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Book Reviews

Mechanics of Machining: An Analytical Approach to Assessing Machinability, by P. L. B. Oxley, Ellis Horwood Ltd., Chichester, U.K. division of John Wiley and Sons, N.Y., 1989, 242 pages.

REVIEWED BY MILTON C. SHAW[1]

This well written and organized monograph presents a very thorough continuum mechanics approach to steady-state metal cutting where the chips produced are in the form of continuous ribbons. The initial method employed is to determine the flow lines experimentally by measuring the distortion of an internal photoresist grid in front of a tool after cutting has been abruptly interrupted by an explosively-activated quick-stop device. These flow lines are used to obtain strains over the deformation zone extending from the tool tip to the free surface.

A plane-strain slip line field approach was first applied assuming a constant shear flow stress (k). At low cutting speeds and for soft annealed materials showing a large tendency to strain harden, the shear zone was relatively extensive and strain rate and temperature effects were negligible. The variation of k due to strain hardening was included in the analysis. At higher, more practical cutting speeds, the shear zone became more concentrated and approximated a shear plane. A parallel-sided shear zone of width ΔS_2 was then adopted and it became advisable to include the influence of strain rate and temperature on k as well as strain hardening.

The effects of strain hardening and strain rate were included by obtaining experimental material constants from a few points of metal-cutting data. The strain rate pertaining was obtained by approximating ΔS_2 from quick-stop photographs and extending the measured values to other values of feed by using what the author refers to as a scaling factor.

This assumes that ΔS_2 is inversely proportional to the length of the shear zone and, hence, to the feed for a given shear angle. Temperature effects are combined with strain rate effects by use of the velocity modified temperature concept.

A useful discussion of the problem of determining the direction of chip flow for cutting tools having an inclination angle, side cutting-edge angle, and nose radius is given in Chapters 8, 9, and 10.

Not included in the analysis is the fact that the resistance to shear flow for a given material depends not only on strain, strain rate, and temperature, but also on the homogeneity of strain pertaining. The latter quantity is related to structure (defect structure due to second phase particles, inclusions, grain boundaries, voids, etc.). These defects can cause the strain along a chip to be very inhomogeneous frequently giving rise to sawtooth chips or even discontinuous chips that involve cylic behavior. Since the width of the deformation zone in metal cutting is usually the same order of magnitude as the defect spacing, a size effect results. That is, the probability of finding a defect of a given intensity in the concentrated deformation zone decreases as the undeformed chip thickness decreases. This is an important reason why the deformation in metal cutting is usually inhomogeneous and why the specific cutting energy increases exponentially with a decrease in feed rate. The author suggests that the increase in specific energy with decrease in feed can be explained completely by an increase in strain rate. However, it should be kept in mind that metal cutting data has been used to evaluate the material constants ignoring the size effect and that the thickness of the deformation zone has been assumed to vary inversely as the shear plane length (feed). These two effects tend to mask the cause of the size effect and could tend to attribute too much of the increase in specific energy with decrease in feed to strain rate and temperature than is actually the case. However, as long as the analysis is used to interpolate and extend experimental metal cutting data and not to ascertain the basic cause of the observed behavior, this is satisfactory. It is somewhat akin to the velocity modified temperature concept but for strain inhomogeneity.

This book provides about the best treatment possible of the metal-cutting process for the case of homogeneous steady-state strain from the continuum mechanics point of view. It should be studied by all serious researchers in this field for the insight it provides into the intricacies of the process. It should be noted that the author clearly indicates in the preface that the material science (structural) aspects of material behavior are not considered in his treatment. As long as this limitation is recognized and kept in mind, this is a useful contribution. However, to ensure that this important point not be overlooked, it is unfortunate that the title did not read "Continuum Mechanics of Metal Cutting."

[1] Arizona State University, Tempe, AZ. Honorary Mem. ASME.

