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STUDY ON THE PENNY PLATFORM OF VARIABLE STATOR VANE IN COMPRESSOR

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Outline

◆ Background

◆ Experimental and numerical study on 2D cascade
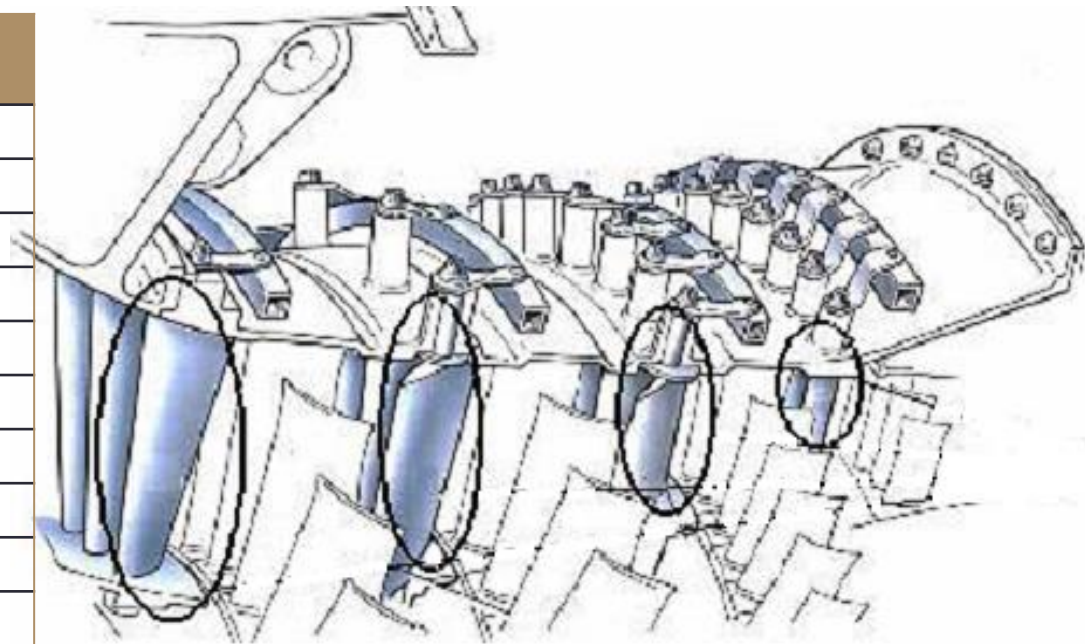
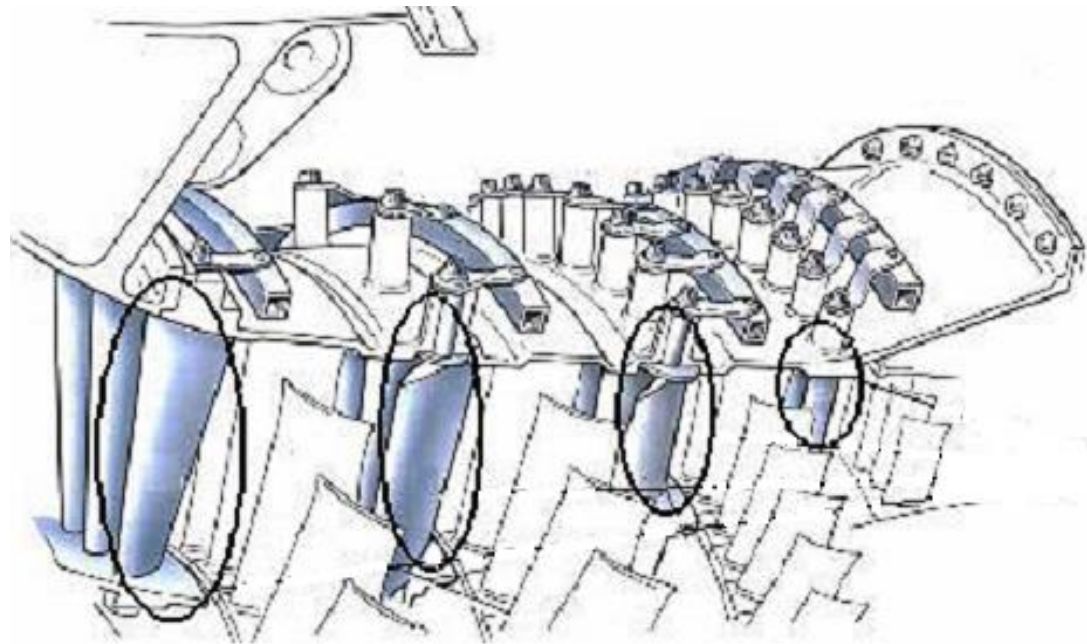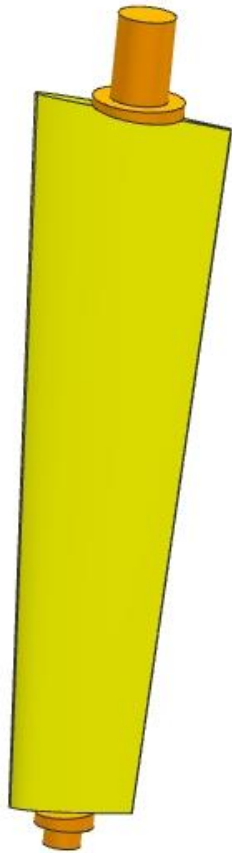◆ Numerical study on 3D cascade

◆ Conclusion

Background

Variable Stator Vane (VSV) is widely used to improve multistage compressor performance at off-design condition.

Engine	VSV/total Stages
CFM56-3	4/9
PW4000	4/11
V2500	4/10
PW2037	5/12
JT9D-7R4E	4/11
CF6-80A	6/14
АЛ-31Ф	3/9
F119	3/6
M88	3/9
EJ200	2/5
TECH56	3/6
GE90	/510

Background

VSV consist of blade and penny platforms.

Backgroud

Previous Design
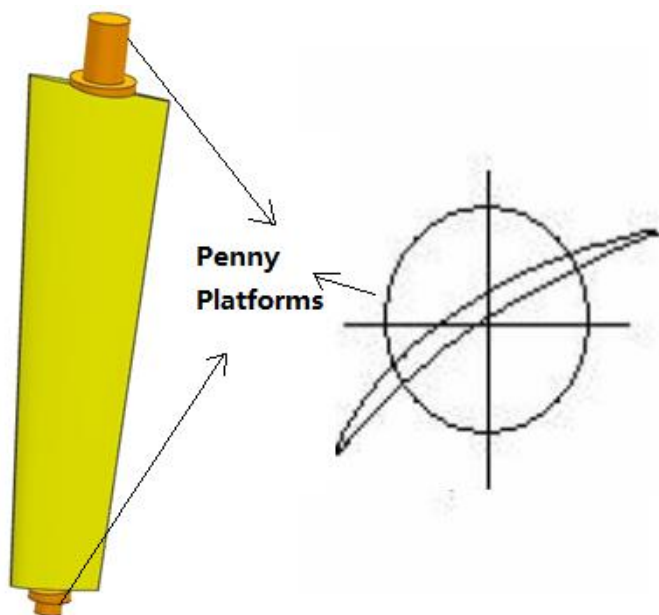
Advanced Design
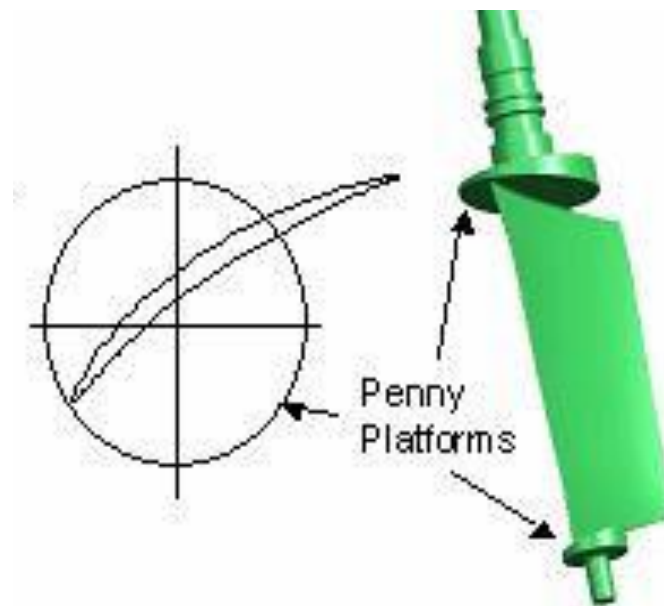
Does the location and size of penny platforms impact on leakage loss only in VSV?

Experimental and numerical study on 2D cascade
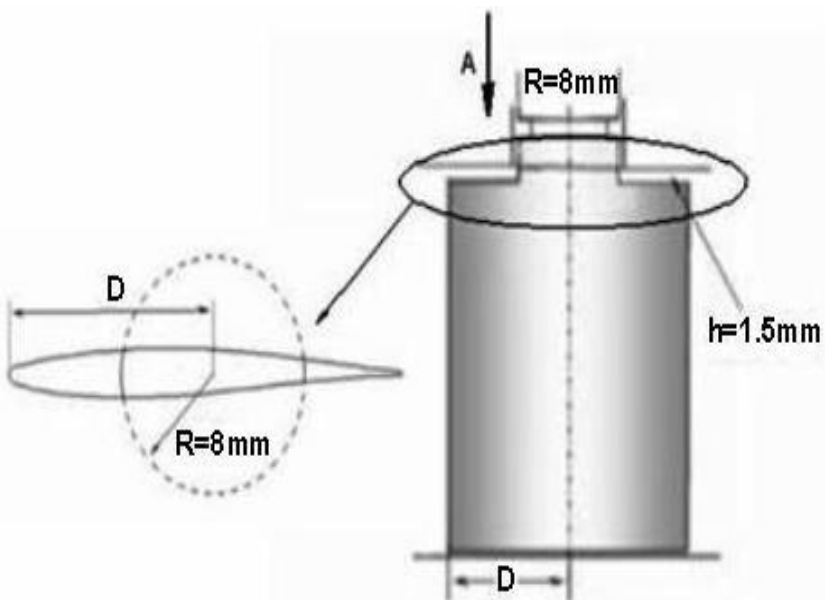
Blade height	100mm
gap	1.5mm
pitch	30mm
chord	34.3mm
Blade number	8

Blade A

Blade B

Blade C

❑ Plane cascade test rig at NUAA

Air supply   Diffuser   Contraction section   Test section
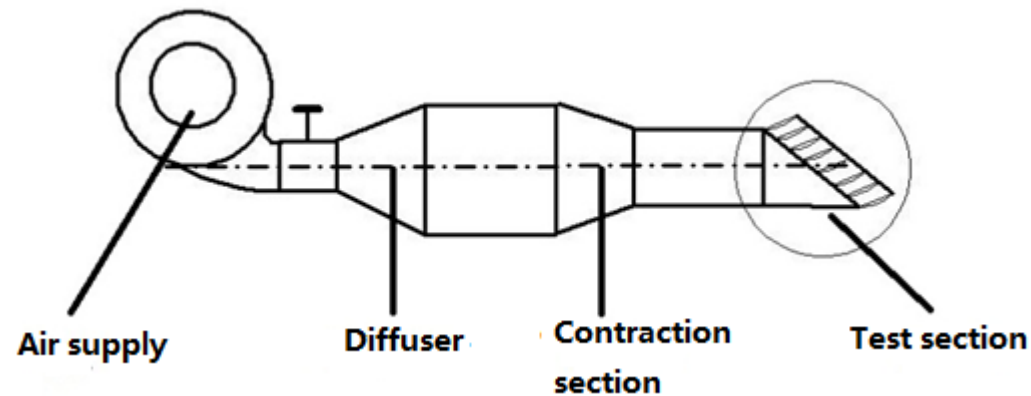
Inflow condition:
Mach：0.5
Attack：0°，10°，20°

Outflow measure:
Total pressure is acquired at a blade passage section downstream of 0.5×blade chord

☐ Expeimental result
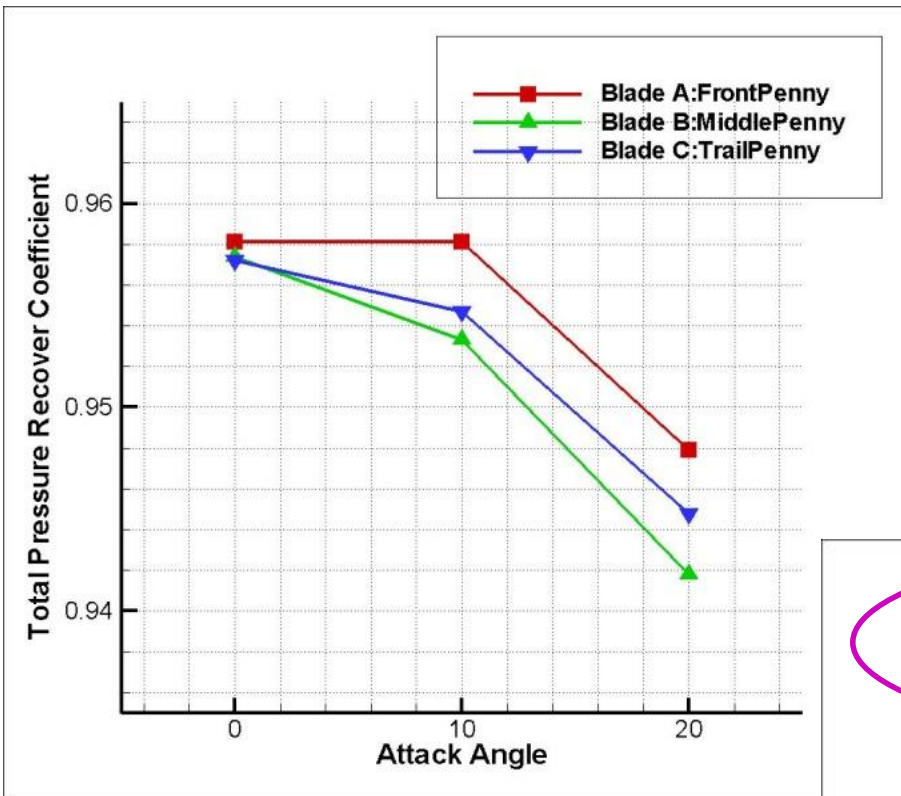
Total pressure recovery coefficient:

Blade A > Blade C > Blade B

Attack of 10°
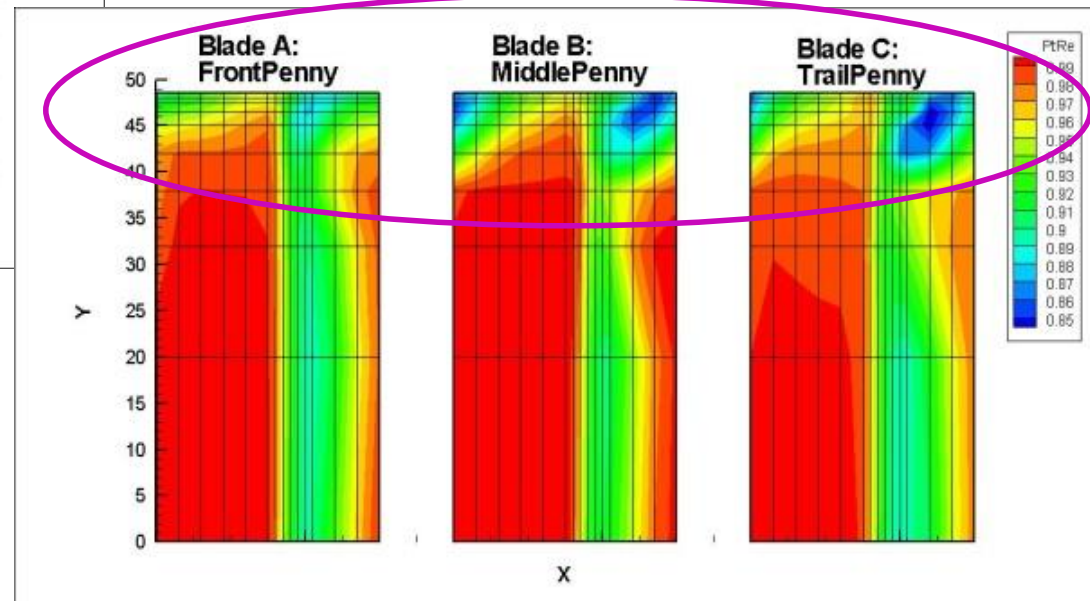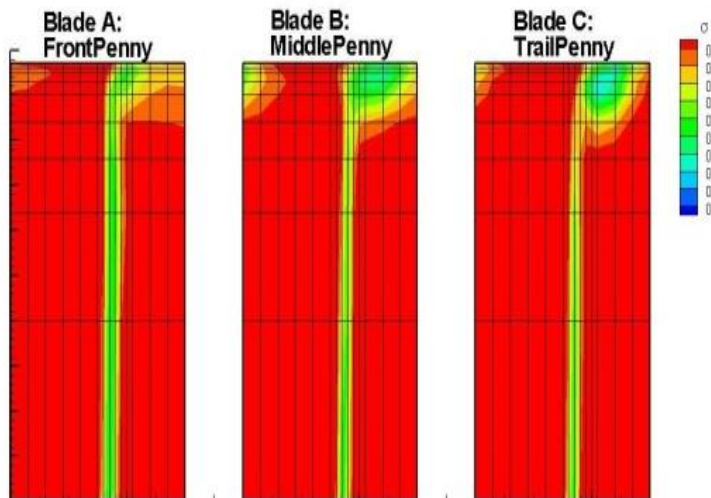
Trends of end-wall loss is consistent with blade loss

❑ CFD method

Mesh: hybird grid,y+<5
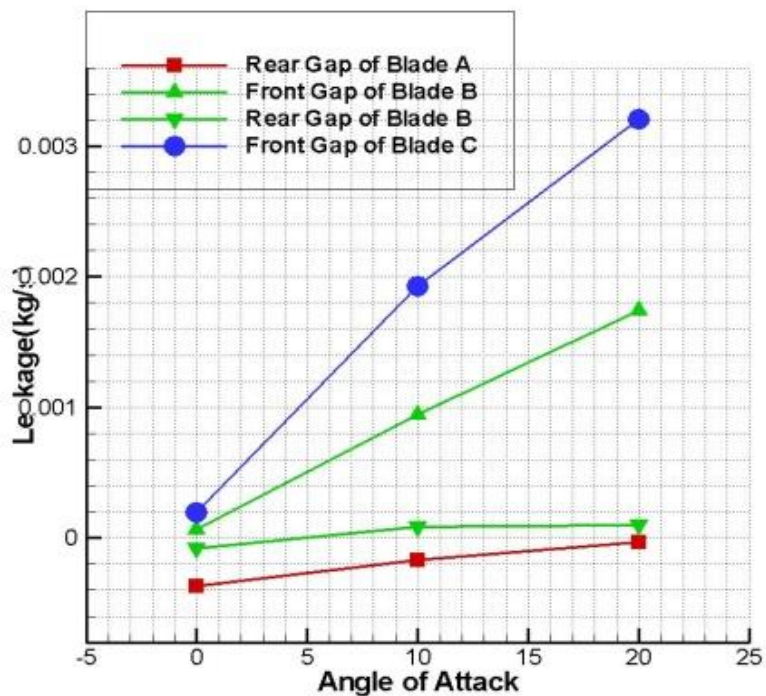Method: commerical CFD software CFX; k-ε turbulent model;
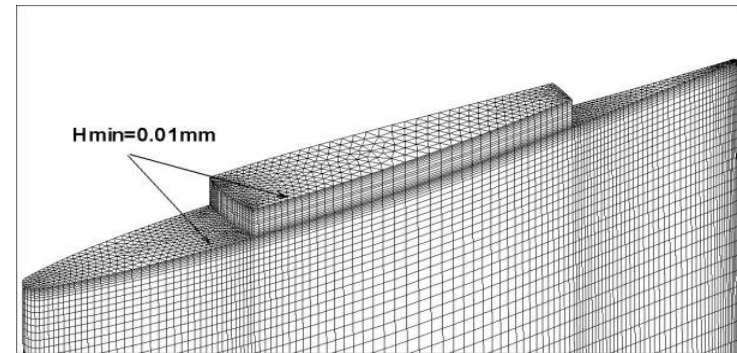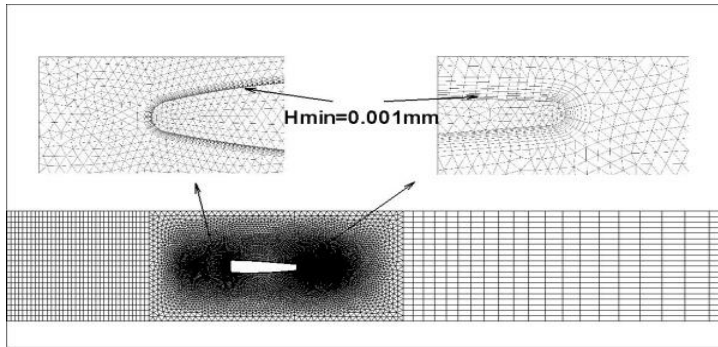
Experimental results

CFD results
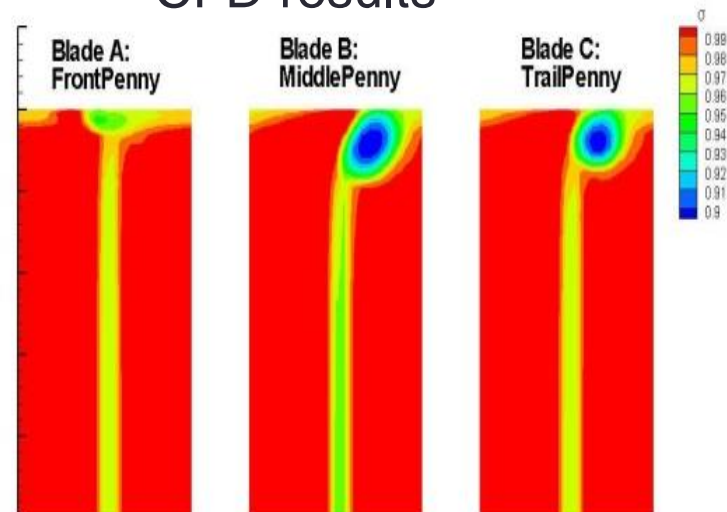
□ CFD result

Leakage flow:
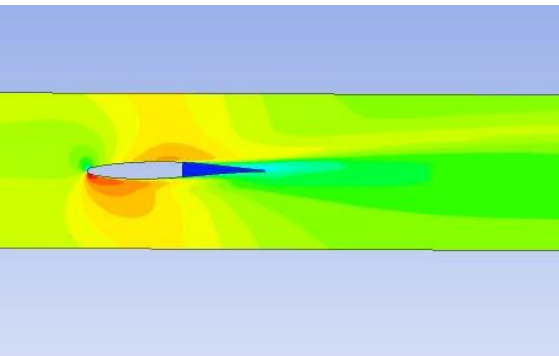
Blade A <   Blade B < Blade C

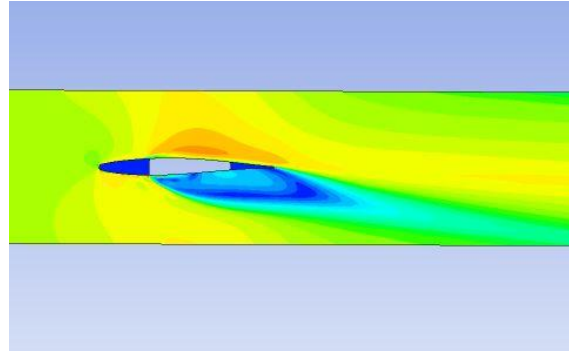Total pressure recovery coefficient:

Blade A > Blade C > Blade B

Endwall loss ≠   leakage loss

□ CFD result
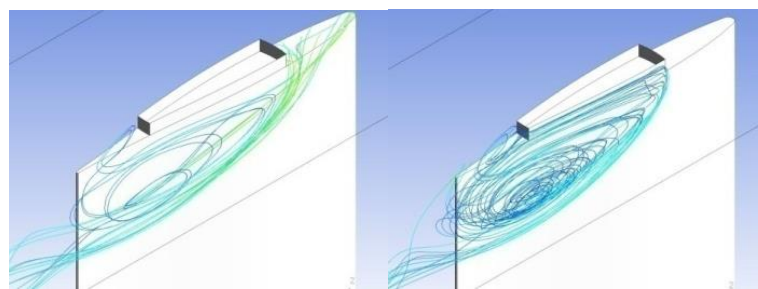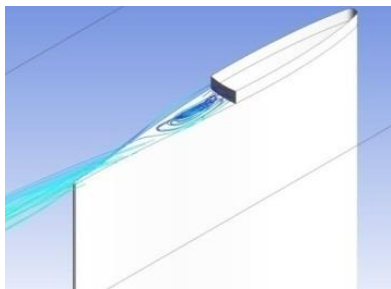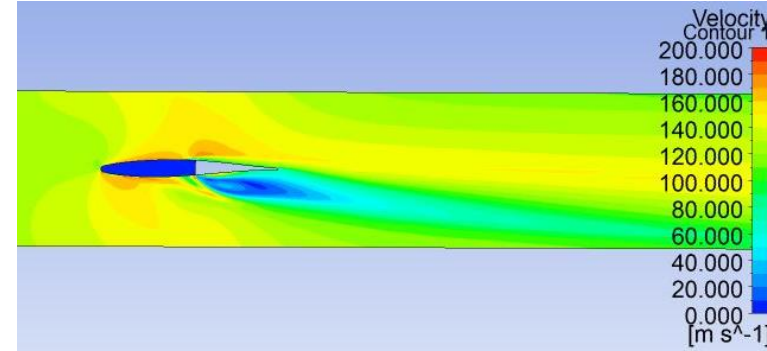
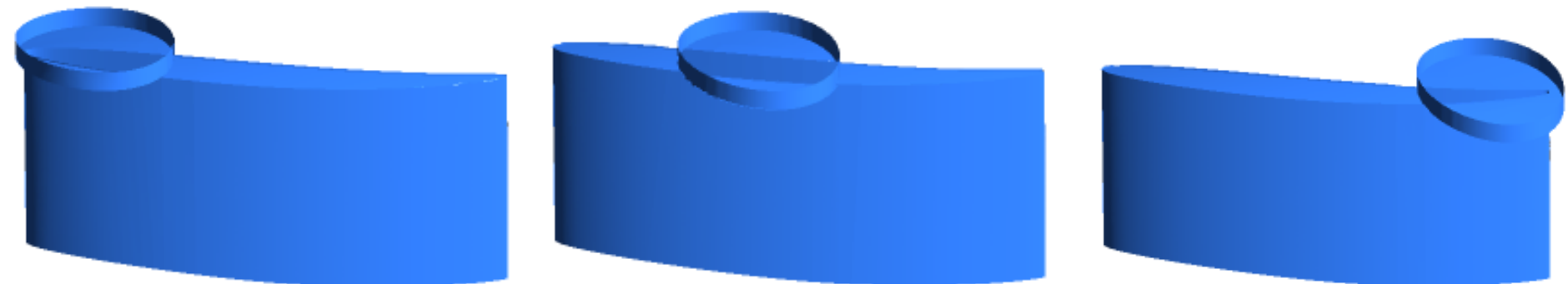Blade A   Blade B   Blade C
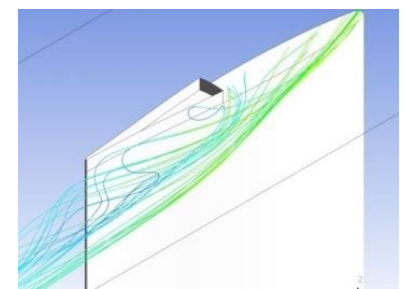
Endwall loss = leakage loss + leakage flow induced loss

Front penny platforms eliminate the induced loss.

Numerical study on 3D cascade

Blade height	56.25mm
Tip gap	4.9mm
solidity	2.24
chord	125mm
Blade number	19
Stagger angle	51.12º

- Tip gap is obtained by blade rotation angle 10º

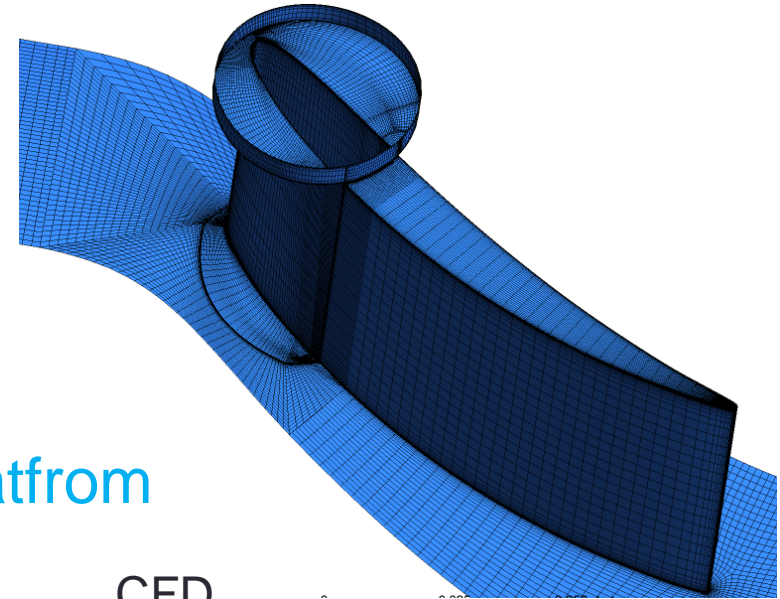- Penny radius is 20mm.

□ CFD method

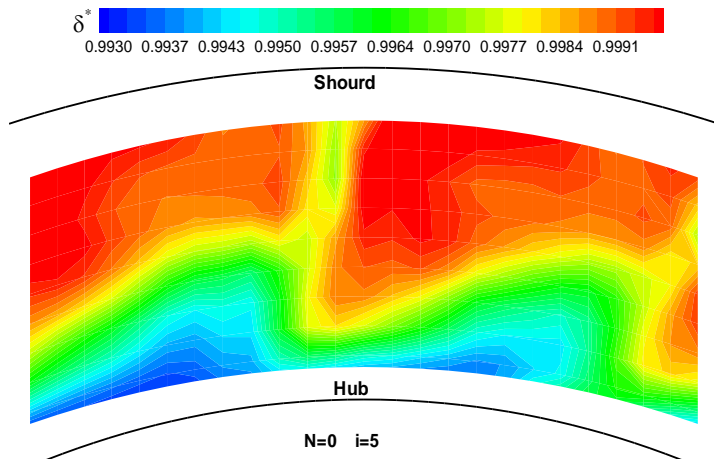Mesh: structured grid,y+<5
Method: CFX; k-e turbulent model;

Boundary condition: inflow attack is 5°;
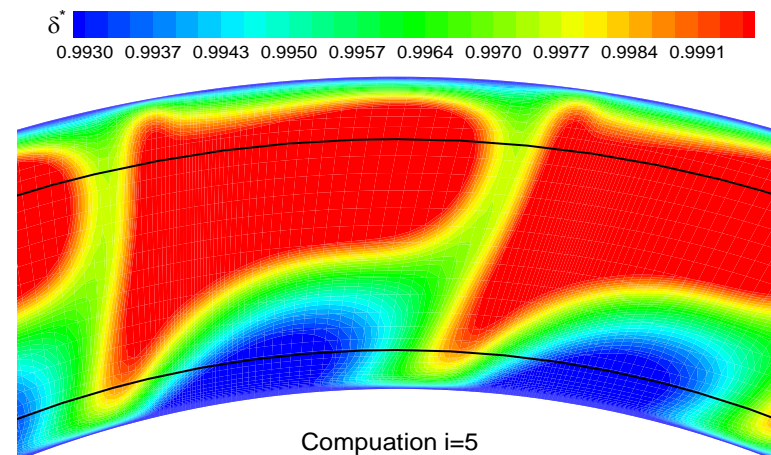   mass flow is 1.9kg/s

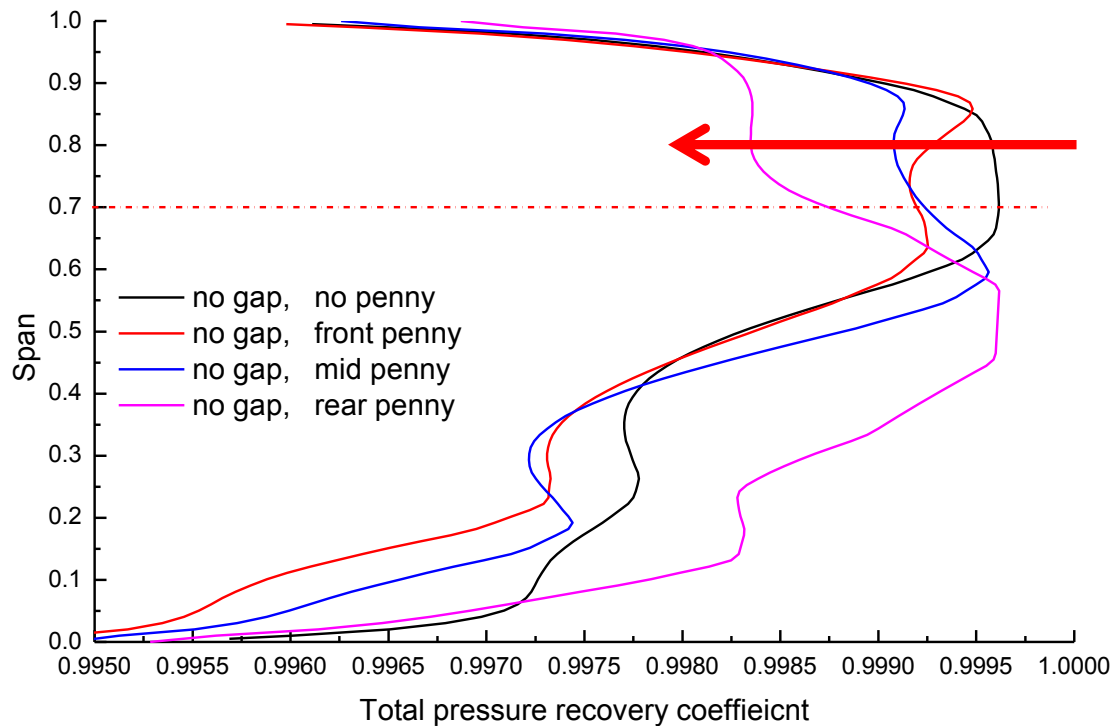# Results of cascade without penny platfrom
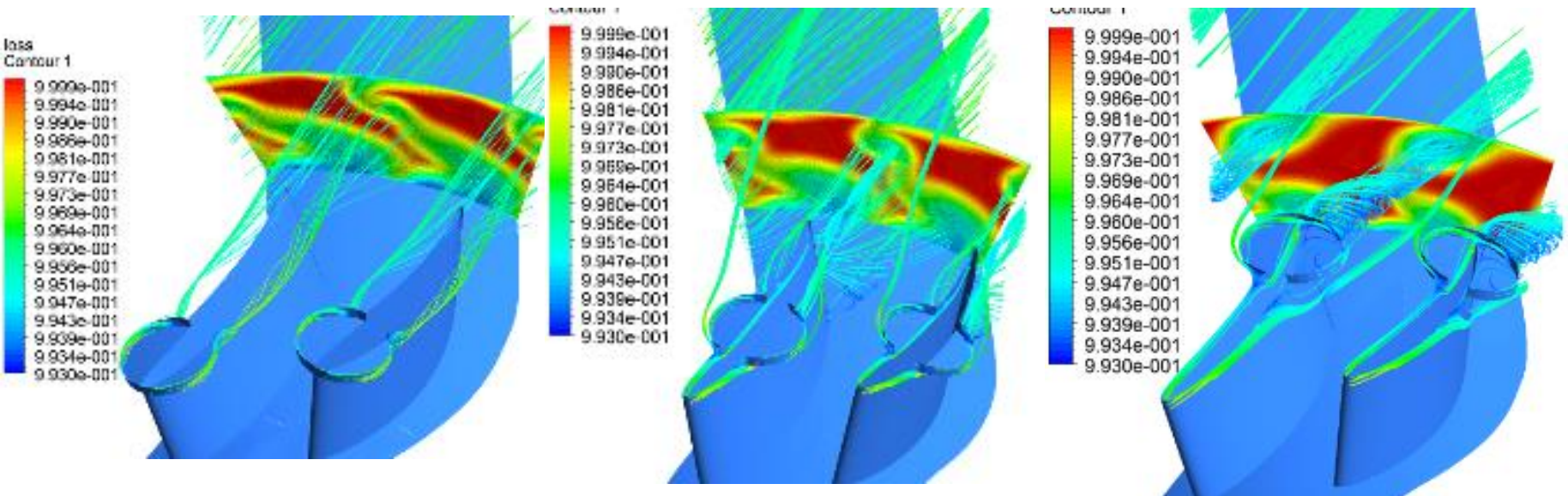
Experimental

CFD

δ^*

0.9930 0.9937 0.9943 0.9950 0.9957 0.9964 0.9970 0.9977 0.9984 0.9991

Shourd

Hub

N=0   i=5

δ^*

0.9930 0.9937 0.9943 0.9950 0.9957 0.9964 0.9970 0.9977 0.9984 0.9991

Compuation i=5

☐ CFD results——cascade without tip gap

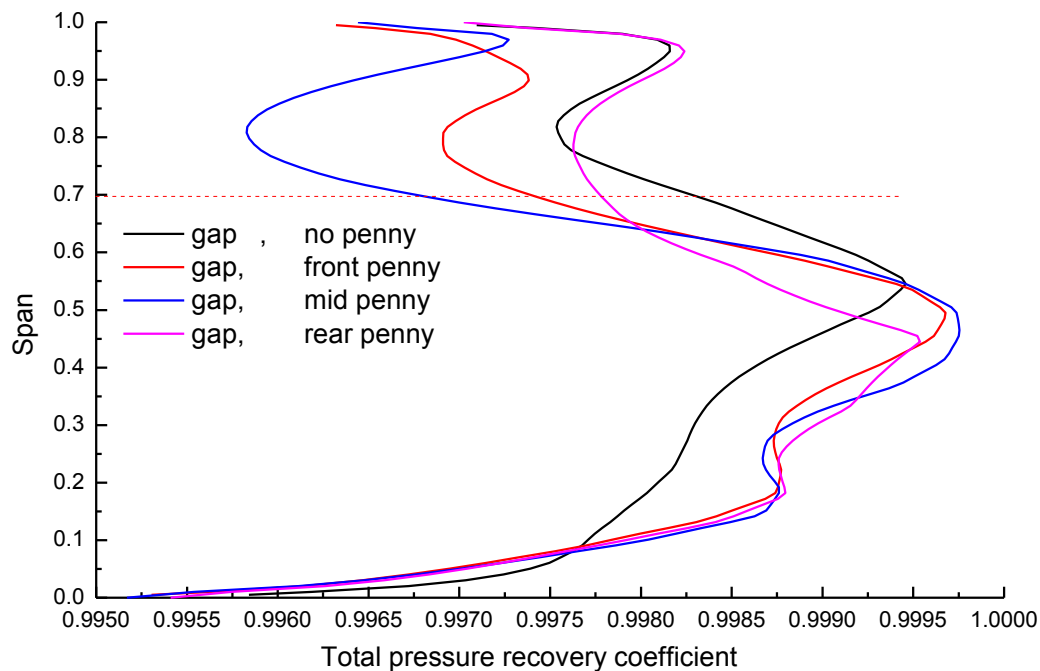**The end-wall loss become larger as it move downstream**

☐ CFD results——cascade without tip gap

Penny platform wake loss is affected by the pressure difference through the blade passage

❑ CFD results——cascade with tip gap
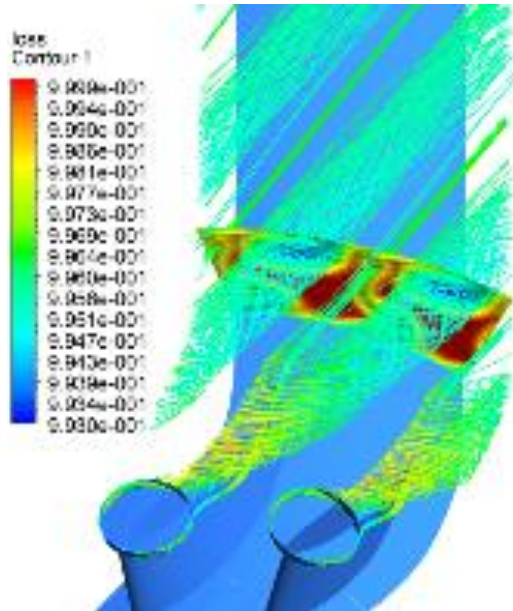

End-wall loss :
Mid penny> front penny> rear penny

End-wall loss of blade shaped penny platform:
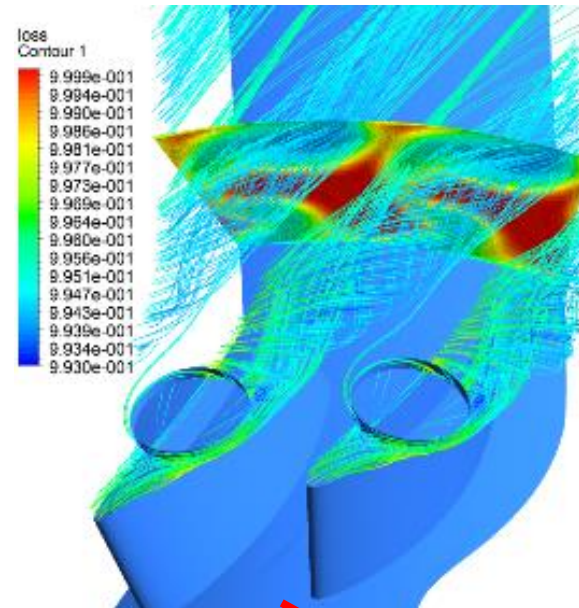**Mid penny>rear penny>front penny**
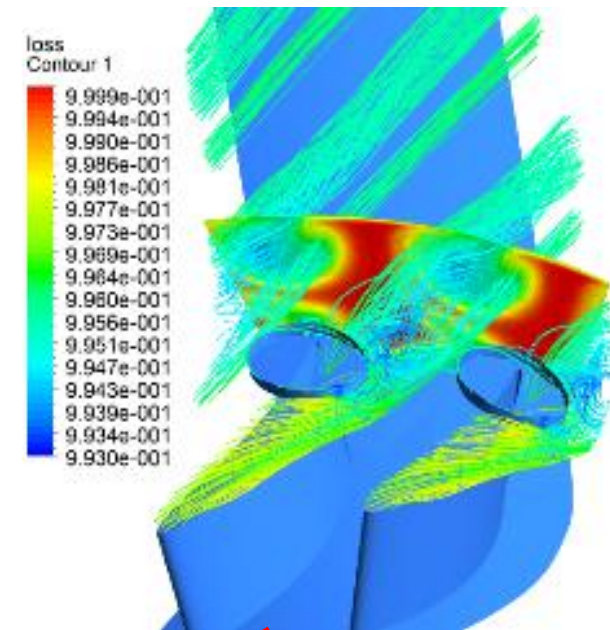
❑ CFD results——cascade with tip gap

Leakage loss +
Penny platforms wake loss

Leakage loss +
Leakage flow induced loss

Conclusion

◆ VSV end-wall loss includes leakage loss and leakage flow induced loss/penny platform wake loss.

◆ Front penny platforms diminish the leakage flow induced loss and generate wake loss around it.

◆ The location and size of penny platforms is determined by end-wall loss. Blades with middle penny has greatest loss.

Thanks for your attention!