2019 대한기계학회 학술대회
제주국제컨벤션센터(ICC제주) 5발표장
2019.11.15(금)

Design and Validation of Low Noise Airfoil Inspired by Flight of Owl

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Presenter : Minsin Kim

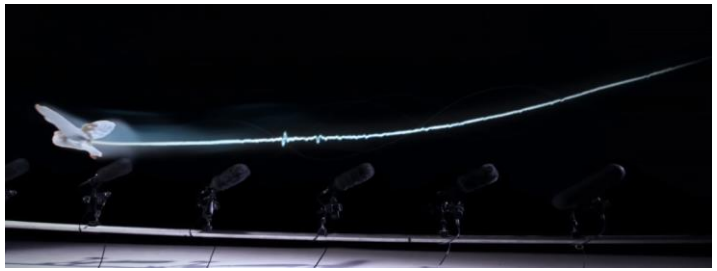
Introduction

Research Background

▲ 비둘기

▲ 매

▲ 올빼미 [1]



올빼미는 다른 조류에 비해 저소음 비행을 함.

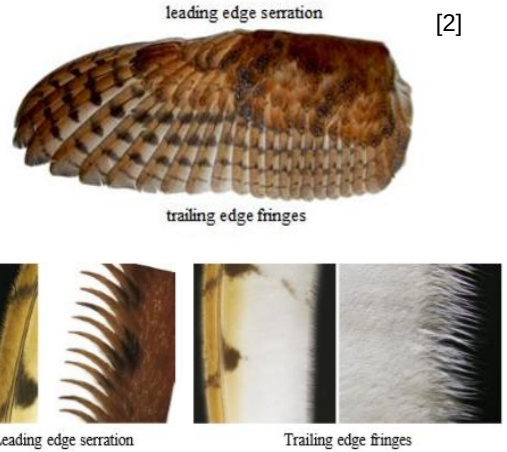
올빼미의 저소음 비행의 특성을 분석하고 이용 → 회전체 및 비행체에서 발생하는 유동여기 소음 문제 개선

[1] Experiment! How Does An Owl Fly So Silently?, Super Powered Owls, BBC, YouTube

Introduction

Literature survey

- **올빼미 저소음 비행 요인**



[2]

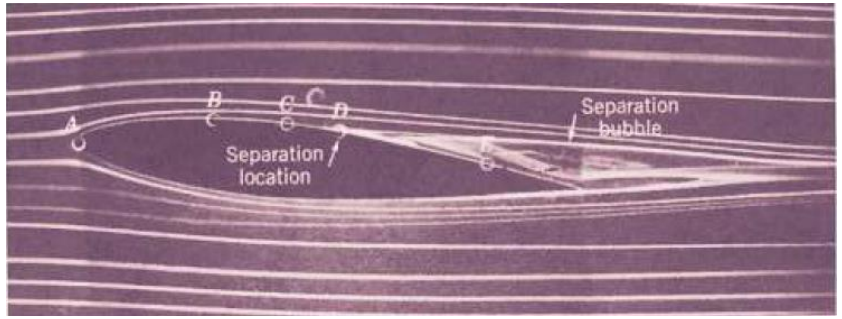
올빼미 날개의 특성[3]

- Leading edge serrations
- Trailing edge fringes
- Velvet-like surface
- Porous and pliant plumage

유동 박리 지연, 후류영역 발달 억제[4]

→ **저소음 비행 가능**

- **익형 주위의 경계층 유동**



[5]

익형 주위 유동가시화, 유동 박리

박리의 위치, 물체 뒤 후류영역의 폭, 그리고
표면의 압력구배는 경계층 유동의 특성에 의존함.

→ **박리점 위치의 확인을 통해 유동의 특성을 유추**할 수 있음.

[2] Winzen, A., B. Roidl, and W. Schröder, 2015, "Particle-image velocimetry investigation of the fluid-structure interaction mechanisms of a natural owl wing." Bioinspiration & biomimetics 10.5
[3] Hermann Wagner, Matthias Weger, Michael Klaas and Wolfgang Schroder, 2016, "Features of owl wings that promote silent flight," Interface focus, Vol.7, No.1, pp. 5-9
[4] Rao, C. and Liu, H., 2018, “Aerodynamic robustness in owl-inspired leading-edge serrations: a computational wind-gust model,” Bioinspiration & biomimetics, Vol. 13, No. 5, 056002
[5] Munson, Okiishi, Huebsch, Rothmayer, 2013, “Fluid Mechanics”, John & Sons Singapore Pte. Ltd

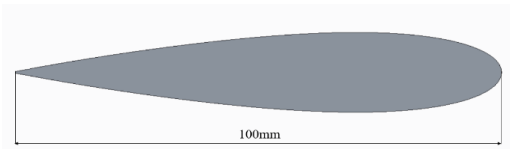
Introduction

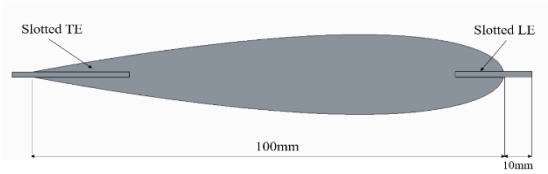
Research Objective

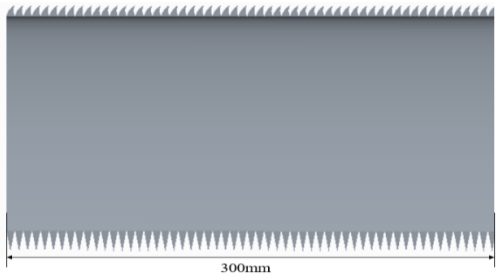
- 올빼미 날개의 특성을 반영한 개선 익형 두가지를 설계한 후, 2D PIV를 통해 기본 익형과의 유동 특성 비교
- 유선, 속도장 분석을 통한 소음 저감 효과 판별

Model

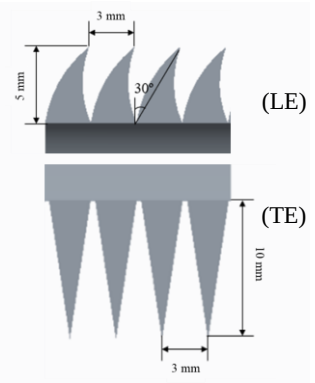
- Moment사의 'Moment2' 3D프린터 사용 (FDM타입)







C0 (기본 익형) **S0 (Serrated model)** **H1 (Serrated hairy model)**

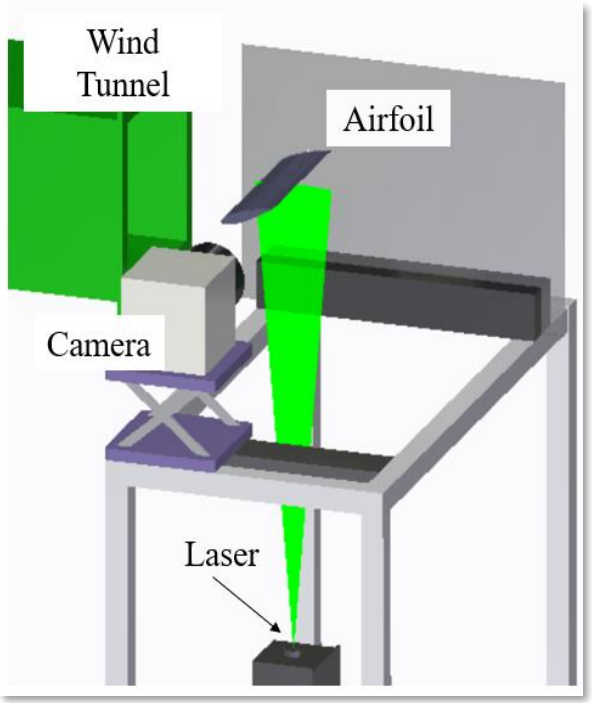


Serration 규격 [6][7]

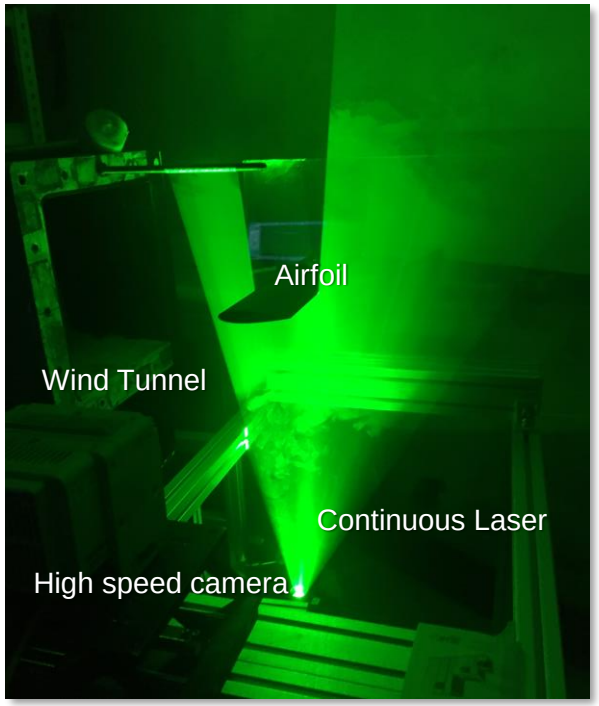
[6] Weger, Matthias, and Hermann Wagner, 2016, "Morphological variations of leading-edge serrations in owls (Strigiformes).", PloS one, Vol. 11, No. 3.
[7] F. Avallone, C. Arce Leon, S Probsting, K. Lynch and D.Ragni, 2016, "Tomograpic-PIV investigation of the flow over serrated trailing-edges," the American Institute of Aeronautics and Astronautics, Vol. 23, No. 5, pp. 3.

2D PIV (air)

Experimental setup



실험 장치 구상 이미지



실제 실험 이미지

실험 준비 요소	설정값
풍동에서 나오는 공기의 평균 속도	2.6 m/s
카메라 (Phantom VEO410L)	5,200 fps (exposure time : 190ms)
이미지 크기	1280*800 pixel 0.16mm/pixel

상사 조건	설정값
올빼미 비행 속도 [8]	2.5~7.5 m/s
특성 길이(Lc)	0.1 m
ρ	1.23 kg/m^3
μ	1.80× 10^{-5} $N \cdot s/m^2$

(* T=15℃ 일 때, 표준대기압 공기의 물성치)

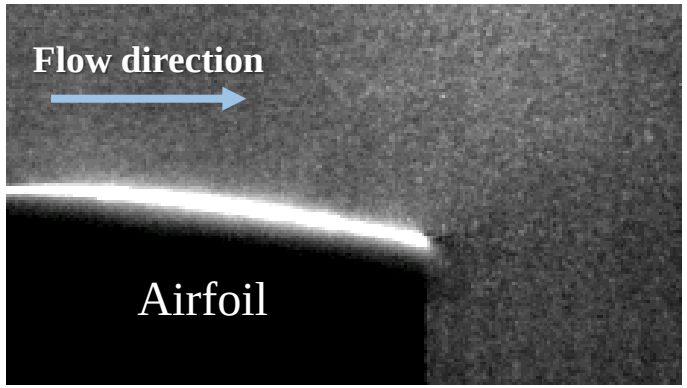
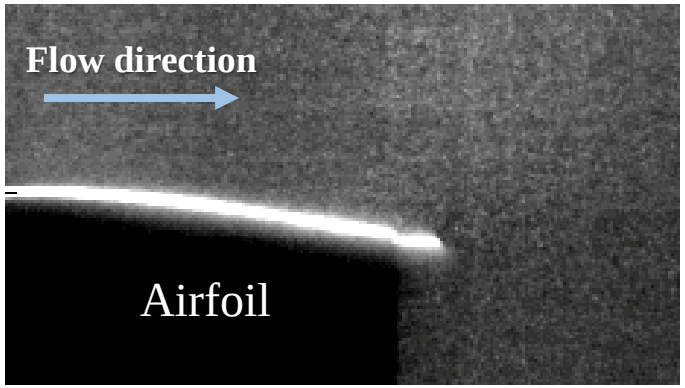
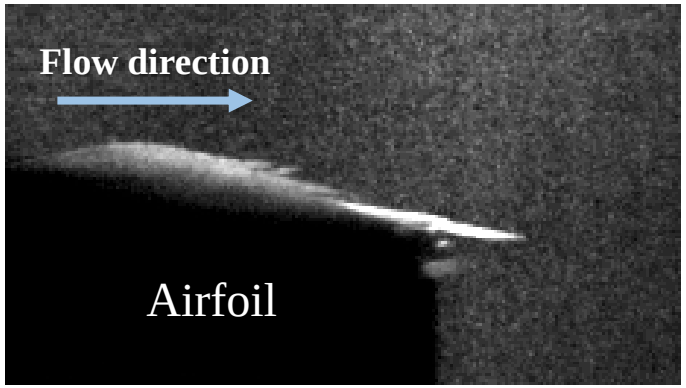
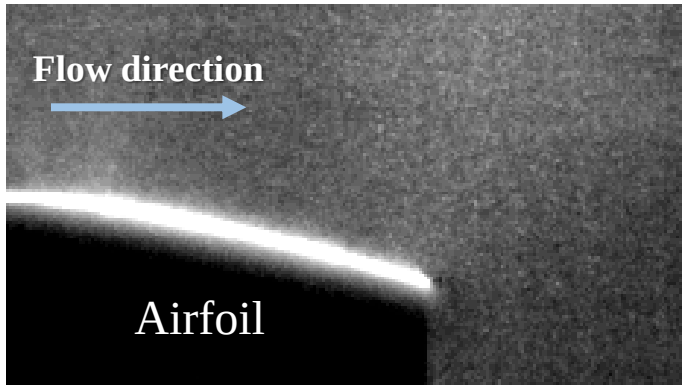
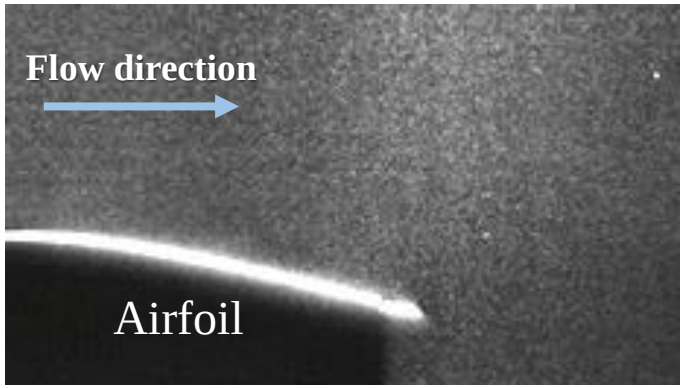
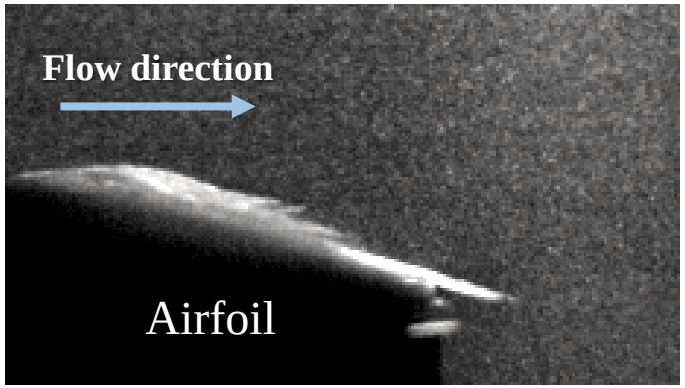
$$Re_L = \frac{\rho V L_c}{\mu} = 17,800$$

[8] Bachmann, T., Blazek, S., Erlinghagen, T., Baumgartner, W., & Wagner, H, 2012, "Barn owl flight", In Nature-Inspired fluid mechanics, Springer, Berlin, Heidelberg, pp. 101-117.

2D PIV (air)

Results

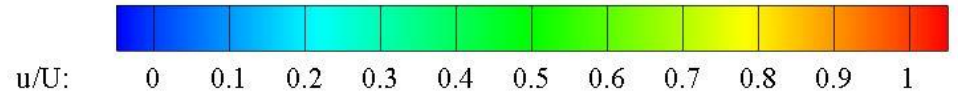
Video

	C0(기본 익형)	S0(Serrated model)	H1(Serrated hairy model)
AoA=0°			
AoA=4°			

2D PIV (air)

Results

Mean velocity field

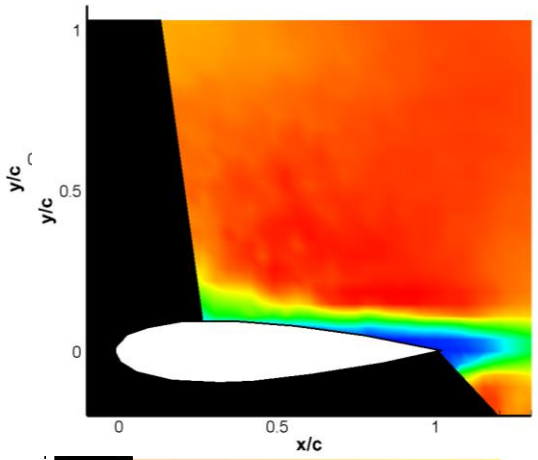


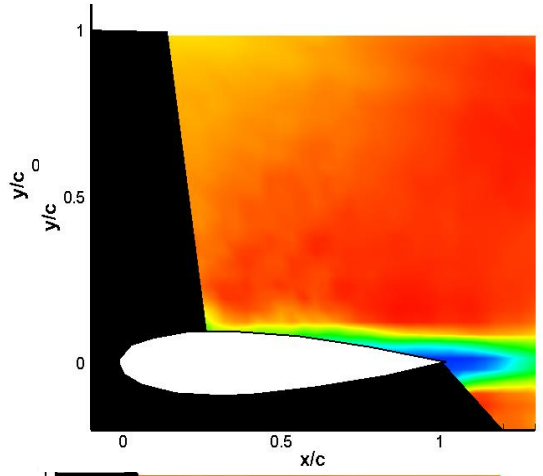
C0(기본 익형)

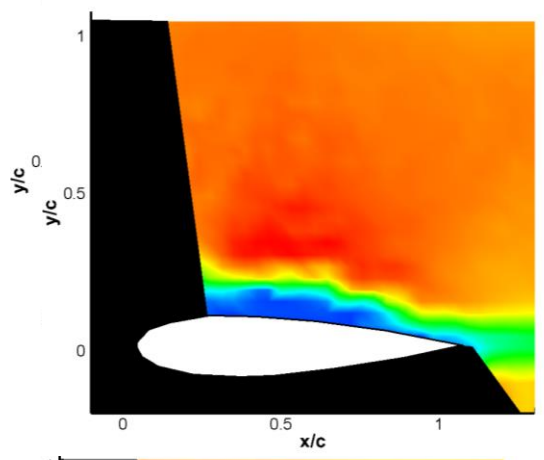
S0(Serrated model)

H1(Serrated hairy model)

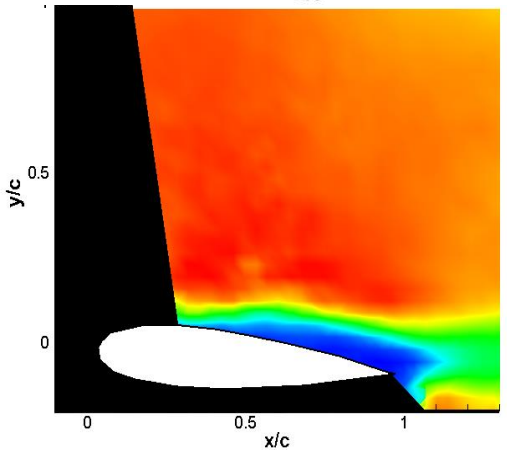
AoA=0°

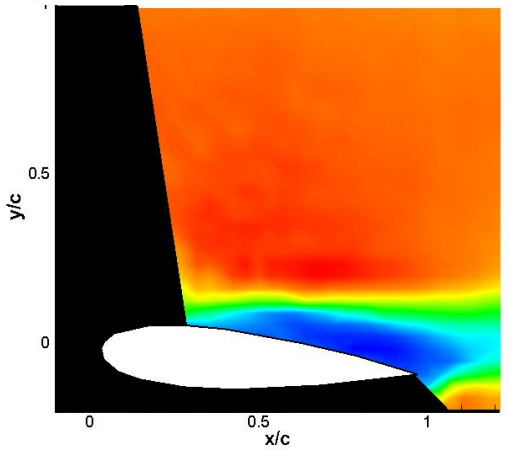


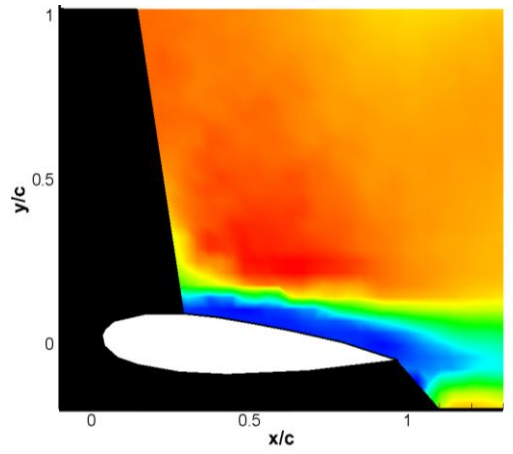




AoA=4°







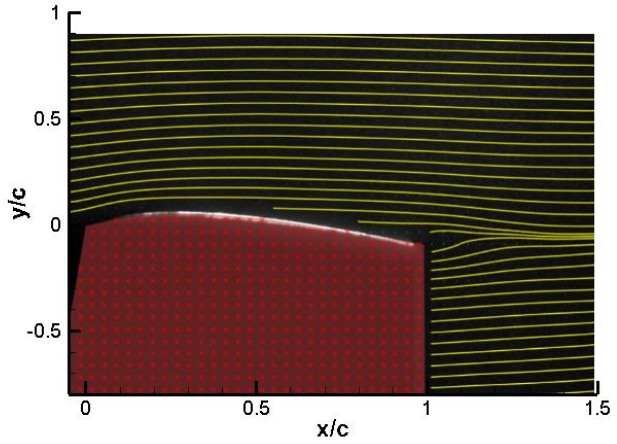
2D PIV (air)

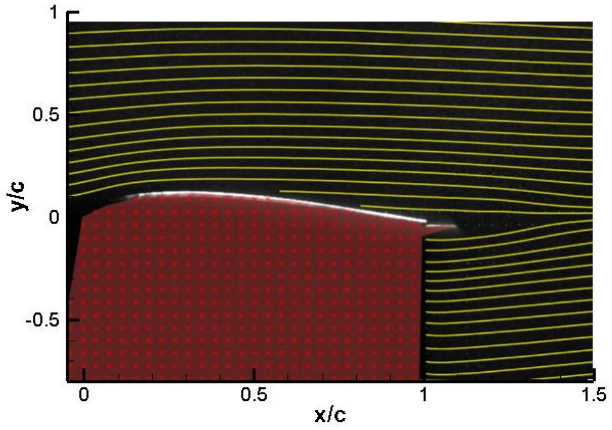
Results

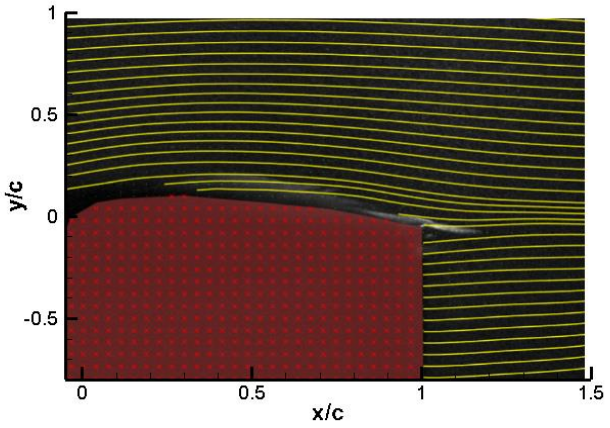
Streamline

C0(기본 익형) S0(Serrated model) H1(Serrated hairy model)

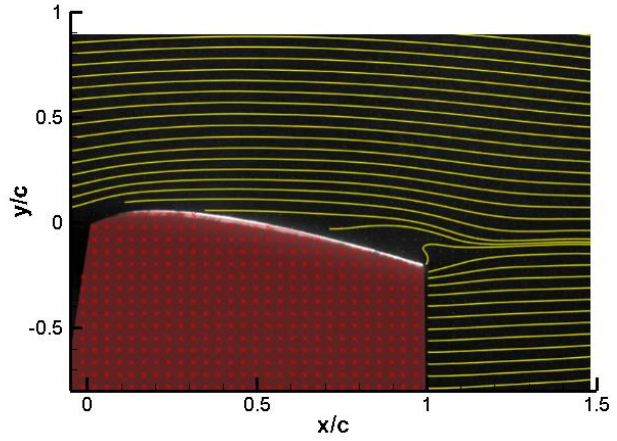
AoA=0°

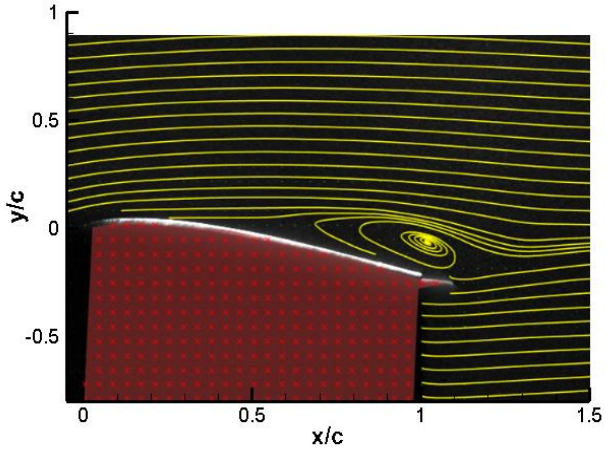


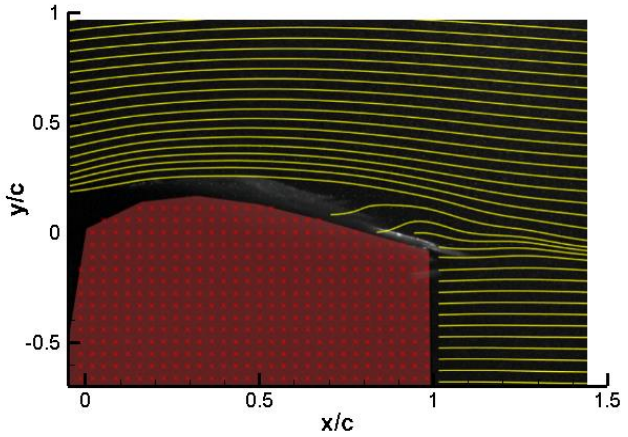




AoA=4°







2D PIV (air)

Results

Separation point

- 평균 속도장에서 벽면 속도 구배가 0인 지점을 찾고 역류 발생을 확인함.

Coordinates of Separation point

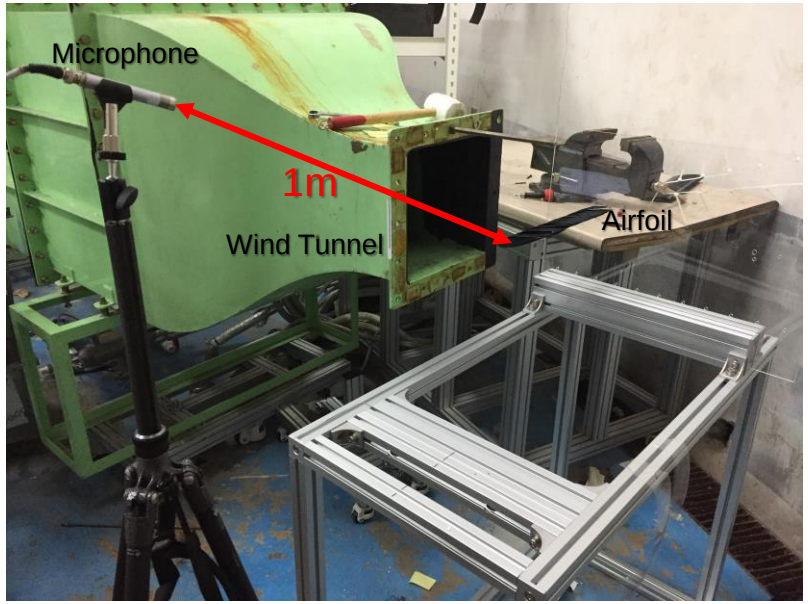
	AoA (°)	x/c	y/c
C0	0	0.812	0.043
	4	0.72	-0.013
S0	0	-	-
	4	0.589	0.006
H1	0	-	-
	4	-	-

Noise mesurement

Experimental setup

- 2D PIV 실험과 동일하게 실험장비를 설치함.
- 소음 측정을 위해 카메라와 레이저 대신 마이크로폰을 사용함.

실험 준비 요소	설정값
Type	Microphone
풍동에서 나오는 공기의 유속	2.6 m/s
Weighting	A-Weighting
Freq. Resolution	1 Hz
Measurement Time	1 sec
Ref. Pressure	20 μPa

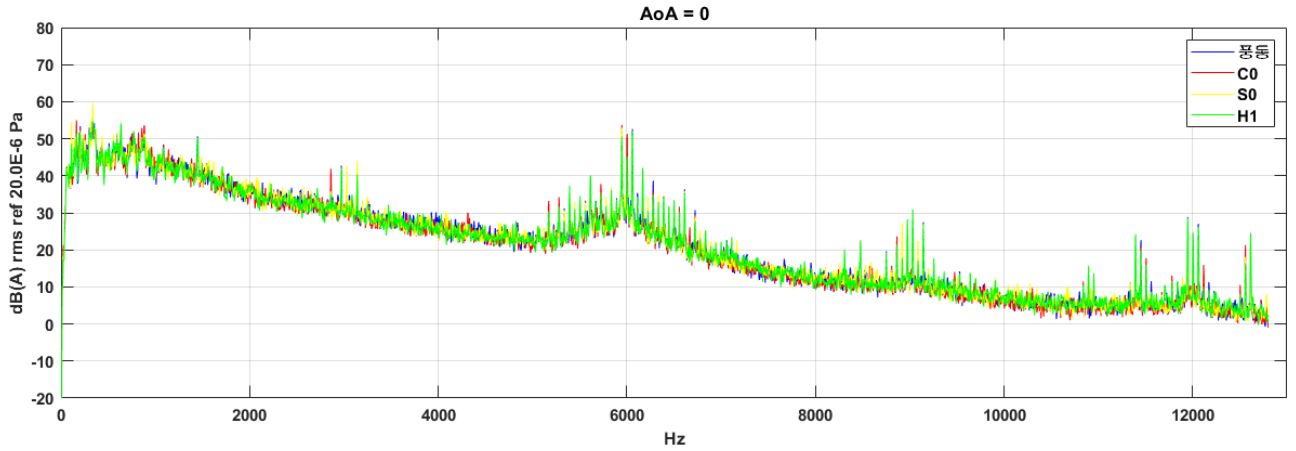


실제 실험 이미지

Noise mesurement

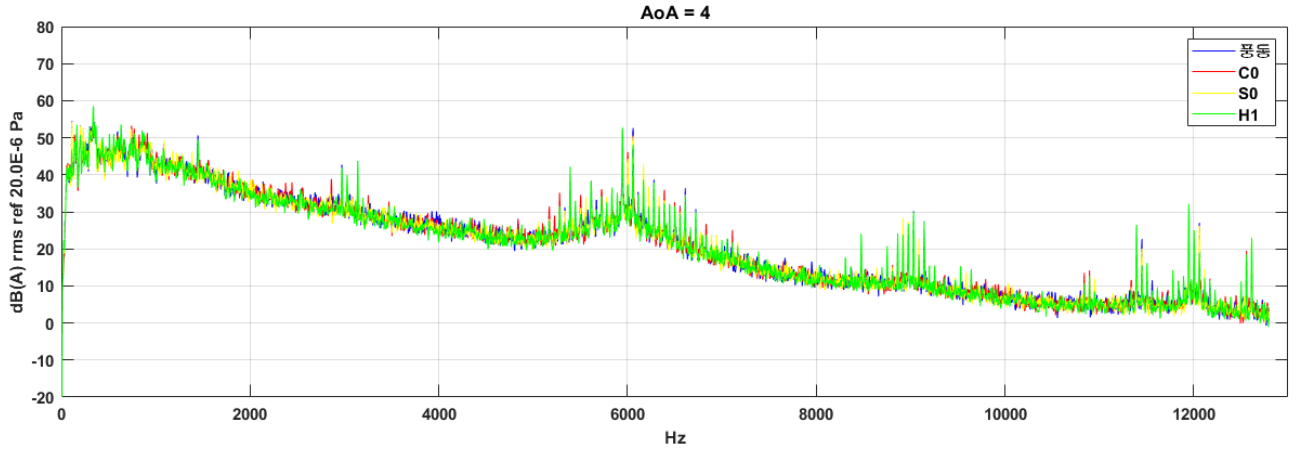
Results

SPL-Frequency(A-Weighting)



AoA=0˚

소음 측정 대상	Overall [dB]
풍동	70.788
C0	70.715
S0	70.785
H1	70.478

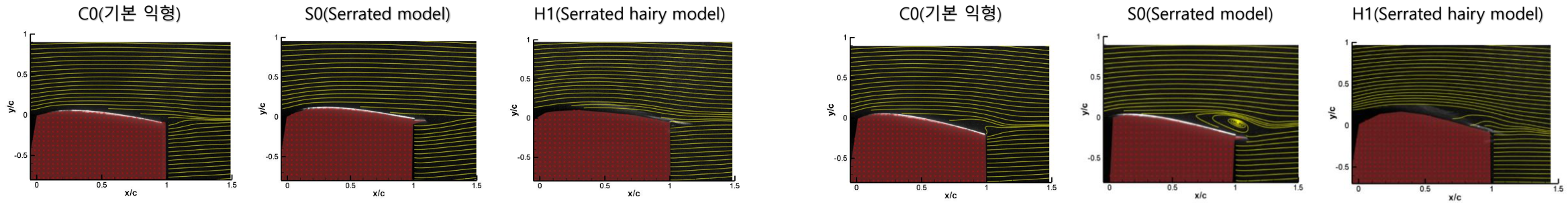


AoA=4˚

소음 측정 대상	Overall [dB]
풍동	70.788
C0	70.707
S0	70.563
H1	70.693

Conclusion

- Visualization을 통해 Serration 적용에 따른 유동장 변화 확인



- Serration 적용 익형에서 유동박리 억제 및 후류영역의 폭과 와류 감소

AoA=0˚ AoA=4˚

- Microphone을 사용한 소음 측정 실험 결과, 유의미한 데이터를 얻지 못하여 추후 무향실에서의 후속 연구 예정

AoA=0˚

소음 측정 대상	Overall [dB]
풍동	70.788
C0	70.715
S0	70.785
H1	70.478

AoA=4˚

소음 측정 대상	Overall [dB]
풍동	70.788
C0	70.707
S0	70.563
H1	70.693

Flexible Hairy Serration 의 박리 지연으로 인한 유동여기 소음 저감 가능성 입증

Thank you for your attention.