# C2.3 HEAVING AND PITCHING AIRFOIL

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## 1 CODE DESCRIPTION

Numerical simulations were performed with a Finite Element Method (FEM) code written in Fortran. The code *Ns2DComp* is an in-house code developed by PhD. Student Weth with the assistance of PhD. Sacco. The code is able to solve Navier-Stokes equations in a compressible scheme. The numerical solution into the element is represented with a linear discretization. The spacial integrals are calculated using Gaussian quadrature rule with three points. Implemented time-stepping algorith is a mixed Runge-Kutta and Adams Bashforth methods, both with a $4^{th}$ order scheme. The code uses OpenMP parallelization with shared memory.

## 2 CASE SUMMARY

We present results for one test case " C2.3 Heaving and Pitching Airfoil ". Before the airfoil starts to move with vertial displacement $h(t)$ and with certain pitching angle $\theta(t)$ we let the flow pass over the aifoil for few real seconds and we saw a convergence in the momentum equation lower than $1e-6$. The machine used for this work was a Linux computer with an Intel I7 X990, 3.47 Ghz processor and 8 Gbytes of Ram. The machine produces a Taubench time of 9.21s on a single core. Simulations were performed with a number of cores of 12 using hyperthreading. Work Units are calculated by formula

$$\tau_{computation}/\tau_{benchmark} \times \sigma \tag{1}$$

where $\sigma$ is the number of cores used and the result is in seconds.

## 3 MESHES

For the Heaving and Pitching Airfoil simulation we use a set of 3 meshes. The domain is a circle with diameter 200 chords, when chord is equal to 1. The airfoil is in the center of the circle. We use fully unstructured grids with triangular elements generated by GiD software. The grid convergence process employed consist in reducing the lenght of the elements which are over the airfoil and in an area near to the airfoil. Each refinement level is generated by splitting the lenght of these elements using the immediate coarser level.

## 4 RESULTS

The results are showed on Tables 1 and 2. The flow conditions are $V_\infty = 1m/s$, $\rho = 1kg/m^3$, $\gamma = 1.4$ and $M = 0.2$. We study the converge of W and I quantities in order to obtain the values accurate to three digits.

| I | W | $1/\sqrt{ndof}$ | Work Units (s) |
|---|---|---|---|
| 2.2507 | 6.0299 | 0.00637 | 201.7 |
| 2.2613 | 6.0599 | 0.00456 | 796.1 |
| 2.2684 | 6.0594 | 0.00289 | 3933.4 |
| 2.2688 | 6.0516 | 0.00143 | 20454.8 |

Table 1: Vertical Impulse. Re=5000

| I | W | $1/\sqrt{ndof}$ | Work Units (s) |
|---|---|---|---|
| 2.2003 | 5.8700 | 0.00637 | 205.6 |
| 2.2055 | 5.8728 | 0.00456 | 1014.2 |
| 2.2005 | 5.8513 | 0.00289 | 4483.0 |
| 2.2029 | 5.8785 | 0.00143 | 22715.3 |

Table 2: Vertical Impulse. Re=1000