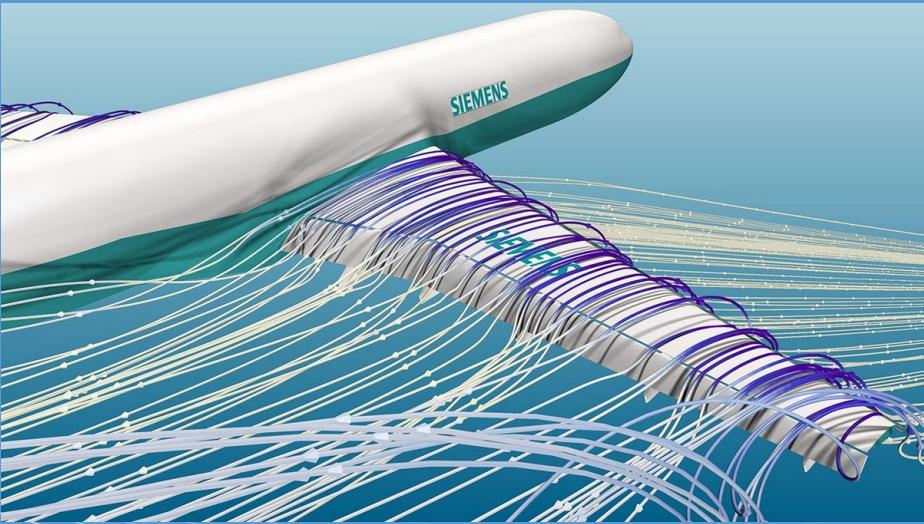


SynthEddy

Simulating Turbulent Flow
with Synthetic Eddy

What is CFD

- Using computer to simulate fluid (air, water, etc) flow and its interactions with other objects.



Credit: ASCENDTECH GROUP



Credit: SolidWorks

Laminar vs Turbulent Flow

- How does CFD simulate turbulent flow?
- (black board)



Credit: <https://commons.wikimedia.org/wiki/User:Tangopaso>



Problem Statement

- Typically, turbulent flow CFD needs to start from laminar flow and let it develop into turbulent flow.
- High computation cost/time.
- Proposal to approximate turbulent flow with artificially generated eddies.

Goal Statement

- Goal:
 - Generate turbulent flow velocity field with user provided eddy profile(s)
- Stretch Goals
 - Generate **realistic** turbulent flow velocity field.
 - Allow common CFD software to obtain initial conditions through this program.

Users / Stakeholders

- CFD users looking to reduced computation time on turbulent flow
- Researchers studying synthetic eddy methods

Theoretical Model

- Velocity fluctuation: sum of all eddies

$$\mathbf{u}'(\mathbf{x}) = \sqrt{\frac{1}{N} \sum_{k=1}^N \frac{q_\sigma(|\mathbf{r}^k|)}{|\mathbf{r}^k|^3} \mathbf{r}^k \times \boldsymbol{\alpha}^k}$$

$$\text{where } \mathbf{r}^k = \frac{\mathbf{x} - \mathbf{x}^k}{\sigma^k}$$

\mathbf{x} : position vector in the flow field
 \mathbf{u}' : fluctuation from average velocity
 k : index of each eddy
 $q_\sigma(|\mathbf{r}^k|)$: Shape function
 σ : eddy length-scale
 $\boldsymbol{\alpha}$: random eddy intensity, with average of 0

Input and Output

- Input
 - Region dimensions $Lx, Ly, Lz: \mathbf{R}^3 +$
 - Average velocity $\mathbf{v}_a: \mathbf{R}^3$
 - Number of eddies $N: \mathbf{Z}+$
 - Eddy length-scale $\sigma: \mathbf{R} +$
 - Shape function?
 - Query: x, y, z, t
- Output
 - Velocity at any given point or time $\mathbf{v}(x, y, z, t): \mathbf{R}^3$

Assumptions

- A1: 3D external flow region
- A2: 1D flow direction
- A3: The synthetic eddy method can indeed mimic turbulent flow for the purpose of being CFD initial conditions
- A4: User can provide appropriate eddy profiles

Requirements

- Functional:
 - R1: Can generate a velocity field given any valid eddy profile input
 - R2: Can provide a realistic eddy profile
 - R3: Generated velocity field must be **divergence-free** (zero sum of velocity fluctuation, required by the theory)
 - R4: Must verify that the queried point is within the flow region
- Non-functional
 - Can interface with common CFD software (constraints?)

Questions / Comments?

- Thank you!
- References
 - Poletto, Ruggero & Craft, T. & Revell, Alistair. (2013). A New Divergence Free Synthetic Eddy Method for the Reproduction of Inlet Flow Conditions for LES. *Flow, Turbulence and Combustion*. 91. 1-21. 10.1007/s10494-013-9488-2.