MULTIDIMENSIONAL FLUID DYNAMICS CALCULATIONS WITH HIGH SPEED COMPUTERS

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II. DISCUSSION OF THE MONITORING SYSTEM

The system is evaluated based on its ability to monitor and control the parameters of the system accurately. The system is designed to provide a reliable and efficient monitoring solution for various applications. The system has been tested in various environments and has shown promising results. The system is also capable of integrating with other systems and devices, providing a comprehensive monitoring solution.

In conclusion, the system is a valuable tool for monitoring and controlling the parameters of the system. The system is easy to use and provides accurate and reliable readings. The system is also adaptable to various applications, making it a versatile tool for monitoring. The system is recommended for use in various industries and applications where accurate monitoring is required.
performed on an IBM 7090 computer. A movie has been prepared of the calculated flow configurations. Each frame of the movie was made directly from the output of the computer through an SC 5020 microfilm recorder. The first half of the film shows the collapse of the bubble when chemical reactions are not allowed. Regions of the flow with temperatures exceeding $1800^\circ K$ are indicated separately. The second half of the film shows a similar calculation in which an Arrhenius type chemical reaction is allowed. In this case a detonation is seen to initiate at the hot spots.

B. Shock Passage through a Bent Channel

The second problem we consider arose in connection with a shock tube study made by Dr. H. Reichenbach at the Ernst-Mach-Institute. Dr. Reichenbach studied a shock passing down a rectangular channel resembling the letter $z$, having two right angle bends, Fig. 1. Numerical calculations simulating his experiments were undertaken at Los Alamos. Comparisons between the numerical calculations and Dr. Reichenbach's experiments were made through the pressure histories at two points in the channel (see Fig. 1).

To handle this problem a pure Lagrangian representation was used for the fluid. In this method fluid elements are represented by particles interacting with neighboring particles through appropriately chosen pairwise forces (the Particle-And-Force method). Since this method does not use a mesh it is particularly suited to problems with complicated boundaries or problems involving large fluid distortions. On the other hand, pressures are determined from the forces of neighboring particles. In order to reduce fluctuations it is necessary to have a large number of particles. The particle number, however, is limited by computer memory size and the computer time available.

The comparison between Dr. Reichenbach's pressure measurements and the calculated pressures at two points in the channel is shown in Fig. 2. The dashed lines represent an average of the experimental pressure histories obtained from pressure transducers. It will be noted that the agreement with respect to shock arrival time and subsequent pressure history is excellent.

Some comments are in order concerning other numerical methods which could be used for this problem. The previously discussed Particle-In-Cell method has difficulty with problems in which stagnation regions occur. This difficulty is associated with the natural fluctuations present in a particle system. Small fluctuations in a stagnation region propagate as spurious signals. This difficulty can be reduced, however, by using a pure Eulerian system which calculates a continuous mass flux across mesh boundaries, instead of the number of discrete particles which cross. The pure Eulerian method reduces density fluctuations and consequently it is less affected by the presence of stagnation regions. A calculation simulating Dr. Reichenbach's experiment has been performed using the pure Eulerian method without particles. The results agree very nicely with the Lagrangian calculation. It should be noted, however, that the pure Eulerian method is not suited for problems involving more than one material. This arises from the difficulty of defining material interfaces.

C. Vortex Street Development

While the previous two examples concerned compressible flow situations the third example illustrates the numerical solution of an incompressible viscous fluid problem. This problem is a study of the time evolution of the wake of a flat plate impulsively accelerated along a channel. The channel height was six times the plate height. Numerical calculations were performed for Reynolds numbers between 15 and 6000.

The calculational method is based on a pure Eulerian system, but differs considerably from the methods previously described. Solutions are obtained at points on a fixed Eulerian mesh for two flow variables, the stream function and the vorticity function. The method of solution consists of solving the appropriate finite difference form of Helmholtz's equation for the vorticity. This solution is then used for the source term in a Poisson equation which governs the stream function. A solution of Poisson's equation is obtained by a convergent iteration method. The cycle is then repeated using the new stream function to calculate velocities which appear in the time advanced vorticity equation. Complete details of the method of solution have been discussed in the literature.

A series of calculated streakline patterns are shown on the right hand side of Fig. 3, for Reynolds numbers of 0, 25, and 100. The shedding of vortices, which starts at a Reynolds number of approximately 40, is quite apparent in the R = 100 picture.
in a manner that is both concise and clear, so as to make the document easy to read and understand.
Figure 1. Schematic drawing of rectangular channel. Pressure histories were recorded at points I and II.
Figure 2. Comparison between calculated pressure histories and the average atmospheric pressure \( p_0 \).

The pressure is measured in units of atm at point II, lower graph. The pressure is measured in units of atm at point I, upper graph, and the relative change of pressure \( \frac{d(p)}{d(t)} \).
Figure 3. Calculated isothermals on left and streaklines on right for various Reynolds numbers with a Prandtl number of unity.
Figure 4. The upper picture illustrates dye trails observed behind a circular cylinder. The lower picture shows the calculated streaklines behind a flat plate. Both pictures correspond to a Reynolds number of 100.