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Computation of Reverse Flow in a Channel with an Obstruction in Front

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Reverse flow occurs in a channel when an obstruction is placed at the entry. The phenomenon involves separation, reattachment and shear layer interaction. The various facets of the phenomenon have earlier been investigated experimentally. Presently, an attempt has been made to compute this flow solving unsteady equations of motion. Preliminary results do predict the occurance of reverse flow.

1. Introduction

When an obstruction is placed at the entry to a parallel walled channel (test channel) placed within another wider channel (Fig.1), it is observed that for certain positions of the obstruction the flow within the test channel can be either stagnant or in a reverse direction i.e. in a direction opposite to that outside (Fig.2a&b). When the gap between the obstruction and the channel entry is sufficiently large, forward flow results (Fig.2c), but it's magnitude, even for very large gap widths will be less than the free stream velocity U_∞. Gowda and Tulapurkara [1], used a flat plate obstruction and studied the influence of various parameters like gap (g), the length of the channel (L) and the Reynolds number (Re), based on the test channel width (w) and velocity U_∞, on the velocity inside the test channel (U_i). In subsequent studies, various facets of the phenomenon like influence of geometry of the obstruction (Gowda et al, [2]), effect of obstructions both at entry and rear end of the test channel (Tulapurkara et al, [3]), and influence of splitter plates (Gowda et al, [4]) have been investigated. Further studies, both flow visualization and pressure measurements have been carried out to obtain a better understanding of the mechanism, which triggers and sustains the reverse flow (Gowda et al, [5]).

Some of the applications where the reverse flow phenomenon can occur are: control of flow, especially to obtain low velocities; heat transfer problems where it may be required to locally have different types of flows; interaction of shear layers at different distances apart; flow past obstruction/constriction in arterial flows under certain physiological situations.

The aim of the present study is to compute this flow, which involves separation, unsteadiness, vortex pairing and convection (Fig.2). It would also provide better insight into the mechanism of pumping of fluid.

3. Governing Equations and Boundary Conditions

The flow domain is shown in Fig.3. It is same as the domain for the flow visualization studies by Gowda and Tulapurkara [1]. The flow through and around the test channel is computed by solving the unsteady Navier-Stokes equations for an incompressible fluid in a two-dimensional geometry. The continuity and momentum equations in dimensionless form with standard notation are

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} = 0$$

$$\frac{\partial u}{\partial t} + u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} = -\frac{\partial p}{\partial x} + \frac{1}{\mathrm{Re}}\left(\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2}\right)$$

$$\frac{\partial v}{\partial t} + u\frac{\partial v}{\partial x} + v\frac{\partial v}{\partial y} = \frac{\partial p}{\partial y} + \frac{1}{\mathrm{Re}}\left(\frac{\partial^2 v}{\partial x^2} + \frac{\partial^2 v}{\partial v^2}\right)$$

The reference velocity is U_∞. The width, w, of the channel (same as the width of the obstruction in the present case) is the reference length. The boundary conditions are 1) no-slip condition on (a) top and bottom walls of the outer channel (b) walls of test channel and (c) surfaces of the obstruction; 2) a uniform velocity profile at the entrance to the domain.

3. Analysis

Preliminary results have been obtained using the code STREAM, which employs finite volume method. The grid used is shown in Fig.4. Some result obtained is shown in Fig.5. Further work is needed to obtain results which compare well with the experimental results (Fig.2). In addition, it is planned to use the PHOENICS code for the computation in future. Also, attempts will be made to compute the flow in cylindrical conduits.

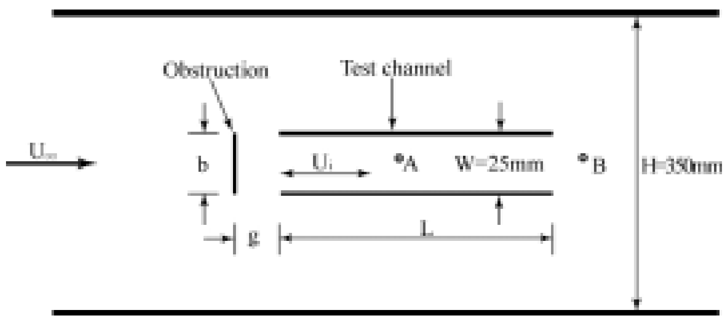

Fig.1 Configuration considered

4. References

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[3] Gowda, B.H.L., Tulapurkara, E.G. and Swain, S.K. 1994 Influence of splitter plates on reverse flow in a channel. Fluid Dynamic Research 21, 319-330.

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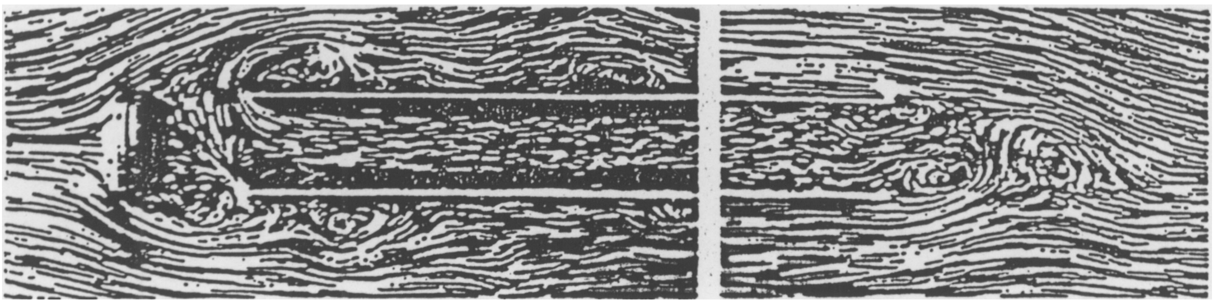
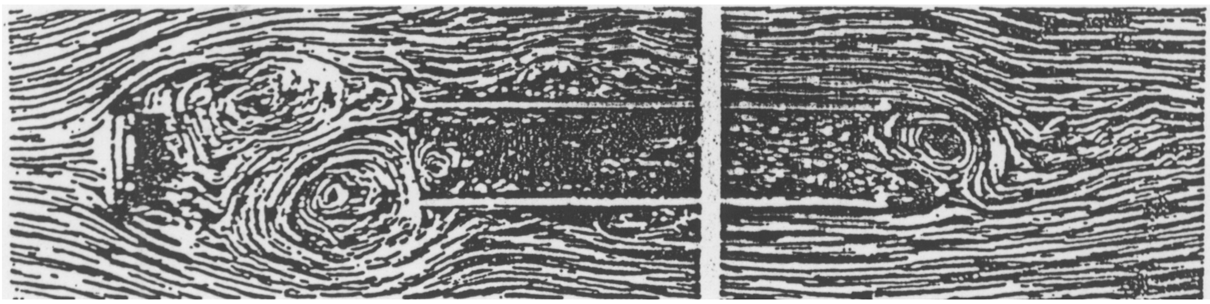
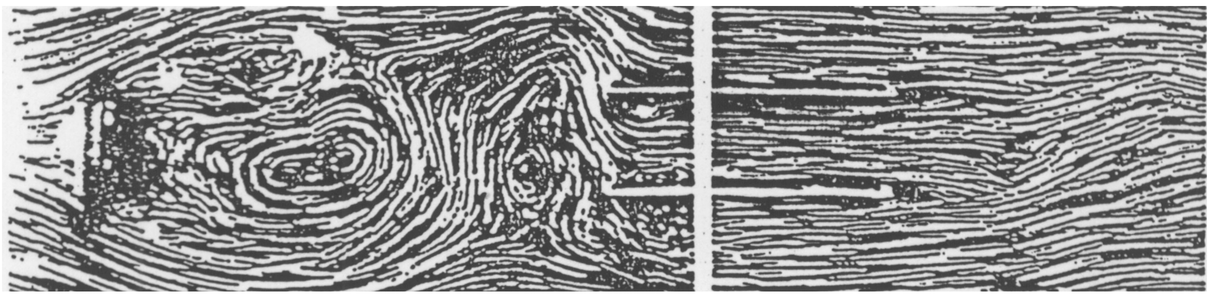
[5] Gowda, B.H.L., Tulapurkara, E.G. and Swain, S.K. 1998 On the mechanism of flow in a channel with an obstruction at the entry. Fluid Dynamic Research 23, 177-187.



a) Reverse flow



b) Stagnant



c) Forward flow

Fig.2 Reverse, stagnant and forward flow

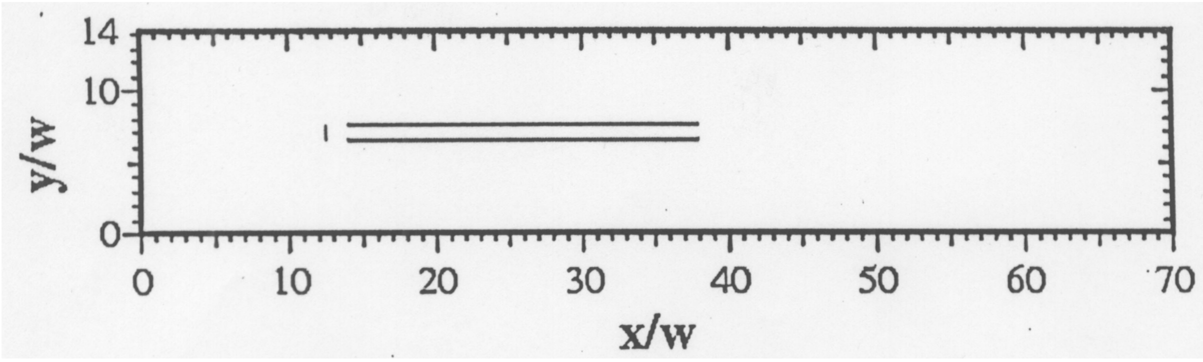


Fig.3 Computational domain

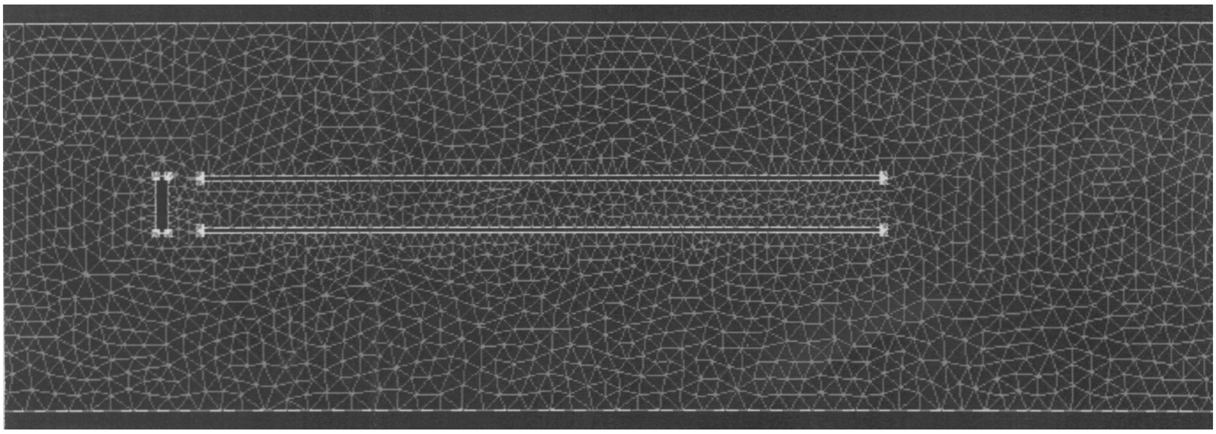


Fig.4 Grid for STREAM code

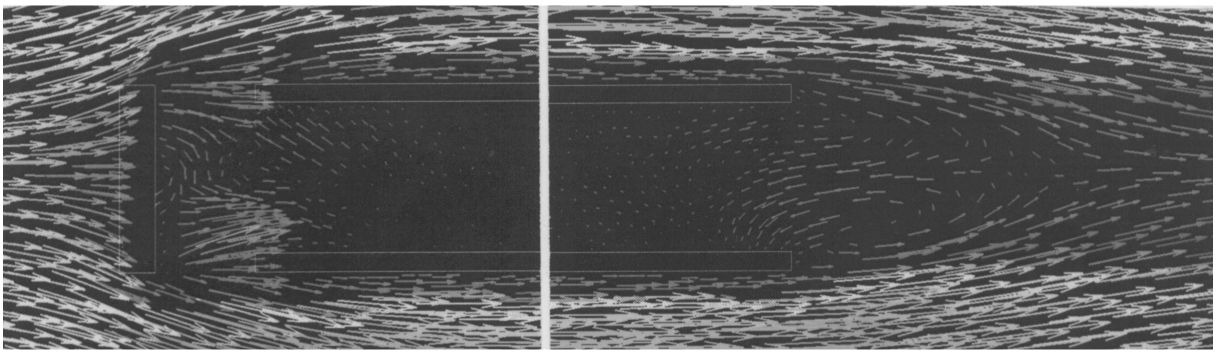


Fig.5 Result from STREAM

入口に障害物を置いた流路内に生じる逆流の数値解析

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流路入口に障害物を設置すると、流路内部に逆流が生じる。この現象は、はく離、再付着および剪断流れの干渉を含む。この現象については様々な観点から多くの実験的な研究がなされてきた。近年の数値流体解析技術の進歩により、このような非定常流れを解析することが可能となっており、本研究では逆流の挙動を究明するための第一段階の解析を行った。

Key wards
Reverse Flow, Stagnation, Forward Flow, Unsteady Navier-Stokes Equations, Continuity Equations, Momentum Equations