Multiphysics problems in ANSYS

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What are multiphysics problems?

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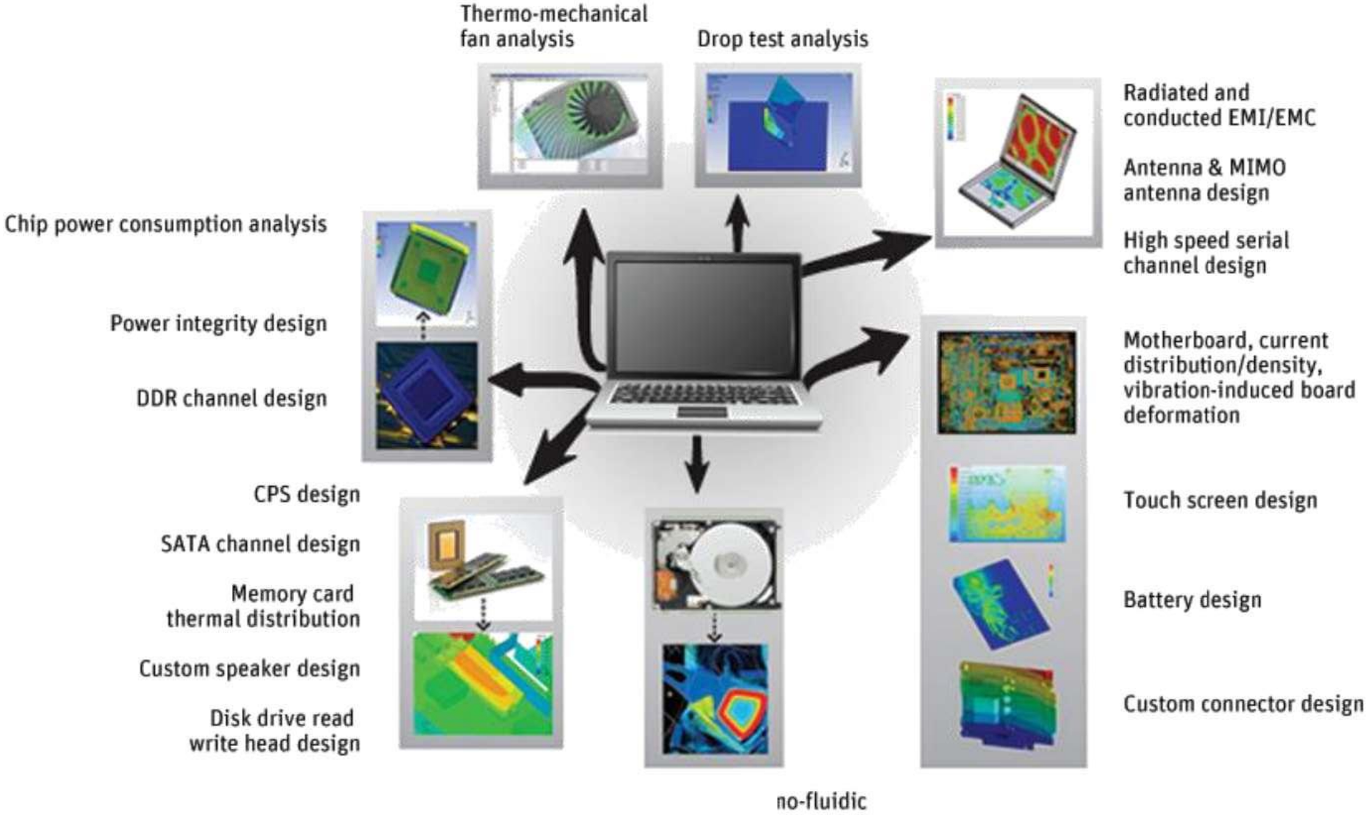
- In real life products and systems **multiple physical processes** occur at once
- Processes can be **interdependent, i.e. coupled**
- In numerical analysis coupling many times **ignored or simplified**
- Simulation engineers are usually single physics
- Coupled analysis more **computationally intensive and complex**
- Can however provide **more realistic results**



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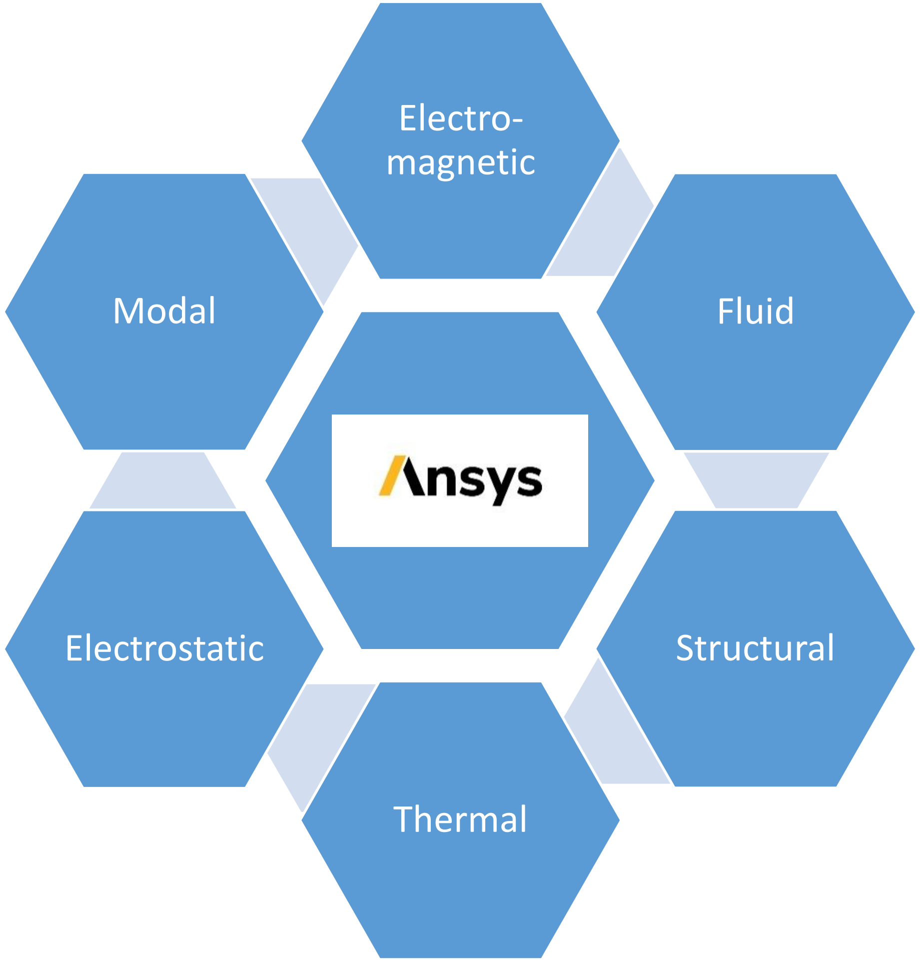
- **General purpose** analysis tool
- Primarily available via Workbench platform but also with APDL, AIM and others
- Can combine **two or more** different but interrelated **physical models**
- **Fully parametric** models across physics, geometry, materials and loads
- **Sequential** or **direct coupling**

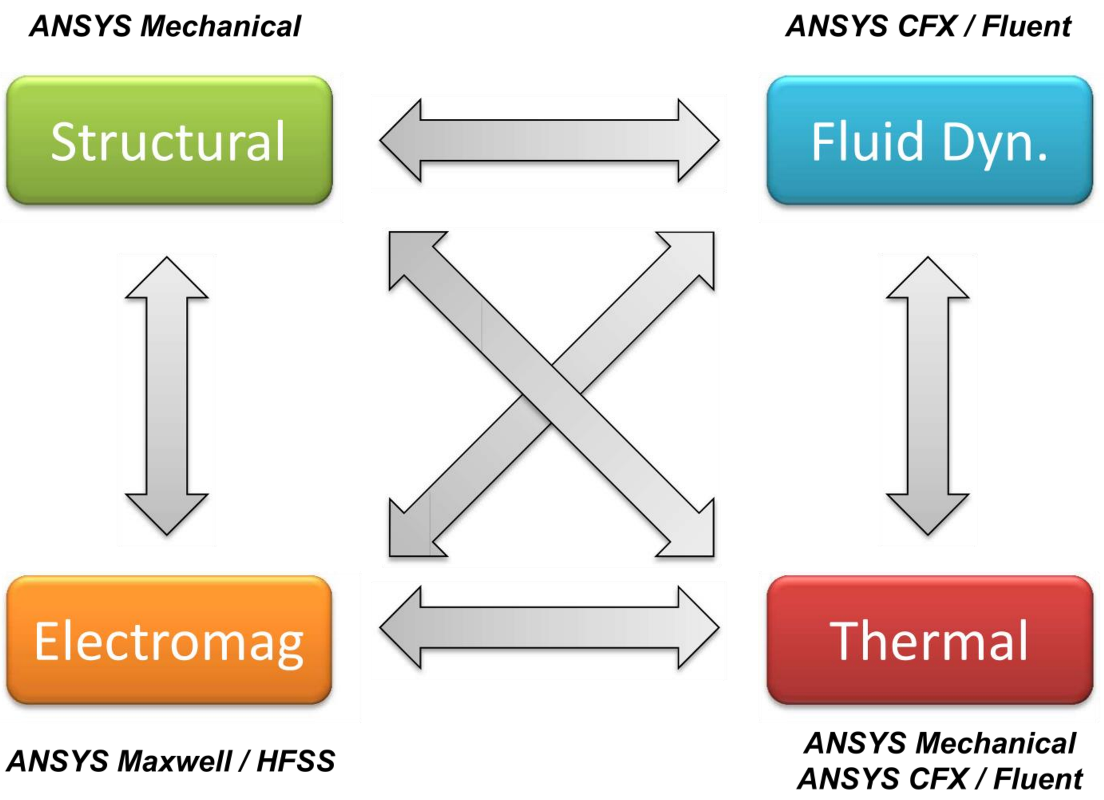


Sequential vs. Direct coupling

- Direct:
  - solves all DOF in a single FEA coefficient matrix system

$$\begin{bmatrix} K_{11} & K_{12} \\ K_{21} & K_{22} \end{bmatrix} \begin{bmatrix} u_1 \\ u_2 \end{bmatrix} = \begin{bmatrix} F_1 \\ F_2 \end{bmatrix}$$

  - coupled effects are accounted for by off-diagonal coefficient terms K_{12} and K_{21}
- Sequential:
  - First solves DOFs for one physical problem (e.g. thermal)
  - Then passes the results as loads and boundary conditions to the second physical problem (e.g. structural)



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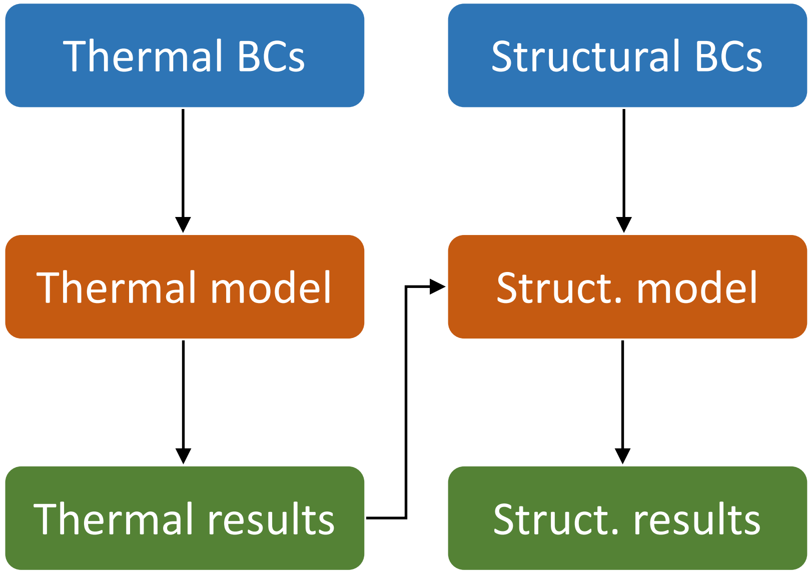
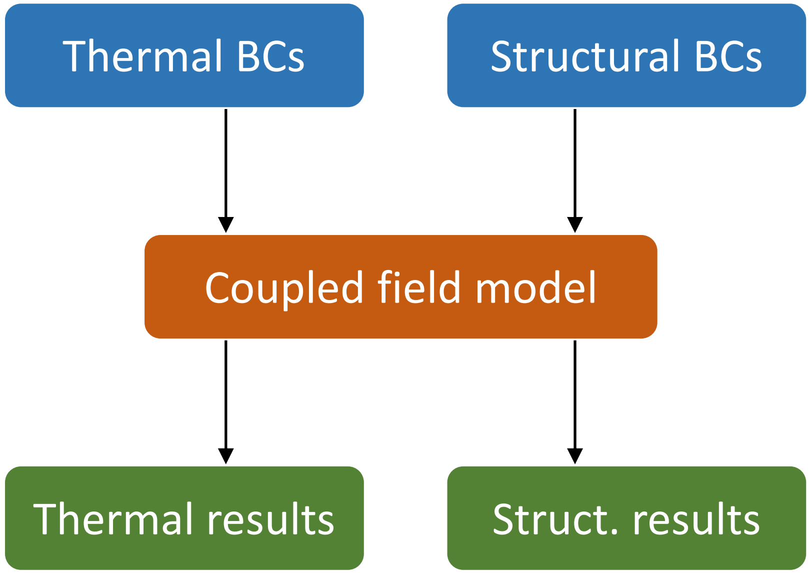
Example: thermomechanical analysis

Sequential coupling



Direct coupling



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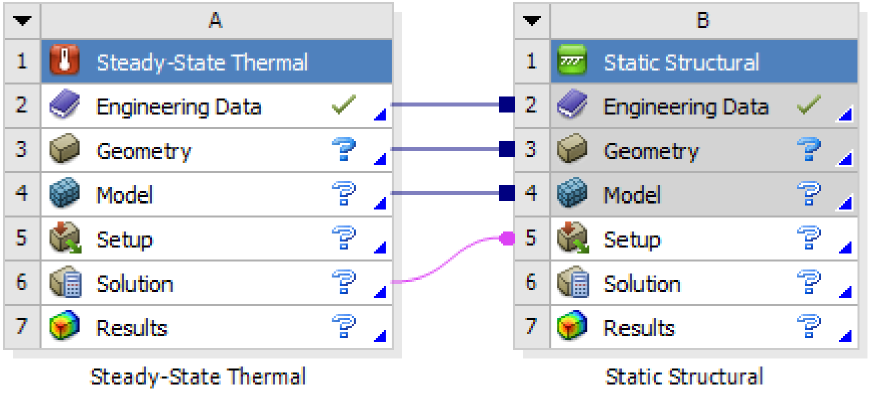
Sequential coupling

- Can be easily achieved in ANSYS Workbench

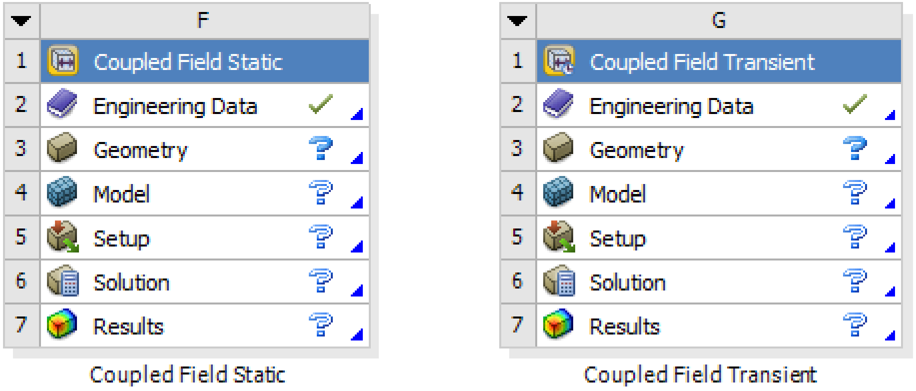


Example – thermomechanical problem:

➢ Thermal state influences mechanical response but not vice versa

Direct coupling

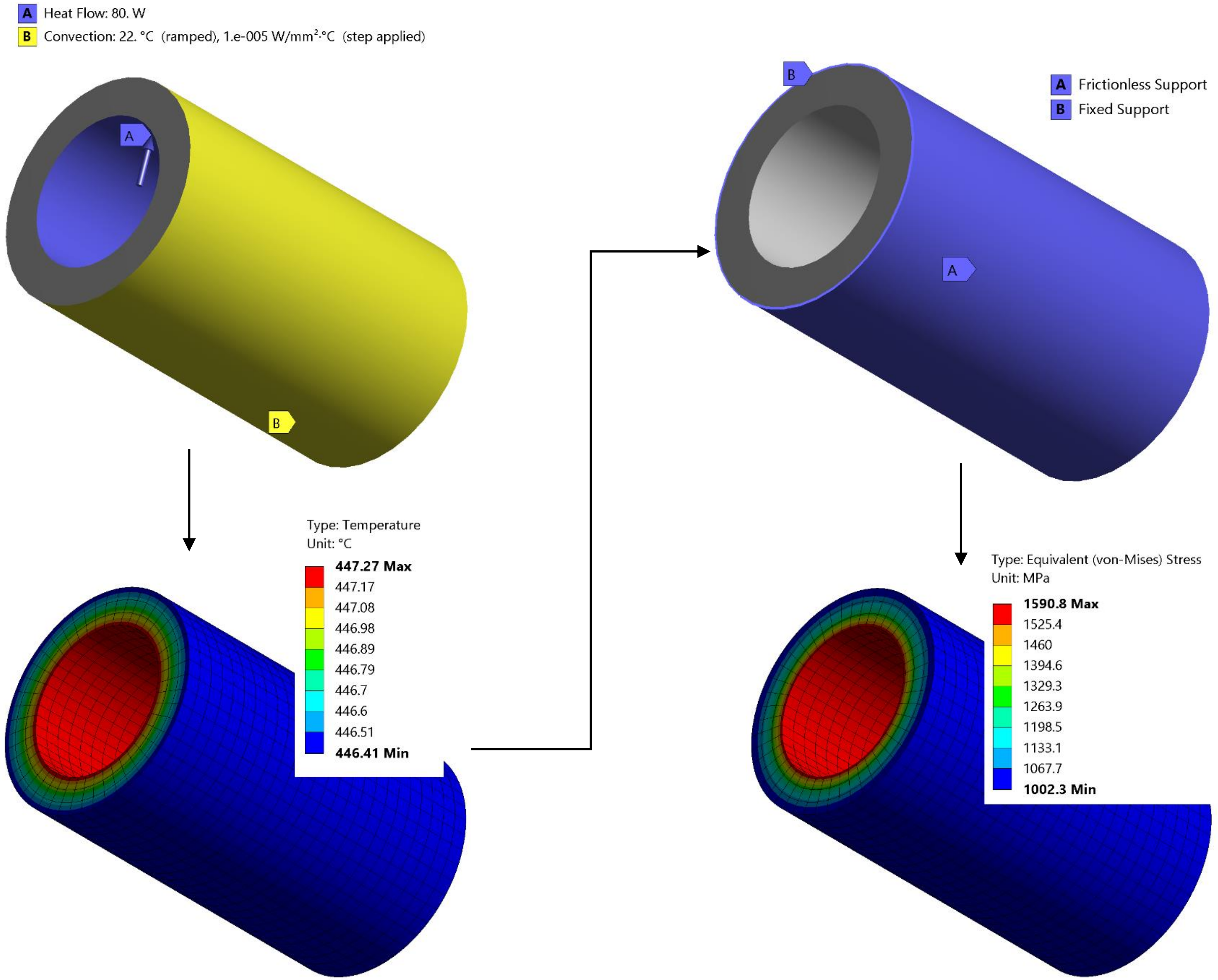
- Two possibilities in Workbench:
  - APDL command programming:
    - Appropriate coupled-field FE needs to be selected
    - BCs/loads need to be applied partly using APDL commands
  - Use of the Coupled field module (recently developed):



Example – Sequential coupling – Thermomechanical problem

- Project*
  - Model (A4, B4)
    - Geometry
    - Materials
    - Coordinate Systems
    - Mesh
      - Sweep Method
    - Steady-State Thermal (A5)
      - Initial Temperature
      - Analysis Settings
      - Heat Flow
      - Convection
      - Solution (A6)
        - Solution Information
        - Temperature
    - Static Structural (B5)
      - Analysis Settings
      - Fixed Support
      - Frictionless Support
      - Imported Load (A6)
        - Imported Body Temperature
      - Solution (B6)
        - Solution Information
        - Equivalent Stress

Transfer to structural analysis



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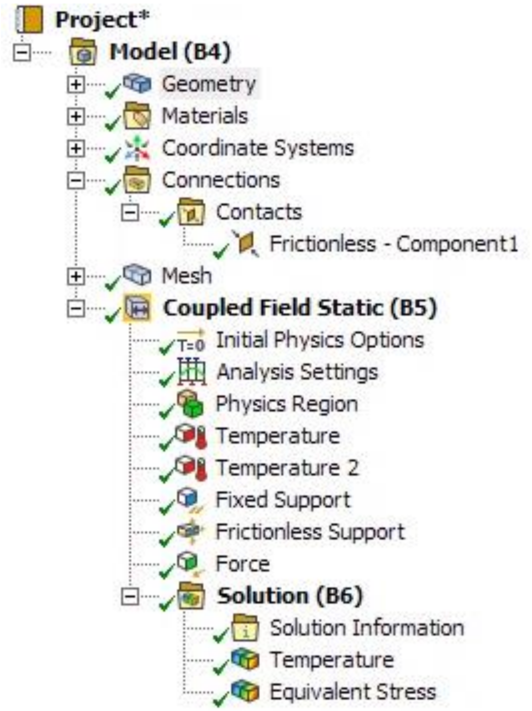
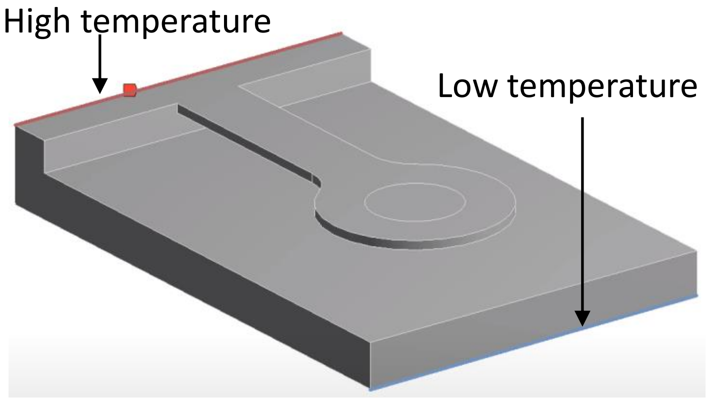
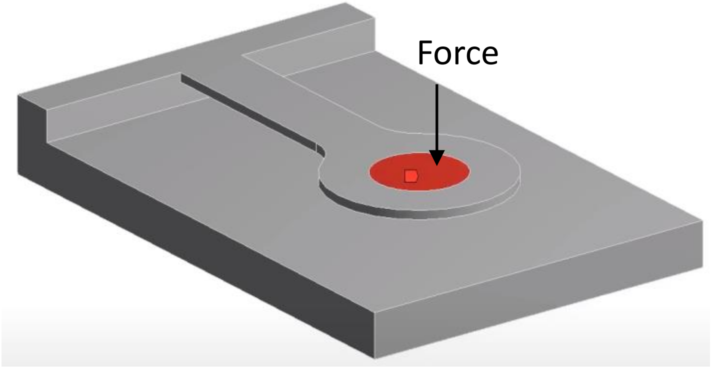
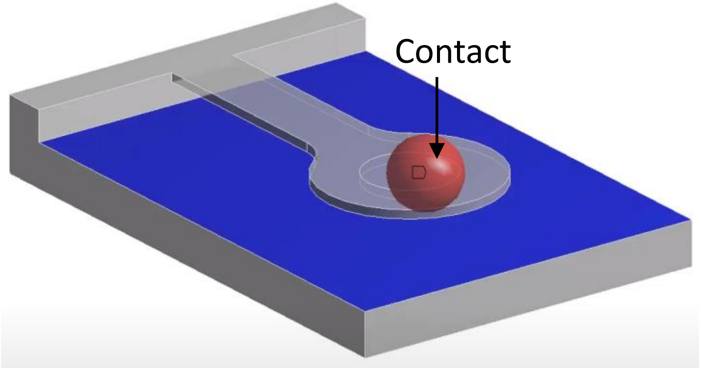
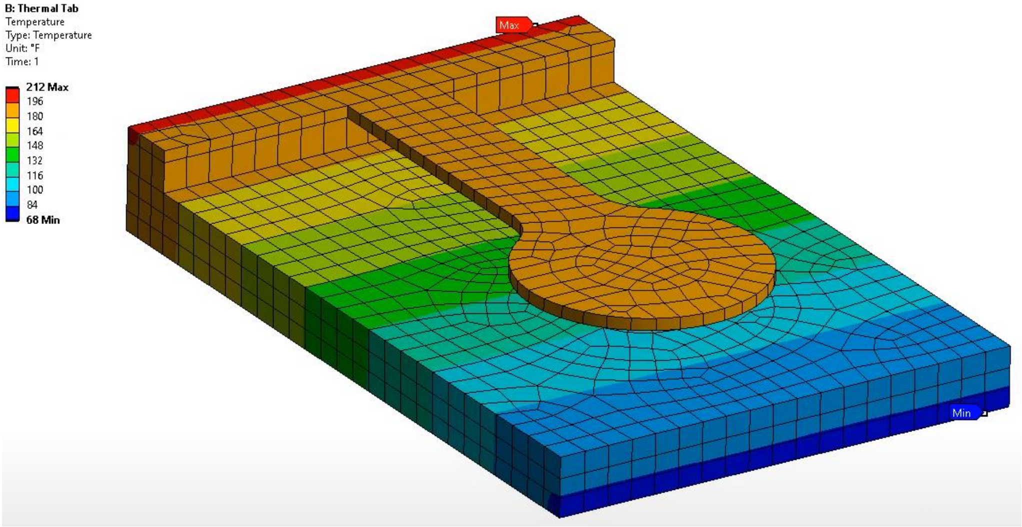
Example – Direct coupling – Thermomechanical problem

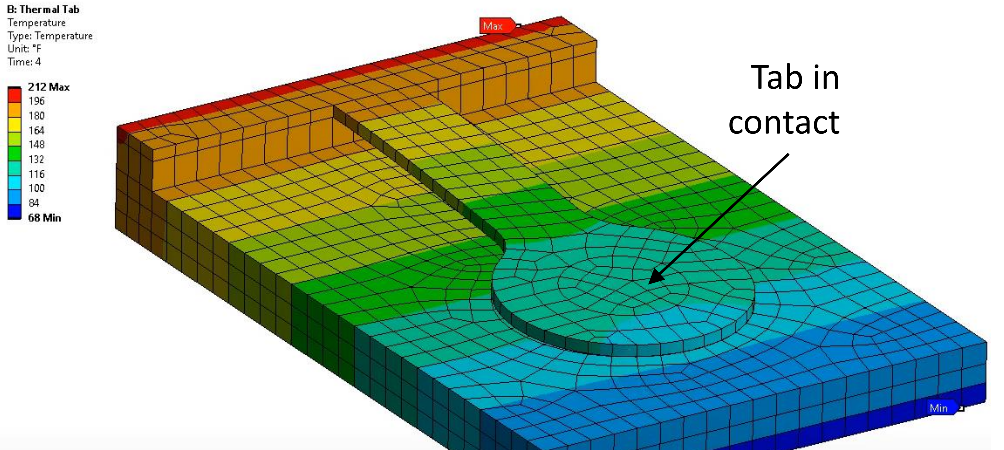








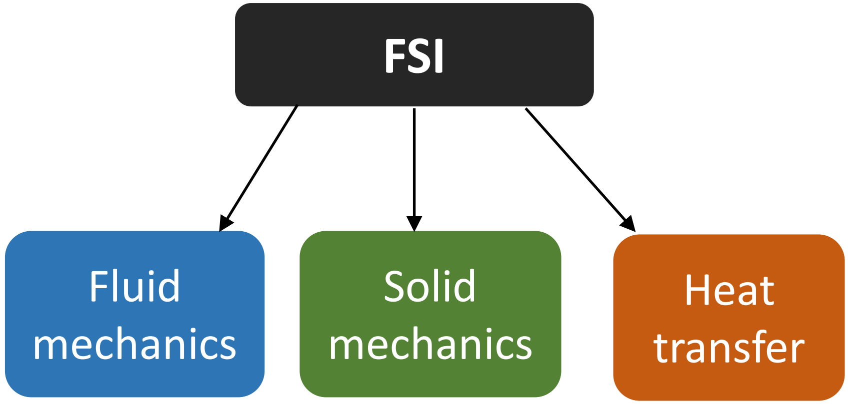




Simtech tutorial

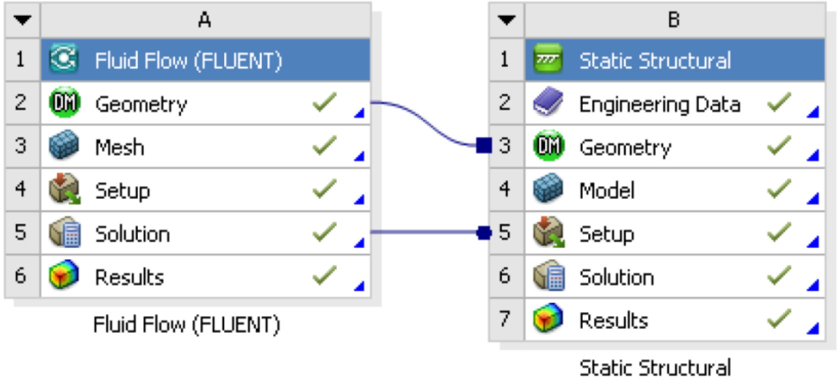
Fluid-structure interaction (FSI) analysis

- More accurately it‘s **fluid-solid** interaction
- Problems where **fluid flow interacts with a solid structure**
- Flow may exert **mechanical or thermal loads** onto solid – 1-way interaction)
- **Structural deformations** could also **influence the fluid flow** – 2-way interaction (direct coupling)
- Why FSI important?
    - ➢ Crucial for understanding many engineering problems
    - ➢ In many systems the **fluid can influence** very importantly the **service life of solid components**
    - ➢ Areas of industry: aerospace, automotive, energy, pharmaceutics, etc.

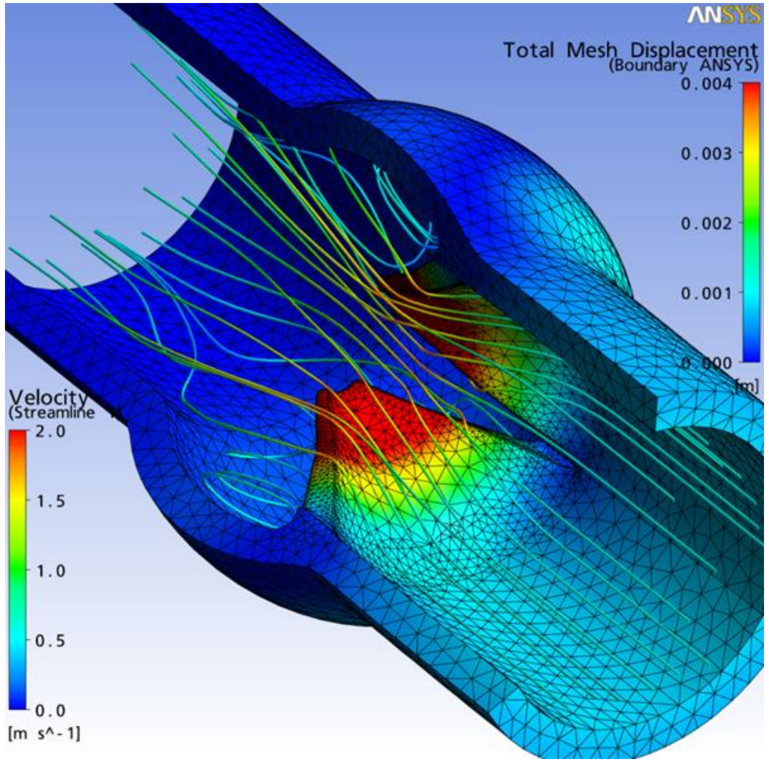


Modelling approaches

- Define the degree of physical coupling between fluid and solid systems
    - Q: How sensitive is one field to a change in the other field?
- Systems that are relativelly independent can be sequentially coupled or even uncoupled



- Strongly physically interdependent systems require strong (direct) numerical coupling



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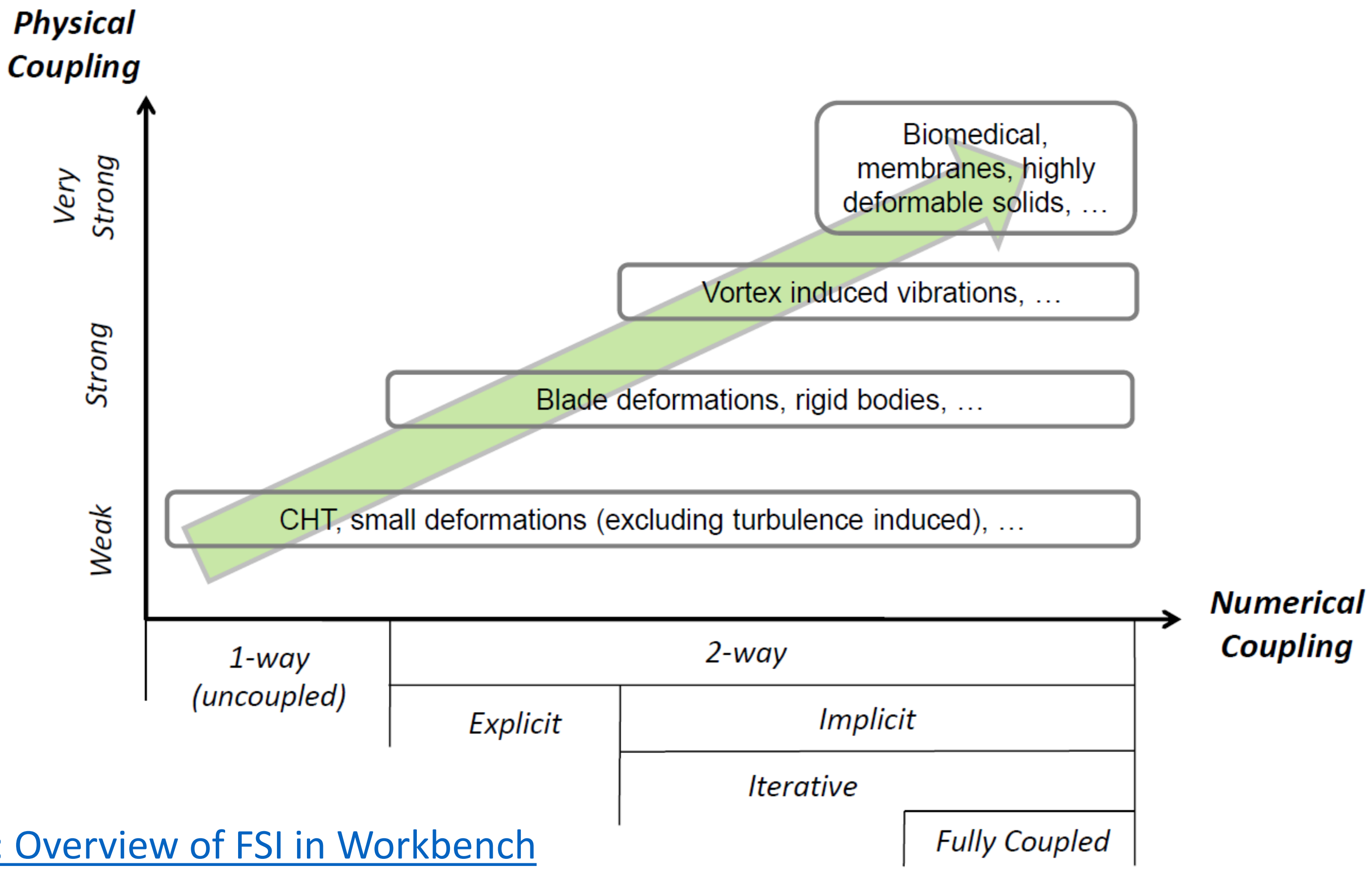
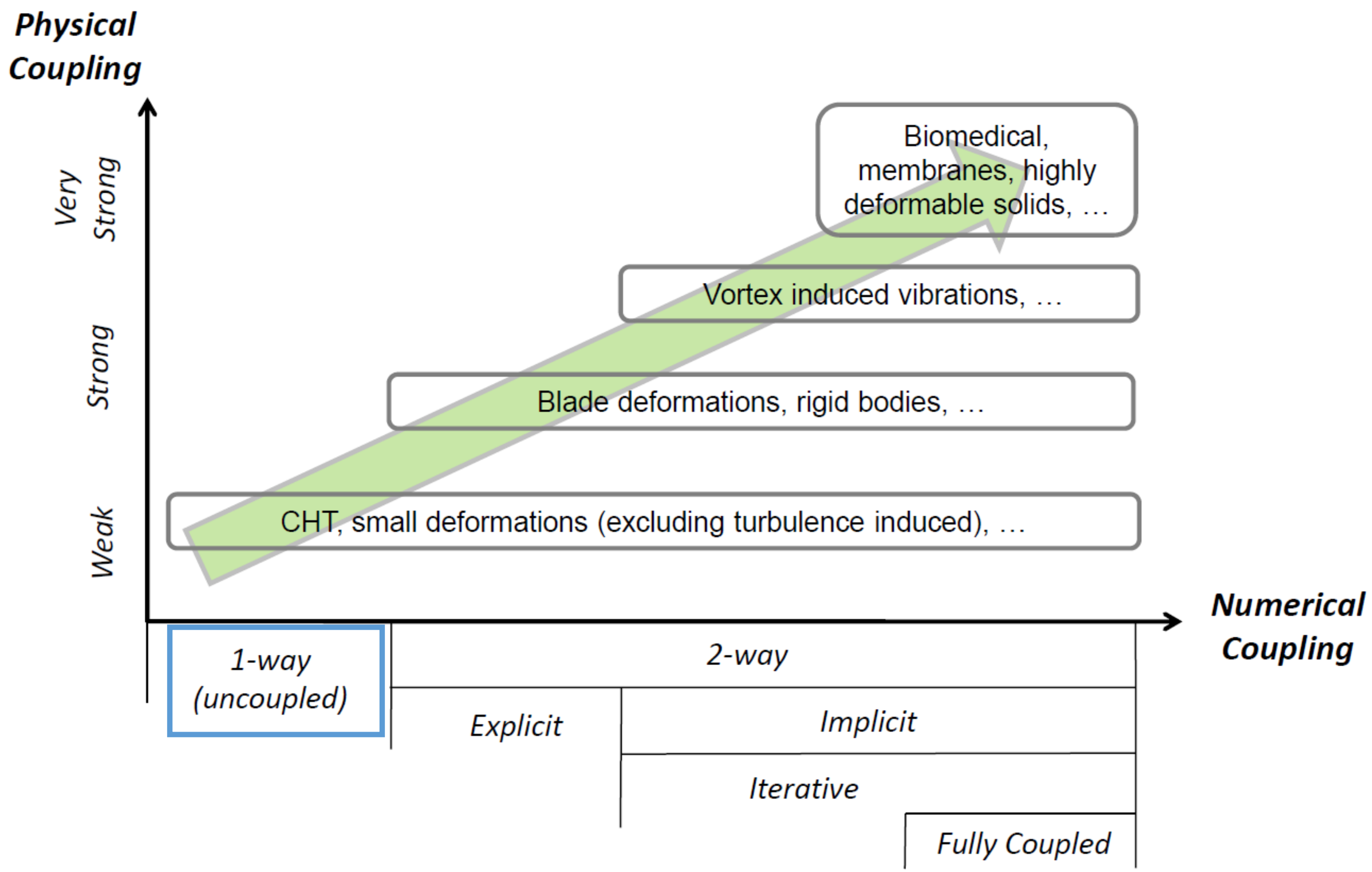


[Lecture: Overview of FSI in Workbench]



1-way (uncoupled)

Solution is obtained for one field (e.g. fluid), then used as a boundary condition or external load for the second field

Suitable for weak physical coupling

Easily done in Workbench: Fluent + Mechanical

- Automated data transfer

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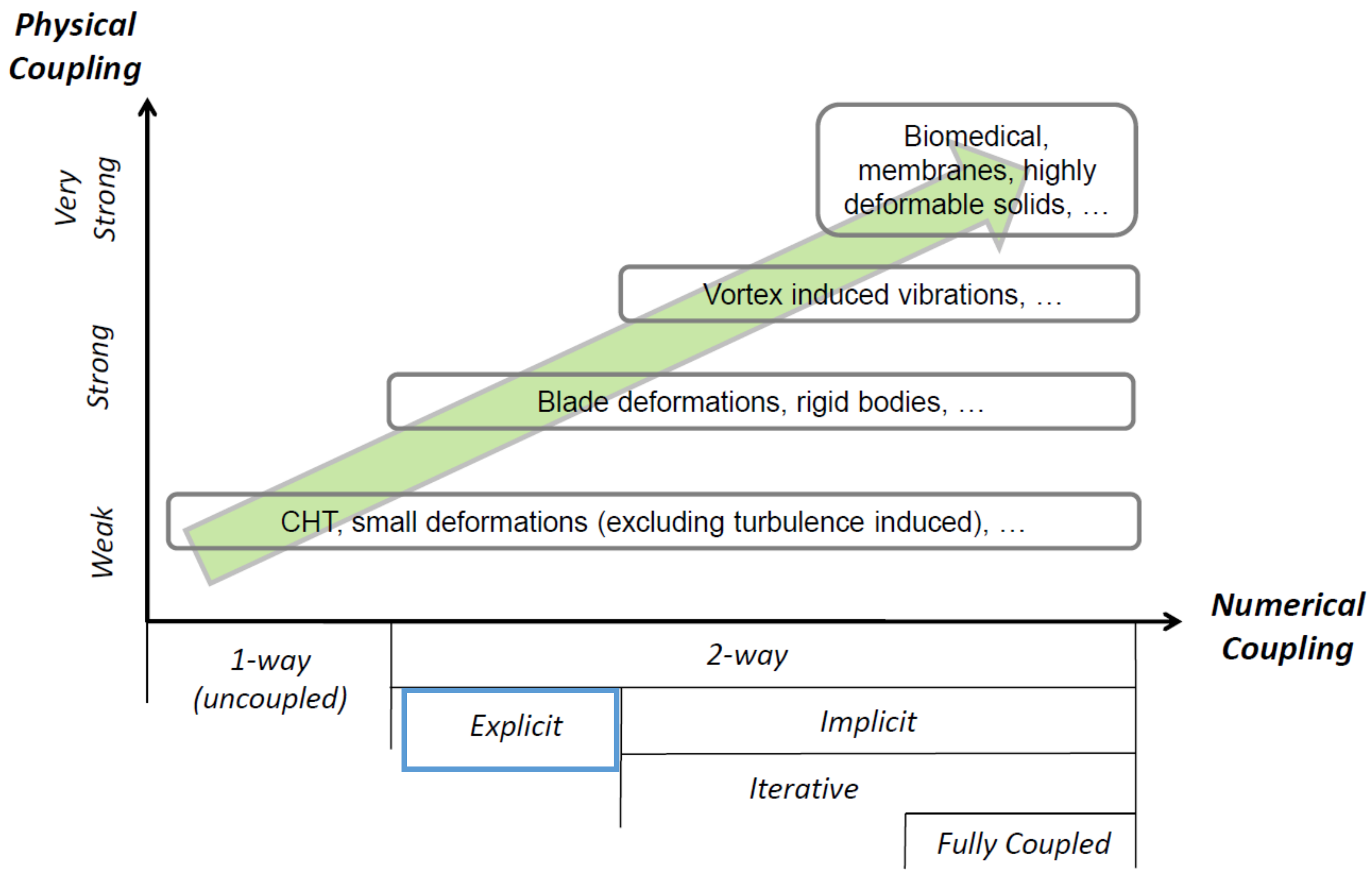

2-way explicit

No iterative solver for calculating fluid-solid interation within a time step

Solid solution based on fluid solution from previous step (or vice-versa)

Generally requires very small time steps

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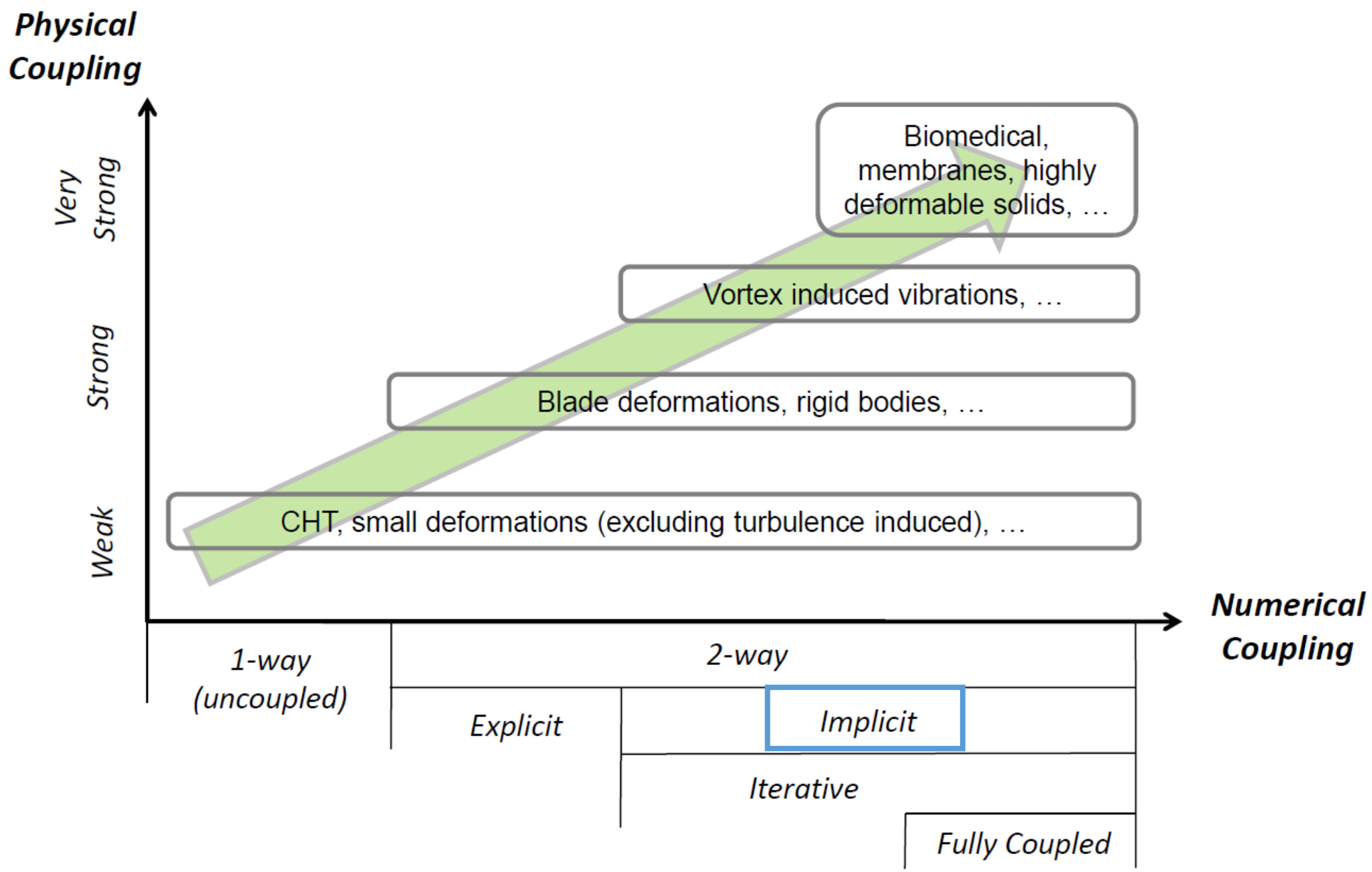

2-way iteratively implicit

Fluid and Solid equations solved separately (separate solvers)

Iterate within each time step to obtain an implicit converged solution

Used in Mechanical Fluent (Workbench)

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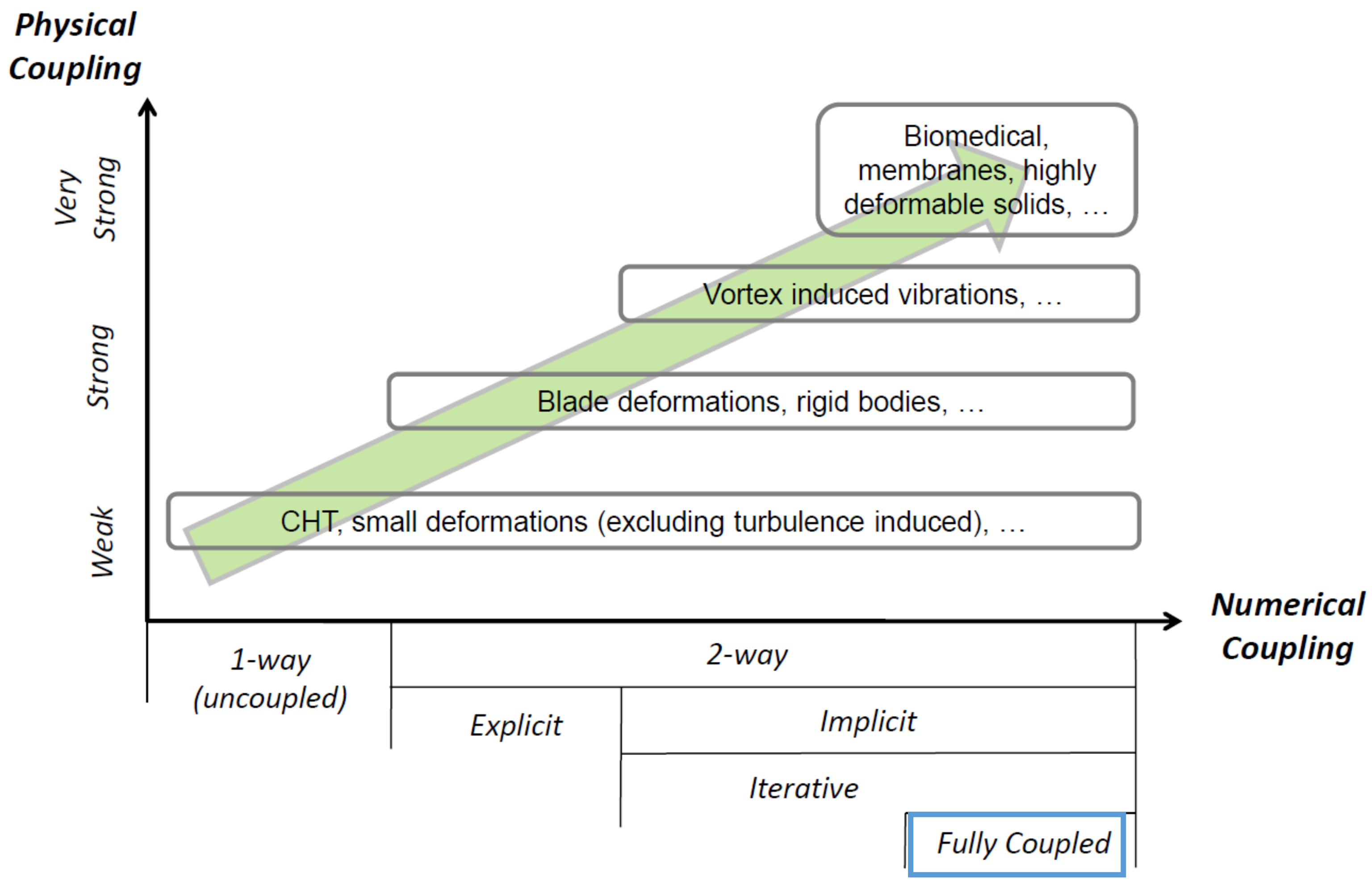

Fully coupled

Fluid and Solid equations solved in a single monolithic matrix – like coupled field solver in thermomechanical example

Fields remain very tightly coupled

Very difficult to solve a monolithic fluid structure matrix

Not available with Mechanical – Fluent coupling

Implicit v. Explicit

In FSI context:

- „implicit“ and „explicit“ hold different meaning than „implicit solver“ and „explicit solver“ in e.g. solid mechanics
- Explicit means the fluid and solid fields are solved separately but there are **no coupling iterations** within a time step
- Implicit means the **dependencies** between the fluid and solid fields are **converged within a time step**:
  - Coupling iterations – iteratively implicit
- Using single fluid-solid matrix – fully coupled

Explicit approach:

- For weak physical interdependence
- Time scales small enough to get right answer on the first coupling iteration

Implicit approach:

- Can be more robust than explicit approach
- Larger time steps can be used
- Mainly used in ANSYS
- Assumption – several iterations needed to get the correct result

Thank you for your attention!

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