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Single Section DES Study of Sirocco Fan

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발표자 : 주종욱(삼성전자)

Background & Motivation

1. Forward-curved centrifugal fan – or Sirocco fan is widely used in many applications because of its better flow capacity with given size and RPM.

2. RANS is notoriously inaccurate in predicting performances of this type of fan.

3. Uncertainty in RANS prediction causes many ₩₩₩ in development stages.

4. Currently, there is no affordable option to accurately predict the performance with full 3D CFD model.

Background & Motivation

It is difficult to understand and analyze the flow around Sirocco fan because …

1. Experiment – flow field data between blades are rare (difficult to measure)
2. Lack of DNS data ➡ difficult to analyze the flow fundamentally.
3. Flow is dominated by separation and unsteady motions. ➡ difficult for RANS but a full 3D LES is very expensive.
4. Flow is highly three dimensional. ➡ difficult to interpret the flow for design purpose. (no clean flow)

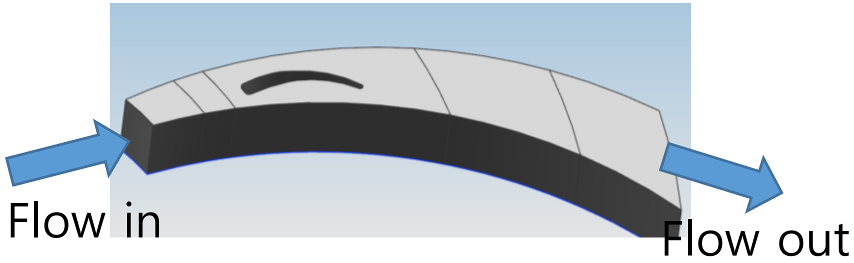
Multi-fidelity approach

In a complex flow environment, it is difficult to understand the flow physics involved in design parameter changes, deterring to design smartly and effectively.

To capture inherent and simple flow features, the following multi-fidelity approach is suggested.

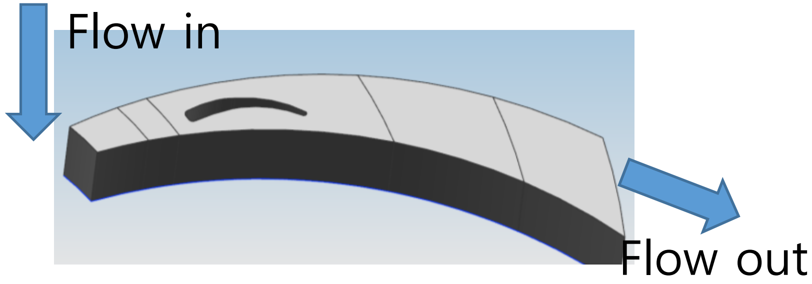
✓ Single Section 2D flow DES

- 1 pitch, partial span domain
- Flow comes and out radially.
- No Scroll



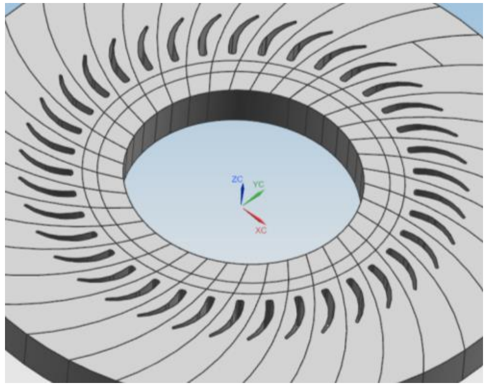
Single Section 3D flow DES

- 1 pitch, full span domain
- Flow come axially and exit radially
- No Scroll



Full 3D flow DES with scroll

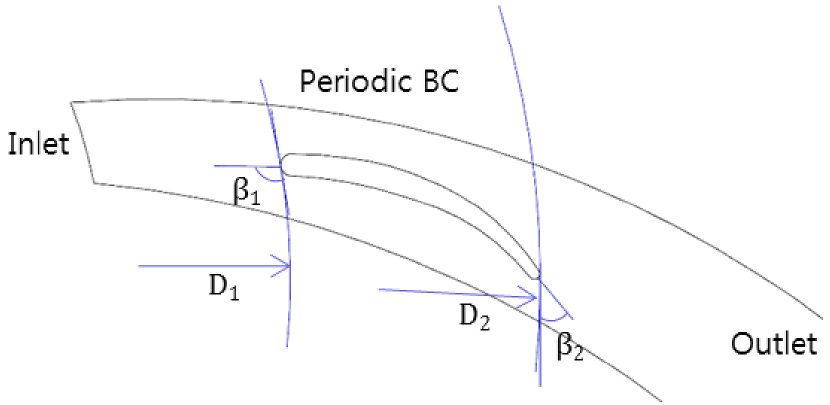
- full pitches and full span
- Flow come axially and exit radially
- Scroll



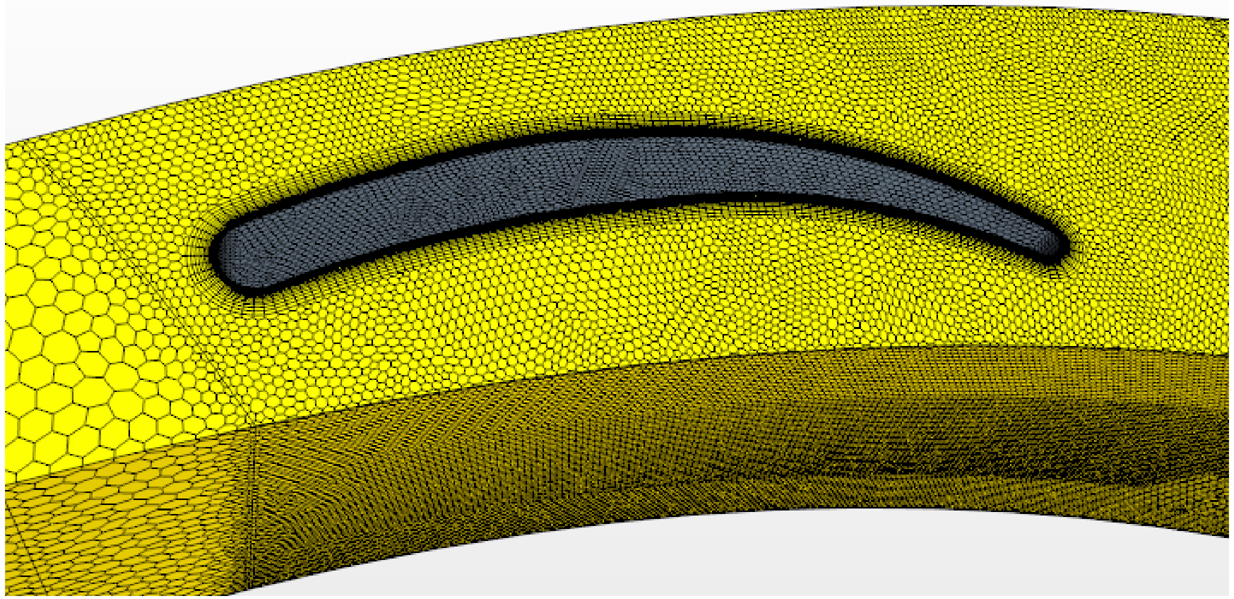
Computational Setting

- Experimental Blade – not a production model

D_1	D_2	β_1	β_2	RPM
110mm	150mm	100°	38°	2600



- Grid
  - 1.2M cells
  - 181 grid in radial chord
  - Span depth – 35% of radial chord



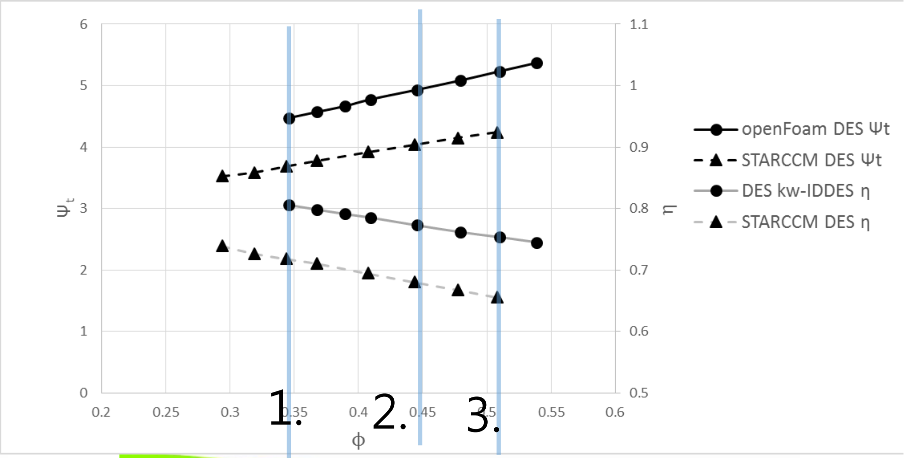
- Boundary condition
  - Stagnation inlet
  - Periodic BC – span & pitch directions
  - Outlet BC

Computational Setting

- DES Model – k-ω base IDDES, openFOAM v1812
- Time step size : 3.515e-6 s, average CLF ~ 0.5
- 12,500 time steps for initial flush out, 12,500 time steps for statistics (~30 blade flow times)

ddtSchemes		backward;
gradSchemes		Gauss linear;
divSchemes	div(phi,U)	Gauss LUST grad(U);
	div(phi,k)	bounded Gauss upwind;
	div(phi,omega)	bounded Gauss upwind;
laplacianSchemes		Gauss linear uncorrected;
snGradSchemes		uncorrected;

Results – Instantaneous velocity field: openFOAM and STARCCM

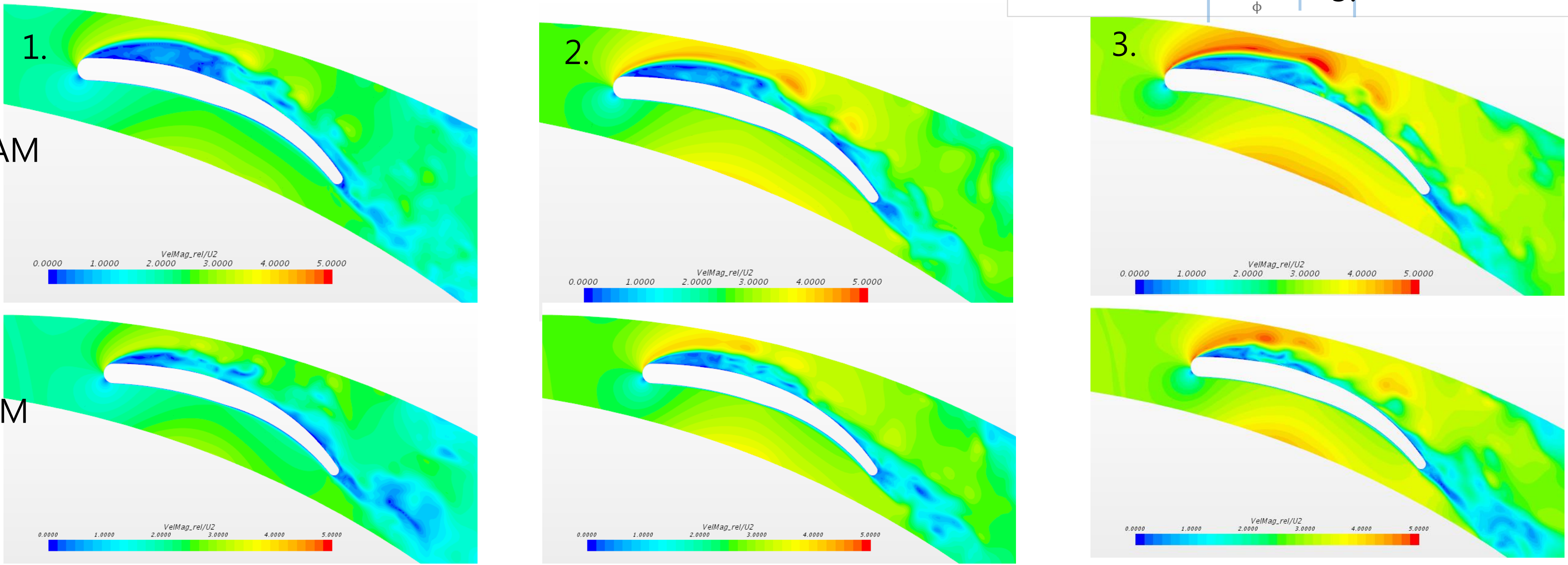


Instantaneous fields indicate the difference in how shear-layers break down in each solver – early break down leads to more loss.

Difference is not ignorable!!!

openFOAM

STARCCM



Conclusion

1. DES cases on 2D geometry for Sirocco fan performed as the first step of multi-fidelity approach.
2. DES predicted less loss and more flow rate than RANS.
3. Better performance predicted in DES is attributed to shorter separation bubbles - enhanced turbulence mixing in the shear layer cause them.
4. The break-down of shear-layer in STARCCM DES appears earlier than in openFOAM DES, promoting more mixing loss.
5. The culprits of the difference are thought to be different k-ω IDDES implementation and numerical discretization.