might be included. From the data on the machining of both metallic and non-metallic materials available in the literature, it should prove possible to assemble diagrams for specific materials, and these could be used both to gauge the effect of specific changes in cutting conditions and to identify those areas of material behaviour on which future work might usefully be focused.

References

1. B. LUNN and J. CHRISTENSEN, *J. Inst. Met.* **98** (1970) 164.
2. R. E. WINTER, *Phil. Mag.* **31** (1975) 766.
3. J. T. BLACK, *Trans. ASME* **93**(B) (1971) 507.
4. W. M. STOBBS, J. KALLEND and J. A. WILLIAMS, *Acta Met.*, to be published.
5. M. F. ASHBY, *ibid* **20** (1972) 887.
6. A. G. ATKINS, *Int. J. Prod. Res.* **12** (1974) 263.
7. A. KOBAYASHI, "Machining of Plastics" (McGraw-Hill, New York, 1967).
8. W. B. PALMER and M. S. M. RIAD, Advances in Machine Tool Design and Research, Proceedings of the 8th International Conference (Pergamon Press, Oxford, 1967) p. 259.
9. J. A. WILLIAMS, Ph.D. Thesis, Cambridge University (1975).
10. H. J. SIEKMANN, *Trans. ASTE* **82** (1958) 271.
11. R. F. RECHT, *J. Appl. Mech.* **31** (1964) 507.

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Comment on "On the background damping in the vicinity of the grain-boundary peak in zinc"

Burdett and Wendler [1] in a recent publication have given some results on the amplitude-dependent damping of zinc. The data were interpreted in terms of a movement of solute atoms from grain boundaries to dislocations and a value of the binding energy between solute and dislocations was obtained by applying the Granato–Lücke [2] theory.

It will be shown that some of the assumptions made by Burdett and Wendler are incorrect and consequently the value given for the binding energy is doubtful. In fact, the data from Figs. 7 to 9 have been plotted as $\log \delta_H$ versus $\log \gamma$ so that each curve can be compared directly with the theoretical expression for torsion [3, 4]. The experimental points and the part of the theoreti-

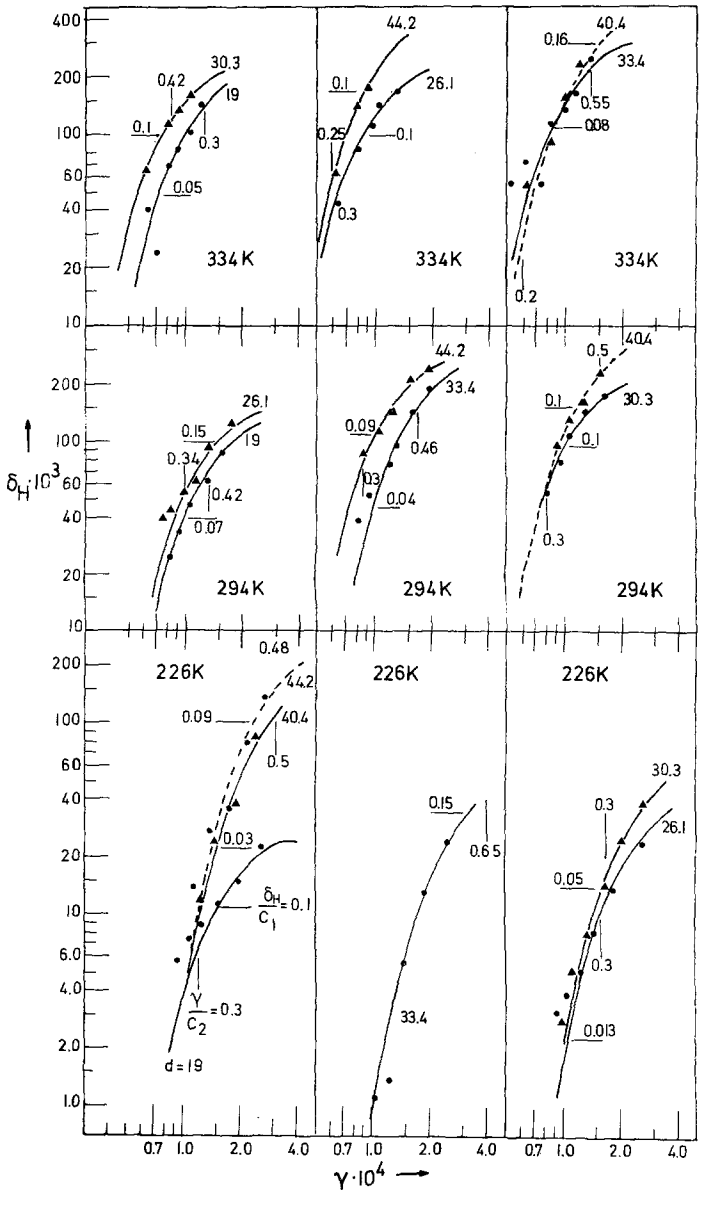

Figure 1 Plot of the data of Figs. 7 to 9 of [1] according to [4].

cal curve where the fitting was made are shown in Fig. 1 for each curve. The corresponding γ/C_2 and δ/C_1 theoretical values chosen to calculate C_1 and C_2 are marked on each curve in the same figure. This way of fitting the experimental data to the Granato–Lücke model is more accurate and less subjective than the usual Granato–Lücke plot since no straight lines have to be drawn through the experimental points. The C_1 and C_2 values obtained from Fig. 1 have been plotted in Fig. 2a and b, at different temperatures, as a function of the grain diameter. It is seen that C_2 (or Y according to [1]) increases with d only at 226 K and remains practically constant at higher temperatures. C_1 (not considered in [1]) increases with the grain diameter at all temperatures. Since $C_2 \sim 1/L_c$ the results of Fig. 2a invalidate the assumption made by Burdett and Wendler that L_c de-

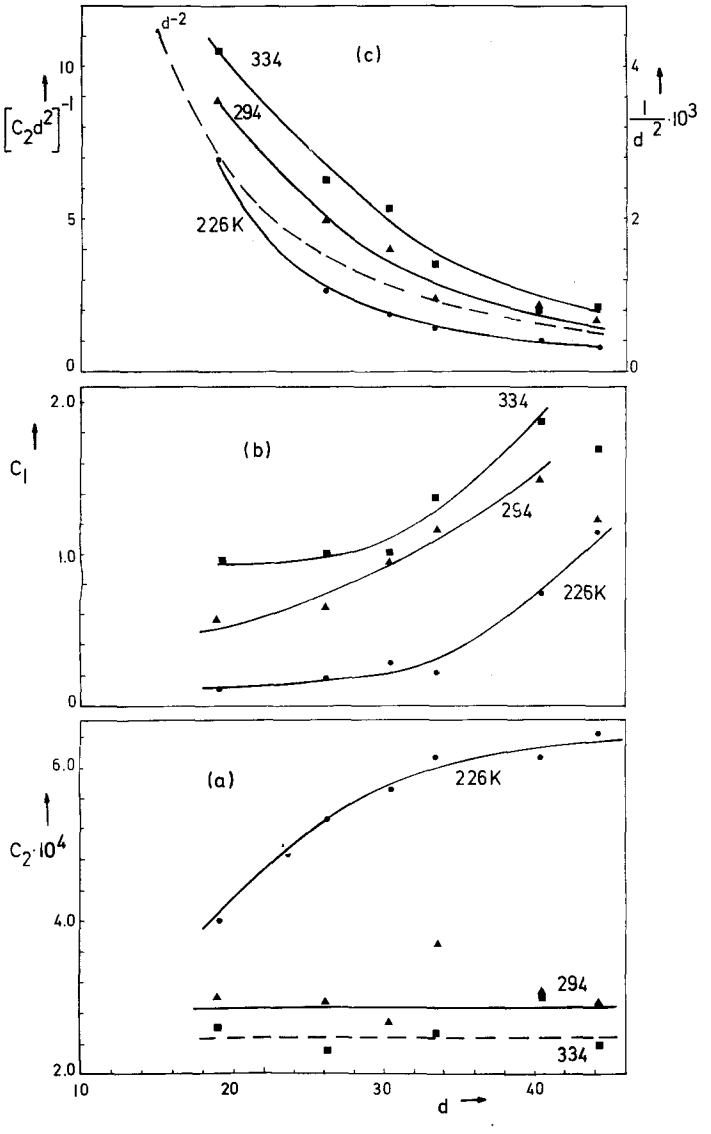

Figure 2(a) and (b) C_1 and C_2, obtained from Fig. 1, as a function of the grain diameter. (c) Plot similar to that of Fig. 10 of [1].

creases on increasing the grain size. The value given by them for the binding energy was obtained by making such assumption and consequently it is meaningless. Furthermore, $C_1 \sim \Lambda L_n^3/L_c$ [2], where Λ is the dislocation density and L_n the average length between major loops. C_2 = constant implies L_c = constant and since C_1 increases with the grain size at all temperatures, ΛL_n^3 must increase, again invalidating the assumption made by Burdett and Wendler about C_D (Equation 10).

Fig. 2c shows a plot similar to Fig. 10 of [1] for the three temperatures. It is seen that these plots are not linear and similar in shape to that of d^{-2} versus d, indicating that this is the dominant term and there is practically no influence of C_2.

In conclusion, it is not certain that the Granato–Lücke theory describes the results given by Burdett and Wendler [1] and no dislocation parameters can be obtained from the data in this context.

References

1. C. F. BURDETT and B. WENDLER, *J. Mater. Sci.* **11** (1976) 817.

2. A. V. GRANATO and K. LÜCKE, *J. Appl. Phys.* **27** (1956) 583.
3. F. POVOLO, *Scripta Met.* **9** (1975) 869.
4. *Idem, J. Mater. Sci.* in press.

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Reply to "Comments on 'On the background damping in the vicinity of the grain-boundary peak in zinc' "

Povolo [1] has suggested that the interpretation of the strain amplitude dependent damping found in zinc [2] in terms of the Granato–Lücke model was incorrect and has suggested that for torsion, the expression for the strain amplitude dependent damping should be

$$\Delta_t = C_1 \frac{C_2}{\epsilon} g\left(\frac{C_2}{\epsilon}\right) \exp\left(-\frac{C_2}{\epsilon}\right), \quad (1)$$

where $g(C_2/\epsilon)$ is a ratio of polynomials and is plotted in [3]. Over the range of strain amplitudes used in the present experiments, $g(C_2/\epsilon)$ varies from 6 to 2.05, whereas $\exp(-C_2/\epsilon)$ varies from 2×10^{-3} to 120×10^{-3}. Thus the change in Δ_t in Equation 1 produced by a change in $g(C_2/\epsilon)$ is small compared to the change produced by a change in $\exp(-C_2/\epsilon)$. The Granato–Lücke model is only an approximation at the tempertures of interest and since Povolo's equation only produces a small change in the level of damping, it is not inconsistent to use the original Granato–Lücke equation.

Furthermore, Povolo's equation is itself only approximate in that $g(C_2/\epsilon)$ is an approximation for a set of experimental integrals to which data cannot be compared. Povolo gives no estimate of the error introduced by this procedure.

It can be seen from Table I in [2] and Fig. 2a in [1] that the values of C_2 are similar in both cases, supporting the use of the original Granato–Lücke equation. If C_2 from [1] is plotted versus d, as Povolo has done, then similar curves would be obtained. It is obvious from the figures that C_1 increases, but this does not invalidate Equation 10 in [2] as has been suggested by Povolo.

In conclusion, although Povolo's papers have shown possible inadequacies in the Granato–Lücke theory, he has not attempted to evaluate the magnitude of his approximations. Fiore and Bauer [4] have made further comments on this aspect which will not be repeated here but which are also extremely relevant to this paper.

The differences between the analysis of the results in terms of the Granato–Lücke equation and Povolo's equation are minor in relation to the basic underlying theory and data can therefore still be satisfactorily explained by the use of the original equation.

References

1. F. POVOLO, *J. Mater. Sci.* **12** (1977).
2. C. F. BURDETT and B. WENDLER, *ibid* **11** (1976) 817.
3. F. POVOLO, *Scripta Met.* **9** (1975) 865.
4. N. F. FIORE and C. L. BAUER, *ibid* **10** (1976) 51.

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Comment on "Additional observations on the strength/nitrided density relationship for a reaction sintered silicon nitride"

It is useful to compare the strength versus density data for reaction sintered Si_3N_4 that Jones and Lindley [1] reported in recent correspondence, with other Si_3N_4 data. This comparison and its implications for further improving the strength of reaction sintered silicon nitride are briefly discussed.