Study of Open-Channel Dynamics as Controlled Process[a]

Discussion by James C. I. Dooge[2] and J. J. Napiorkowski[3]

The proposal to use linearized solutions of the St. Venant equation as a basis for the control of open channel systems (Ermolin 1992) is to be welcomed. The linear solution for a prismatic channel of semi-infinite length [corresponding to (39) of the paper] was derived for a rectangular channel with Chezy friction by Deymie (1935) and independently by Dooge and Harley (1967). More recently it has been shown (Dooge 1980, Dooge et al. 1987a) that the solution can be generalized to any shape of prismatic channel and any friction law by using the ratio of the kinematic wave speed to the average velocity at reference conditons (m^*) to embody the effects on flow conditions of the channel shape and friction law. This parameter m^* may be expressed in terms of the parameters used in the paper as:

$$m^* = \left(\frac{N}{2}\right)\left(\frac{s_0}{b_0 h_0}\right) \qquad (56)$$

The system properties of the general linear response for a semi-infinite channel to a δ-function input have been derived (Dooge et al. 1987b, Kundzewicz and Dooge 1989). The completely general solution for a channel of finite length with boundary conditions and reflections at both upstream and downstream ends has also been derived (Dooge and Napiorkowski 1987). All these linear solutions are expressed in terms of exponential and modified Bessels functions.

The author suggests (Ermolin 1992) the simplification of the channel response function rather than an attempt to control on the basis of the full linear response. The model chosen is the replacement of the body of the impulse response by an exponential decay. The expression under the integral sign in (39) approaches an exponential decline as the value of sigma approaches zero. This approach is more rapid for circular sections than for rectangular sections. A comparison of the simplified model proposed by the author with hydrologic models reveals that it is equivalent to a lagged version of the Muskingum flood-routing model (Dooge 1973; Napiorkowski et al. 1982) in which the storage in the channel reach $S(t)$ is taken as a linear function of the inflow (Q_1) and the outflow $Q_2(t)$.

The writers feel that in the control problem it should not be too difficult to handle a response involving modified Bessel functions of the first order by using a Chebyshev polynomial representation of the Bessel function and applying Gaussian quadrature (Harley and Dooge 1968). The writers agree that, in applying the classical control theory of the 1960s, it is convenient to represent the transfer functions of a controlled object in terms of such elements as "transport delay" and "inertia terms." However, the alternative approach of using moment matching to calibrate the parameters should give smoother performance (Strupczewski and Kundzewicz 1979).

Finally, we would mention briefly some omissions and errors in the paper:

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[a]January, 1992, Vol. 118, No. 1, by Y. A. Ermolin (Paper 26504).

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(1) It is not mentioned in the paper that the solution in (39) implies certain restrictions on the value of the Froude number (i.e., $\mathsf{F} < 1$) and on the value of the exponent N; (2) the limiting relative amplitude for very large frequencies can be shown to be given by $\exp[(\gamma - \rho\beta)x]$ and is thus finite rather than zero as indicated in Fig. 2 of the paper; and (3) there are minor typographical errors in (52) and in (54) of the paper.

Appendix. References

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The approximate tranfer function proposed by the author in (45) is interesting. Using this transfer function, the author obtained an approximate solution for the propagation of a unit-step flood flow and compared the predicted results with those obtained from an exact linear solution given in (39). The maximum discrepancy between the two sets of prediction, i.e., exact linear and approximate, was noted to be 7%. Assuming that this discrepancy remains small, the author routed a sinusoidal flood using the approximate transfer function; exact results were not computed for this case.

The writer agrees with the author's observation that "the majority of cases [for determining open channel dynamics] use numerical integration of continuity and momentum equations and are . . . . not always convenient

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