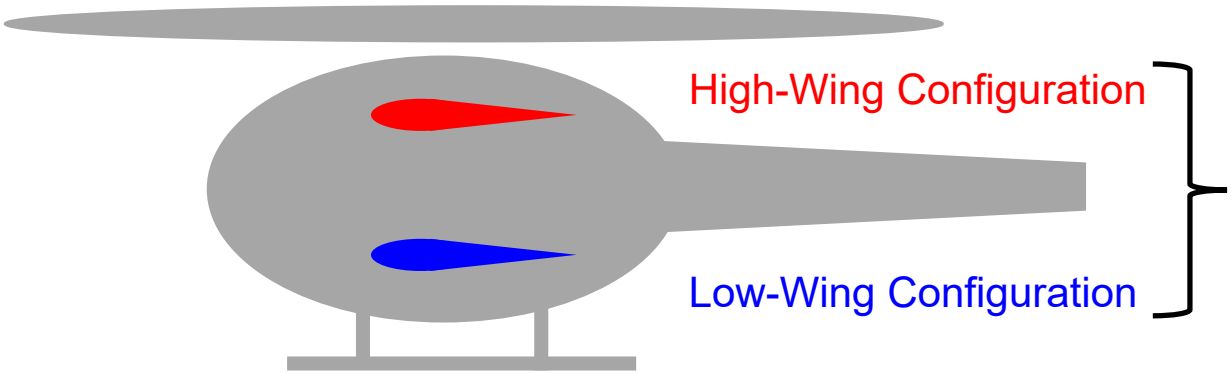
Effect of Wingspan on the Trend of Download for Winged Helicopters in Hover



Which is more efficient for hovering ?

Experimental Research

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National Defense Academy

Background

Winged helicopter has long been studied for enhancing maneuverability or high-speed flight.

1950s

http://www.aviastar.org/helicopters_eng/mcdonnell_xv-1.php

https://vertipedia.vtol.org/aircraft/getAircraft/aircraftID/291

https://en.wikipedia.org/wiki/Lockheed_AH-56_Cheyenne

https://en.wikipedia.org/wiki/Piasecki_X-49_SpeedHawk

2010s

https://www.airbus.com/en/who-we-are/our-history/helicopters-history/x3

Background

There are high and low-wing configurations for winged helicopters

High-Wing Configuration

https://vtol.org/qr/march-2012

https://www.airbus.com/en/who-we-are/our-history/helicopters-history/x3

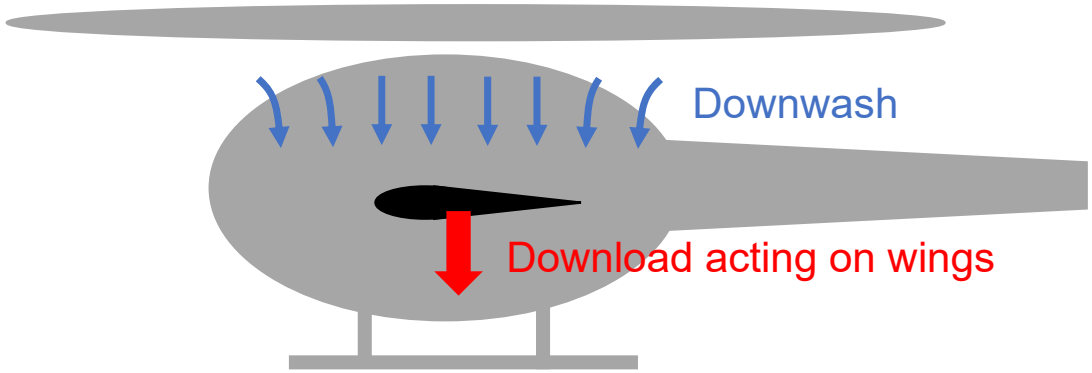
Low-Wing Configuration

https://en.wikipedia.org/wiki/Piasecki_16H_Pathfinder

https://www.popsci.com/technology/bell-360-invictus/

Background

One problem with winged helicopters

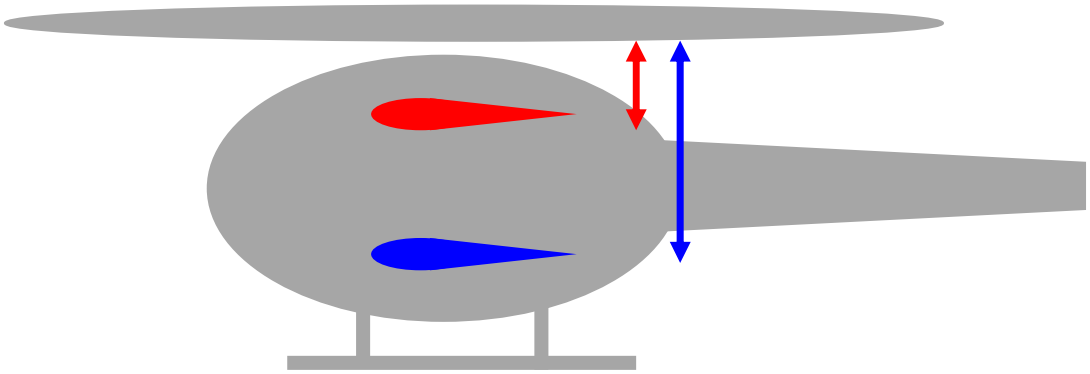


Low-speed flight
or
Hovering

Studies (including for tiltrotors) have been conducted to reduce wing downloads.

These researches are summarized in the paper (Sugawara et al. 2020)

Background



The distance between the rotor and wing affects the hovering performance

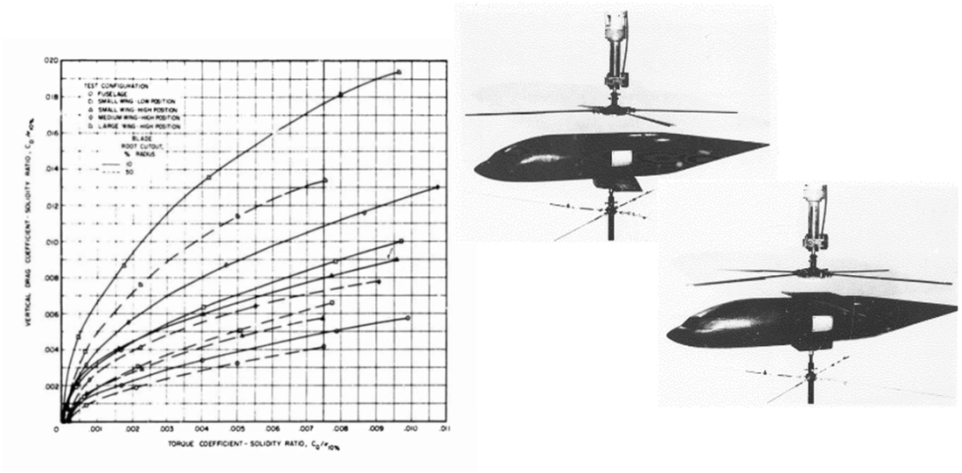
High-wing configuration is more efficient for hovering!

Low-wing configuration is more efficient for hovering!

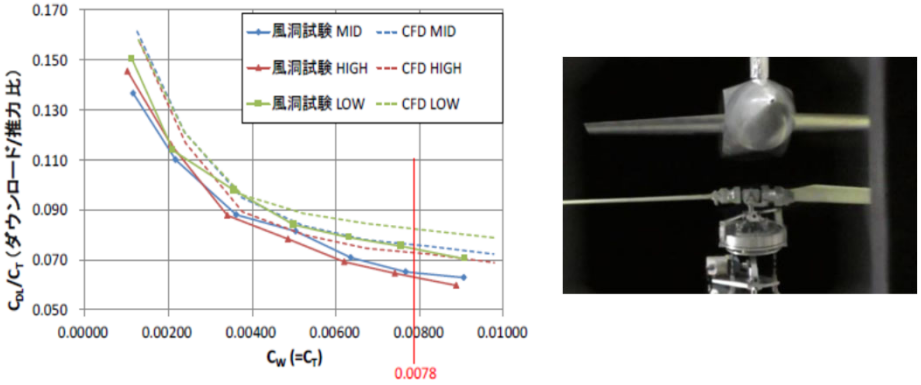
There is no unified view…
It is worthwhile to examine!

Background

High-wing configuration is better(smaller download)



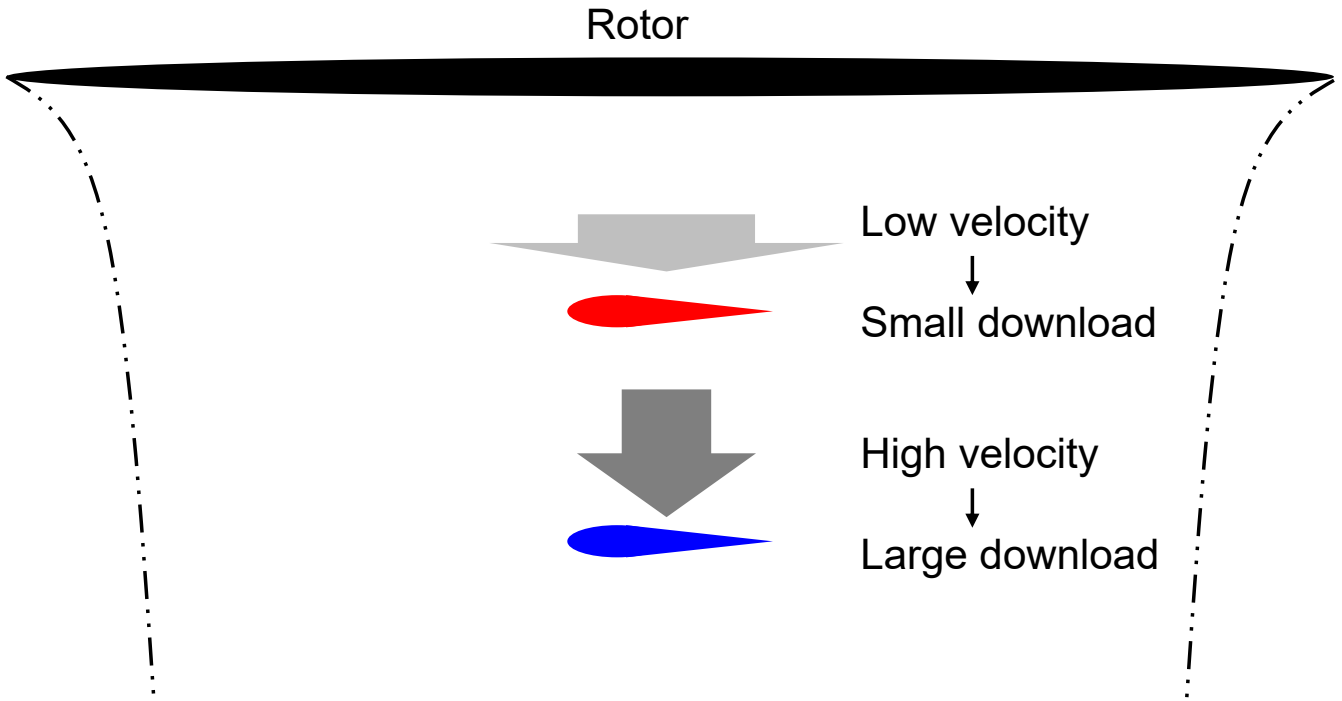
Cassarino, 1970



Kobayashi et al., 2019

Background

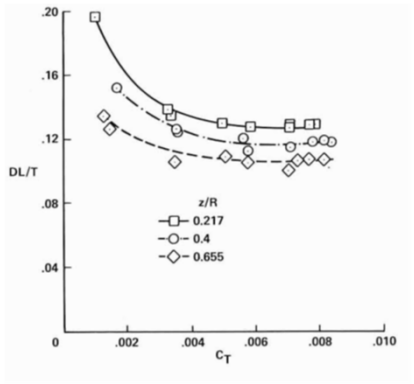
High-wing configuration is better(smaller download)

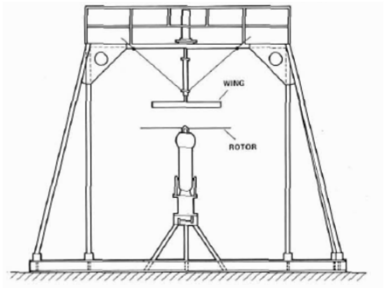


Explanation by momentum theory

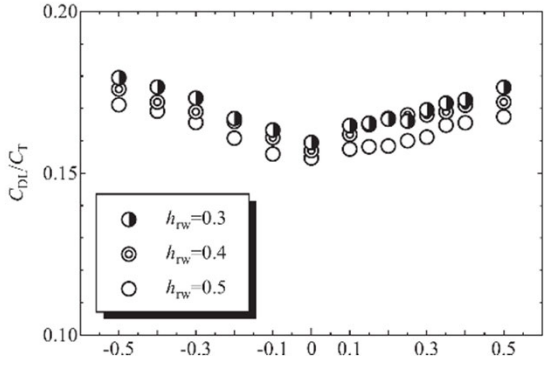
Background

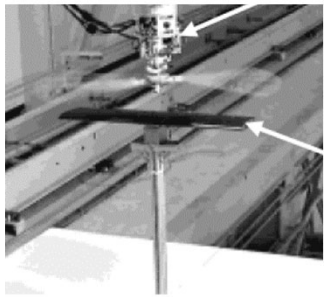
Low-wing configuration is better(smaller download)





Felker and Light, 1988

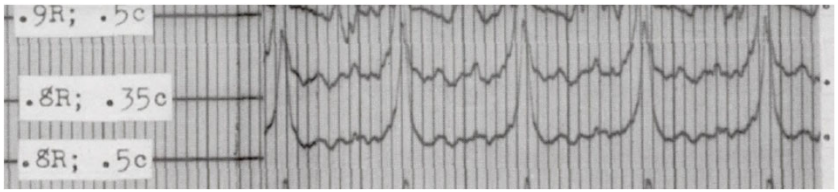




Nakashima and Itoga, 2018

Background

Low-wing configuration is better(smaller download)



High-wing

Low-wing

Time history of pressure on the wing surface
(Makofski and Menkick, 1958)

Explanation by periodic load

Background

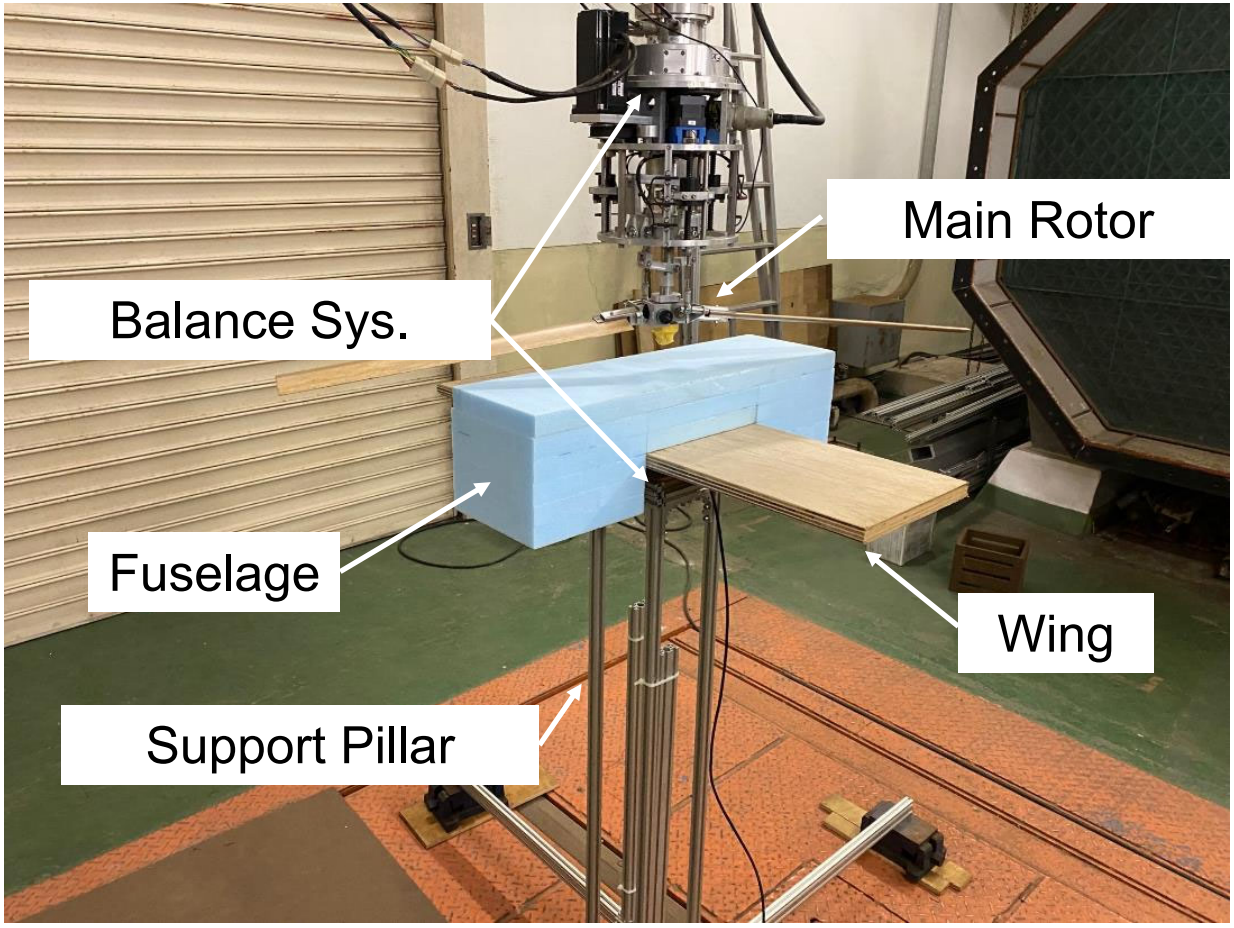
Experimental conditions of previous studies

	High-wing is better		Low-wing is better	
	Cassarino,1970	Kobayashi et al., 2019	Felker and Light, 1988	Nakashima and Itoga, 2018
Fuselage	**exist**		**none**	
Wingspan (ratio to rotor diameter)	**0.50** **(Relatively short)**	**0.61** **(Relatively short)**	**0.75** **(Relatively long)**	**0.79** **(Relatively long)**

Objectives of this research

- Confirming if the relationship between the download and rotor-wing distance is reversed by the existence of fuselage or changing wingspan.
- If it is reversed, consider the cause of it.

Experimental Apparatus

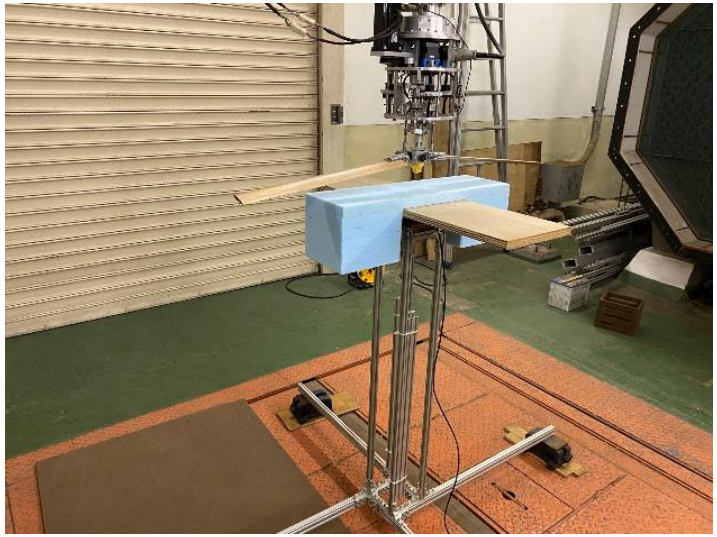


Details of Rotor	
Rotor Radius	569mm
Blade Chord	60mm
Airfoil	NACA0015
Twist	None
Number of blades	2
Hinge offset	17mm
Root cutout	113mm

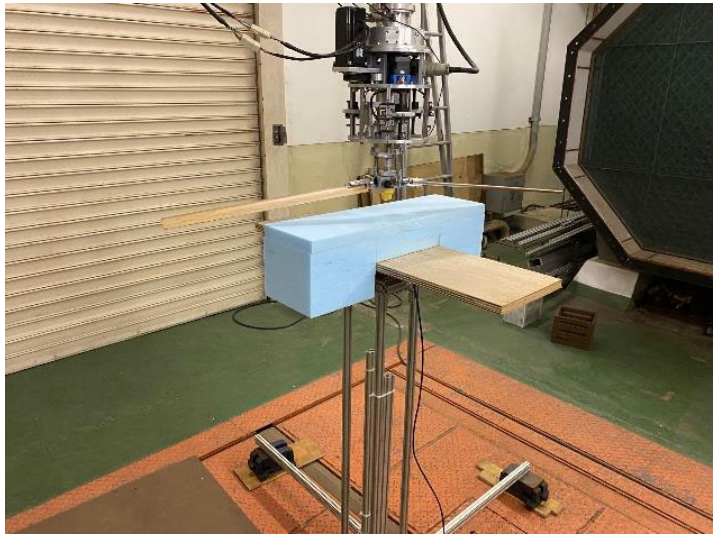
Details of Fuselage	
Length	644mm (1.13R)
Width	189mm (0.33R)

Details of Wing	
Span	897mm(0.79D), 569mm(0.5D)
Cord	242mm (0.43R)

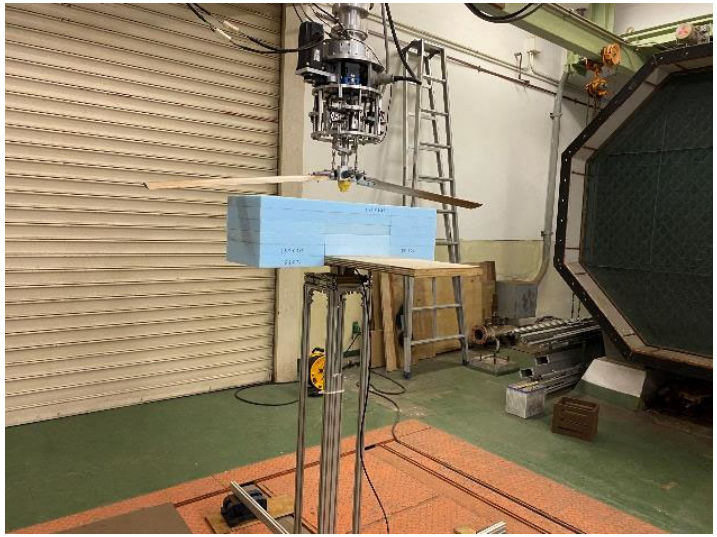
Experimental Conditions



z/R=0.2



z/R=0.3



z/R=0.4

z: Distance between rotor and wing
R: Rotor radius

Experimental Conditions

Rotor operating torque

$C_Q = 4.75 \times 10^{-4}$

(Corresponding to approximately $C_T = 5 \times 10^{-3}$)

$C_Q = 8.5 \times 10^{-4}$

(Corresponding to approximately $C_T = 8 \times 10^{-3}$)

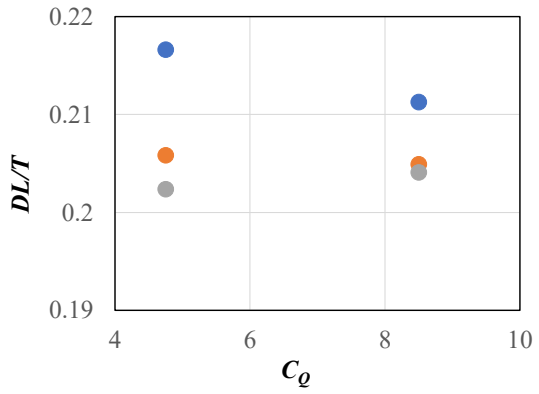
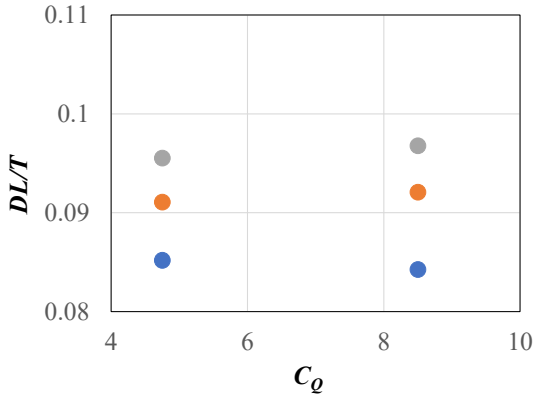
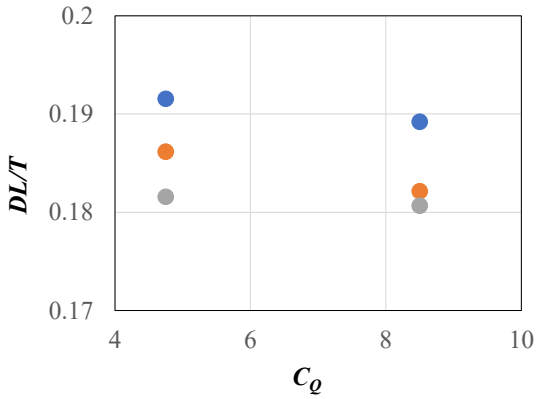
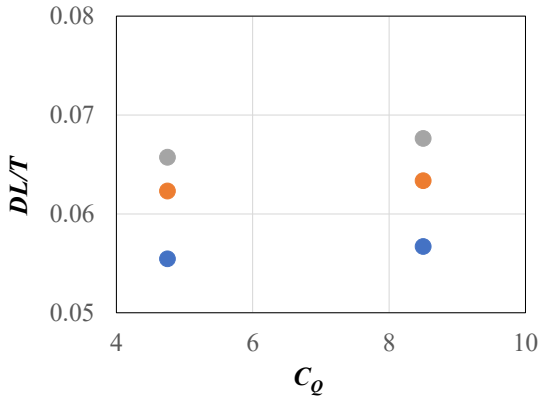
Wingspan

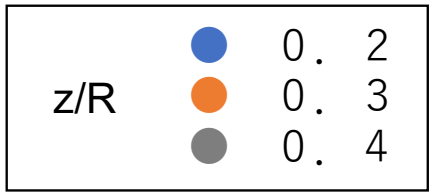
0.79R

0.5R

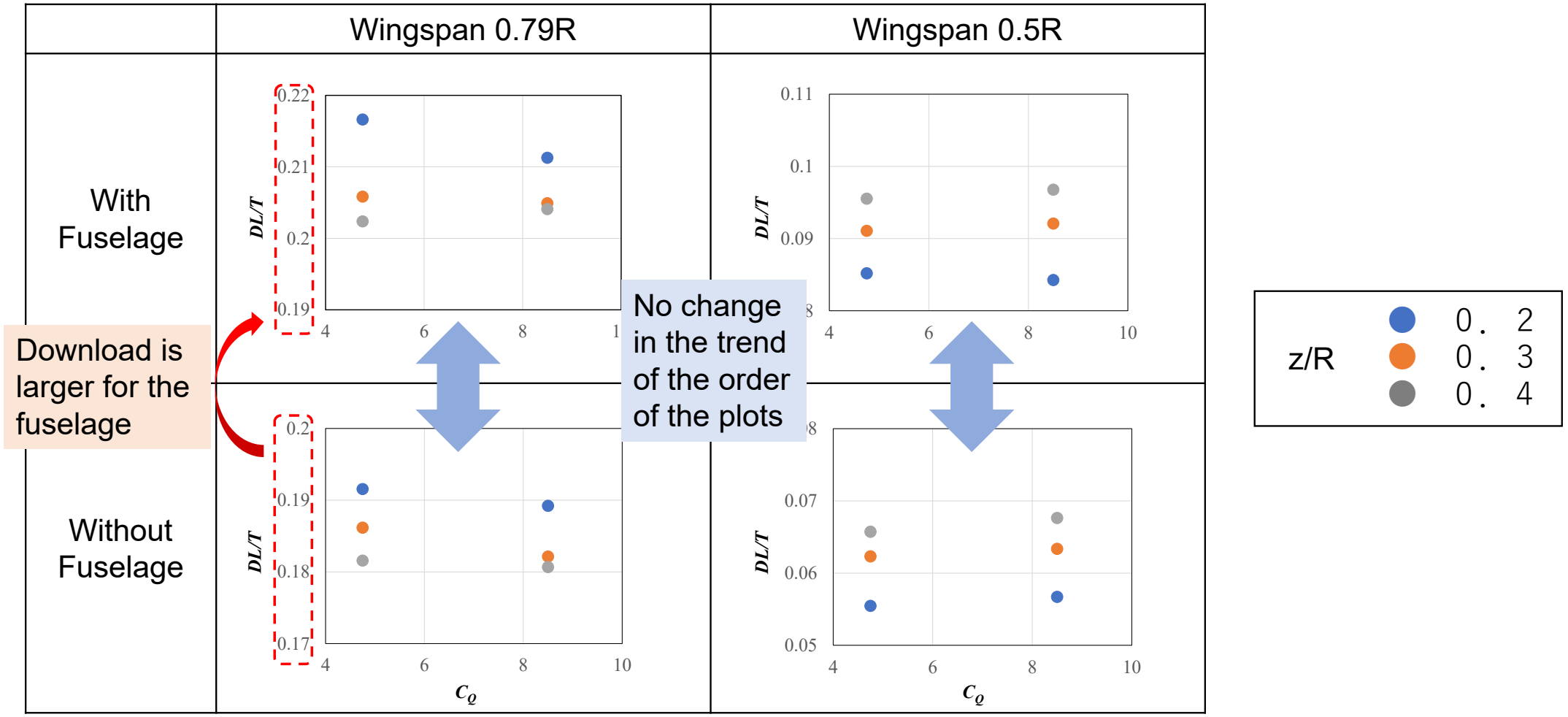
With or without fuselage

Results

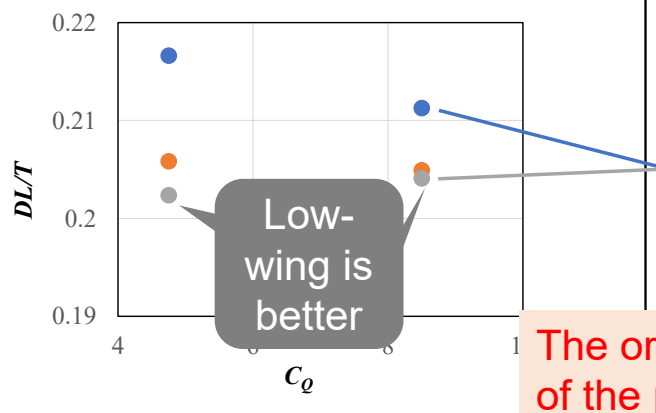
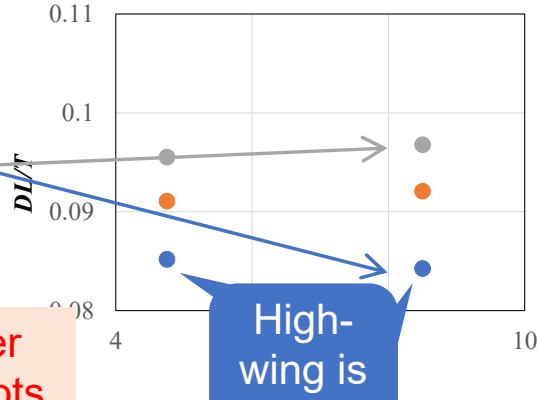
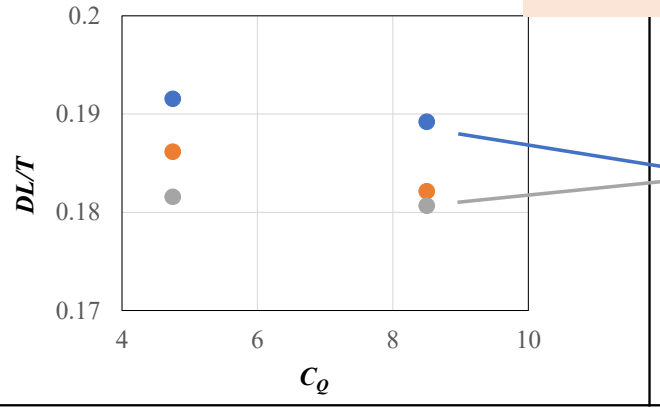
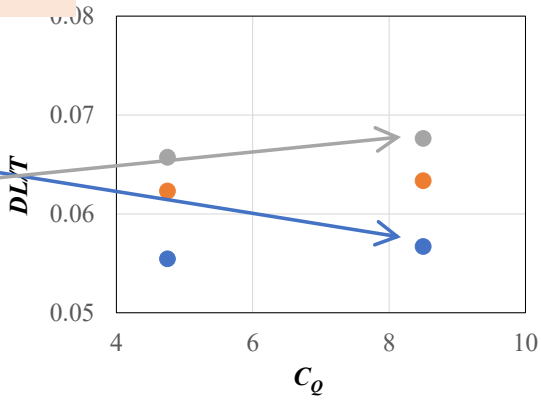
	Wingspan 0.79R	Wingspan 0.5R
With Fuselage		
Without Fuselage		



Results


Wingspan 0.79R
Wingspan 0.5R
With Fuselage
Without Fuselage
Download is larger for the fuselage
No change in the trend of the order of the plots
DL/T
C_Q
z/R
0.2
0.3
0.4

Results

	Wingspan 0.79R	Wingspan 0.5R
With Fuselage		
Without Fuselage		

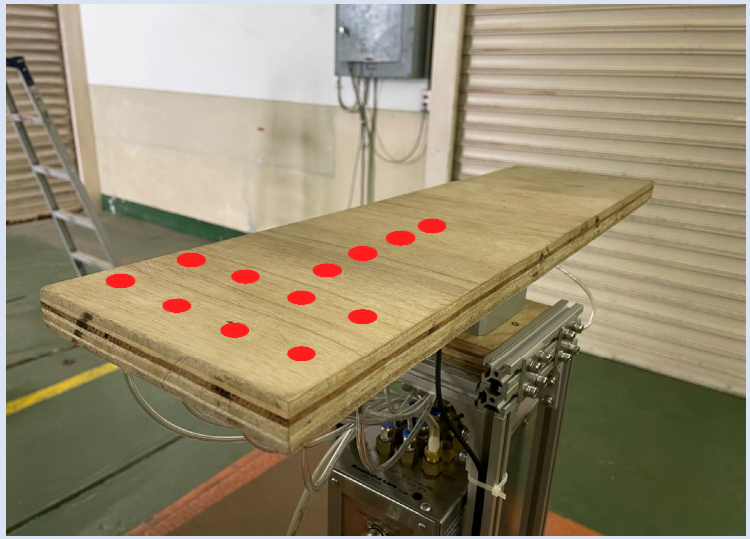
Verification and Discussion

Details of Rotor	
Rotor Radius	360mm
Blade Chord	60mm
Airfoil	NACA0015
Twist	None
Number of blades	2
Hinge offset	17mm
Root cutout	113mm

$C_Q = 4.75 \times 10^{-4}$

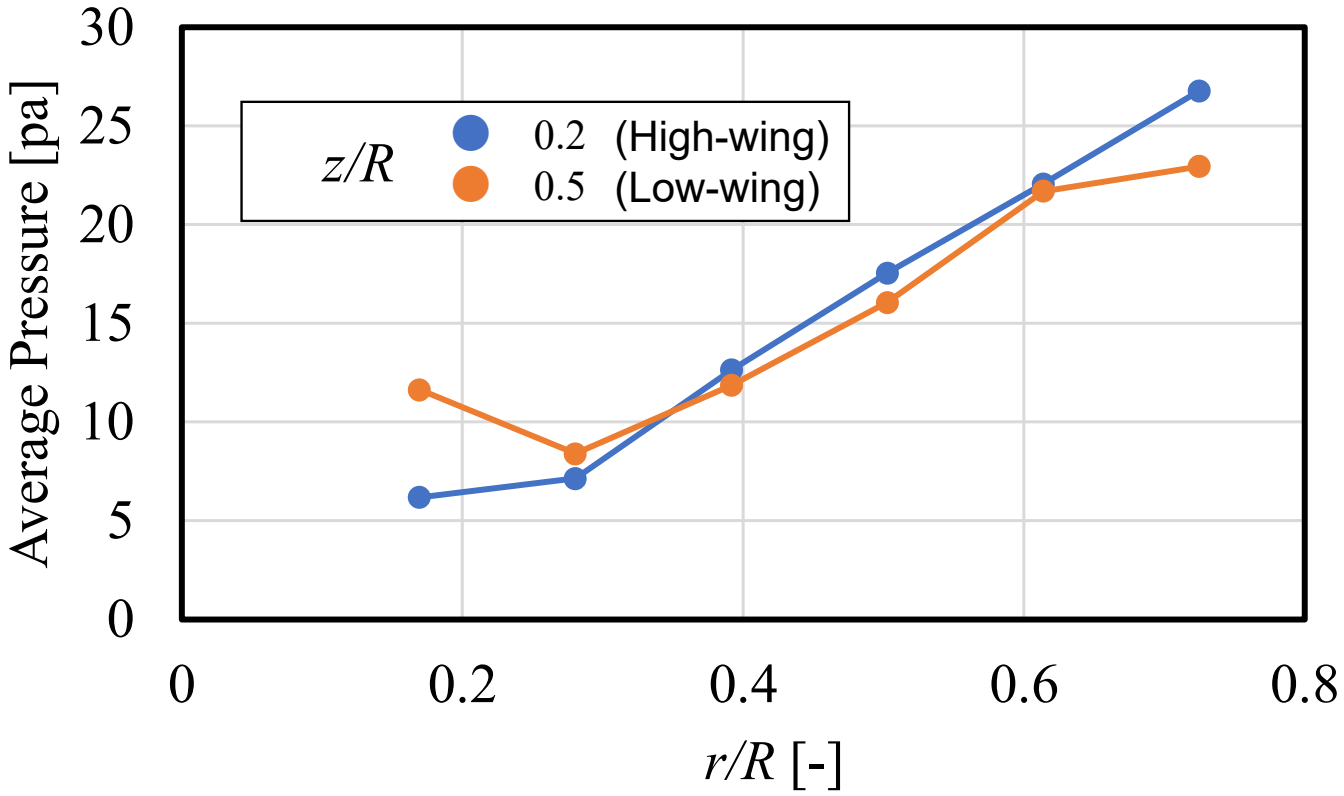
Corresponding to
Approximately
$C_T = 7 \times 10^{-3}$

Details of Wing	
Span	582mm(0.81D)
Cord	157mm(0.44R)



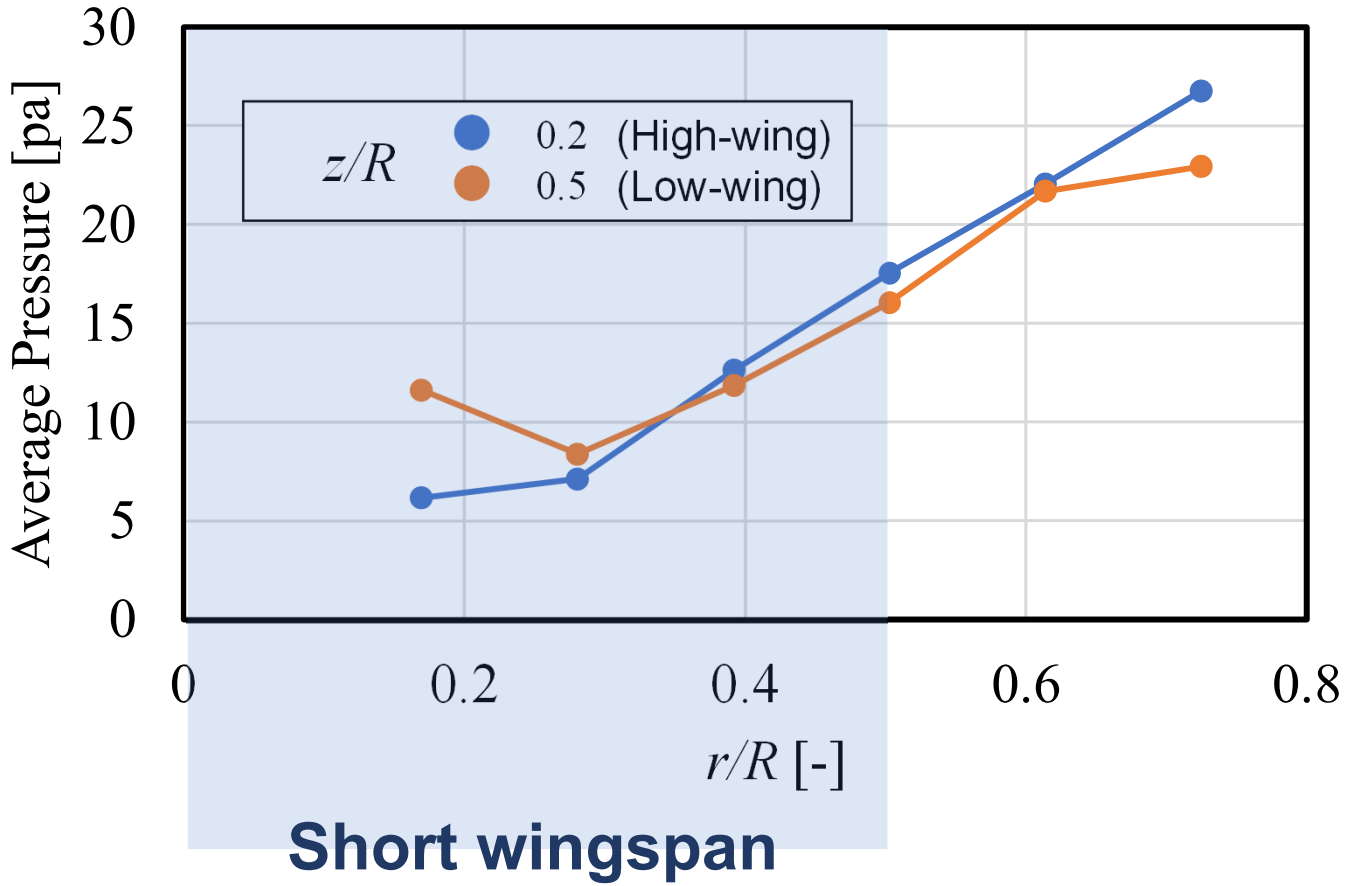
● Pressure ports

Verification and Discussion

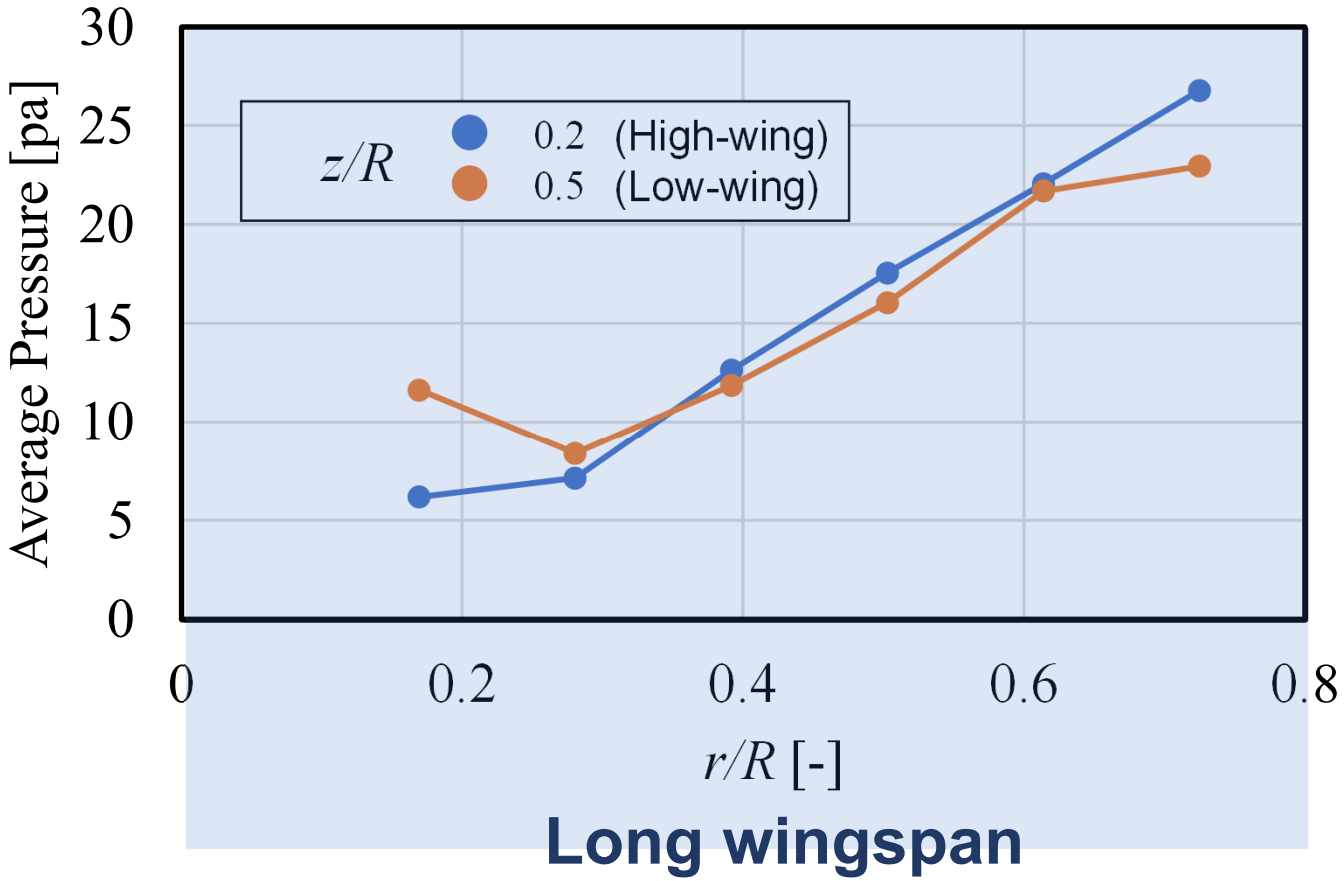


r: Distance from the rotor center
R: Rotor radius

Verification and Discussion

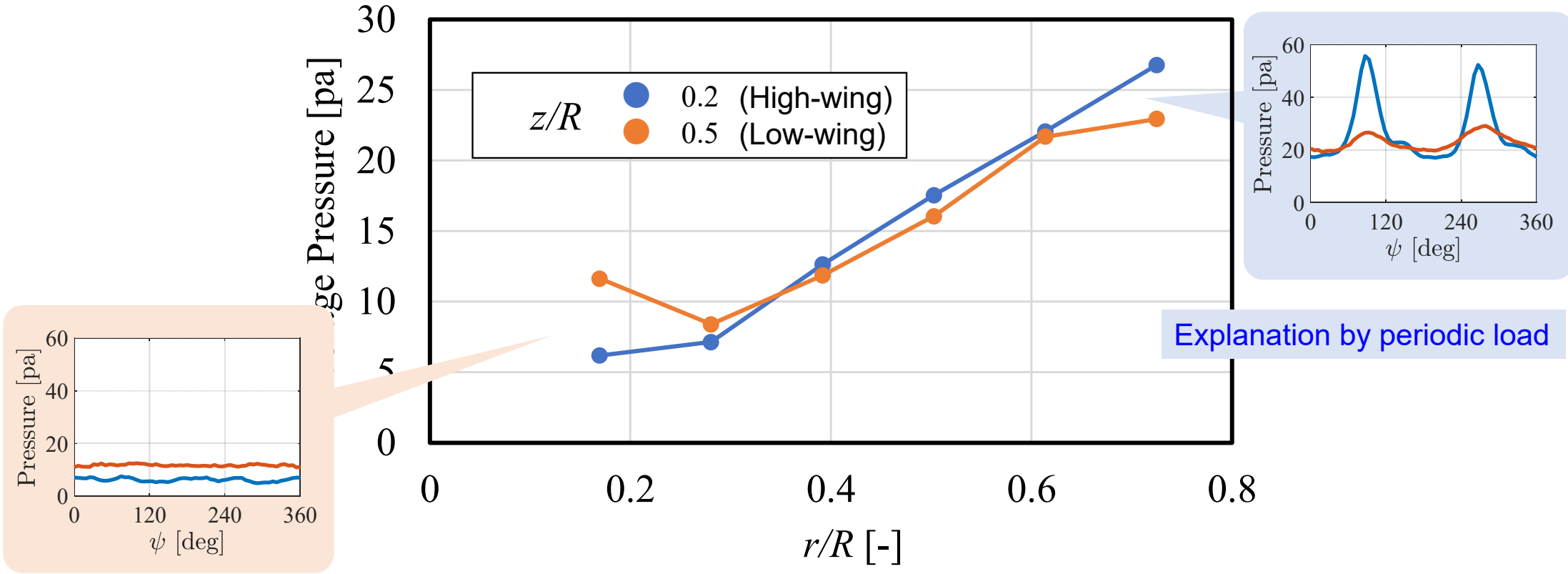


Verification and Discussion



Long wingspan

Verification and Discussion



Conclusion

- Download of winged helicopter in hover is experimentally investigated.
- There are both cases where the download becomes larger and smaller as the rotor-wing distance increases.
- The download trend was inversed by changing wingspan; it can at least partially be explained by mixing the momentum theory and periodic load.