

DISCUSSION

quadrature by Filon⁴ and the first-degree formula, advanced by Yuan and McElhaney,⁵ are accurate.

For experimental purposes the writer thinks it more useful to select the trial impact load $P(t)$ by measuring the strain and then solve the integral equation (5) rather than by choosing simple step or ramp loading as was done in the paper.

Employing the first-degree formula and giving due regard to the propagation speed of axial elastic wave, the numerical solution of the integral equation (5) has indeed been accomplished⁵ by an inversion process to which the second-degree Filon's formula does not apply.

Authors' Closure

The authors thank Mr. Yuan for his discussion.

When the strain-time curves for a bar subjected to step loading are obtained using Love's equation, we found that the agreement is generally good except that the theory predicts shorter rise times and more accentuated wakes. In the belief that the discrepancies are mainly due to the fact that the experimental loading is more gradual, we substituted ramp for step loading in the theory and concluded that we were correct in our belief. Mr. Yuan's suggestion that we reverse the procedure and find the theoretical pressure based on the experimentally determined stress-time curves would be a far more complicated way of arriving at the same conclusion.

⁴Filon, L. N. G., "On a Quadrature Formula for Trigonometric Integrals," *Proceedings, Royal Society of Edinburgh*, Series A, Vol. 49, 1928-1929.

⁵Yuan, H. F., and McElhaney, J. H., "On a New Method of the Hopkinson Pressure Bar," Paper No. 1593, presented at 1969 SESA Fall Meeting, Houston, Texas.

Non-Darcy Flows Through Fibrous Porous Media¹

G. EMANUEL² and J. P. JONES.³ In their paper,¹ the authors contribute greatly to the fundamental understanding of a liquid flowing in porous media. They express the friction factor, f , as $f = R^{-1} + c$, and propose this as a general representation for a class of fibrous porous media. They also inquire whether similar correlations exist for other classes of flow in porous media. In this regard, an important type of flow is that of a gas flowing through a porous medium. Green and Duwez⁴ studied the flow of nitrogen gas through sintered porous-metal samples, and indeed found that the foregoing correlation adequately represented their data. However, they explicitly omit compressibility from their analysis, even though some of their experiments involved large mass flow rates where compressibility ought to be important. Emanuel and Jones⁵ theoretically studied compressible flow through a porous plate and showed that choking of the flow

¹By G. S. Beavers and E. M. Sparrow, published in the December, 1969, issue of the *JOURNAL OF APPLIED MECHANICS*, Vol. 36, TRANS. ASME, Vol. 91, Series E, pp. 711-714.

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⁴Green, L., Jr., and Duwez, P., "Fluid Flow Through Porous Metals," *JOURNAL OF APPLIED MECHANICS*, Vol. 18, TRANS. ASME, Vol. 73, Mar. 1951, pp. 39-45.

⁵Emanuel, G., and Jones, J. P., "Compressible Flow Through a Porous Plate," *International Journal of Heat and Mass Transfer*, Vol. 11, May 1968, pp. 827-836.

in the plate can occur and that the Dupuit-Forscheimer relation must be replaced by a compressible analog. The choking aspect has been verified experimentally by Shreeve.⁶

Authors' Closure

The authors are grateful to Drs. Emanuel and Jones for providing further background on the problem and, in particular, for appending several relevant references.

⁶Shreeve, R. P., "Supersonic Flow From a Porous Metal Plate," *AIAA Journal*, Vol. 6, Apr. 1968, pp. 752-753.

Transverse Vibration of a Viscoelastic Column With Initial Curvature Under Periodic Axial Load¹

P. H. FRANCIS.² Professor Stevens has made a very useful contribution to the dynamic theory of thin columns by introducing, simultaneously, the effects of initial curvature and viscous material damping. The initial curvature implies a nonzero lateral response at all dynamic load levels, while the viscoelastic material properties renders this response frequency-dependent. The representation chosen for the viscoelastic modulus, $E(1 + i\eta)$, is particularly good in that the ensuing analysis is much more transparent than would be the case had an operator form been chosen. Also, this representation is likely to be more suitable in many practical applications. The excellent agreement between the theory and the experiments with plexiglas columns gives further veracity to the mathematical model.

The discussor would like to offer two comments which may have bearing on further extensions of this problem. The first is that subharmonic response has been found to be the dominant instability in many physical systems having small or negligible viscous losses and governed by equations of the Mathieu type. It would therefore be of interest (as alluded to by the author) to examine the response characteristics of the column in the neighborhood of $\omega \approx 2\Omega$. This would enable one to judge whether his system parameters are such that subharmonic resonance is apt to be a problem.

The second comment deals with the form of the initial curvature, which is taken to be the fundamental eigenmode of the system. It would be useful now to examine the effect of a localized "imperfection," to assess its influence on the stability behavior. It would seem that local imperfections would characteristically influence both the amplitude response and the location of the stability regions in a weaker manner than is predicted by the present choice of initial curvature. If this is indeed so, the present analysis would represent, in a certain sense, "conservative" design practice.

J. C. WILEY.³ Professor Stevens is to be complimented on a very lucid and detailed treatment of both analytical and experimental aspects of the problem. The experimental techniques are particularly interesting and can probably be used effectively in

¹By K. K. Stevens, published in the December, 1969, issue of the *JOURNAL OF APPLIED MECHANICS*, Vol. 36, TRANS. ASME, Vol. 91, Series E, pp. 814-818.

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