FLUID STRUCTURE INTERACTIONS

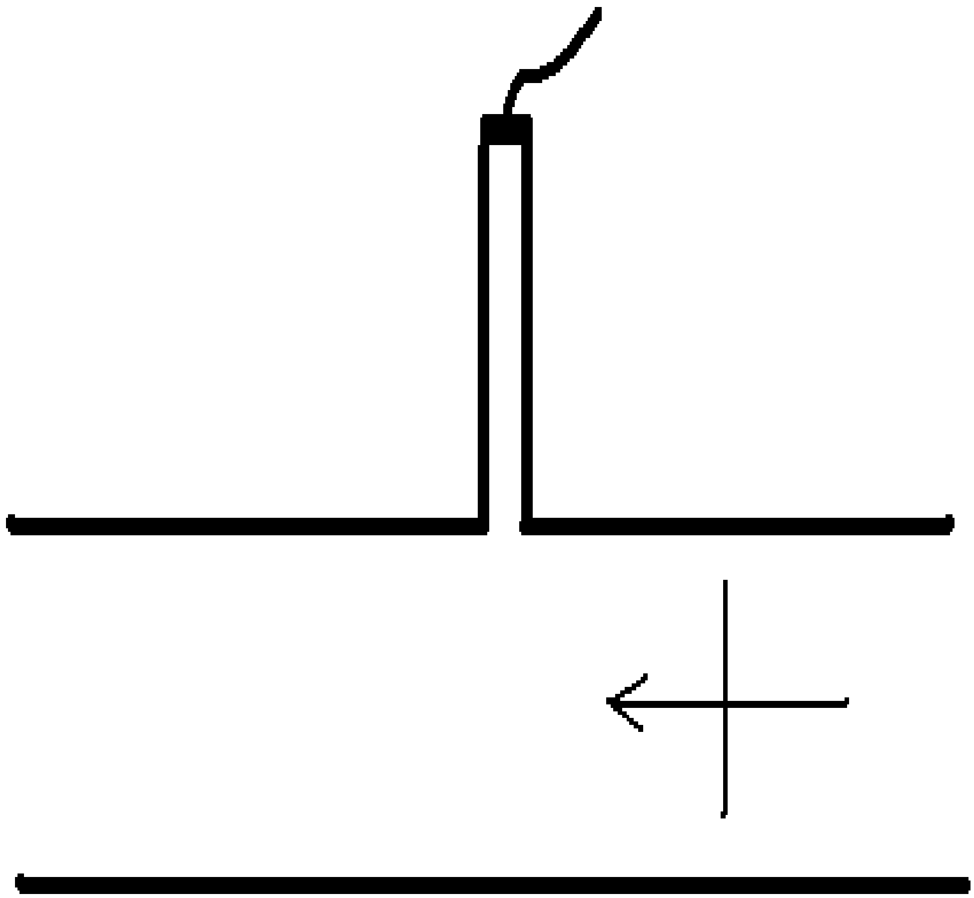
QUIZ #1

A small deadend pipe is attached to a large pipe. The large pipe has a water reservoir at its upstream end and a valve at its downstream end. The pressure P_o inside both pipes is 15BAR and the flow speed U_o inside the large pipe is 1m/s. The wave speed for both pipes is 500m/s. Assume that friction losses and gravitational forces are insignificant. Also assume that the small pipe does not influence what goes on inside the large pipe.

Using wave propagation concepts, describe what happens inside the small pipe following a sudden valve closure in the large pipe. [20] Sketch the graphical water hammer plot for the small pipe. [20] Check the plot algebraically. [20] Develop a 3 point method of characteristic template for the small pipe and use it to get the pressure and flow velocity at 3 points in the pipe step by step in time. [30] Sketch the graphical water hammer plot for the small pipe for the case where there is a small stable leak at the deadend. [10]

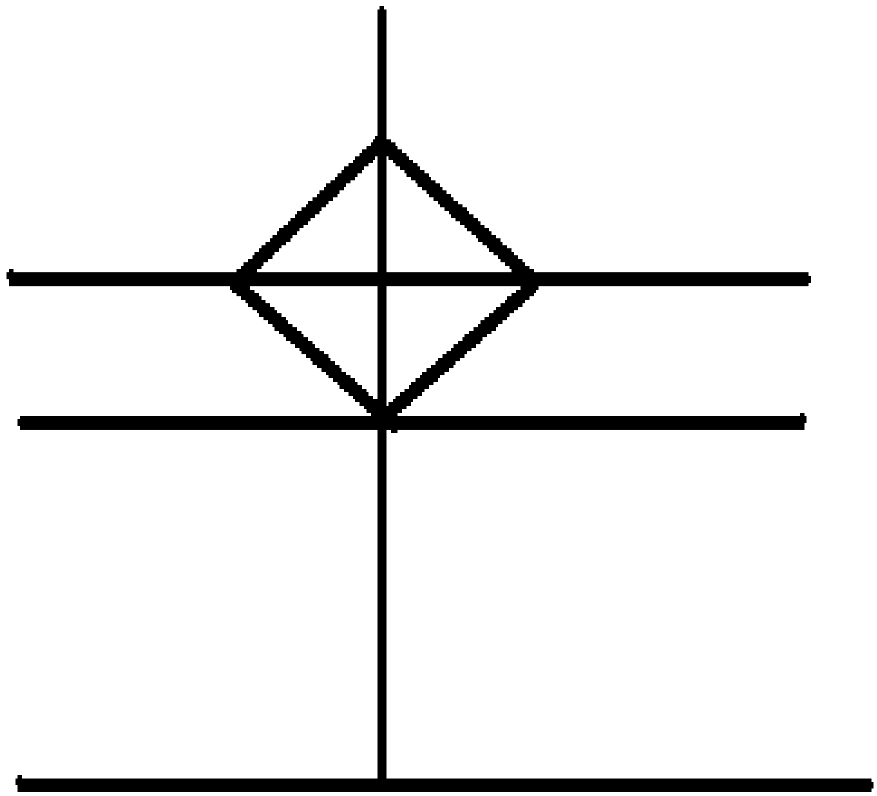
WAVES IN DEADEND PIPE

Sketch on the next page shows the setup. When the surge wave generated by sudden valve closure in the large pipe passes the entrance to the small pipe, it creates a pressure imbalance there. This causes a flow into the small pipe. The flow speed depends on the wave speed of the small pipe. As this is the same for both pipes, the flow speed into the small pipe is the same as that initially in the large pipe. A wave propagates into the small pipe. Behind this wave there is surge pressure and inflow. When this wave hits the deadend, it creates a flow imbalance. Extra surge pressure is needed to take the inflow away. The surge pressure doubles. A wave propagates away from the deadend. Behind this wave is fluid at rest and double surge pressure. When this wave reaches the large pipe, it creates a pressure imbalance. This causes a backflow from the small pipe into the large pipe. A wave propagates into the small pipe. Behind this wave is backflow and single surge pressure. When this wave hits the deadend, it creates a flow imbalance. This causes a suction which cancels the surge pressure. A wave propagates away from the deadend. Behind this wave is fluid at rest and suction pressure relative to the pressure in the large pipe. When this wave reaches the large pipe, it creates a pressure imbalance. This causes an inflow from the large pipe into the small pipe. A wave propagates into the small pipe. This completes a cycle.

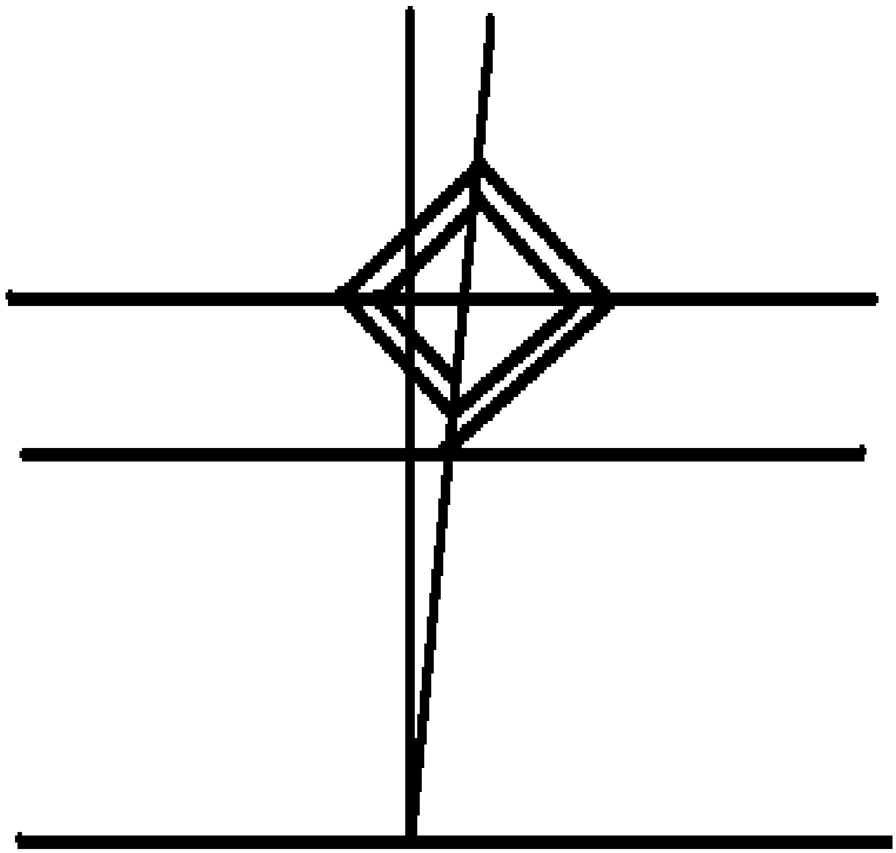


GRAPHICAL WATER HAMMER

The graphical water hammer plot is shown on the next page. The boundary conditions for the deadend pipe are zero flow at the deadend and constant surge pressure at the entrance. The plot starts at the deadend where pressure and flow speed are both known. We move along an F wave from the deadend to the small pipe entrance where the pressure is the surge pressure in the large pipe. The intersection of the F wave line with the surge pressure line there shows that there in an inflow into the small pipe. We move from the entrance to the deadend along an f wave. The intersection of the f wave line with the zero flow line there shows that surge pressure doubles. We move along an F wave from the deadend to the small pipe entrance. The intersection of the F wave line with the surge pressure line there shows that there is a backflow from the small pipe. We move from the entrance to the deadend along an f wave. The intersection of the f wave line with the zero flow line there shows that surge pressure is cancelled by suction pressure. This completes one cycle. When there is stable leak at the deadend, the plot resembles a regular stable leaky valve. It starts at the deadend on the leaky valve characteristic.



SEALED DEAD END



DEADEND WITH LEAK

ALGEBRAIC WATER HAMMER

The algebraic water hammer equations are:

$$P_D - P_E = -\rho a\,[U_D - U_E] \qquad U_D = 0$$

$$P_E = P_O + \Delta P \qquad P_E - P_D = +\rho a\,[U_E - U_D]$$

$$U_E = U_D + [P_E - P_D]/\rho a$$

$$P_O = 15\text{x}10^5 \qquad \rho a = 5\text{x}10^5 \qquad \Delta P = 5\text{x}10^5$$

$U_D = 0$ $P_D = 15\text{x}10^5$ $P_E = 20\text{x}10^5$ $U_E = +1$

$P_E = 20\text{x}10^5$ $U_E = +1$ $U_D = 0$ $P_D = 25\text{x}10^5$

$U_D = 0$ $P_D = 25\text{x}10^5$ $P_E = 20\text{x}10^5$ $U_E = -1$

$P_E = 20\text{x}10^5$ $U_E = -1$ $U_D = 0$ $P_D = 15\text{x}10^5$

METHOD OF CHARACTERISTICS

The method of characteristics equations are:

$$U_K = 0 \qquad [P_K - P_B] + \rho a\, [U_K - U_B] = 0$$
$$P_K = P_B + \rho a\, [U_B - U_K]$$

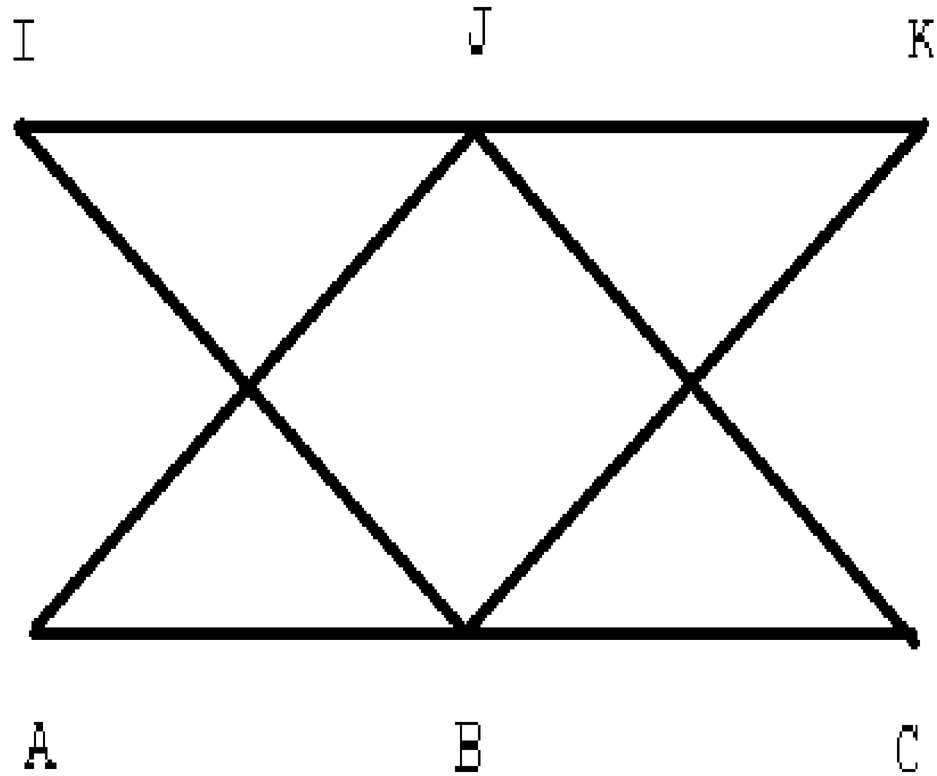
$$P_I = P_o + \Delta P \qquad [P_I - P_B] - \rho a\, [U_I - U_B] = 0$$
$$U_I = U_B + [P_I - P_B]/\rho a$$

$$P_J = 0.5\, [\, [P_A + P_C] + \rho a\, [U_A - U_C]\,]$$
$$U_J = 0.5\, [\, [U_A + U_C] + [P_A - P_C]/[\rho a]\,]$$

$$U_K = 0 \qquad P_K = 15x10^5 + 5x10^5\, [0-0] = 15x10^5$$

$$P_I = 15x10^5 + 5x10^5 = 20x10^5$$
$$U_I = 0 + [20x10^5 - 15x10^5]/[5x10^5] = 1$$

$$P_J = 0.5[[15x10^5 + 15x10^5\,] + [5x10^5][0-0]] = 15x10^5$$
$$U_J = 0.5\, [[0+0] + [15x10^5 - 15x10^5]/[5x10^5]] = 0$$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