Vortex shedding from arbitrary arrangements of cylinders – an application of the boundary element method to the Navier-Stokes equations.

Computational Engineering & Design Centre

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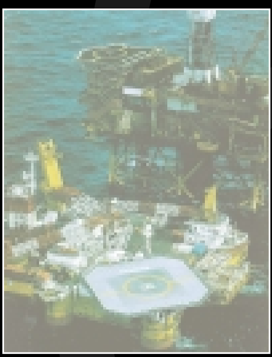
In many engineering applications structures are built from arrangements of cylinders. For example in offshore structures.

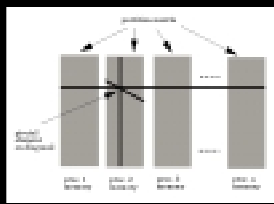


A diving support vessel moored alongside a production platform.

Although the fluid forces resulting from the Karman vortex street in the wake of an isolated cylinder are well understood little is known about the flow patterns and hence the forces induced on groups of cylinders in close proximity to each other. The resulting flow field can be counter intuitive and very sensitive to changes in parameters such as separation of the cylinders and alignment to the flow.

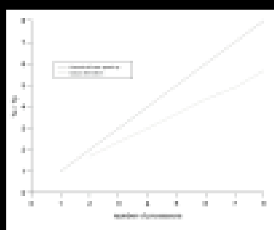
Through the use of Computational Fluid Dynamics (CFD) it is possible to investigate these flows and gain insight into their behaviour with a view to improving the design of structures. Such flows, which involve vortex shedding from bluff bodies, are separated and time dependent in nature. This makes computational modelling difficult and costly with long CPU times required to solve even small problems. For this reason a boundary element method which solves the Navier-Stokes equations (developed at Southampton University) is being applied to the problem. This method, known as the Viscous Boundary Element method (VBE), seeks to reduce the requirement for very fine and high quality meshes used by traditional finite volume techniques.

In order to reduce execution time, a parallel version of the VBE method has been developed which makes use of a number of parallel algorithms including a distributed memory Gauss elimination routine. A schematic of its operation across the distibuted memory is shown below :



A schematic of a Gaussian elemination across distributed memory.

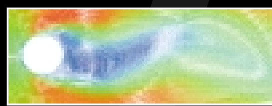
The scalability of this algorithm is illustrated below. Here Ts and Tp represent the execution time for the sequential and parallel Gauss eliminations respectively.



Scalability of the parallel Gaussian elimination.

This algorithm demonstrates the possibility of acceptable parallel performance even when large amounts of inter-processor communications are necessary. Such scalability can only be achieved on massively parallel machines such as the IBM SP2 which has a high speed communications switch. The distributed memory of the IBM SP2 also allows operations on extremely large matrices to be carried out very quickly.

Flow fields from the latest version of the VBE are shown below for an isolated cylinder and two cylinders side by side in close proximity.



An isolated cylinder at Re=100.

Two cylinders side by side. Re=100, gap is 1/2 Diameter.

All calculations were performed on the IBM SP2 at Southampton University with parallelism achieved through the use of message passing interface (MPI).

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