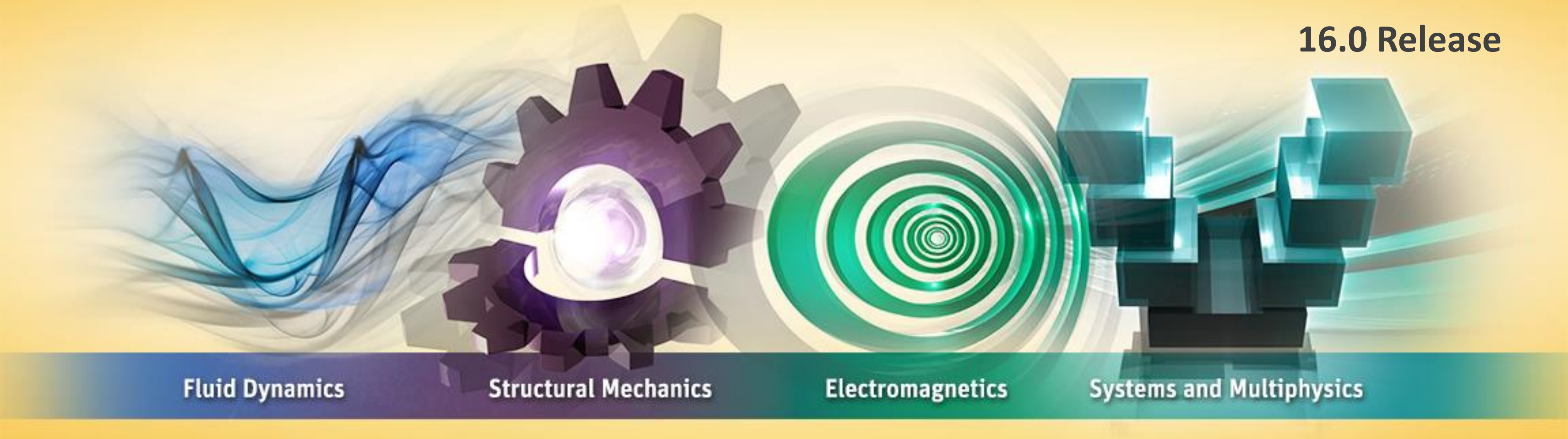
# Lecture 11: Transient Flows

16.0 Release




## Introduction to ANSYS CFX

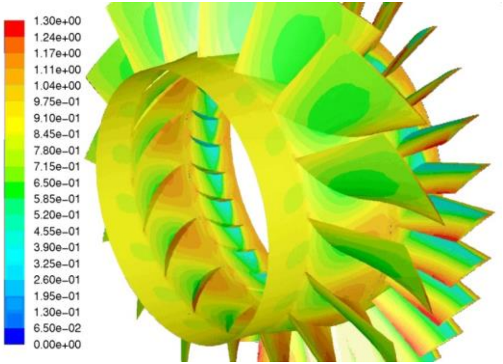
# Introduction

- **Lecture Theme:**
  - **Performing a transient calculation is similar to performing a steady-state calculation, but there are additional considerations. More data is generated and extra inputs are required.**
- **Learning Aims – you will learn:**
  - **Transient flow calculations are becoming increasingly common due to advances in high performance computing (HPC) and reductions in hardware costs. You will understand what transient calculations involve and be able to perform them with confidence**

# Overview

- **Unsteadiness can be**
  - **Natural - growth of instabilities, non-equilibrium initial state**
    - **natural convection flows, turbulent eddies, fluid waves**
  - **Forced - time-dependent boundary conditions, source terms, accumulation/depletion…**
    - **pulsing flow, rotor-stator interaction, tank filling**

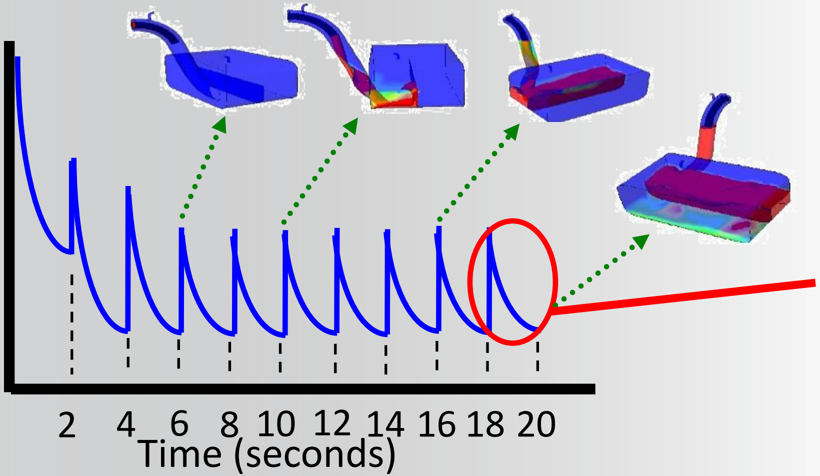
- **Transient simulations allow extraction of**
  - **Natural frequencies (e.g. Strouhal Number)**
  - **Spectral data – fast Fourier transform (FFT)**
  - **Time-averaged and/or RMS values**
  - **Time-related parameters (e.g. time to cool a hot solid)**

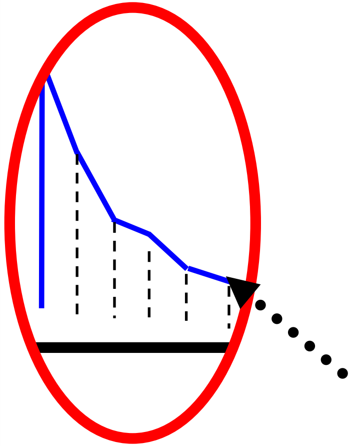



- **More expensive to run & complex to analyse than steady state**

# How to Solve a Transient Case

- **Transient simulations are solved by computing a solution for many discrete points in time**
- **At each time point we must iterate to the solution**



Timestep = 2 s

Initial Time = 0 s

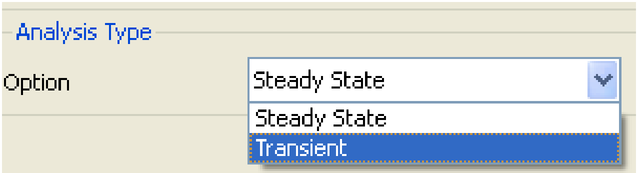
Total Time = 20 s

Coefficient Loops = 5

5 coefficient Loops

# How to Solve a Transient Case

- Similar setup to steady state



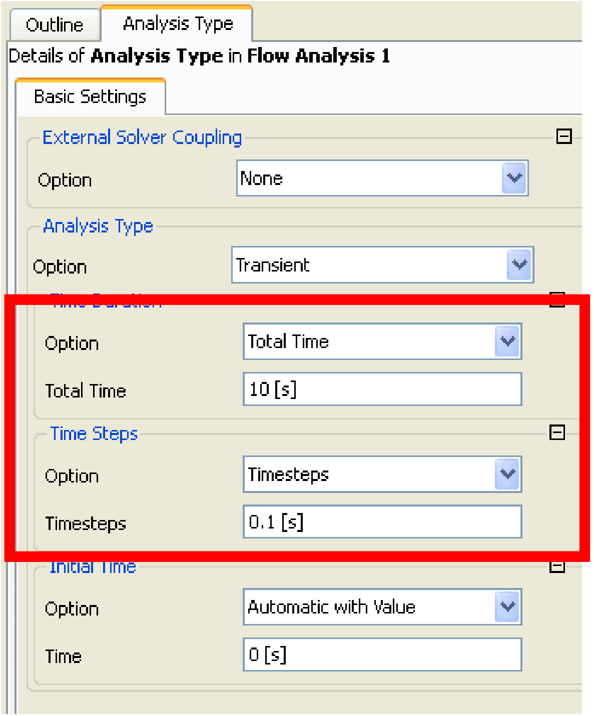

- The general workflow is:
  – Set the Analysis Type to Transient
  – Specify the transient time duration to solve and the time step size
  – Set up physical models and boundary conditions as usual
    - Boundary conditions may change with time
  – Prescribe initial conditions
    - Use physically realistic initial conditions, such as a steady solution
  – Assign solver settings
  – Configure transient results files, transient statistics, monitor points
  – Run the solver



# Time Duration and Time Step

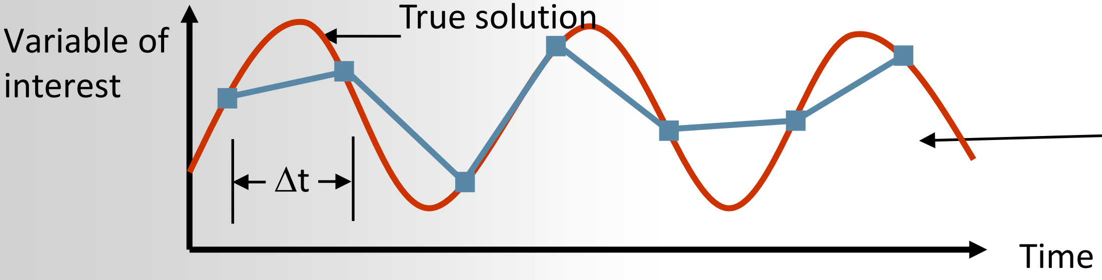
- **Set the Time Duration**
  - Specify time period, either per run or overall
- **Set the Time Step size**
  - Can be fixed, a list or expression
- **Time Duration/Timesteps**
  - Should resolve in a reasonable number of outer iterations



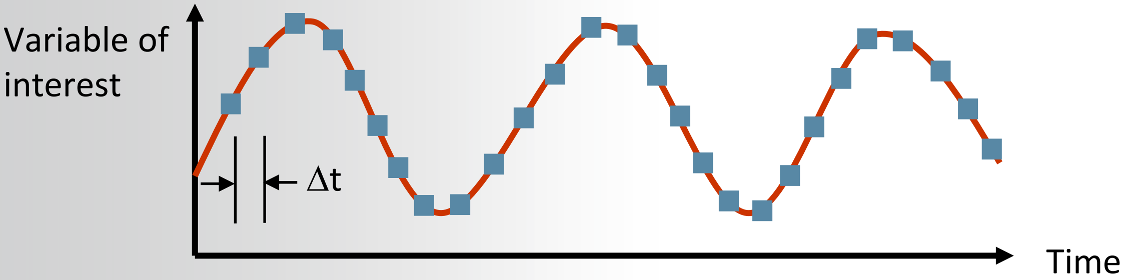

Introduction | Motivation | Setup | **Time Steps** | Output

# Time Duration and Time Step

- The Time Step size is an important parameter in transient runs
  - It must be small enough to resolve time-dependent features




Time step too large to resolve transient changes. The true behaviour has not been resolved.




A smaller time step can resolve the true solution

# Time Duration and Time Step

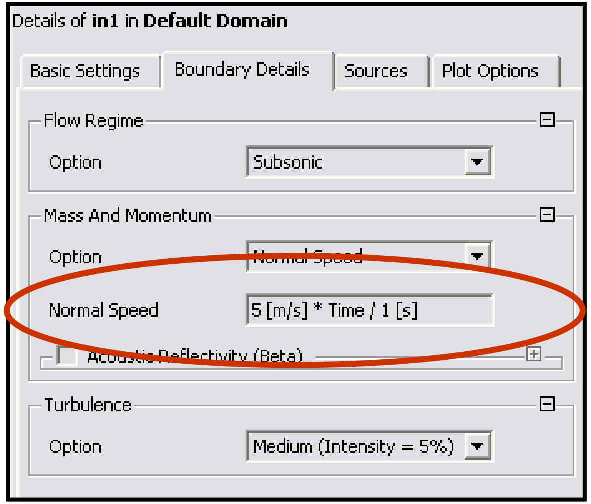
- The quantity of interest may be changing very slowly (temperature in a solid), but you may not be able to use a large timestep if other quantities (velocity) have smaller timescales
- The Courant Number can be used to estimate a time step:

$$\text{CourantNumber} = \frac{\text{Velocity} \times \Delta t}{\text{ElementSize}}$$

  - Number of mesh elements the fluid passes through in one timestep
  - Average and maximum Courant number is reported in the Solver out file
  - Recommended average values are 2 – 10, in some cases higher values are acceptable
- A smaller timestep will typically improve convergence

# Boundary Conditions

- **If required, boundary conditions can be functions of time instead of constant values**
  - **Velocities, Mass flows, pressure conditions, temperatures, etc. can all be expressed as functions**
  - **In CEL expressions use "t" or "Time"**
  - **Can read in time varying experimental data through User FORTRAN**

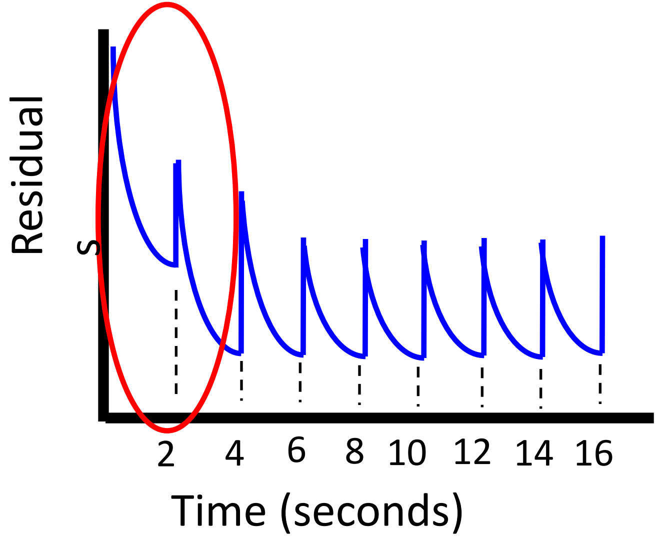



Introduction | Motivation | Setup | Time Steps | Output

# Initialization

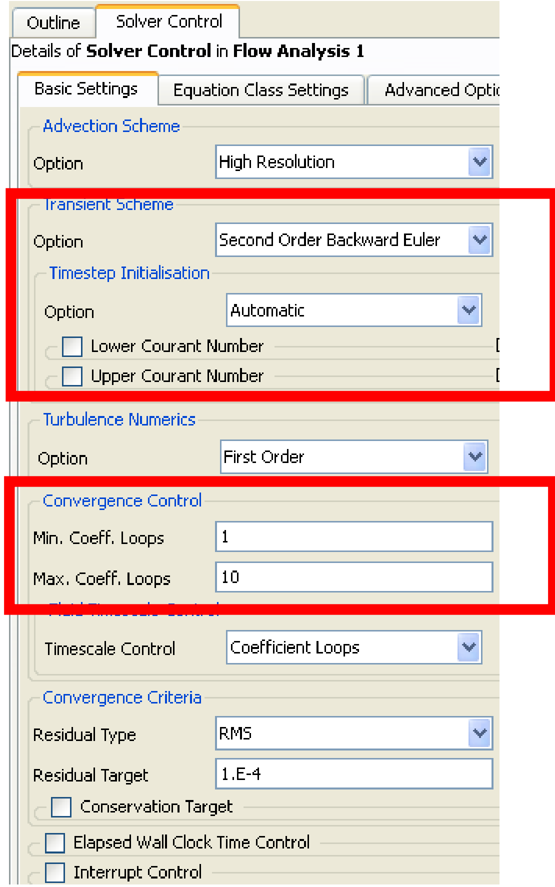
- **Physically realistic initial conditions should be used**
  - **A converged steady state solution is often used as the starting point**
- **If a transient simulation is started from an approximate initial guess, the early timesteps will not be accurate**
  - **The first few timesteps may not converge**
  - **A smaller time step may be needed initially to maintain solver stability**
  - **For cyclic behavior the first few cycles can be ignored until a repeatable pattern is obtained**



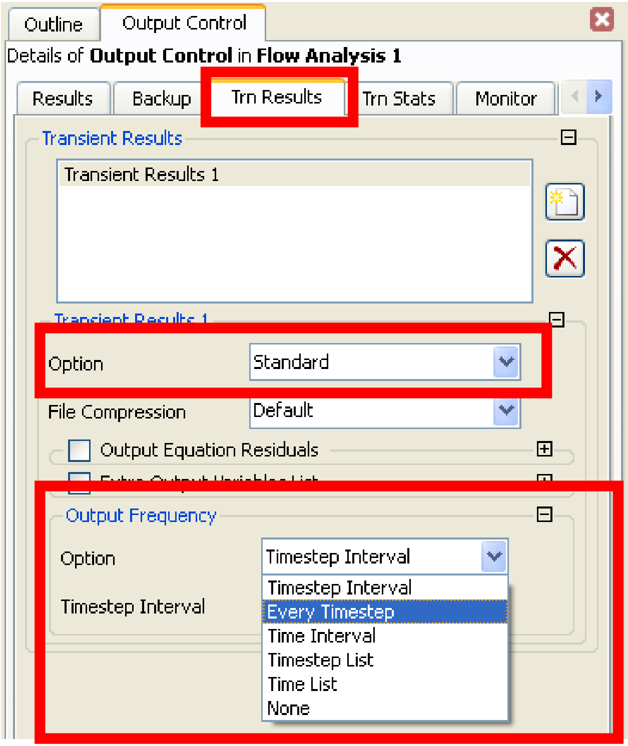
# Solver Control

- **Transient scheme - numerical algorithm for transient term**
  - **Default is recommended**
- **Timestep Initialisation controls starting point for next timestep**
  - **Default: Automatic is recommended**
- **Aim at 3-5 loops to converge each timestep**
  - **Complex physics may need more loops**
  - **Reduce timestep size rather than increase number of loops**
- **Solution proceeds to next timestep regardless of whether the convergence criteria was met → monitor the solution**



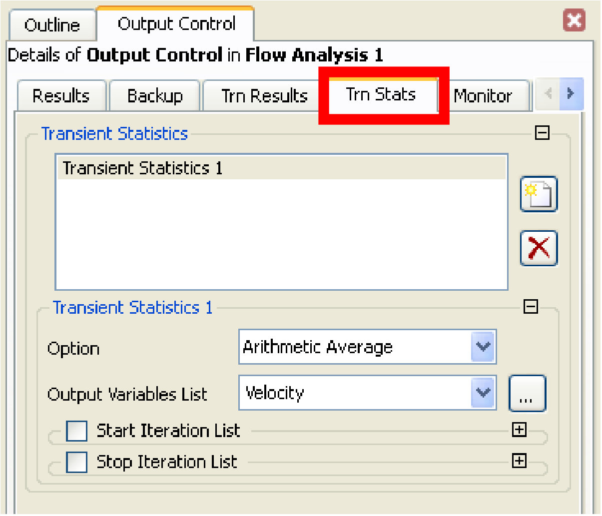
# Output Control

- **Transient Results**
  - **Need to define under Output Control**
- **Transient Results Option**
  - **Standard (full result file)**
  - **Smallest (restart possible)**
  - **Selected Variables**
    - **Pick only variables of interest → smaller files**
    - **Specify whether or not to Include Mesh**
- **Output Frequency**
  - **Controls how often results are written**



# Output Control

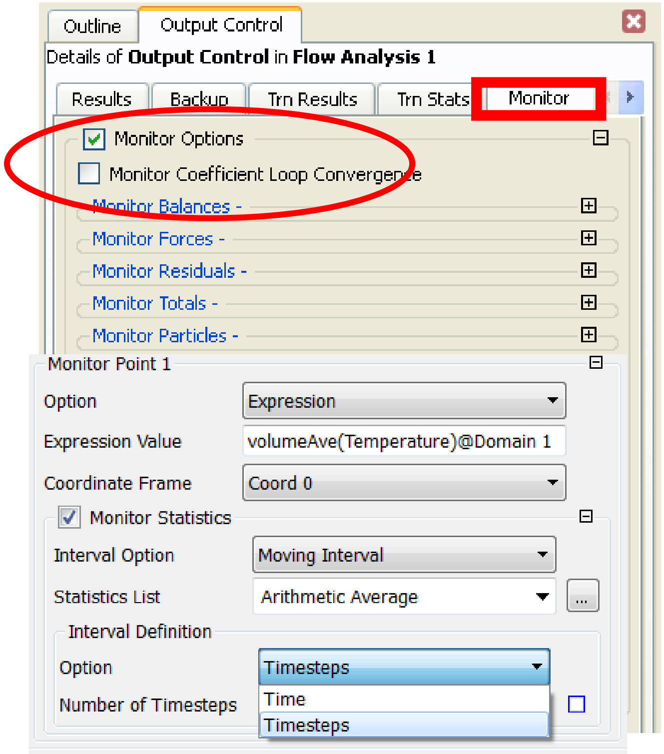
- **Transient Statistics**
  - **Used to generate running statistics for solution variables**
- **Arithmetic Average, RMS, Minimum, Maximum, Standard Deviation and Full (everything) are available options**
- **Pick the variables of interest**
- **Start and Stop Iteration List defines when to begin and end collecting the statistics**




Introduction | Motivation | Setup | Time Steps | Output

# Output Control

- **Monitor Coefficient Loop Convergence**
  - **To check that solution is converging within a timestep**
- **Interval Definition for Monitor Statistics is in terms of Time or Timesteps**




**Tip: Monitors create a transient history chart in the CFX Solver Manager. This is easier and quicker than creating the chart in CFD-Post and does not require writing a series of transient results files**

# Solver Output

- **Each time step now contains coefficient loop output**
- **Courant number information at the start of each timestep**
- **Make sure convergence has been achieved by the end of the timestep by monitoring the RMS and MAX residual plots**

```
======================================================================
|                      Timestepping Information                      |
----------------------------------------------------------------------
|          Timestep         |  RMS Courant Number  |  Max Courant Number |
+---------------------------+----------------------+---------------------+
|         2.5000E-04        |         0.12         |         2.42        |
----------------------------------------------------------------------

======================================================================
TIME STEP =     945 SIMULATION TIME = 5.9000E-02 CPU SECONDS = 8.384E+04
(THIS RUN:      236                   5.9000E-02               8.384E+04
----------------------------------------------------------------------
COEFFICIENT LOOP ITERATION =     1              CPU SECONDS = 8.384E+04
----------------------------------------------------------------------
|       Equation            | Rate | RMS Res | Max Res |  Linear Solution |
+---------------------------+------+---------+---------+------------------+
| U-Mom                     | 0.89 | 4.0E-07 | 1.2E-05 |        1.7E-01  ok|
| V-Mom                     | 0.94 | 3.6E-07 | 1.0E-05 |        2.6E-02  OK|
| W-Mom                     | 0.83 | 3.1E-07 | 1.1E-05 |        1.1E-01  ok|
| P-Mass                    | 0.94 | 4.0E-06 | 4.6E-04 |  6.2   3.6E-02  OK|
+---------------------------+------+---------+---------+------------------+
| K-TurbKE                  | 1.00 | 4.7E-05 | 9.2E-04 |  5.8   2.8E-06  OK|
| E-Diss.K                  | 0.97 | 2.9E-05 | 7.7E-04 |  7.5   8.7E-07  OK|
+---------------------------+------+---------+---------+------------------+
----------------------------------------------------------------------
COEFFICIENT LOOP ITERATION =     2              CPU SECONDS = 8.395E+04
----------------------------------------------------------------------
|       Equation            | Rate | RMS Res | Max Res |  Linear Solution |
+---------------------------+------+---------+---------+------------------+
| U-Mom                     | 1.05 | 4.2E-07 | 1.6E-05 |        1.2E-01  ok|
| V-Mom                     | 0.93 | 3.4E-07 | 1.1E-05 |        7.4E-02  OK|
| W-Mom                     | 1.23 | 3.9E-07 | 1.5E-05 |        1.1E-01  ok|
| P-Mass                    | 0.72 | 2.9E-06 | 3.7E-04 |  6.2   4.6E-02  OK|
```

Introduction | Motivation | Setup | Time Steps | **Output**

# Workshop 06 Vortex Shedding

- **Simulation of vortex shedding behind a cylinder**
  - Transient analysis
  - Fast Fourier Transform
  - Calculation of Strouhal number for comparison with experiment