LEADING EDGE DISTRIBUTED AND NON-DISTRIBUTED ELECTRIC PROPULSION COMPARISON ON A MOVING VESSEL DECK

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AGENDA

- Introduction
- History Overview
- Future of Aviation
- Distributed electric propulsion characteristics
- Analysis assumptions
- Simulation results
- Conclusions

Introduction

What is Distributed Propulsion?

- Formal definition of a Distributed Propulsion system has not yet been established
- Outdated proposition „An aircraft employing three engines or more”
- More accurate proposition: „Propulsion system where the vehicle thrust is produced from an array of propulsors located across the air vehicle”

HISTORY OVERVIEW

Dornier DO-X

Hughes H-4 Hercules

Aircrafts from early days of aviation employing combustion engine based Distributed Propulsion

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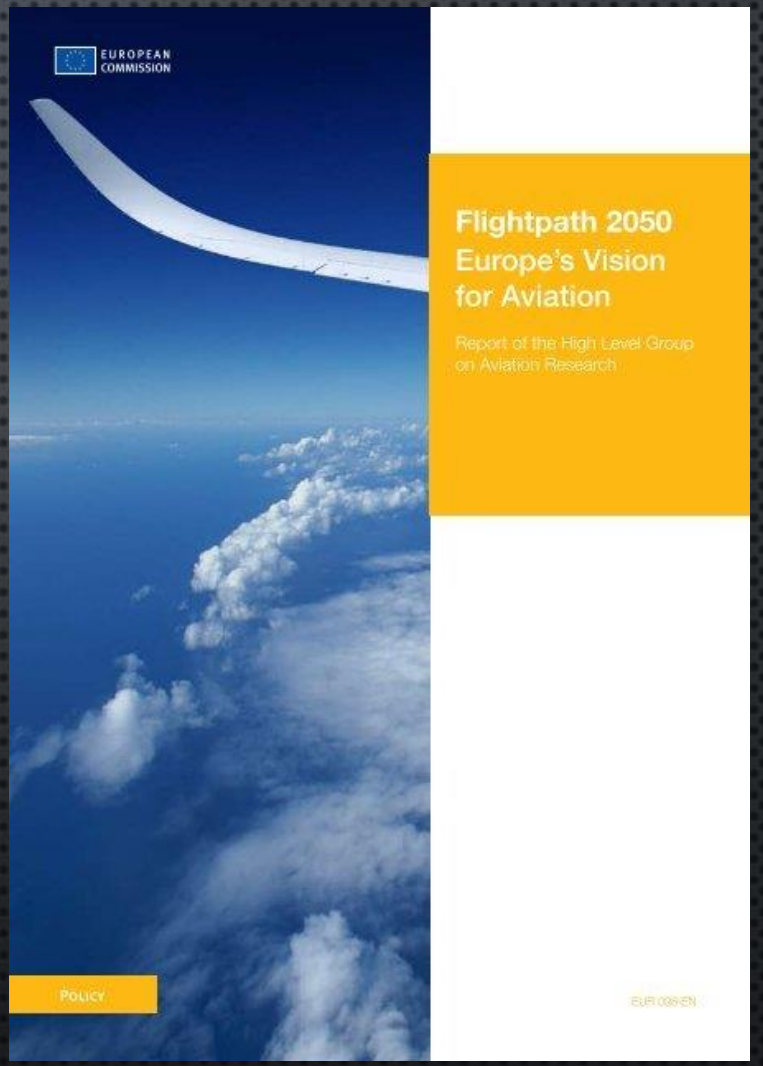
FUTURE OF AVIATION

FLIGHTPATH 2050 EUROPE'S VISION FOR AVIATION

- 90% JOURNEYS SHORTER THAN 4 HOURS
- 75% REDUCTION IN CO2 EMISSIONS
- 90% REDUCTION IN NOX EMISSIONS
- 65% REDUCTION IN THE PERCIEVED NOISE EMISSIONS RELATIVE TO YEAR 2000 AIRCRAFT
- 80% REDUCTION IN ACCIDENTS NUMBER COMPARED TO YEAR 200



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DISTRIBUTED ELECTRIC PROPULSION PROJECTS

DISTRIBUTED ELECTRIC PROPULSION CHARACTERISTICS

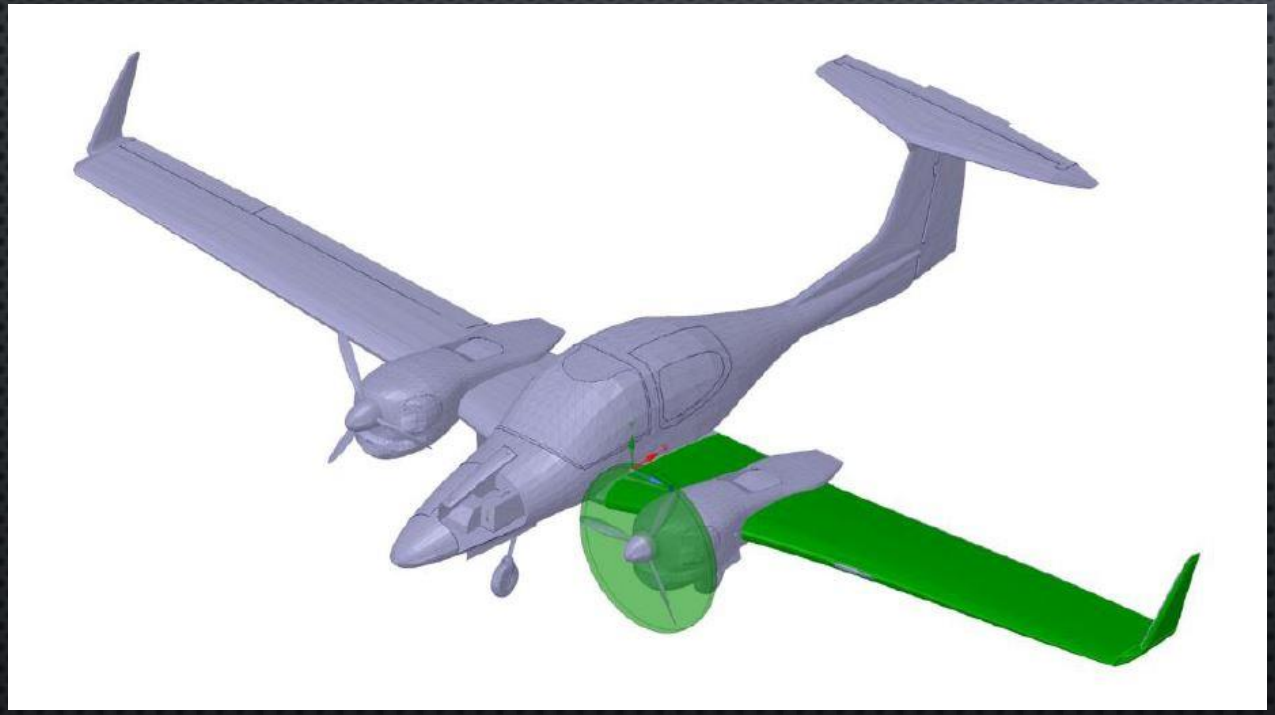
- Easy adaptation of electric engine technology in aviation
- Redundancy and safety
- Thrust vectoring
- Modification of aerodynamic characteristics

ANALYZED AIRCRAFT

DA42 Twin Star specifications	
Wingspan	13.55 m
Wing area	16.29 m^2
Powerplant	2 × 125 kW
Empty weight	1,251 kg
Gross weight	1,999 kg
Maximum speed	365 km/h
Cruise speed	326 km/h
Service ceiling	5,486 m

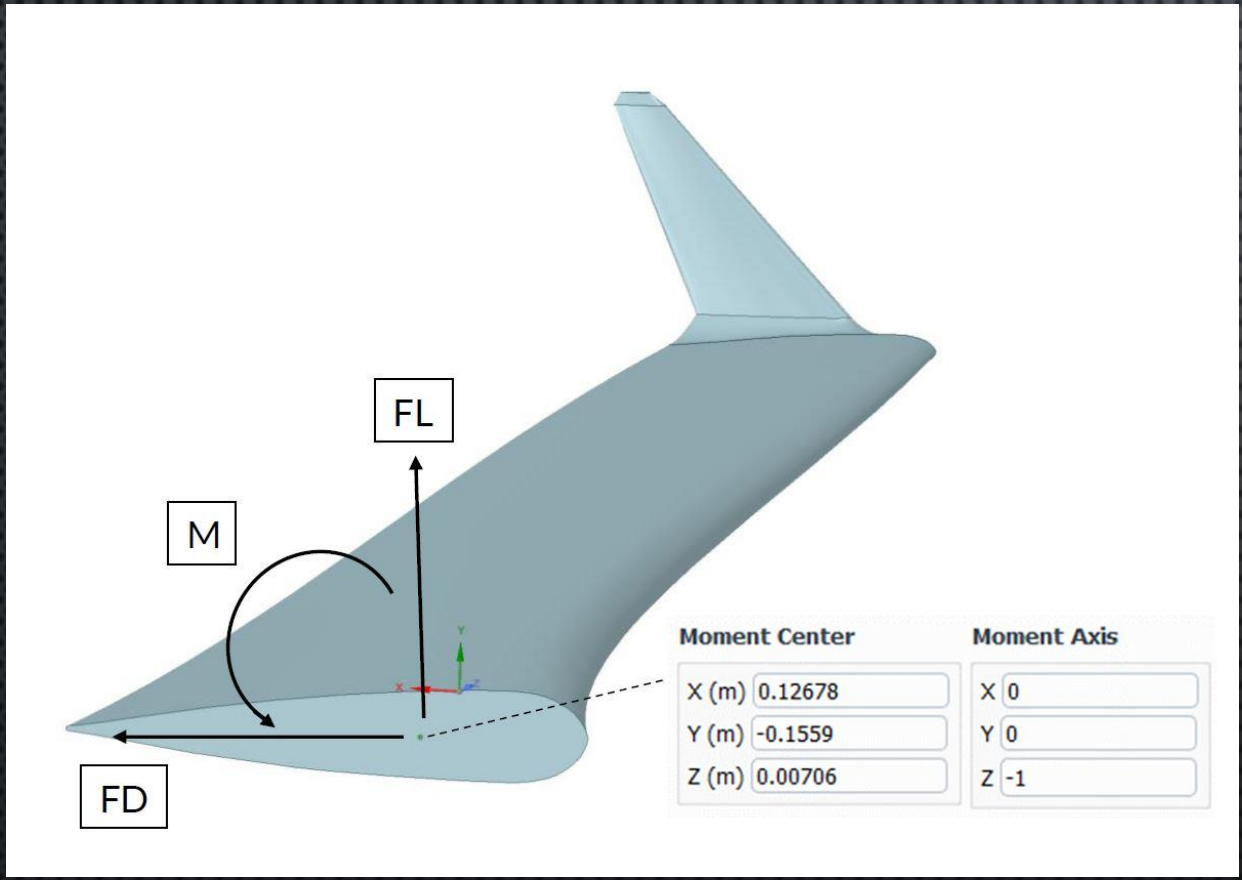
Diamond DA42 Twin Star

SIMULATION



Simulation parameters	
Flow velocity	326 km/h
Altitude	4 877 m
Air density	0,7457 kg/m3
Air temperature	-15 °C
Dynamic viscosity	1,65 x 10^{-5} kg/m*s
Angle of attack	3°
Turbulence model	K-ε with enhanced wall treatment

ANALYSIS CONFIGURATIONS



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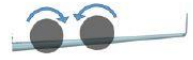
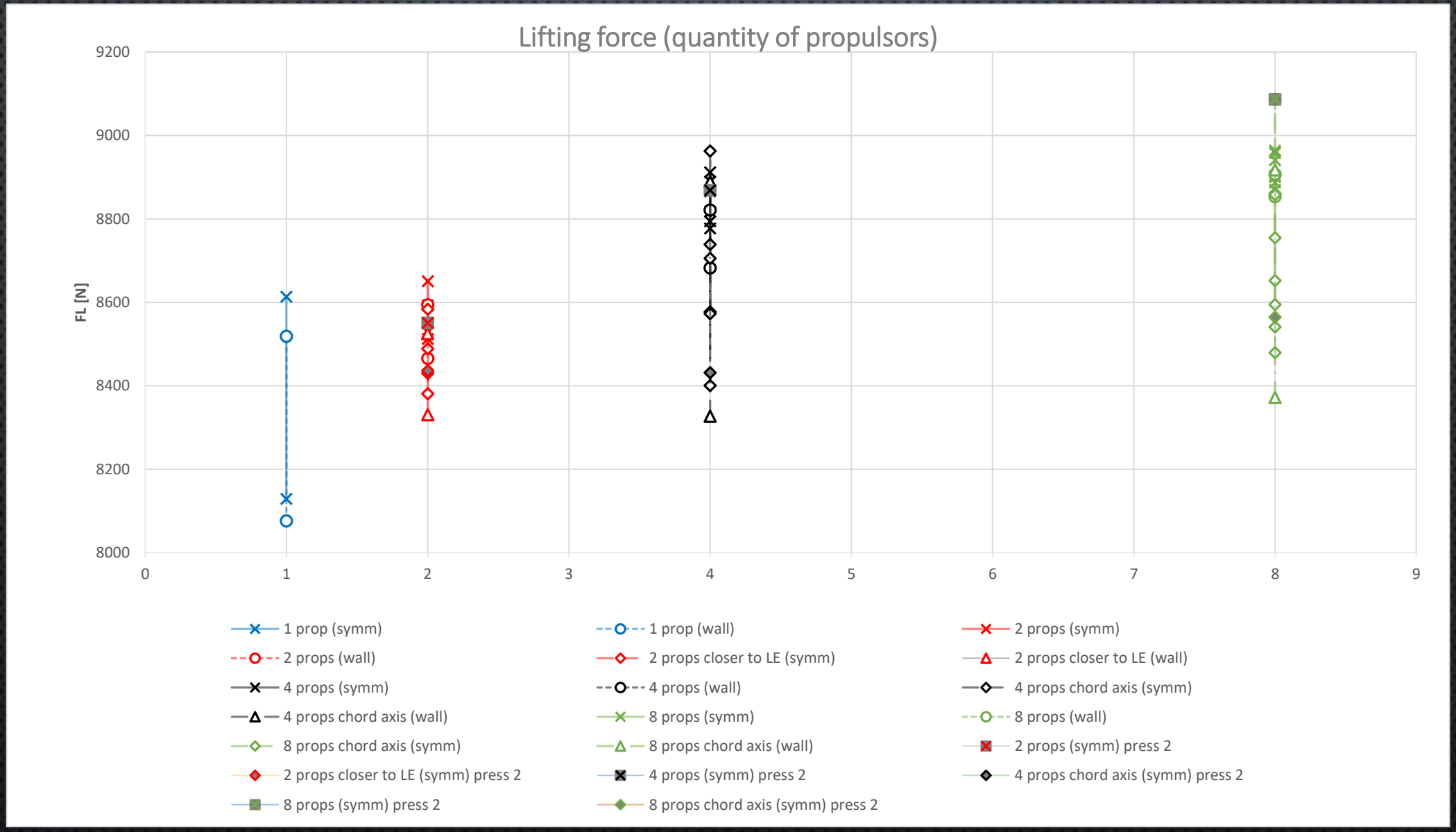
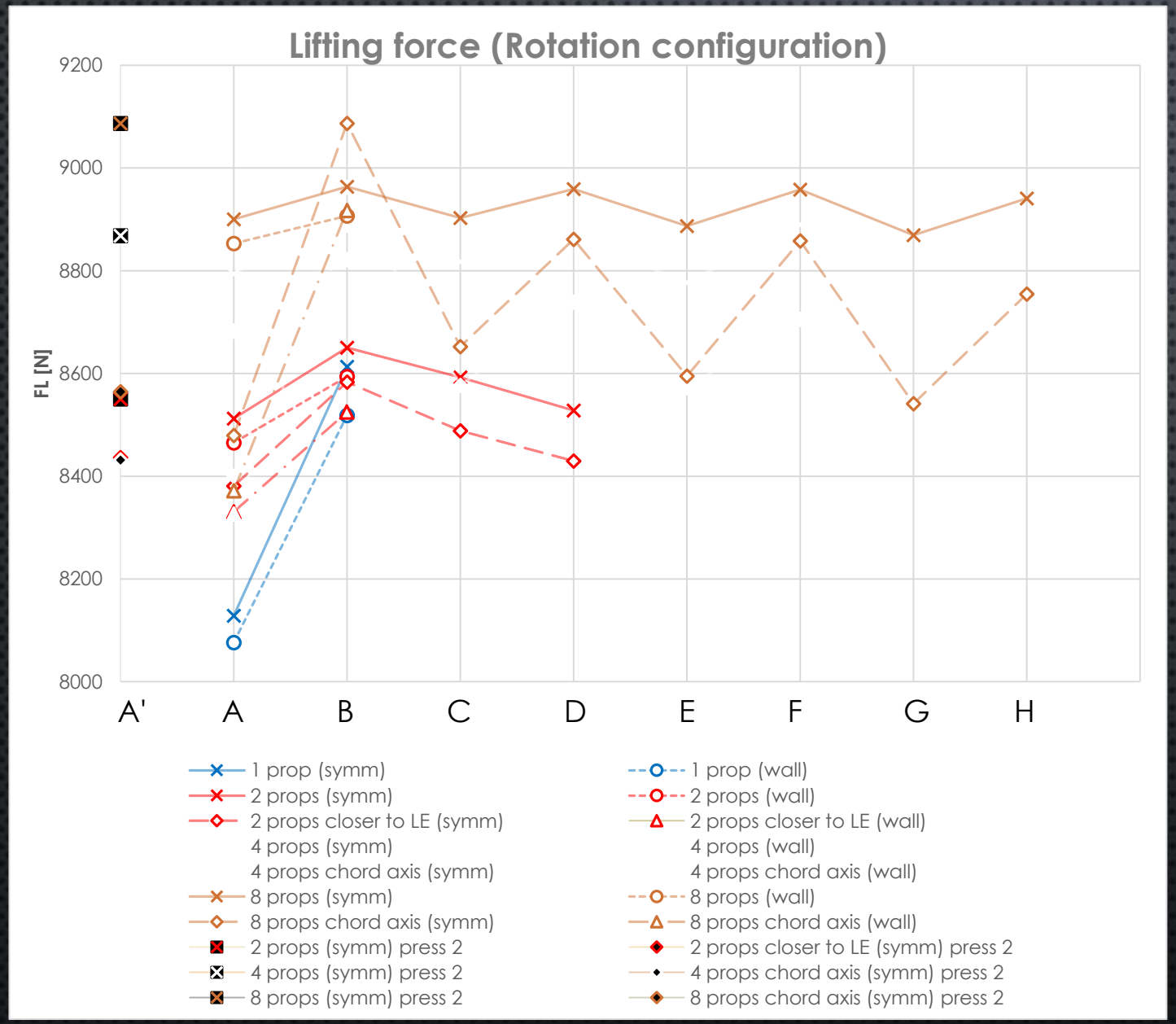
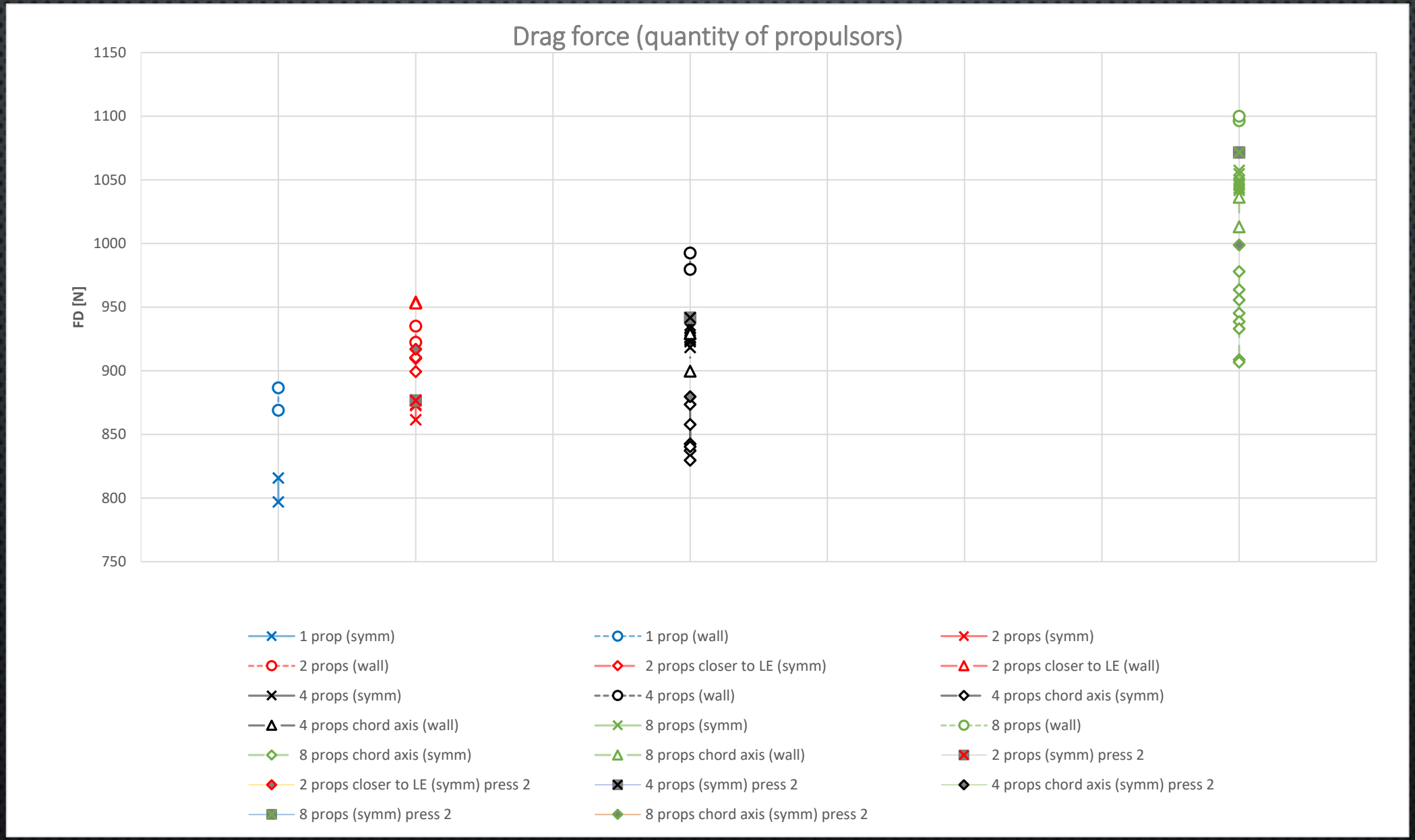
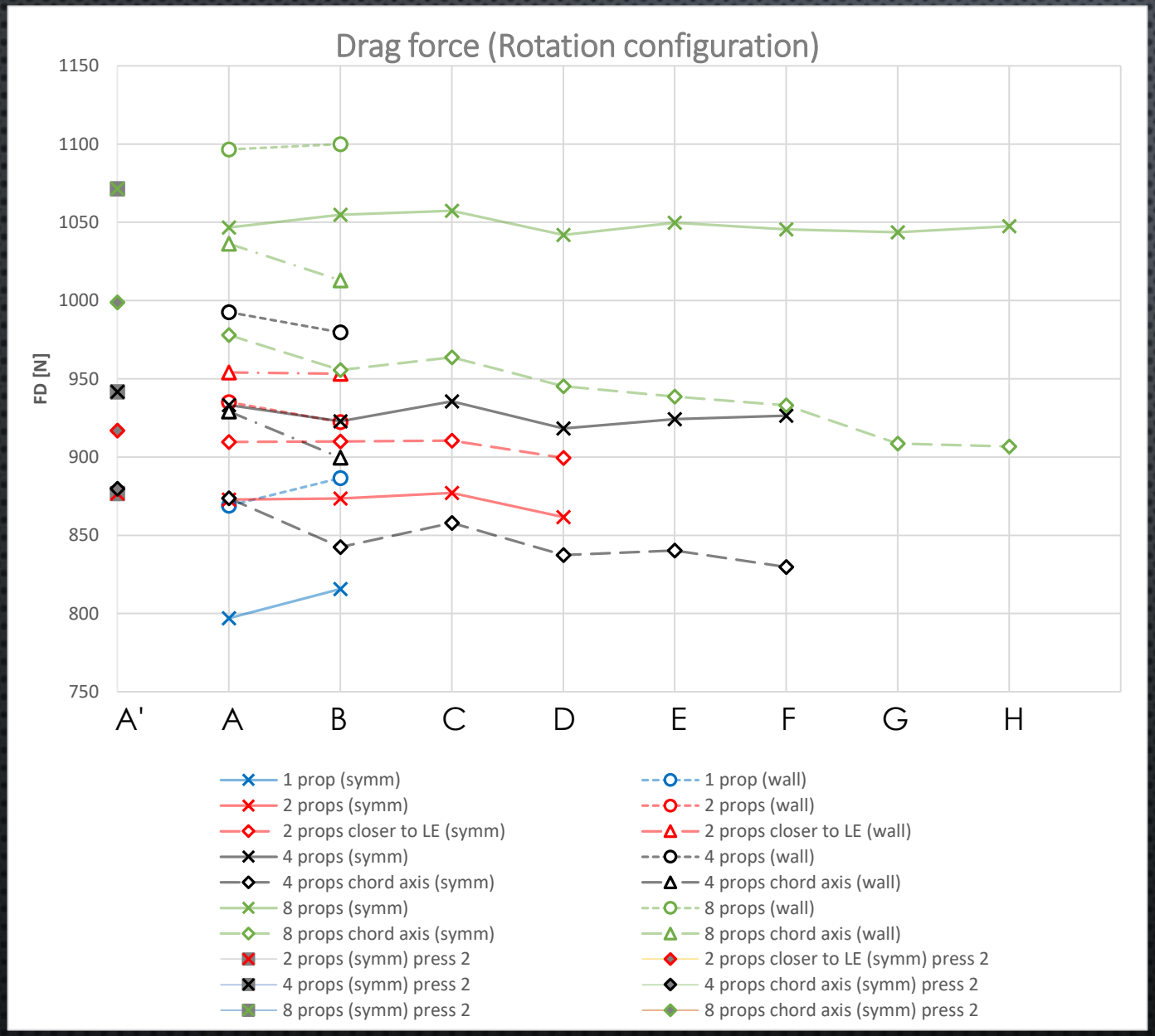
B				
C	-			
D	-			
E	-	-		
F	-	-		
G	-	-	-	
H	-	-	-	

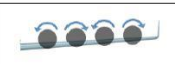
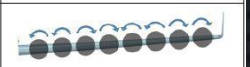

Lifting force (quantity of propulsors)
FL [N]
9200
9000
8800
8600
8400
8200
8000
0
1
2
3
4
5
6
7
8
9
1 prop (symm)
1 prop (wall)
2 props (symm)
2 props (wall)
2 props closer to LE (symm)
2 props closer to LE (wall)
4 props (symm)
4 props (wall)
4 props chord axis (symm)
4 props chord axis (wall)
8 props (symm)
8 props (wall)
8 props chord axis (symm)
8 props chord axis (wall)
2 props (symm) press 2
2 props closer to LE (symm) press 2
4 props (symm) press 2
4 props chord axis (symm) press 2
8 props (symm) press 2
8 props chord axis (symm) press 2


Lifting force (Rotation configuration)
FL [N]
9200
9000
8800
8600
8400
8200
8000
A'
A
B
C
D
E
F
G
H
1 prop (symm)
2 props (symm)
2 props closer to LE (symm)
4 props (symm)
4 props chord axis (symm)
8 props (symm)
8 props chord axis (symm)
2 props (symm) press 2
4 props (symm) press 2
8 props (symm) press 2
1 prop (wall)
2 props (wall)
2 props closer to LE (wall)
4 props (wall)
4 props chord axis (wall)
8 props (wall)
8 props chord axis (wall)
2 props closer to LE (symm) press 2
4 props chord axis (symm) press 2
8 props chord axis (symm) press 2

A				
B				
C	-			
D	-			
E	-	-		
F	-	-		
G	-	-	-	
H	-	-	-	


Drag force (quantity of propulsors)
FD [N]
1150
1100
1050
1000
950
900
850
800
750
1 prop (symm)
1 prop (wall)
2 props (symm)
2 props (wall)
2 props closer to LE (symm)
2 props closer to LE (wall)
4 props (symm)
4 props (wall)
4 props chord axis (symm)
4 props chord axis (wall)
8 props (symm)
8 props (wall)
8 props chord axis (symm)
8 props chord axis (wall)
2 props (symm) press 2
2 props closer to LE (symm) press 2
4 props (symm) press 2
4 props chord axis (symm) press 2
8 props (symm) press 2
8 props chord axis (symm) press 2


Drag force (Rotation configuration)
FD [N]
1150
1100
1050
1000
950
900
850
800
750
A'
A
B
C
D
E
F
G
H
1 prop (symm)
1 prop (wall)
2 props (symm)
2 props (wall)
2 props closer to LE (symm)
2 props closer to LE (wall)
4 props (symm)
4 props (wall)
4 props chord axis (symm)
4 props chord axis (wall)
8 props (symm)
8 props (wall)
8 props chord axis (symm)
8 props chord axis (wall)
2 props (symm) press 2
2 props closer to LE (symm) press 2
4 props (symm) press 2
4 props chord axis (symm) press 2
8 props (symm) press 2
8 props chord axis (symm) press 2

A				
B				
C	-			
D	-			
E	-	-		
F	-	-		
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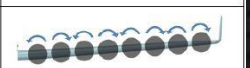
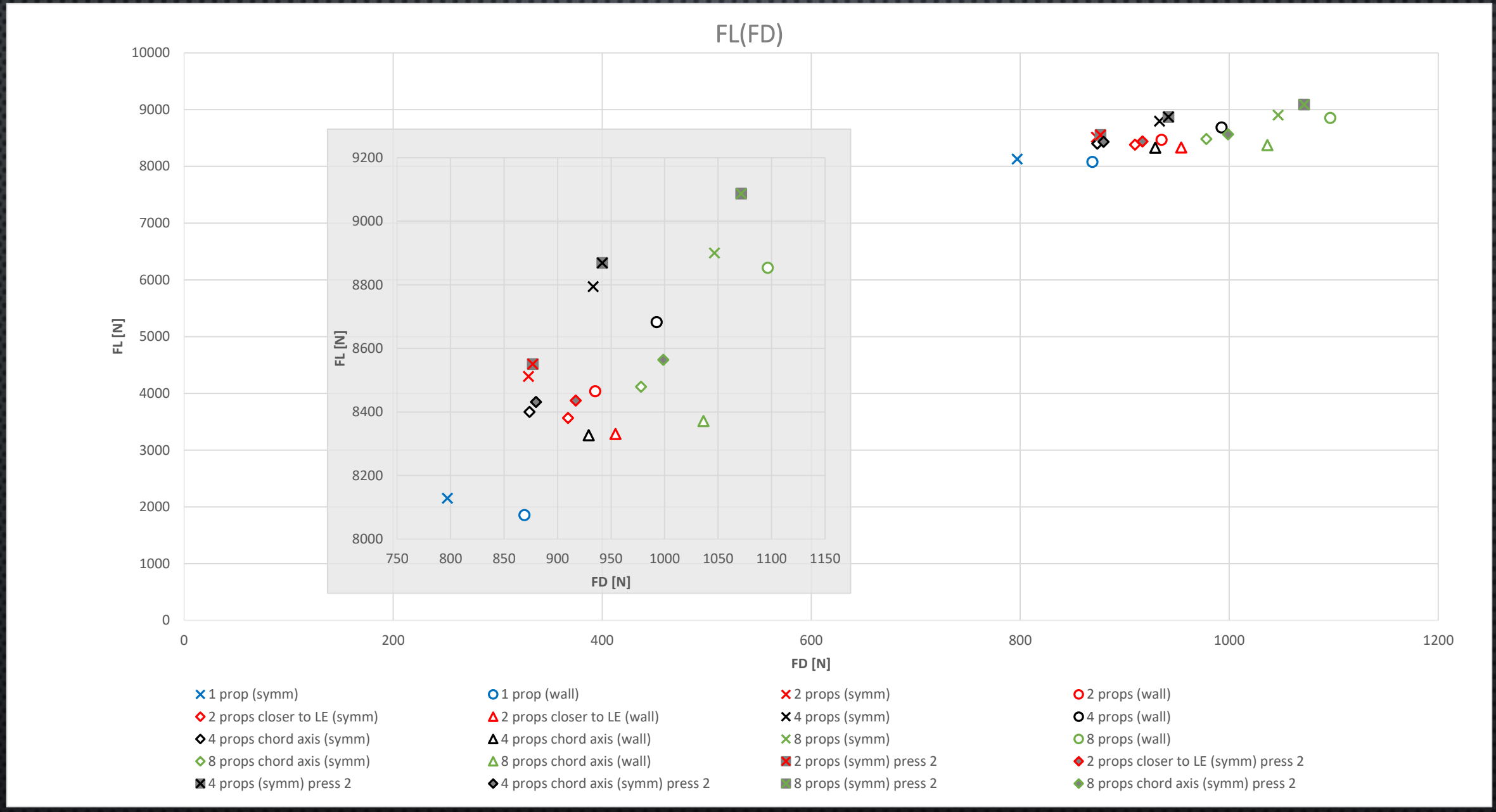
H	-	-	-	


FL(FD)
FL [N]
FD [N]
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
0
200
400
600
800
1000
1200
9200
9000
8800
8600
8400
8200
8000
750
800
850
900
950
1000
1050
1100
1150
1 prop (symm)
1 prop (wall)
2 props (symm)
2 props (wall)
2 props closer to LE (symm)
2 props closer to LE (wall)
4 props (symm)
4 props (wall)
4 props chord axis (symm)
4 props chord axis (wall)
8 props (symm)
8 props (wall)
8 props chord axis (symm)
8 props chord axis (wall)
2 props (symm) press 2
2 props closer to LE (symm) press 2
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4 props chord axis (symm) press 2
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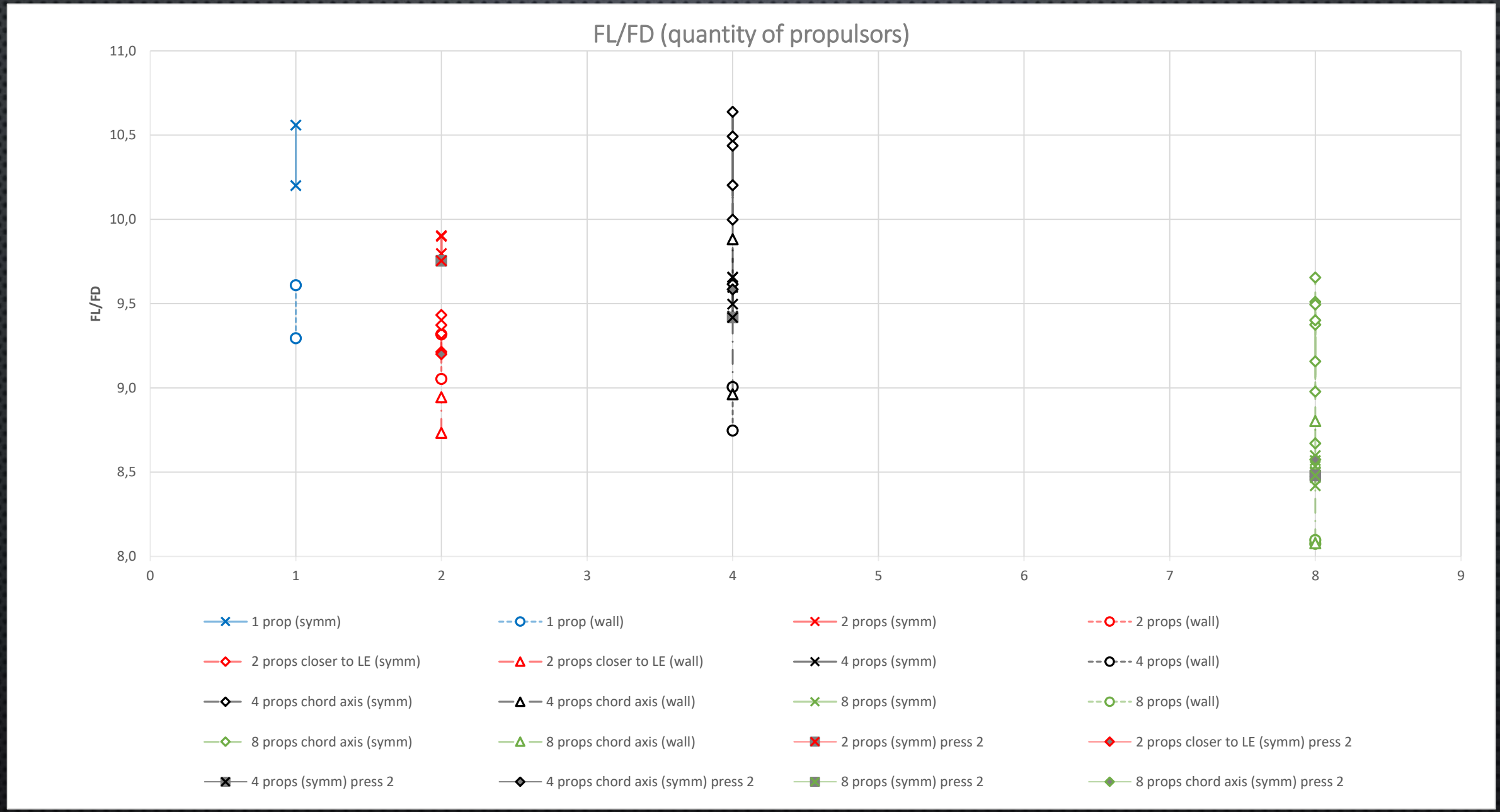
FL/FD (quantity of propulsors)
FL/FD
11,0
10,5
10,0
9,5
9,0
8,5
8,0
0
1
2
3
4
5
6
7
8
9
1 prop (symm)
1 prop (wall)
2 props (symm)
2 props (wall)
2 props closer to LE (symm)
2 props closer to LE (wall)
4 props (symm)
4 props (wall)
4 props chord axis (symm)
4 props chord axis (wall)
8 props (symm)
8 props (wall)
8 props chord axis (symm)
8 props chord axis (wall)
2 props (symm) press 2
2 props closer to LE (symm) press 2
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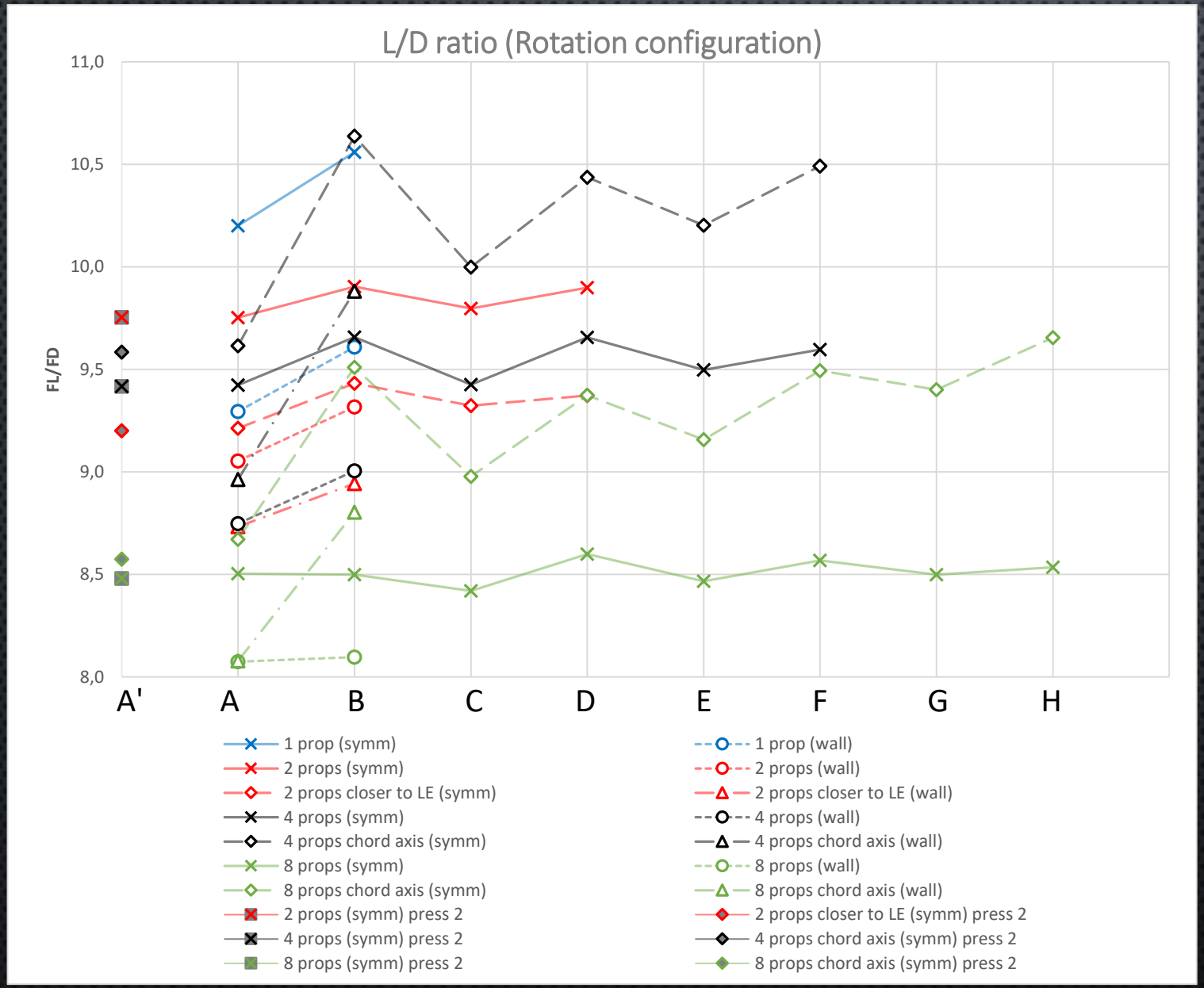
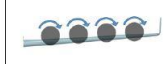
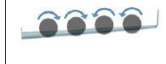
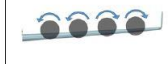
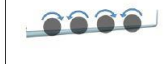
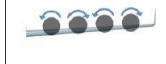
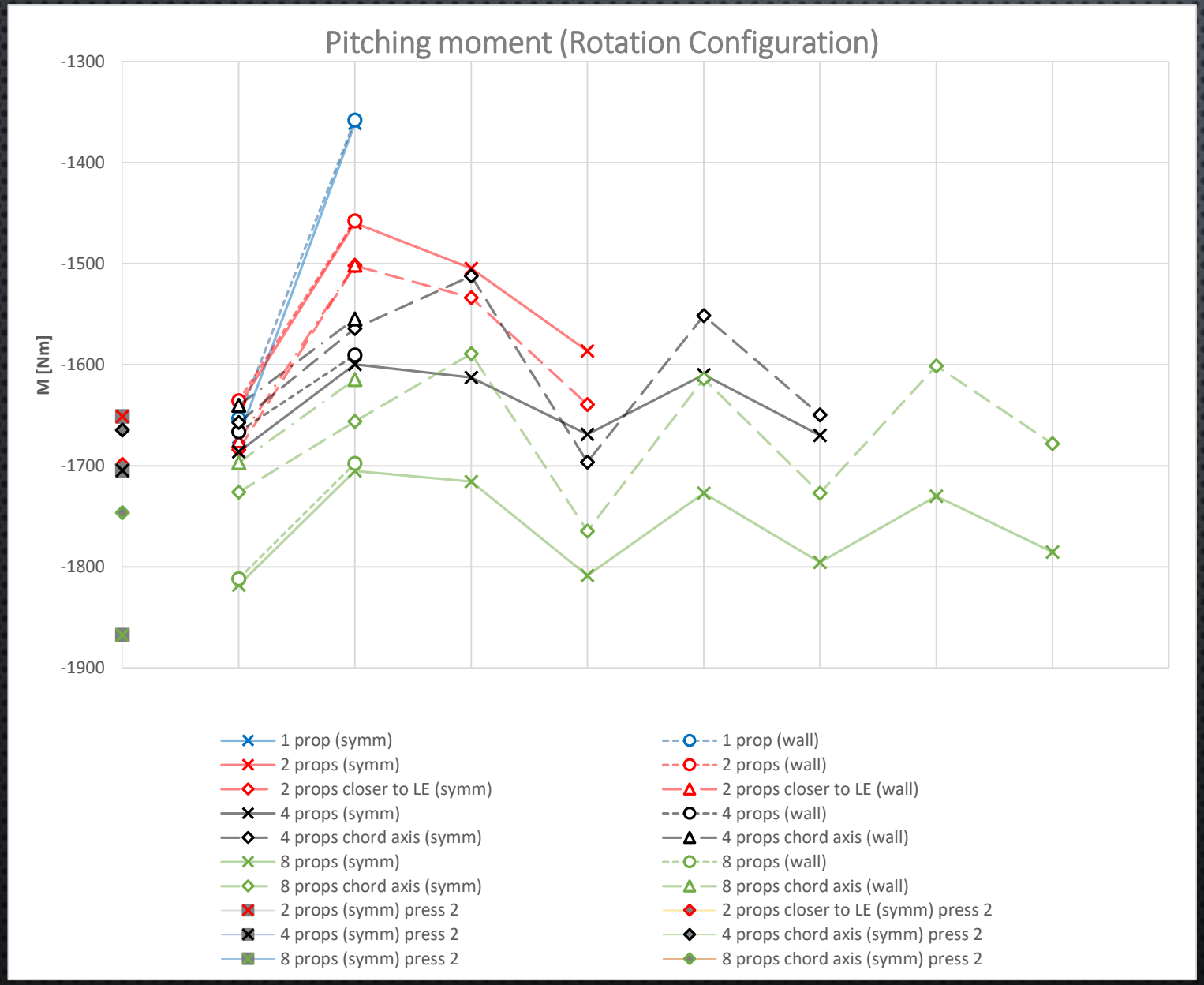
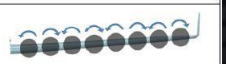
8 props chord axis (symm) press 2

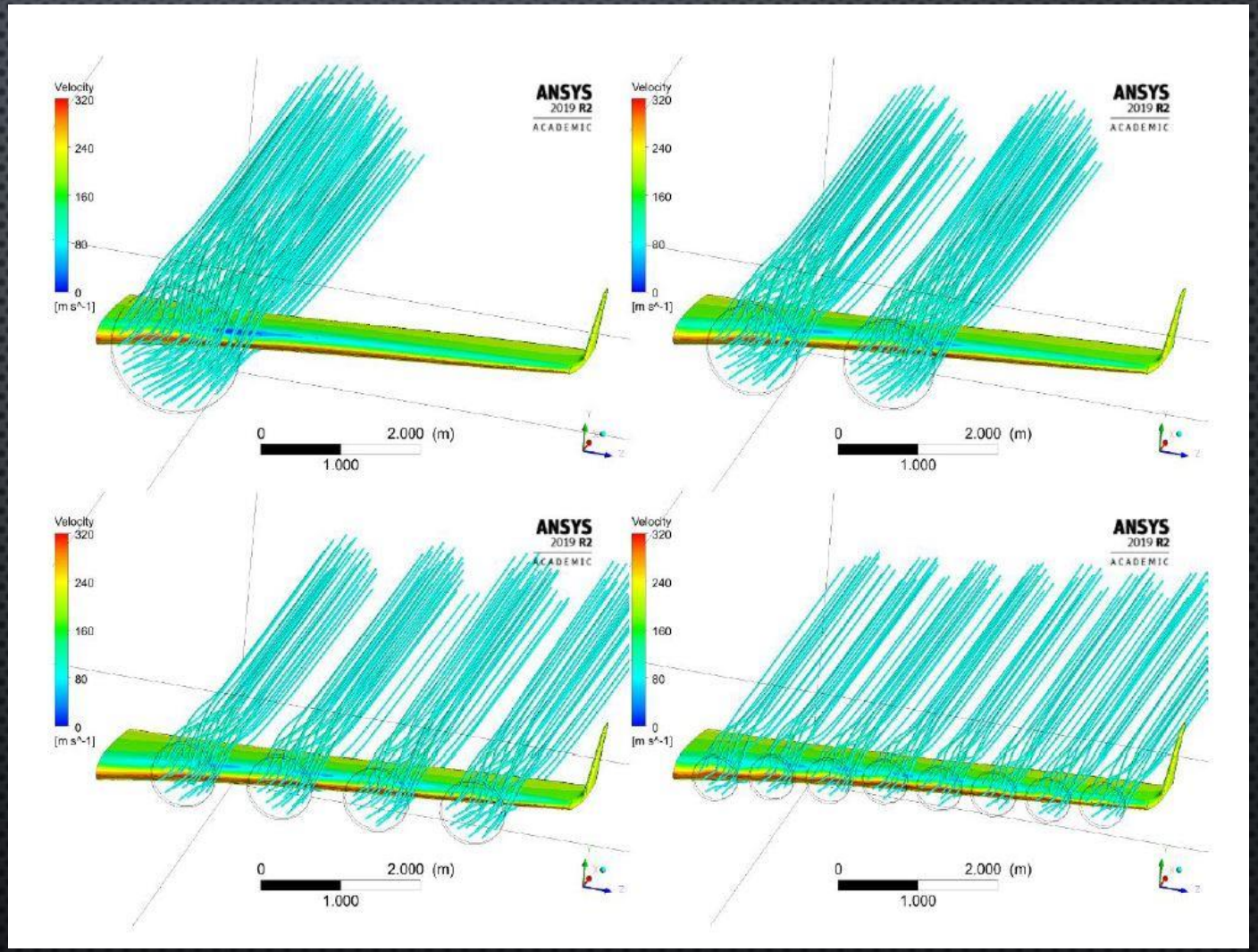

L/D ratio (Rotation configuration)
FL/FD
11,0
10,5
10,0
9,5
9,0
8,5
8,0
A'
A
B
C
D
E
F
G
H
1 prop (symm)
2 props (symm)
2 props closer to LE (symm)
4 props (symm)
4 props chord axis (symm)
8 props (symm)
8 props chord axis (symm)
2 props (symm) press 2
4 props (symm) press 2
8 props (symm) press 2
1 prop (wall)
2 props (wall)
2 props closer to LE (wall)
4 props (wall)
4 props chord axis (wall)
8 props (wall)
8 props chord axis (wall)
2 props closer to LE (symm) press 2
4 props chord axis (symm) press 2
8 props chord axis (symm) press 2

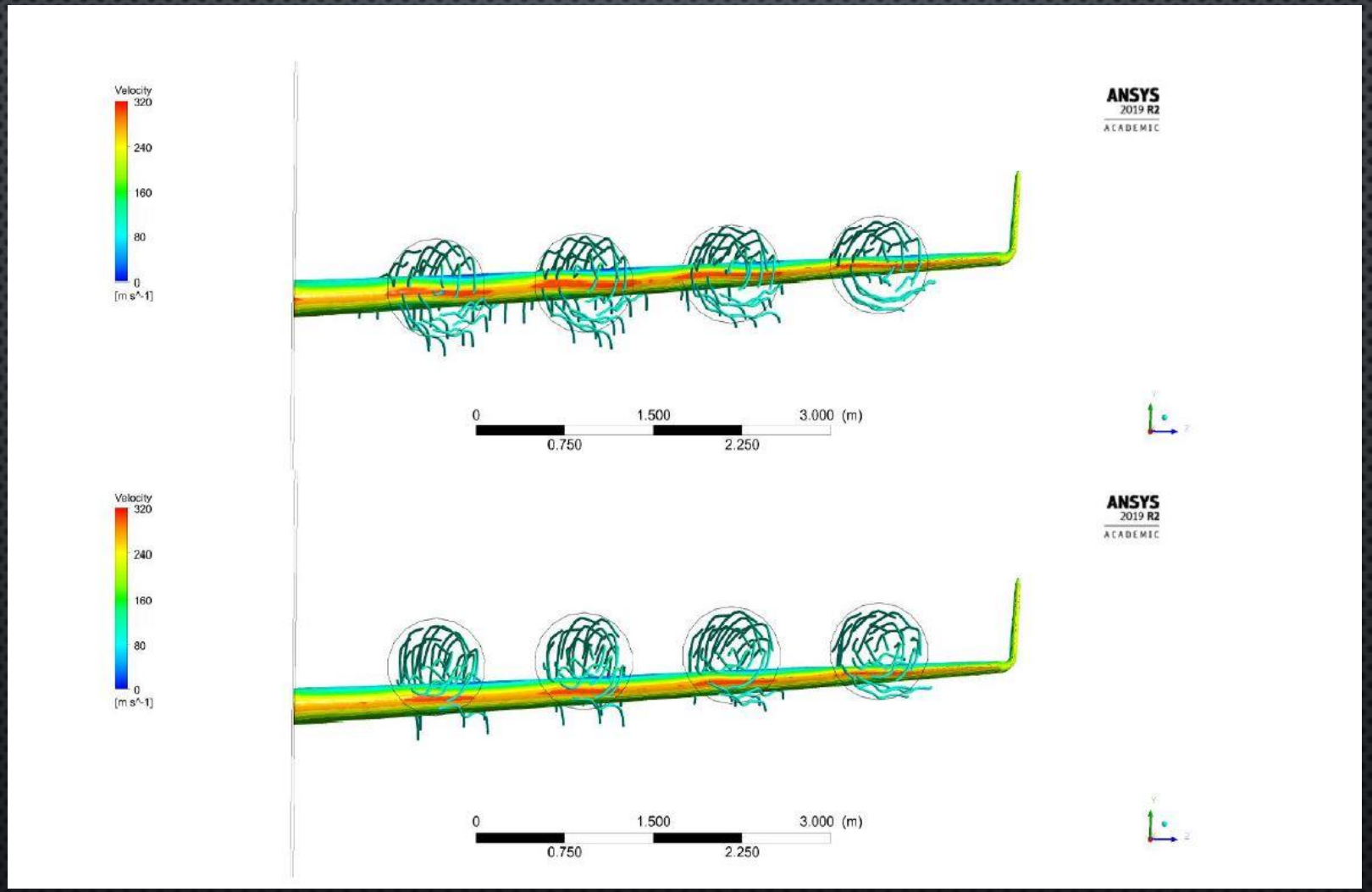
A				
B				
C	-			
D	-			
E	-	-		
F	-	-		
G	-	-	-	
H	-	-	-	

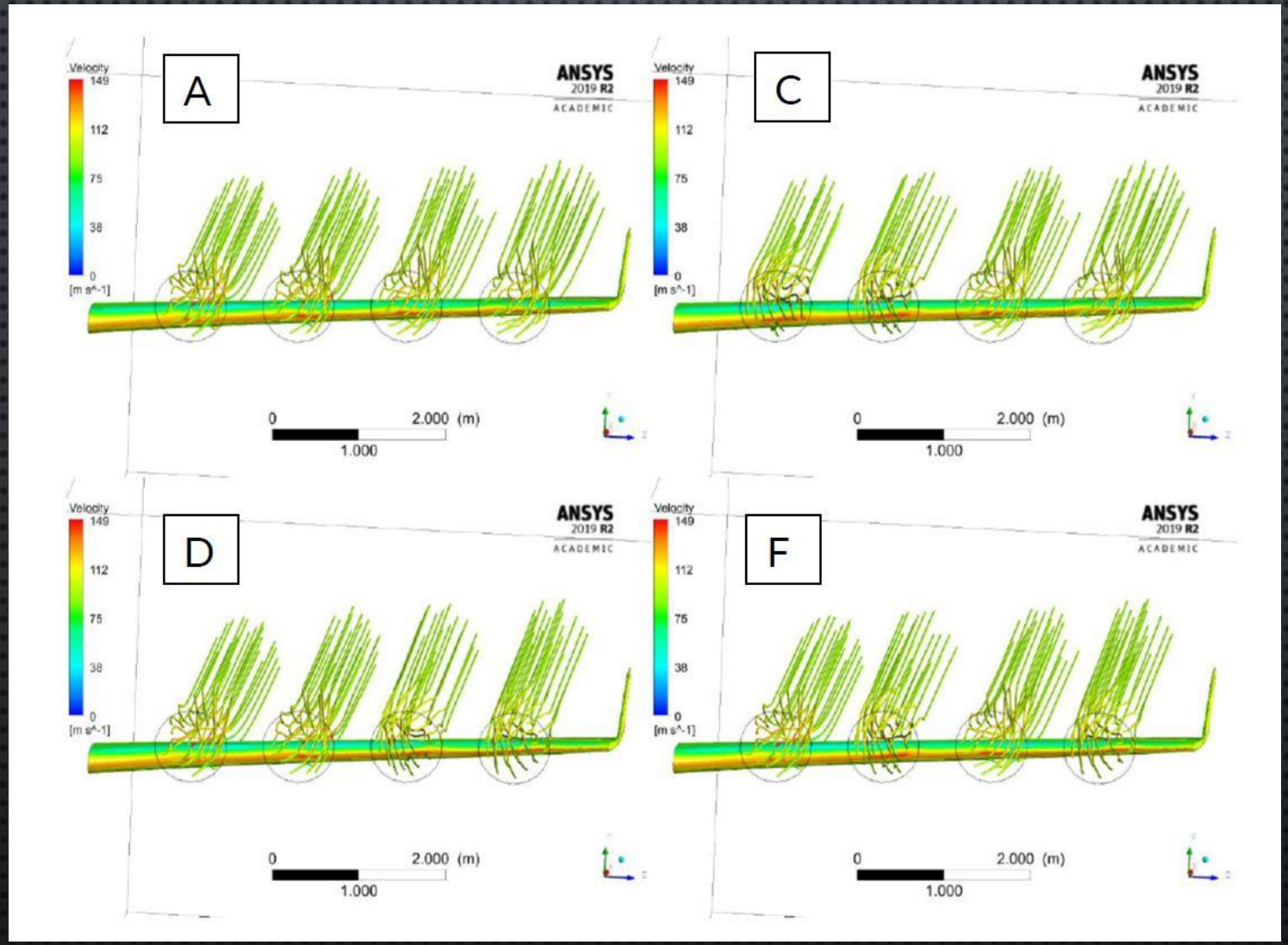

Pitching moment (Rotation Configuration)
M [Nm]
-1300
-1400
-1500
-1600
-1700
-1800
-1900
1 prop (symm)
2 props (symm)
2 props closer to LE (symm)
4 props (symm)
4 props chord axis (symm)
8 props (symm)
8 props chord axis (symm)
2 props (symm) press 2
4 props (symm) press 2
8 props (symm) press 2
1 prop (wall)
2 props (wall)
2 props closer to LE (wall)
4 props (wall)
4 props chord axis (wall)
8 props (wall)
8 props chord axis (wall)
2 props closer to LE (symm) press 2
4 props chord axis (symm) press 2
8 props chord axis (symm) press 2

A				
B				
C	-			
D	-			
E	-	-		
F	-	-		
G	-	-	-	
H	-	-	-	

FLOW VISUALIZATION




Velocity
320
240
160
80
0
[m s^-1]
ANSYS
2019 R2
ACADEMIC
0
1.500
3.000 (m)
0.750
2.250
Velocity
320
240
160
80
0
[m s^-1]
ANSYS
2019 R2
ACADEMIC
0
1.500
3.000 (m)
0.750
2.250


A
C
D
F
Velocity
149
112
75
38
0
[m s^-1]
ANSYS
2019 R2
ACADEMIC
0
2.000 (m)
1.000

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CONCLUSIONS

- Distributed electric propulsion enables to easily adapt electric propulsion to aviation
- DEP generates greater lifting force and also grater drag, to achieve better aerodynamic characteristics wing geometry must be modified
- Configuration of rotation and propulsion geometry is crutial for DEP optimization