IMPORTANCE OF NUMERICAL EFFICIENCY FOR REAL TIME CONTROL OF TRANSIENT GRAVITY FLOWS IN SEWERS

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Numerical efficiency—achieving a given level of accuracy with the least Central Processing Unit (CPU) time—is of paramount importance in transient flow modeling of sewerage systems. This is particularly important (i) for large sewerage systems containing a wide range of flow controls such as gates and pumps and/or (ii) for systems requiring real-time flow model for their operation. The Tunnel and Reservoir Plan (TARP), which was adopted by the Metropolitan Water Reclamation District of Greater Chicago in 1972 to address the combined sewer overflow (CSO) pollution and flooding problems in the Chicago-land area, is an example of systems requiring a highly efficient transient model. In this paper, the accuracy and efficiency of two second-order explicit Finite-Volume Godunov-Type Schemes (GTS) [HLL and Guinot] and one fixed-grid Method of Characteristics (MOC) scheme with space–line interpolation are investigated using problems whose solution contain features that are relevant to transient flows in sewers such as shocks and expansion waves.

The results show that the two GTS schemes are significantly faster to execute than the MOC scheme, and in some cases, the accuracy produced by the two GTS schemes can not be matched by the accuracy of the MOC scheme, even when a Courant number close to one and a large number of grids is used. One of the tests used in this paper consists of a sudden opening of a gate separating two pools of still water with different depths (10 m and 3 m) mid-way of a 1000 m long sewer with a diameter of 15 m. The sewer is assumed to be frictionless and horizontal with zero water flux at the boundaries. The absence of friction and gravity forces and the imposition of zero flux at the boundaries imply that the total energy is conserved throughout the transient. Therefore, any dissipation found in the results is solely due to numerical dissipation. It is shown by comparison of energies (main paper) that for the same grid size and for the same Courant number, the two GTS schemes are more accurate than the MOC scheme. However, a comparison of the numerical efficiency requires measuring the CPU time needed by each of the schemes to achieve the same level of accuracy.

To compare the efficiency of these schemes, for instance before the shock and rarefaction waves have interacted with the zero-flux boundaries, the numerical dissipation against the number of grids is plotted on log-log scale and shown in Figure 1. Figure 1 shows that the numerical dissipation is linearly (on log log scale) reduced when the number of grids is increased. However, when convergence is close to being achieved, the reduction of the numerical dissipation asymptotically tends to zero. These linear relationships were fitted to power functions which equations are shown in this same figure. Using these equations, the number of grids needed by each of the schemes to achieve two different levels of accuracy were computed (See justification on main paper). These in turn were used to compute the CPU times. These results are presented in Table 1. To get significant CPU times, the simulation time was arbitrarily extended to 10000 seconds (See justification on main paper). Notice in this table that to achieve the same degree of accuracy, the MOC approach requires a much finer grid size than the two GTS methods. In addition, this table shows that to achieve a specified level of accuracy, the two GTS schemes are about 100 to 300 times faster to execute than the MOC approach. This clearly shows the advantage of GTS schemes over the MOC scheme for real time control.

Table 1. Comparison of efficiency ($Cr = 0.3$, $t = 10000$ s, $S_f = 0$, $S_0 = 0$) [Nx is No of grids]

Description		HLL	Guinot	MOC
$(E_0 - E)/E_0 = 2\%$	Nx	42	42	1324
	CPU time (s)	2.44	2.55	819.2
$(E_0 - E)/E_0 = 3\%$	Nx	23	22	468
	CPU time (s)	0.83	0.73	104.2

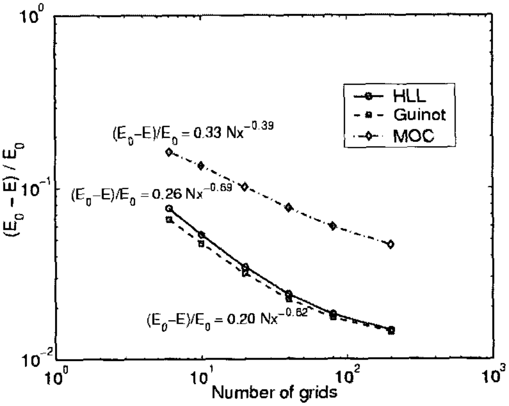

Fig. 1 Relation between numerical dissipation and number of grids for test No 1 ($Cr = 0.3$, $t = 36$ s, $S_f = 0$, $S_0 = 0$)