Discussion

M. L. Baxter, Jr.1 The two papers under discussion are particularly significant since they illustrate a trend which is likely to continue and to have a marked effect on engineering and scientific advance. This is the trend toward the use of high-speed computation equipment to tabulate in advance complex design data so as to reduce the engineering man-hours required on a job.

The authors are to be commended for furnishing machine designers with tables for cam pressure angles and curvatures, and particularly their maximum values.

The increasing availability of high-speed computers carries with it some implications which we as engineers should consider. In the past, an equation or formula was not of much practical use unless it could be reduced in some way to yield direct explicit results with a minimum of trial and error, and naturally considerable emphasis was placed on this phase of the derivation. In addition to reducing the labor of hand calculation, this procedure had the advantage of requiring that the problem be reduced to its real fundamentals, and the resulting equations were frequently of a much simpler form than might have been expected at the start of the problem. Then, furthermore, it was frequently possible to see by inspection the effect of changes in various parameters.

We may naturally ask whether this sort of analytical refinement is justified in the light of the new computers, or is any sort of solution satisfactory so long as it is right? Many of us would be sorry to see this attitude carried to extremes, not only because there will always be some hand calculation done, but because we feel it would represent a step backward. On the other hand, there is no doubt that certain refinements in the derivation justifiably can be omitted if the results are to be tabulated, no one will need to do it again, and there is plenty of spare computer capacity.

The formulas derived in the papers under consideration represent the modern approach. They are correct, and the results have been tabulated or graphed. The writer would like, however, to continue and to have a marked effect on engineering and scientific advance. This is the trend toward the use of high-speed computation equipment to tabulate in advance critical and complex design data so as to reduce the engineering man-hours required on a job.

The difference in length of formulas is so marked, particularly in the case of curvature, that one might suspect that both cannot be correct, or that they do a different job. Nevertheless, assurance is given that they are both correct, and that they give the same starting data.

The difference can be attributed chiefly to point of view. At the time the writer's paper appeared, it was clear that hand-computation methods would have to be used, so every effort was made to reduce to a simple form. Nevertheless, by the use of appropriate kinematic and geometrical principles as well as the principles of elementary calculus, the derivations are not very long. The authors, on the other hand, knowing the power of the electronic computer, have not felt it necessary to be seriously concerned with the length of formulas so long as they are correct.

The engineer will have to decide for himself what compromise between these views to adopt on his own problems. Certainly the advent of computers promises to make many advances possible in the machine-design field which cannot be ignored.

REFERENCE

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Comparison of Methods

I Pressure Angle

Assuming that the following values are given or have been determined:

\[ \beta, \tau, R_0, l, c, \delta_0, \delta, R, \text{ and } (d\delta)/(d\theta); \]

Kloomok and Muffley

\[ \psi = \cos^{-1} \left( \frac{c^2 + R^2 - l^2}{2Rc} \right) \]

\[ a = \frac{\pi}{2} - \sin^{-1} \left( \frac{c}{R} \sin \delta \right) \]

\[ + \tan^{-1} \left[ \frac{1}{R^2 - \frac{c^2 - R^2 - l^2}{2Rc \sin \delta}} \right] \]

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\[ \tan a = \cot \delta - \frac{1}{c} \left( \frac{1}{\sin \delta} \right) \]

II Curvature

Assuming that the following values are given or have been determined

\[ \beta, \tau, R_0, l, c, \delta_0, \delta, R, \]

\[ \frac{d\gamma}{d\theta} \text{ or } F'(\theta), \text{ and } \frac{d^2\gamma}{d\theta^2} \text{ or } F''(\theta); \]

Kloomok and Muffley

\[ \cos \psi = \frac{c^2 + R^2 - l^2}{2Rc} \]

\[ f'(\theta) = \frac{lec}{R} F'(\theta) \sin \delta \]

\[ f''(\theta) = \frac{(lec \sin \delta)}{R} \left( \frac{d^2\gamma}{d\theta^2} \right) + \frac{(lec \cos \delta)}{R} \left( \frac{d\gamma}{d\theta} \right)^2 - \left( f'(\theta) \right)^2 \]

\[ \frac{d\psi}{dR} = \frac{1}{R c \sin \psi} \left( \frac{R \cos \psi}{\sin \psi} - f'(\theta) \right) \]

\[ \frac{d}{d\theta} \left( \frac{d\psi}{dR} \right) = \frac{1}{2Rc \sin \psi} \left( f'(\theta) - \left[ c^2 - R^2 - l^2 \right] \right) \]

\[ g'(\theta) = \pm \frac{d^2\psi}{d\theta^2} = \frac{d^2\psi}{dR^2} \]

\[ g'(\theta) = \pm \frac{d^2\psi}{dR^2} \left( \frac{d\psi}{dR} \right) \left( + \text{ toward pivot} \right) \]

\[ g'(\theta) = \pm \frac{d^2\psi}{d\theta^2} \left( - \text{ away from pivot} \right) \]

\[ \frac{dR}{d\phi} = \frac{f'(\theta)}{g'(\theta)} \]
\[
\frac{d^2R}{d\phi^2} = \frac{g'(\theta)f'(\theta) - f'(\theta)g'(\theta)}{[g']^2}
\]
\[
\rho = \frac{\left[R^2 + \left(\frac{dR}{d\phi}\right)^2\right]^{1/2}}{R^2 + 2\left(\frac{dR}{d\phi}\right)^2 - R^2} \quad \cdots \quad [2]
\]

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\[
\tan \alpha = \cot \delta - \frac{1}{\rho} \left(1 - \frac{d\gamma}{d\theta}\right) \cos \alpha
\]

\[
\frac{1}{\rho} = \frac{c}{\sin \delta} \left\{1 + \frac{t \cos \alpha}{c \sin \delta}
\left[\frac{d\gamma}{d\theta} \left(1 - \frac{d\gamma}{d\theta}\right) \sin \alpha - \frac{d^2\gamma}{d\theta^2} \cos \alpha\right]\right\}
\]

**Authors' Closure**

Our congratulations are due Mr. Baxter for his prior derivation of exactly equivalent equations for radius of curvature and pressure angle in a highly refined form.

There is no need for Mr. Baxter to become alarmed. In high-speed computers even more so than in slide-rule or desk-calculator computation, a premium is placed on efficient operation. It must be remembered that owing to the sequential character of digital computers, programming must be done in stepwise fashion, one term at a time. A reduction in the area occupied by the equations is not necessarily significant. Within this framework analytic refinement is definitely justified provided the cost of this refinement does not exceed the economy realized thereby. There are many problems presented to computers these days which, by this criterion, are borderline cases.

At any rate a highly refined analytic solution is hardly sufficient for the harried engineer. What is of much more significance to him is a method for arriving at numerical values quickly and easily. "The trend toward the use of high-speed computation equipment to tabulate in advance critical and complex design data so as to reduce engineering man-hours required on a job," which Mr. Baxter recognizes, is today indeed a reality.

This closure applies to ASME Papers Nos. 55-SA-29 and 55-SA-38.