# Numerical simulation of waves around two-dimensional immersed bluff bodies

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## 1 Introduction

This work concerns the numerical simulation of waves around a totaly immersed bluff body. The flow is assumed to be two dimensional and the fluid is incompressible. Viscous effect are assumed to be confined in a limited region surounding the bluff body. The method could also be applied to the problem of a floatting body, although such application will not be considered hereafter. Thus, the waves are modelized as inviscid waves, also they can be strongly affected in this model by fluid motion which are entirely due to viscous effects. The numerical model is constituted of three parts:

1. A numerical simulation of two dimensional non linear unsteady waves
2. A artificial wave generation procedure
3. A numerical simulation of the viscous flow around a two dimensional bluff body.

All these models are merged in a single model by means of a coupling procedure which assumes that any two of them can be considered as a pertubation of the third one. A particular feature is that the viscous flow model only require a limited meshed region. This implies that the distance between the free surface and the bluff body must be large enough to prevent any intersection between the free surface and the meshed zone boundary. This drawback is balanced by the possibility for any body which respects this condition to move so it constitutes the only restriction to be considered to the application of the present model to the floating body problem. Although the present model can be applied to sea keeping problems through the use of the classical strip theory, it is also expected by the authors to constitute the first step to the numerical derivation of a fully three dimensional model.
We now describe each one of the three above mentioned part. The whole method can be interpreted as a multidomain method in which the equations in each subdomain can be different. Although the present result only concerns a fixed body, this one will be called hereafter "the floating body". The only part of the computational domain where a grid is required is the surounding of this body. The general sketch of the discretization is presented on figure 1 below.

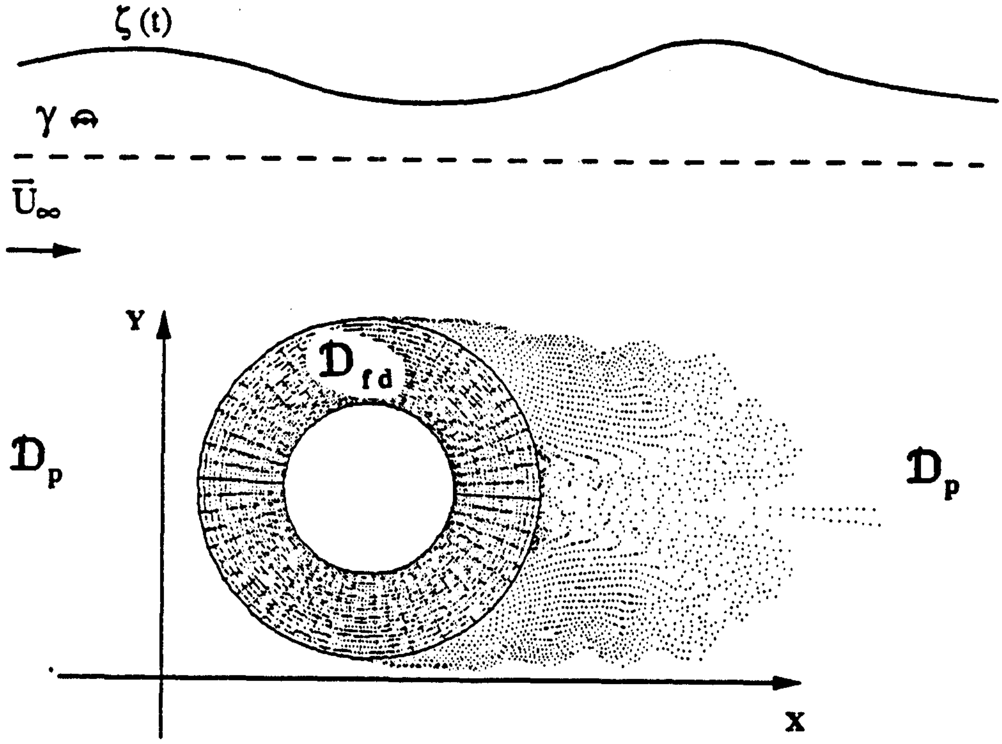

Figure 1: *Spatial discretization of the computational domain*

# 2 The numerical model

**The unsteady free surface model**

Because the aim of the present algorithm is to compute the flow around a surface ship hull, the unsteady waves are computed by using a numerical model derived from the method which has been successfully applied by Daube[3] to wave resistance problems. The flow is assumed to be inviscid and the equations are solved in integral forms. The free surface is discretized by using sources and the kinematic and dynamic boundary conditions are combined in order to provide a relation similar to that which has been proposed by Dawson. The numerical scheme which is used to solve this equation is specially designed to account for the radiative condition. It has been extended straightforwardly to unsteady flows and seems to have the same good properties that the original method of Daube. It has been checked by computing the solution of some classical problems. Unsteady flows are presented on figure 2 and 4 below at a Froude number of 0.3.

**The numerical waves generation**

The numerical waves are generated by means of a fixed vortex of periodic strength located at a distance downstream of the free surface. This way of generating waves is somewhat artificial if it is compared to the different approaches which have been proposed. The two main ways to generate waves are to use a numerical matching beween a linear unbounded domain and a non linear bounded[1] one or to simulate a wave maker[2]. In comparison, our artificial wave generator only requires a bounded computational domain and did not imply the solution of the difficult wetting problem at the contact point of the free surface on the wave maker. The only problem to be solved is that the non linear periodic flow associated to such a configuration is not readily monochromatic. This has to be checked by a spectral analysis. The result obtained for a vortex whose strength is:

$$\gamma = \gamma_0 \sin(\omega t)$$

with $\gamma_0 = 0.2$ and $\omega = 2\pi$, located at a distance $h = 0.1$ under the mean free surface is illustrated on figure 2 below. The resulting wave has been found to be very close to a monochromatic one, with wavelength $\lambda = 0.64$, amplitude $A = 0.024$ and same pulsation.

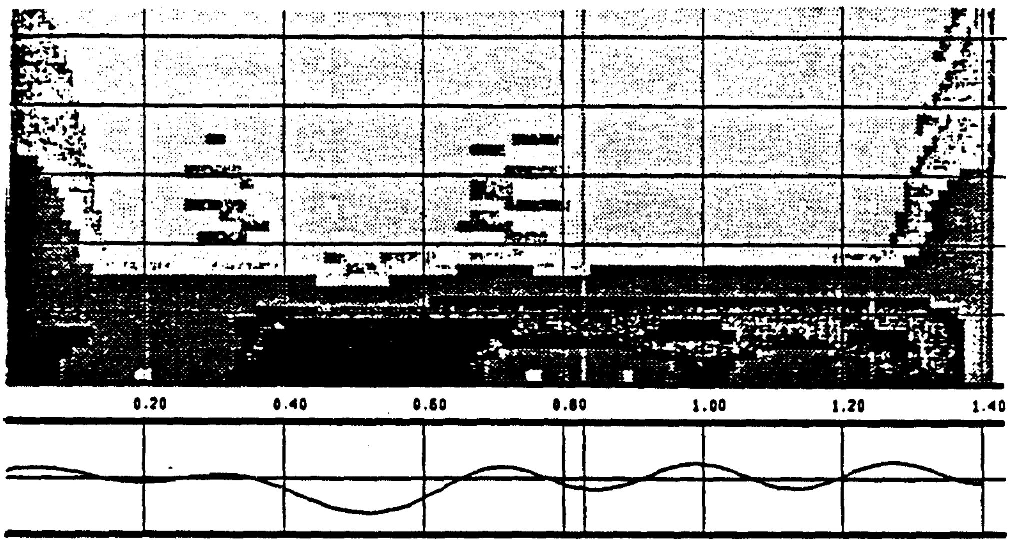


Figure 2: *Spectral analysis of the waves generated by a periodic vortex*

<u>The viscous flow model</u>

In the viscous domain, the Navier Stokes equations are solved. The numerical scheme is based[4] on a inner decomposition of that domain in a region close to the solid walls $\mathcal{D}_{fd}$ and a far field region $\mathcal{D}_p$. The flow in domain $\mathcal{D}_{fd}$ is computed by means of a finite difference solver which uses the Navier Stokes equations expressed in a stream function / vorticity formulation. In domain $\mathcal{D}_p$, a velocity / vorticity formulation is used and the equations are solved by means of a vortex method. The matching process between these two domains uses the integral formulation of the vorticity equation. This enables us to account easily for any kind of external perturbation. The method has previously been applied to different external flows. As an example, figure 3 shows the instantaneous streamlines pattern for the flow around a cylinder at a Reynolds number of 3000.

# 3 The numerical results

The numerical results concerns the flow at moderate Reynolds number around a circular cylinder. The external flow is obtained by using the above described wave generator. The conditions are those which has been used on figure 2 and the center of the cylinder is located at a distance of three radius under the mean free surface. The figure shows the vortical wake which is represented by the particles location. The free surface is not represented here.

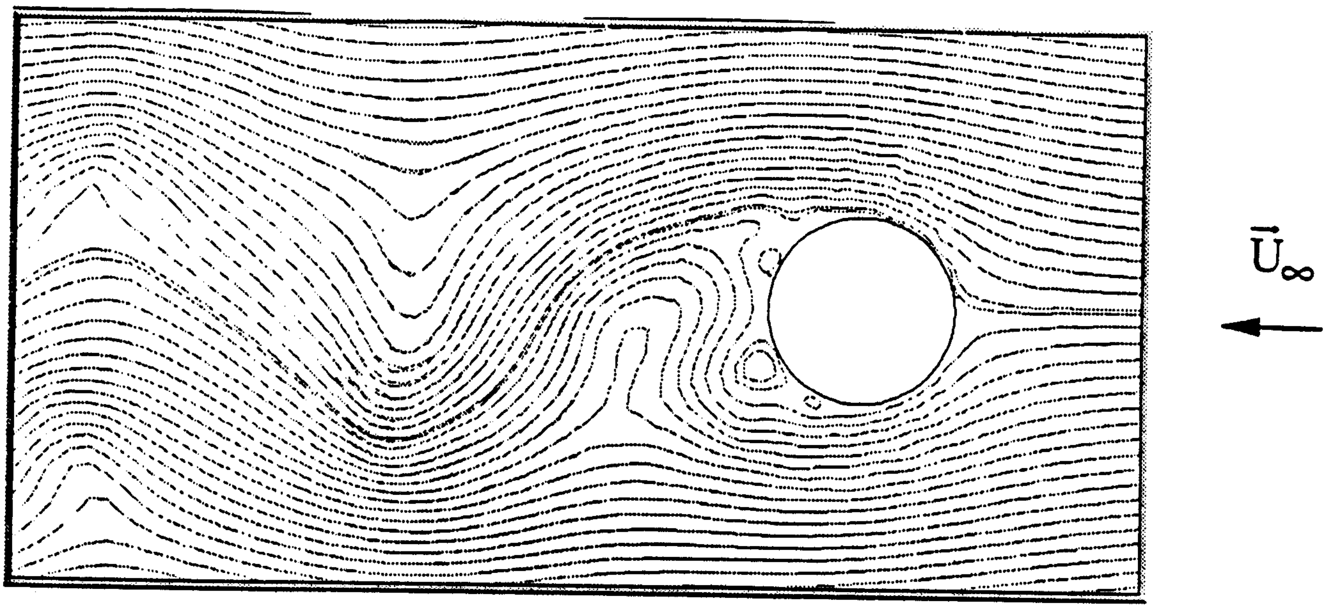


Figure 3: *Unsteady wake behind a circular cylinder in a uniform stream* $\mathcal{R}_e = 3000$ *and* $t = 26$.

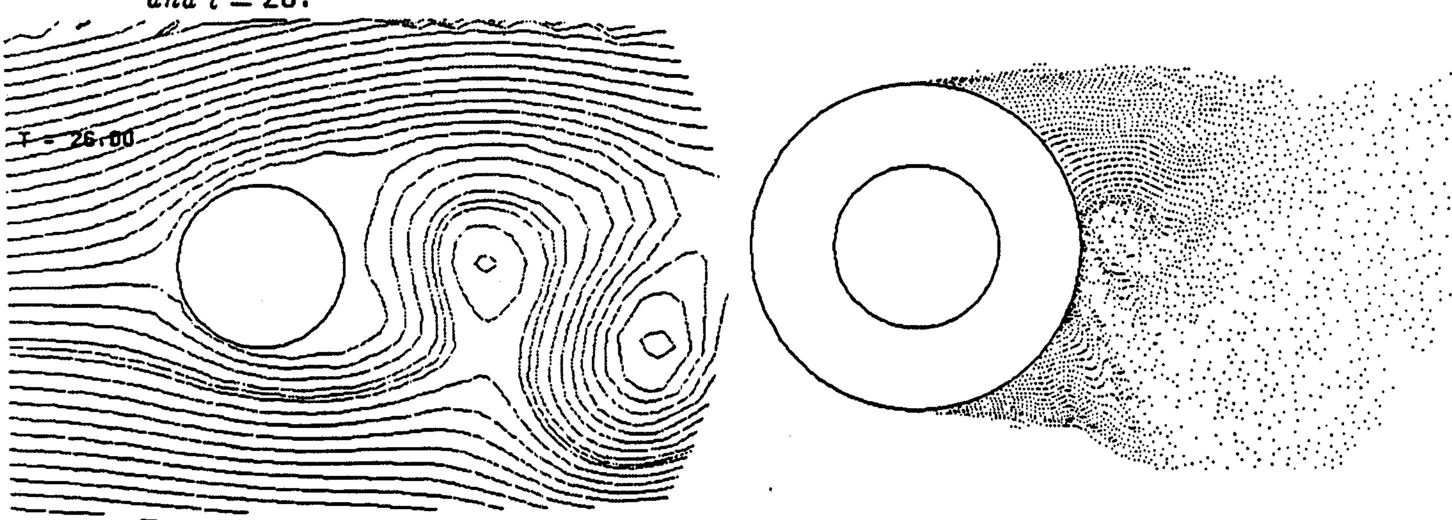


Figure 4: *Unsteady streamlines and corresponding particles behind a circular cylinder with incident waves* $\mathcal{R}_e = 3000$ *and* $t = 26$.

# References


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