



AdVanced Aerodynamic Tools for lArge Rotors

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Avatar Blind Test Campaign

CASE 1: High Reynolds number characterisation of DU00-w-212 Airfoil

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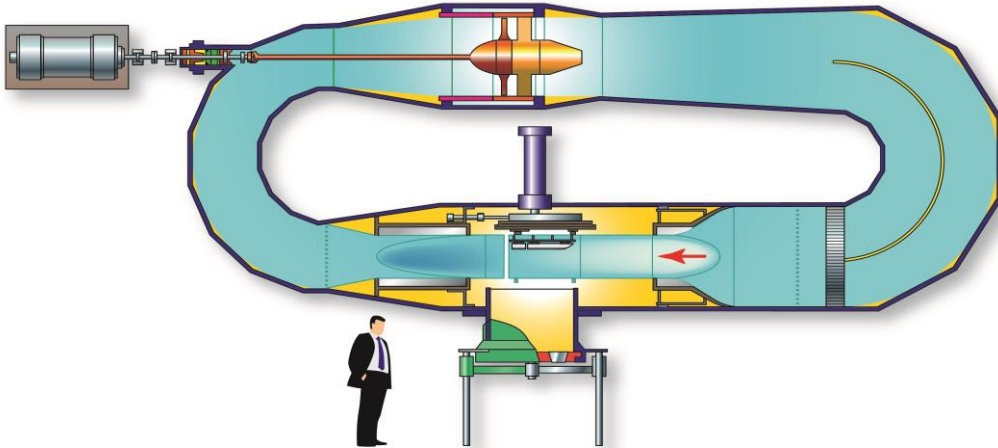
This project has received funding from the European Union's Seventh Programme for research, technological development and demonstration under grand agreement No FP7-ENERGY-2013-1/n° 608396 .



EWEA 2015 Paris, Avatar Workshop

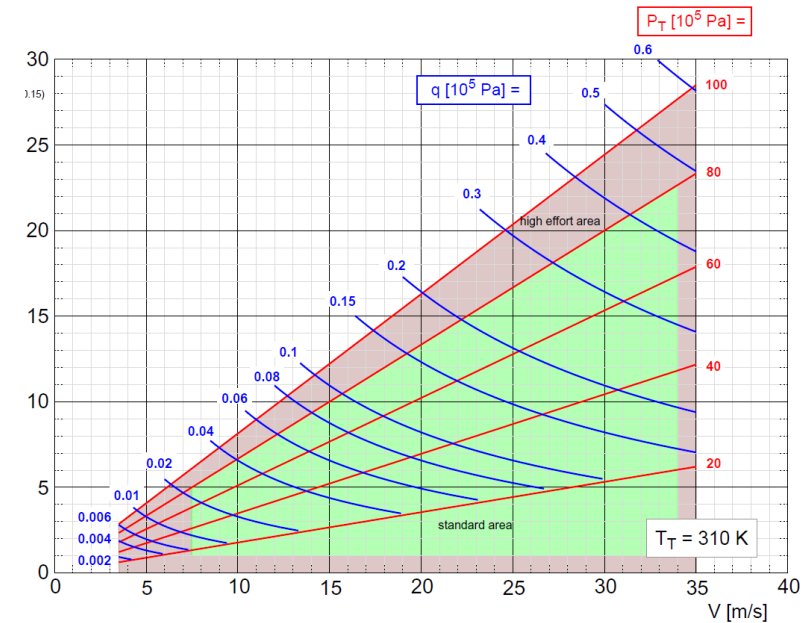
- Experiments
 - DNW-HDG Wind Tunnel
 - Test Section
 - Model and Instrumentation
- Test Cases and Participants
- Results
 - C_l predictions
 - C_d predictions
 - C_l/C_d predictions
 - Transition locations
 - Effect of Inflow turbulence intensity
- Conclusions

DNW-HDG Wind Tunnel



General Tunnel Characteristics

Test section : 60cmx60cm
 Fan Rpm : 200 – 820 Fan blade angle
 fixed
 Tunnel Pres. : $1 - 100 \times 10^5$ Pa
 Tunnel Temp. : ambient to 45° C



Test Section

Probe
holder for
hot wire

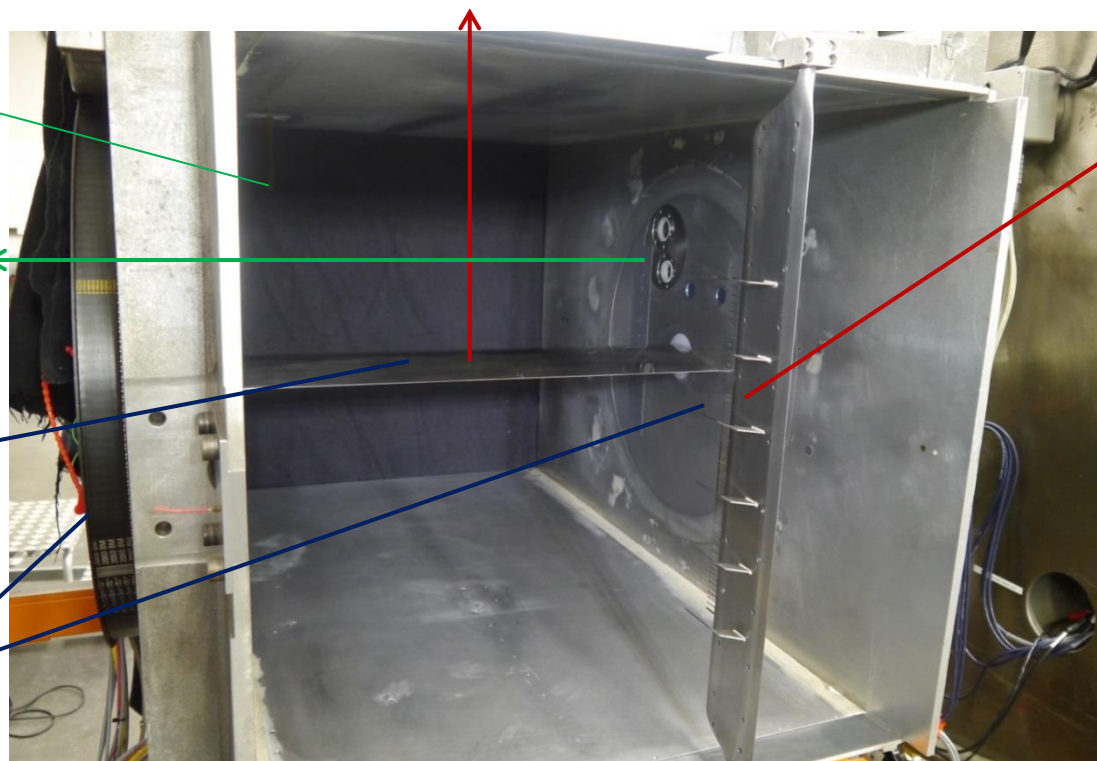
90 PTs at half span

Wake rake
118 pitot tubes
6 pressure taps

Sensicam & UV LED's
Flow visualization

Kulites
4 pressure side
1 suction side

3-component
Balance

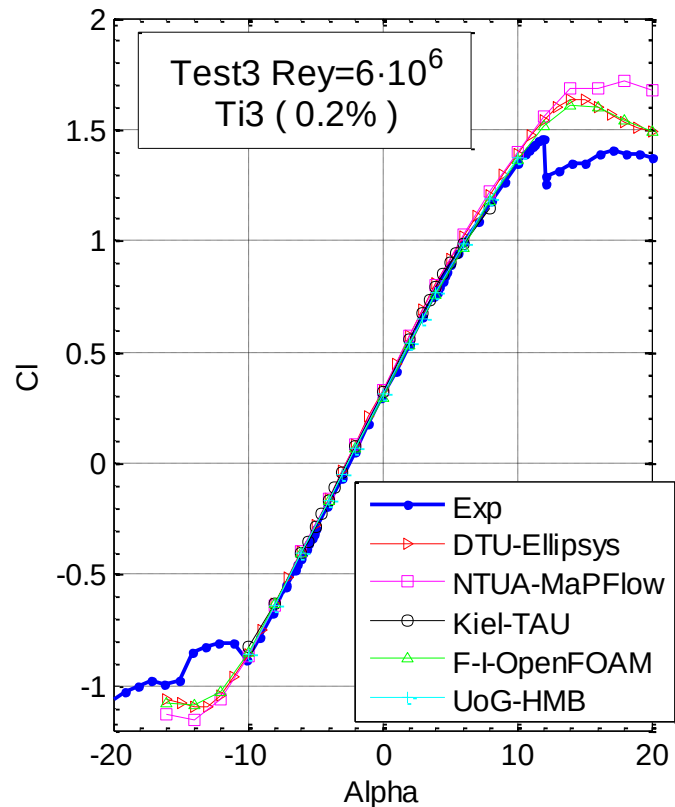
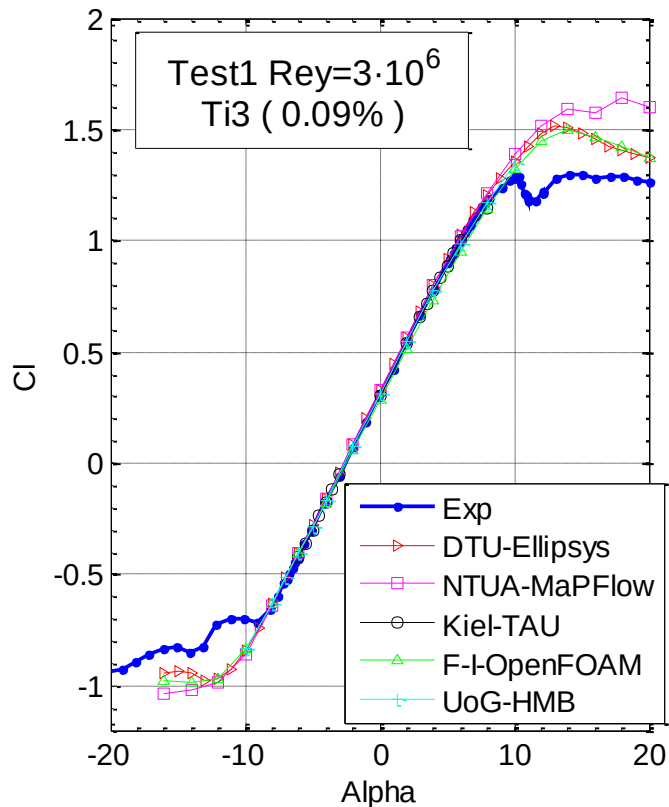


Participants/Codes

			Test 1. Re=3mil	Test 2. Re=6mil-1	Test 3. Re=6mil-2	Test 4. Re=9mil-1	Test 5. Re=9mil-2	Test 6. Re=12mil	Test 7. Re=15mil	
			P _t [bars]	12	34	67	34	67	67	60
			V _{tunnel} [m/s]	25.6	19	10	28.6	15	20	28.4
Full CFD	DTU/EllipSys	Fully turbulent								
		Transition	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	KIEL/TAU	Fully turbulent								
		Transition	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	NTUA/Mapflow	Fully turbulent								
		Transition	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	UoG/HMB	Fully turbulent	Yes							Yes
		Transition	Yes		Yes					
	Forwind-IWES/OpenFOAM	Fully turbulent	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
		Transition								
Panel Methods	USTUTT/XFOILvUSTUTT	Fully turbulent								
		Transition	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	ORE Catapult/XFOILv6.96	Fully turbulent								
		Transition	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

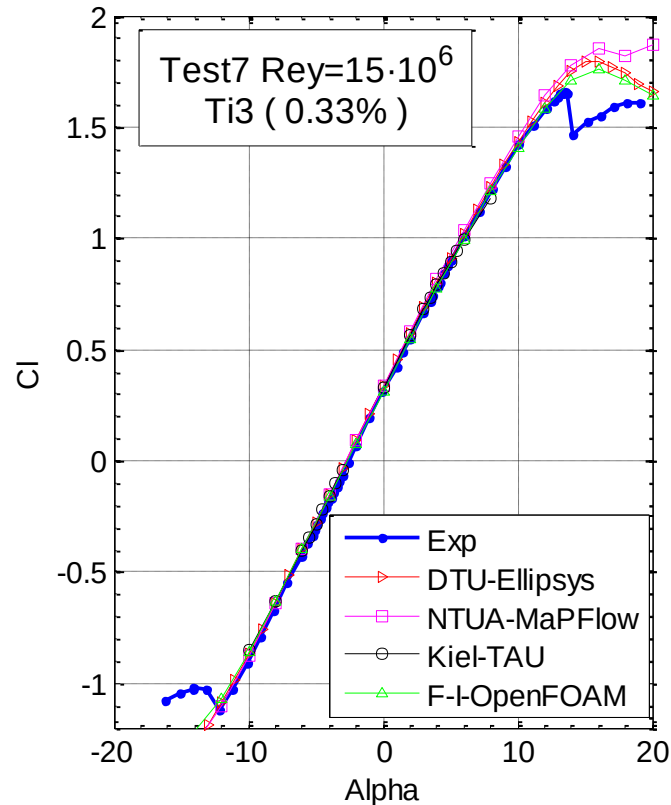
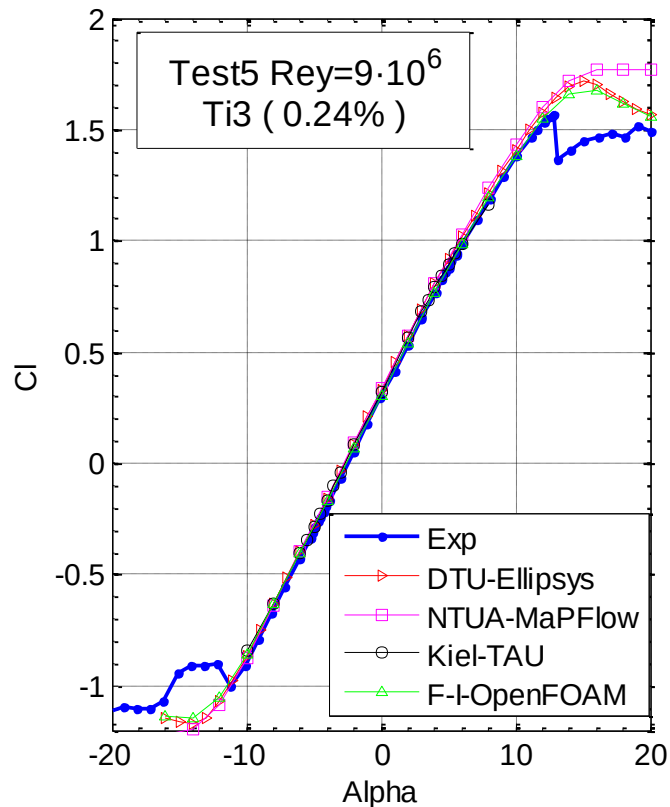
Results

Cl predictions – Full CFD



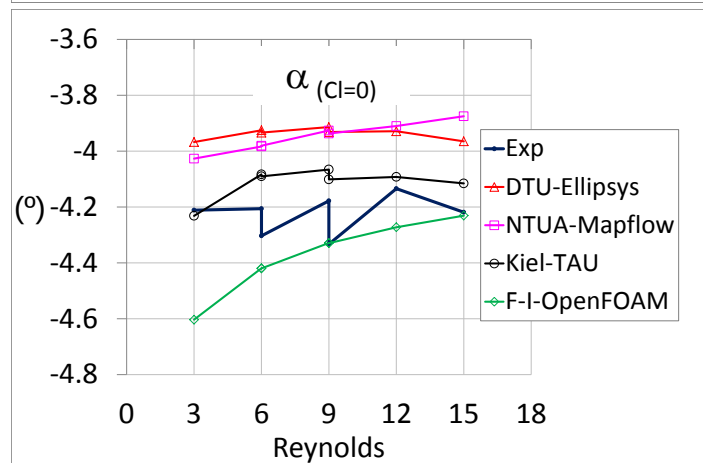
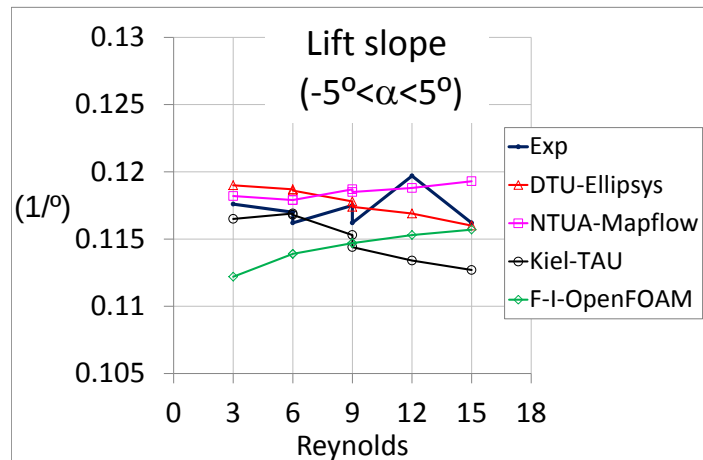
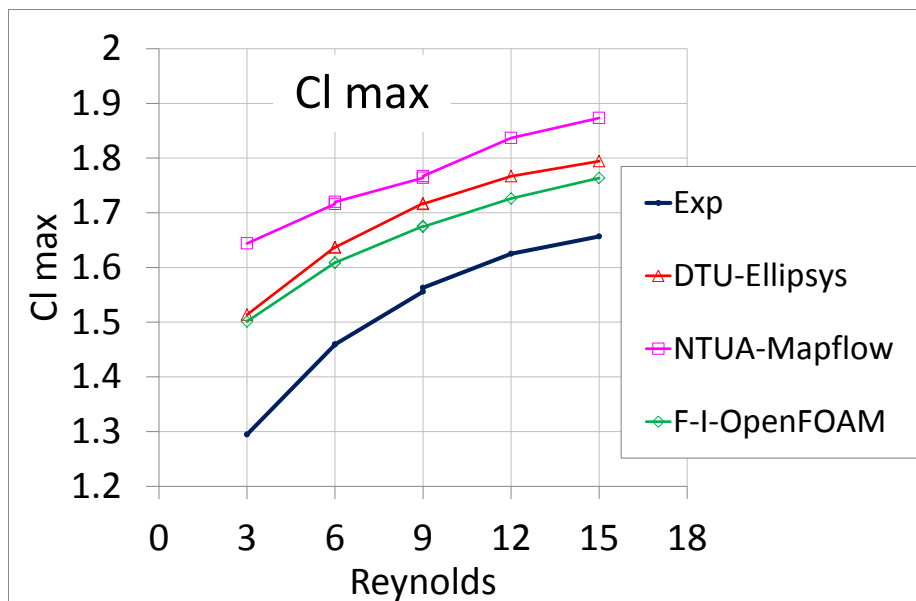
Results

Cl predictions – Full CFD



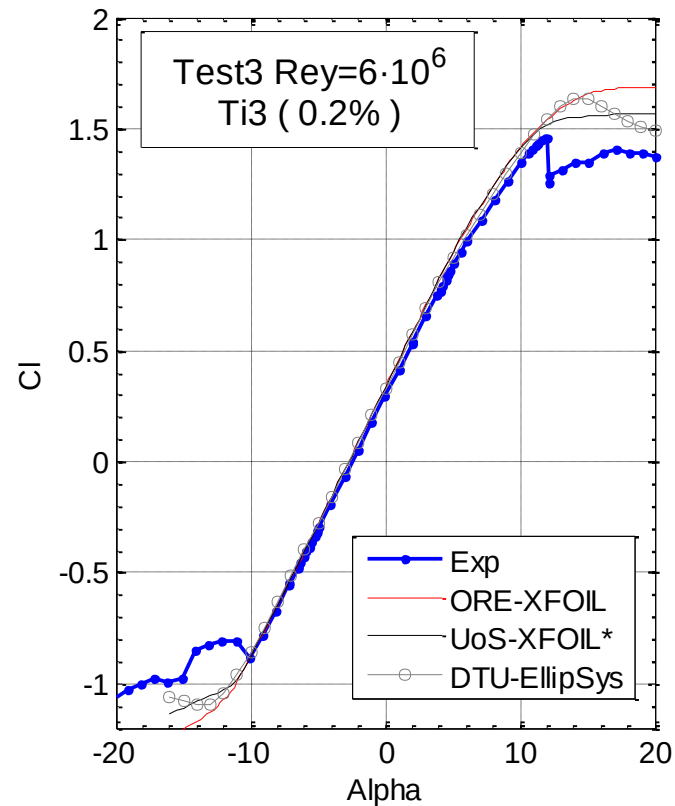
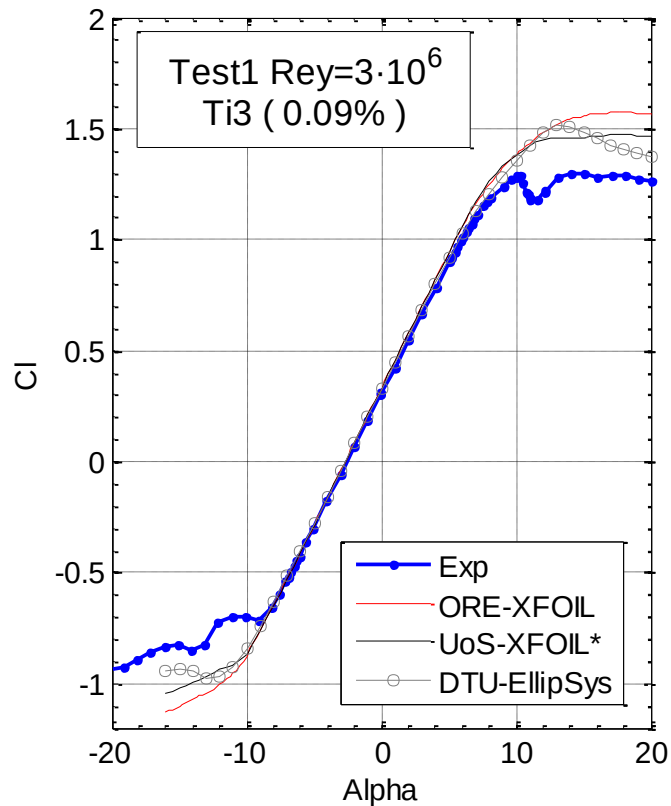
Results

Cl predictions – Full CFD



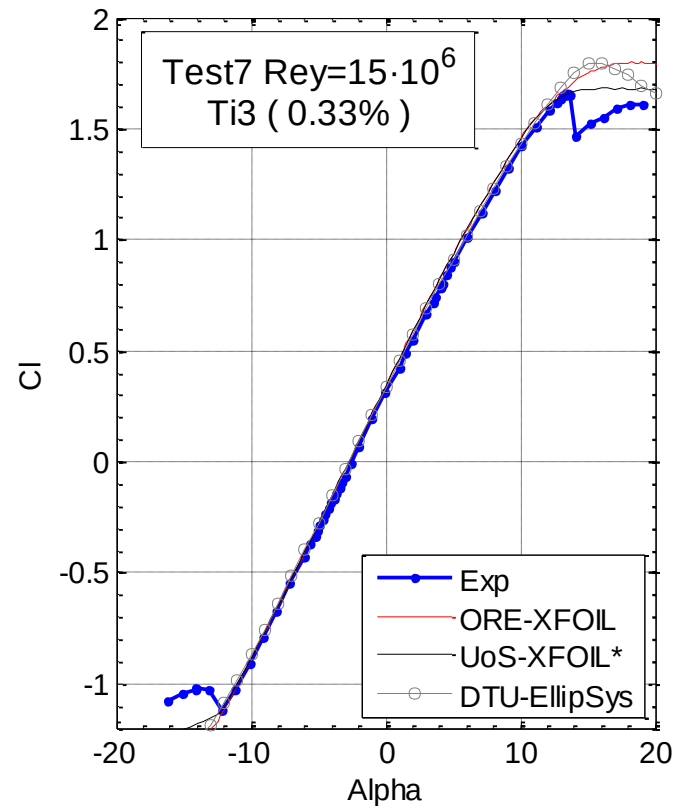
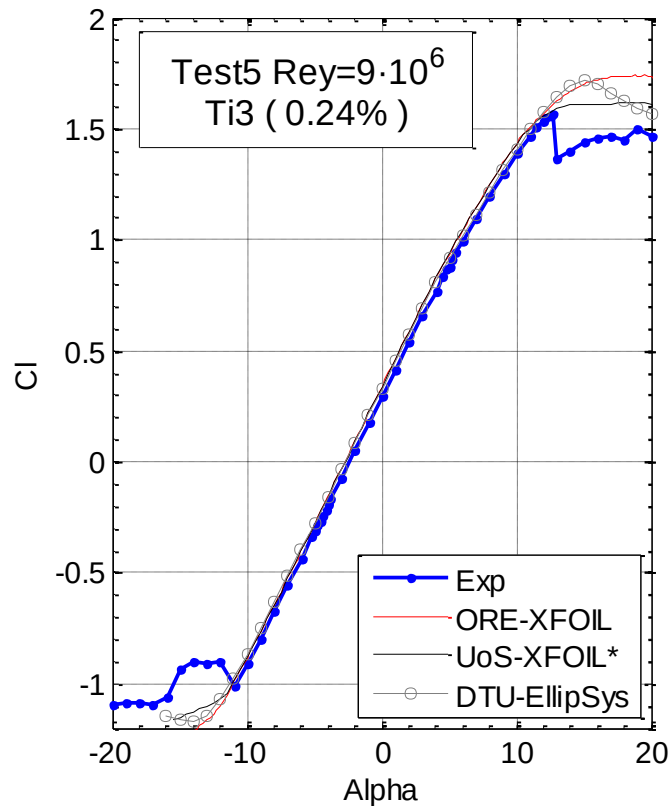
Results

Cl predictions – Panel codes



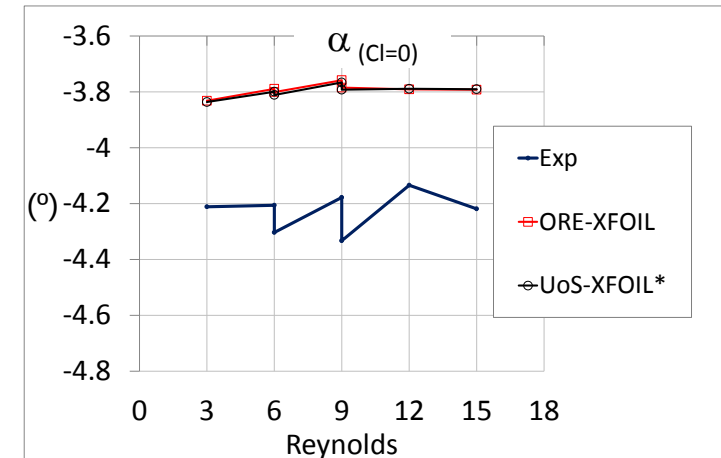
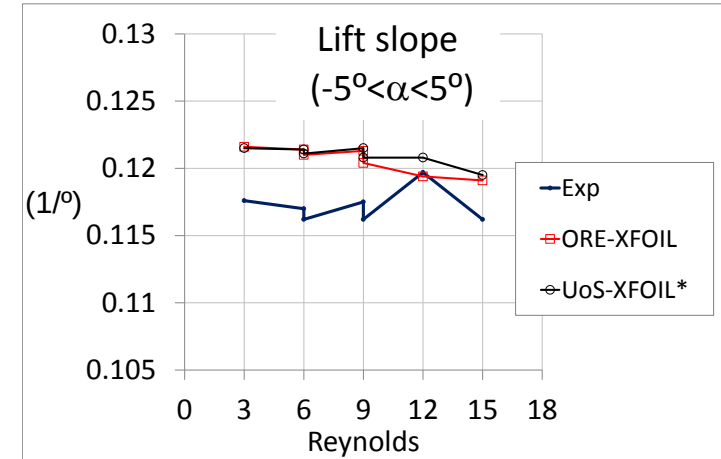
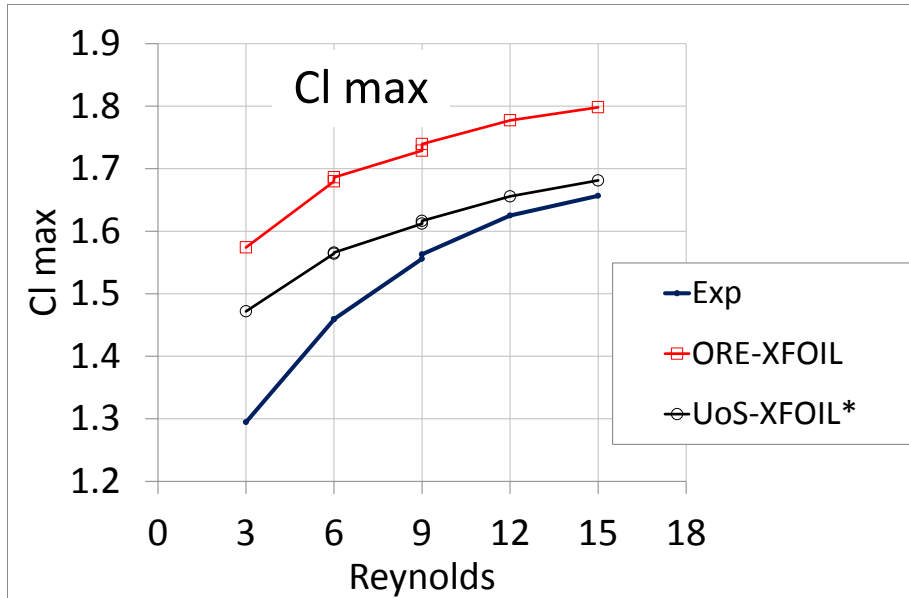
Results

Cl predictions – Panel codes



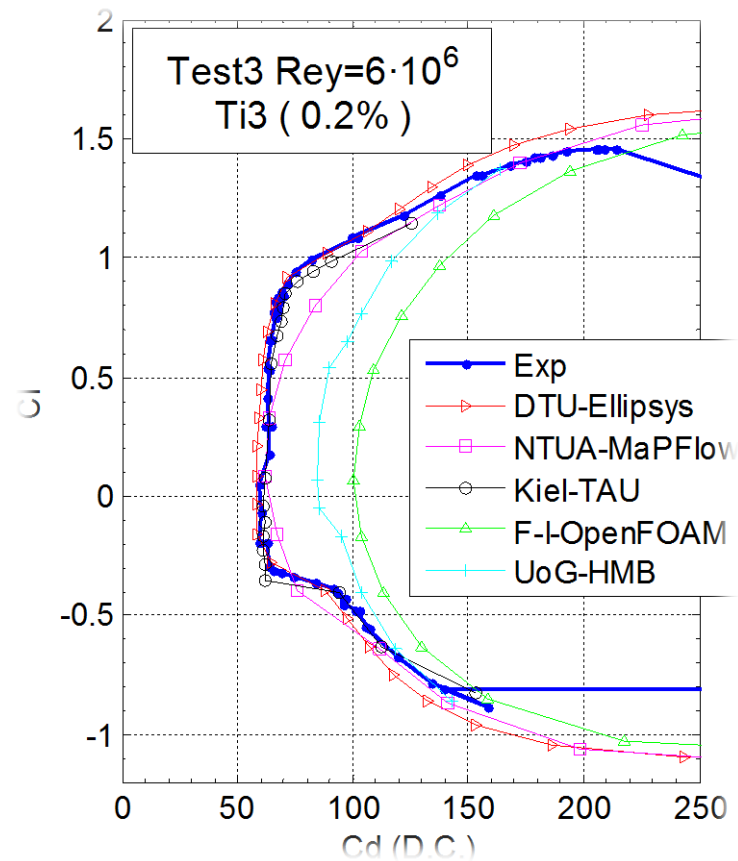
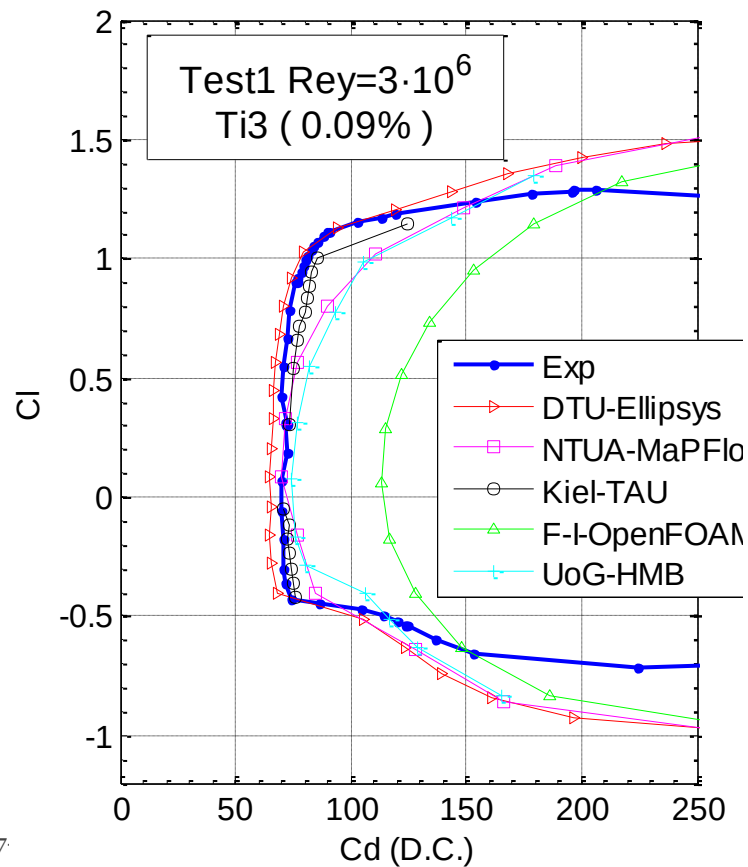
Results

Cl predictions – Panel codes



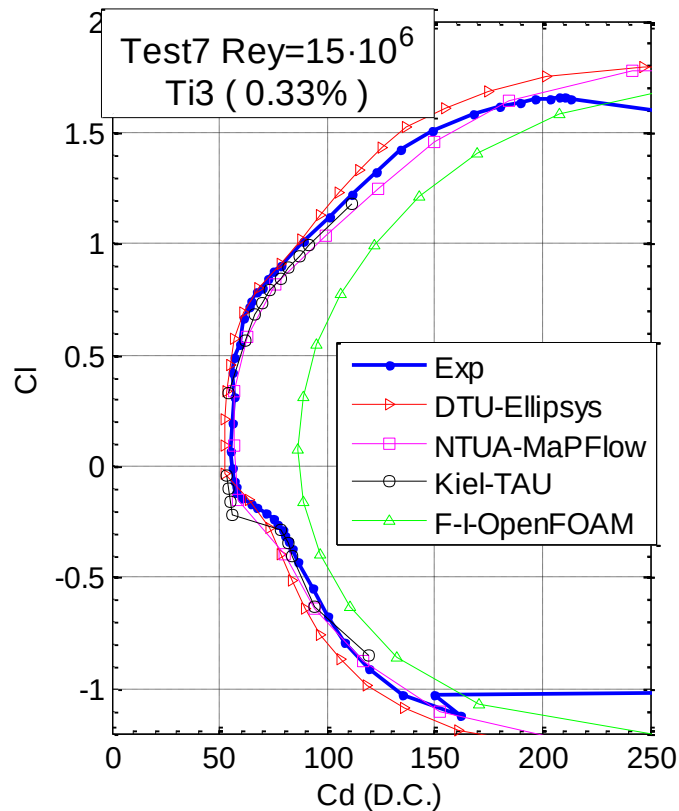
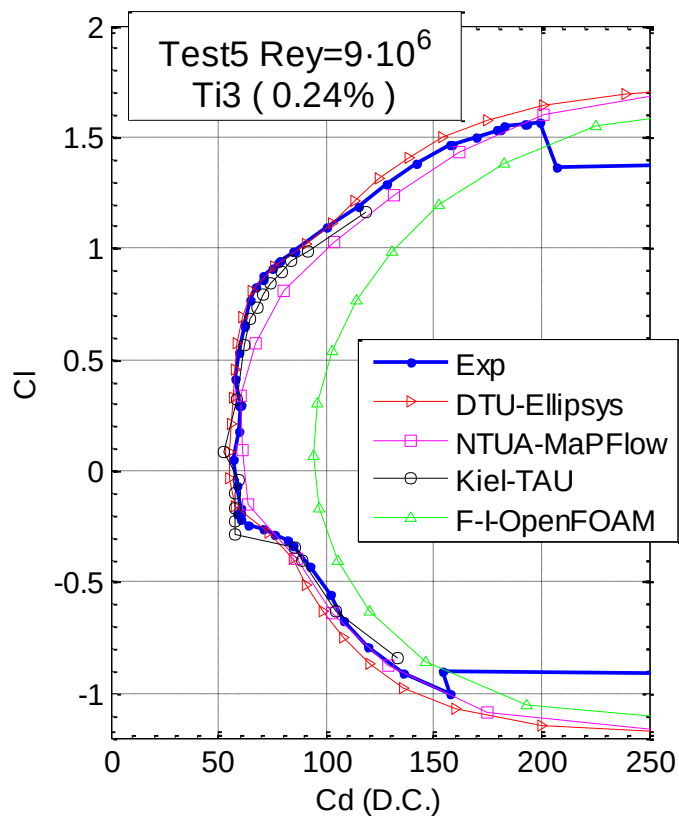
Results

cd predictions – Full CFD



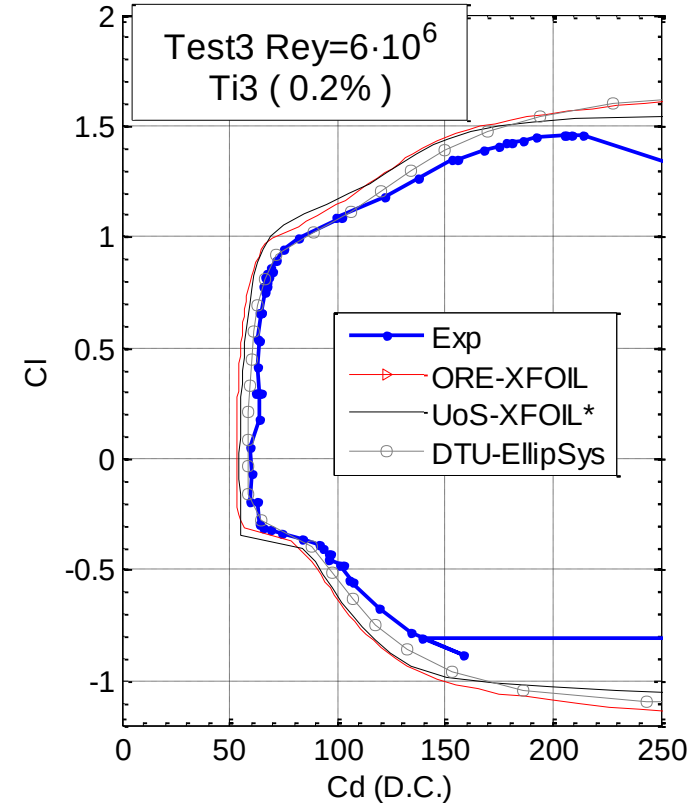
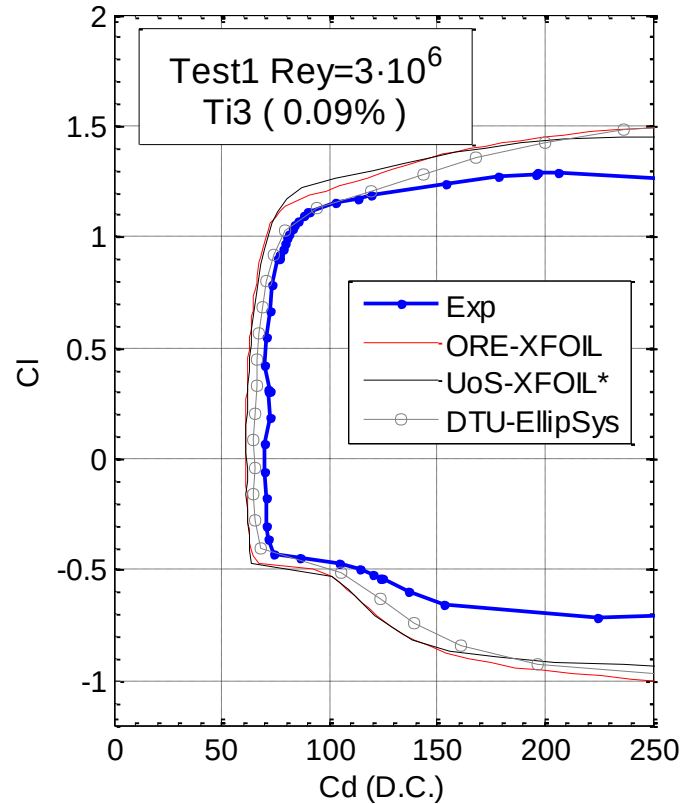
Results

cd predictions – Full CFD



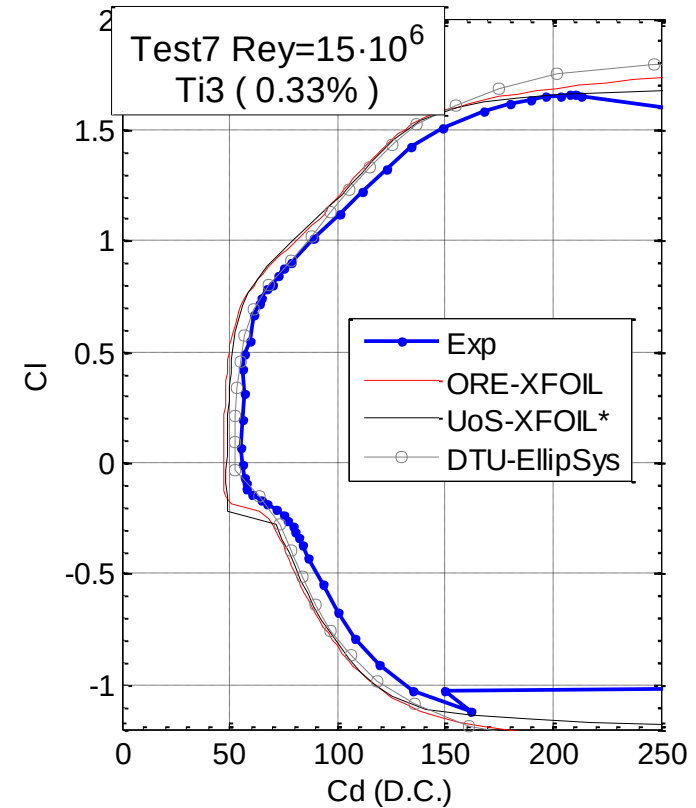
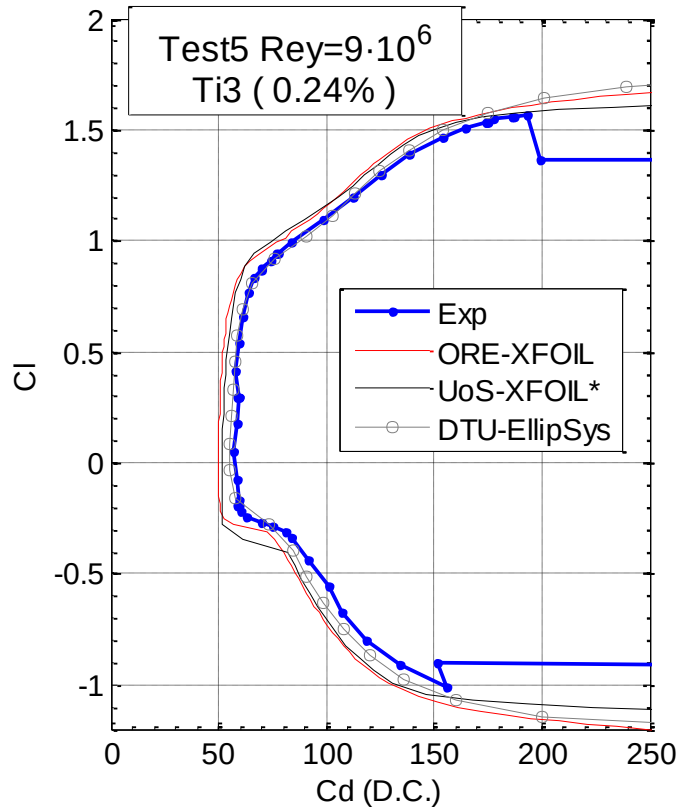
Results

cd predictions – Panel codes



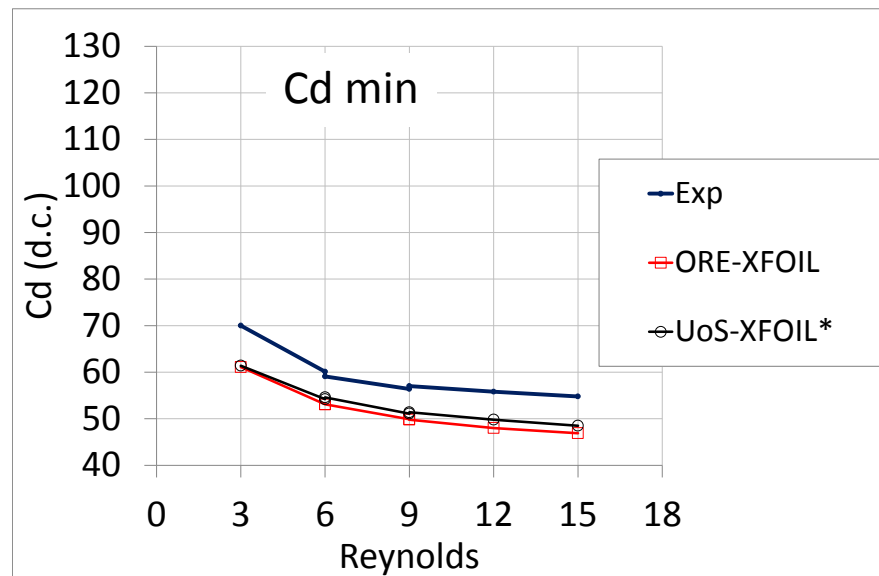
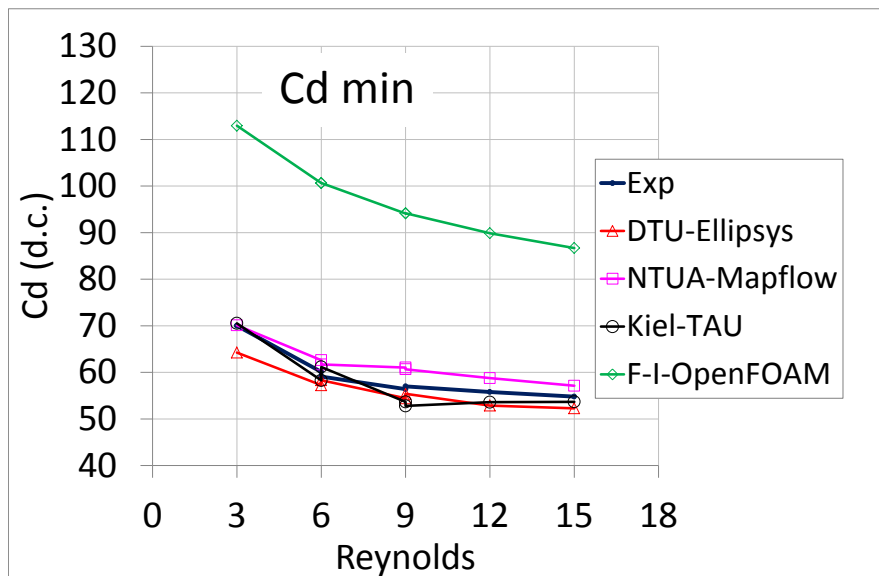
Results

cd predictions – Panel codes

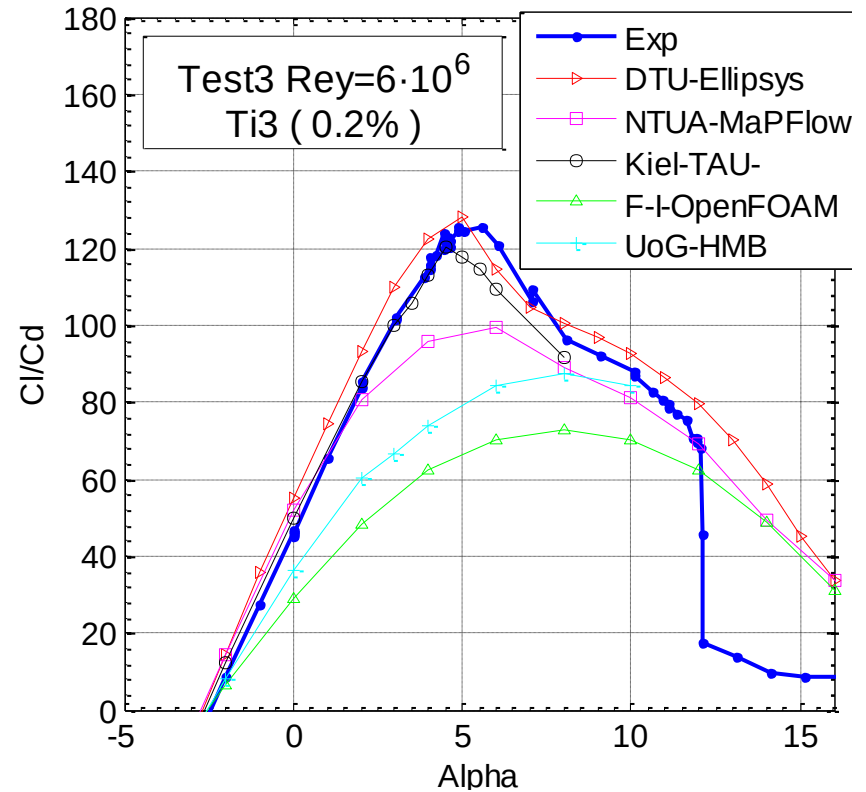
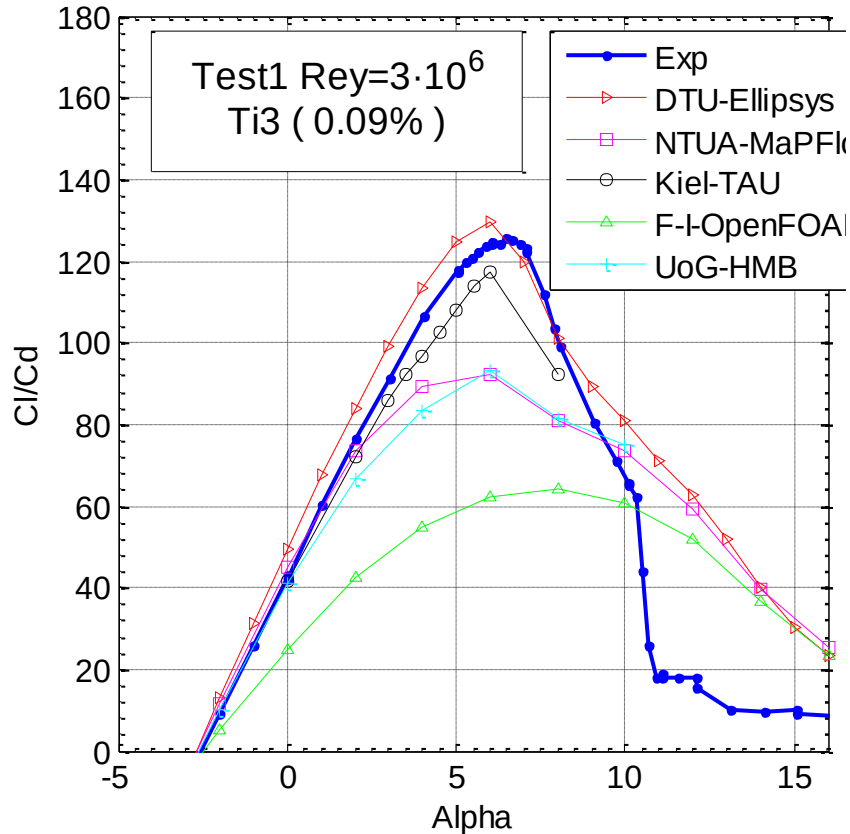


Results

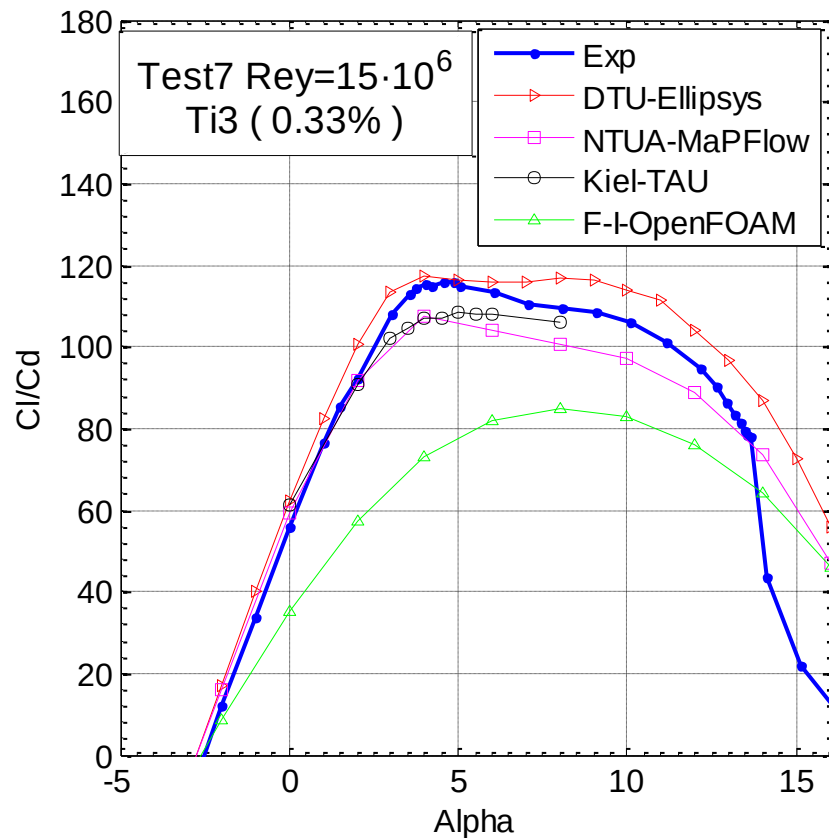
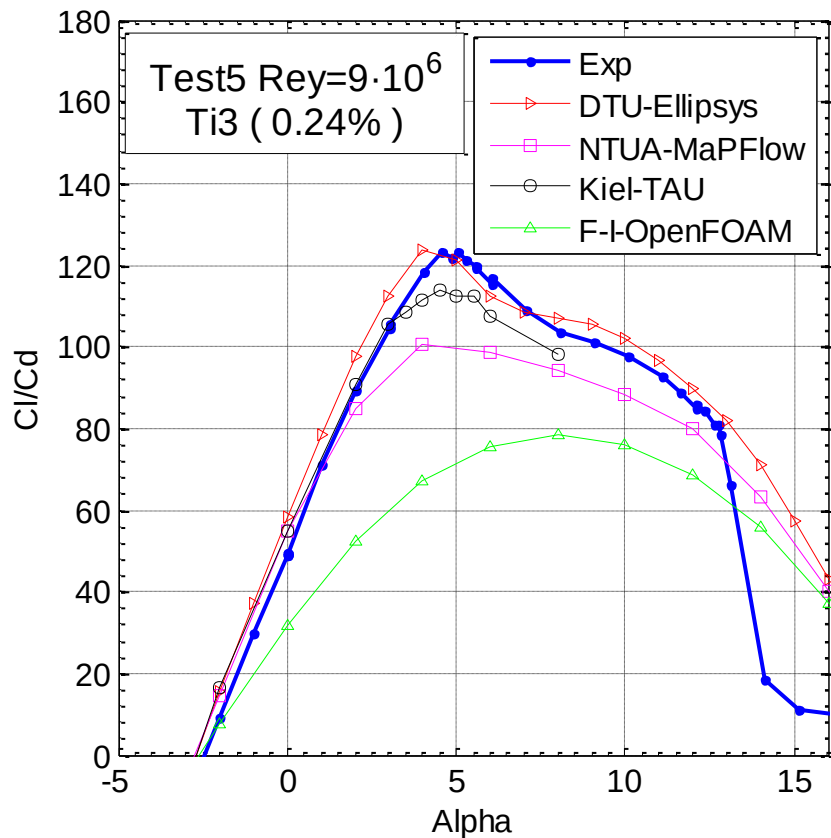
Re effects in Cd trends



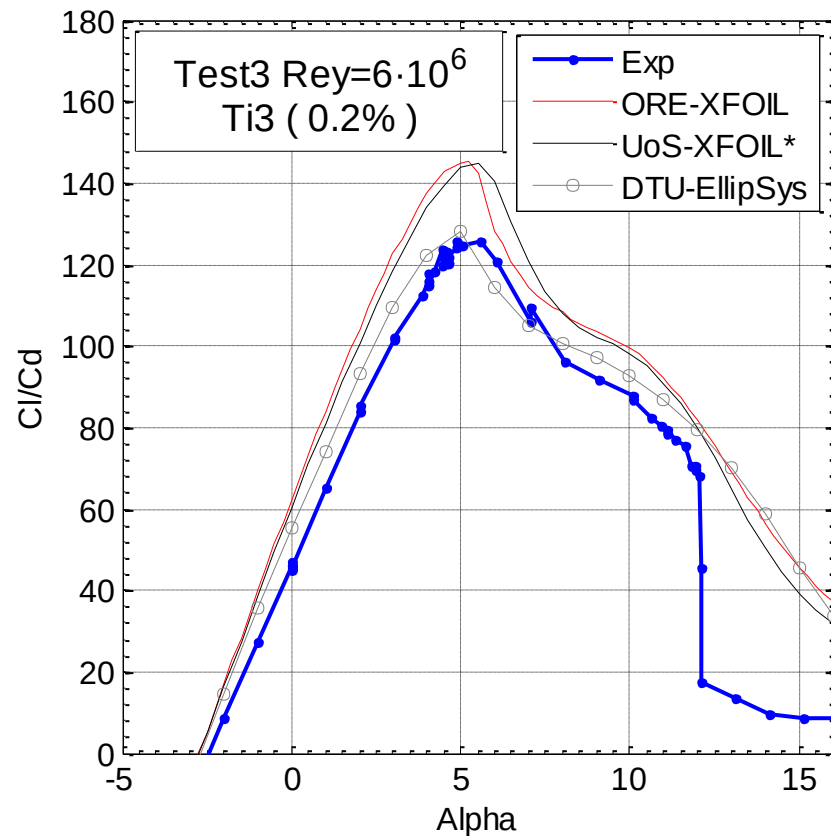
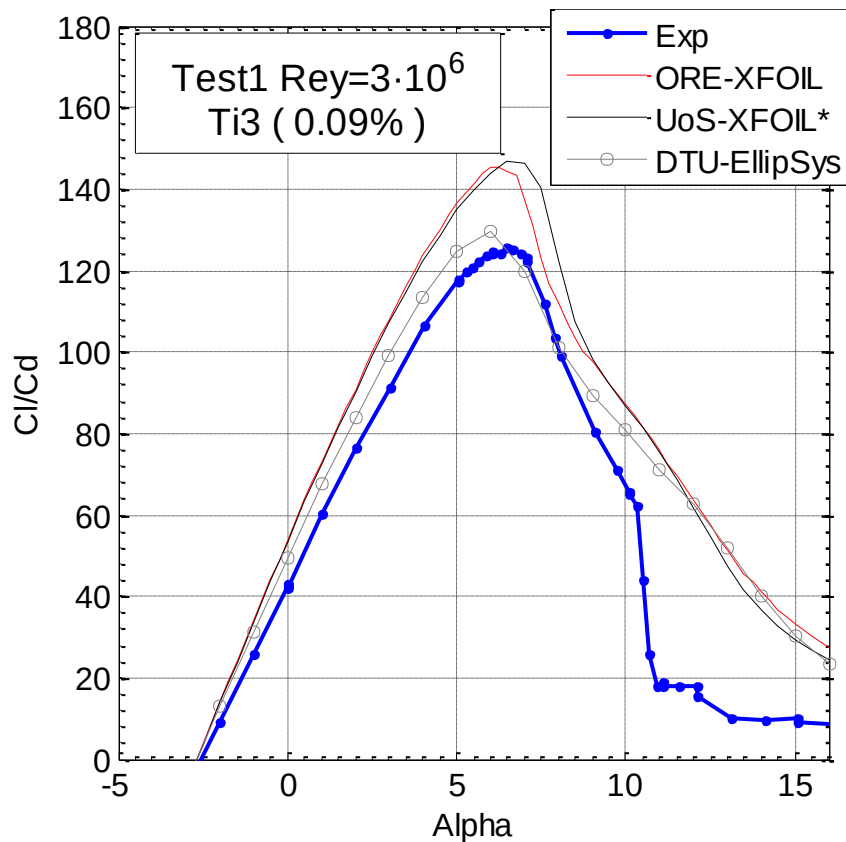
Effect in Blade Design parameter: Cl/Cd – Full CFD



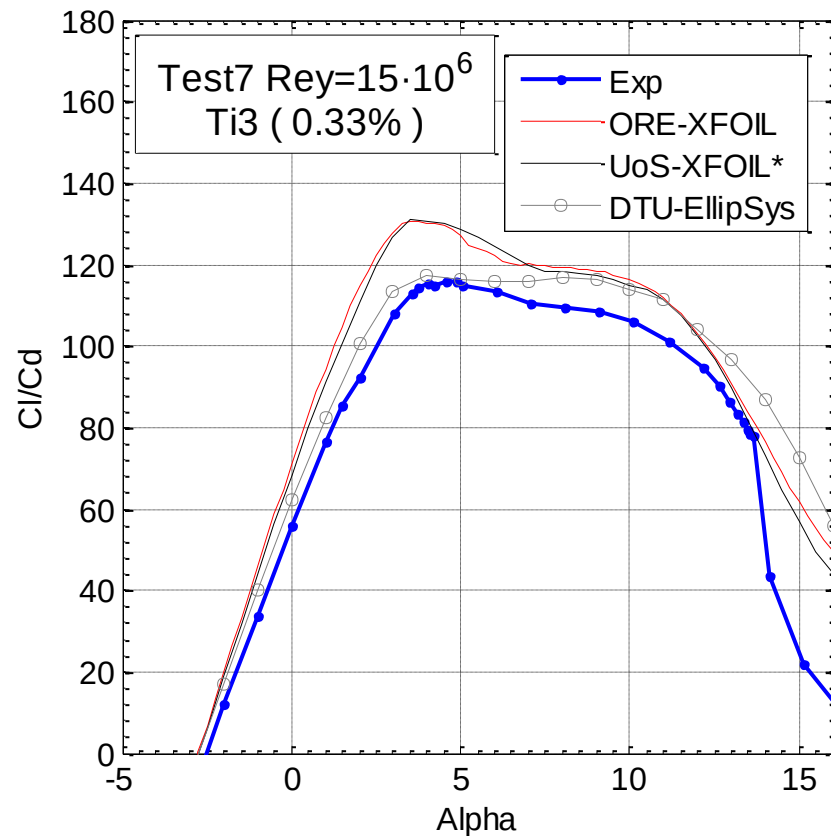
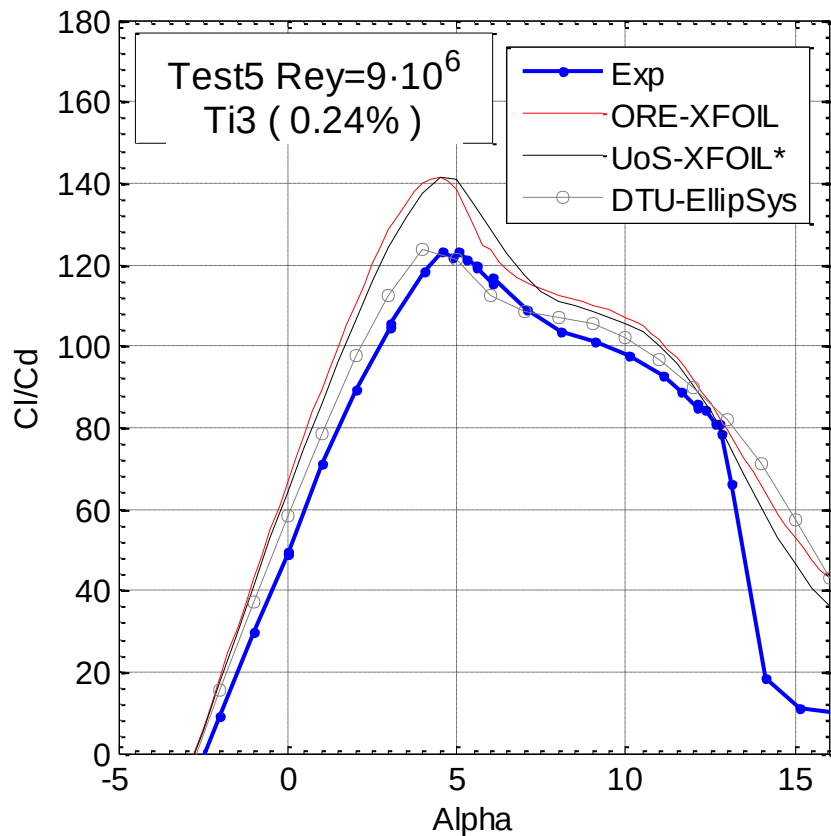
Effect in Blade Design parameter: Cl/Cd – Full CFD



Effect in Blade Design parameter: Cl/Cd – Panel Codes

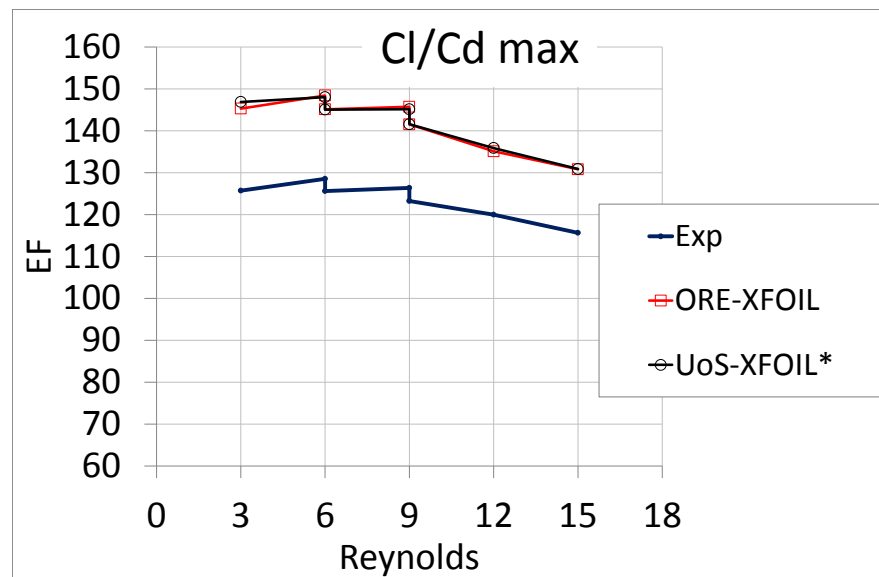
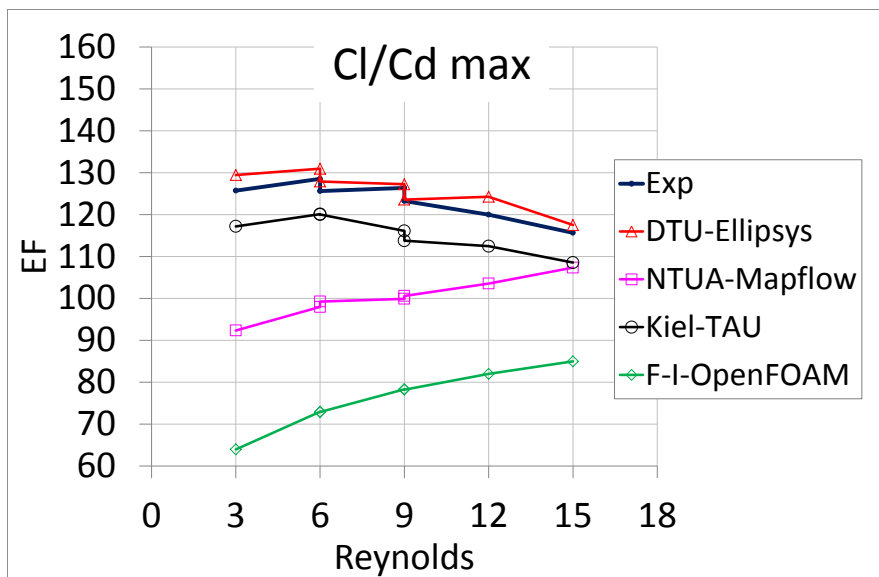


Effect in Blade Design parameter: Cl/Cd – Panel Codes

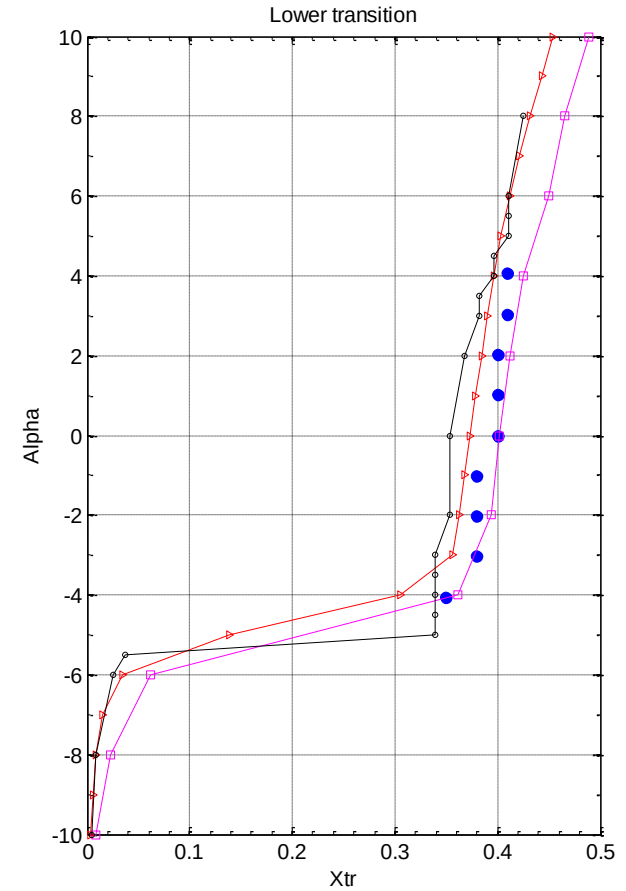
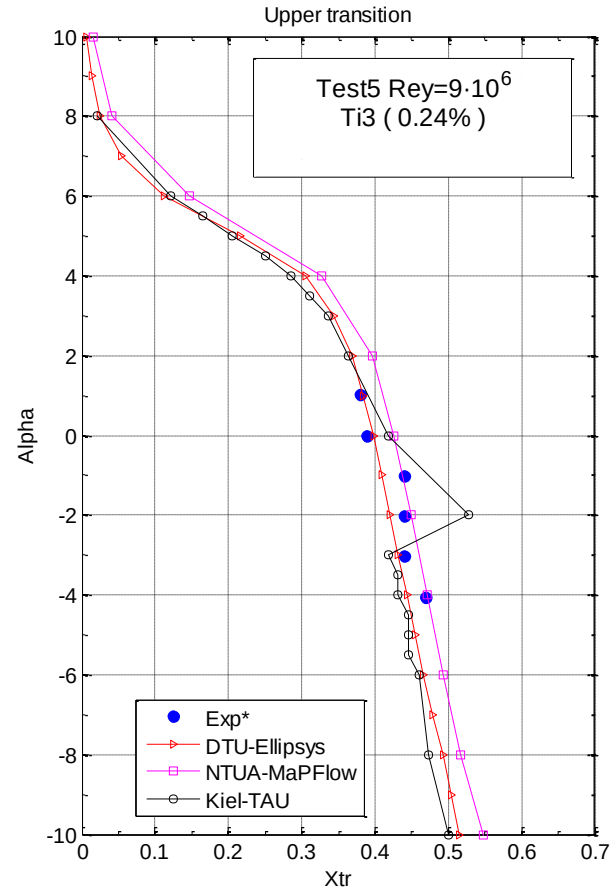


Results

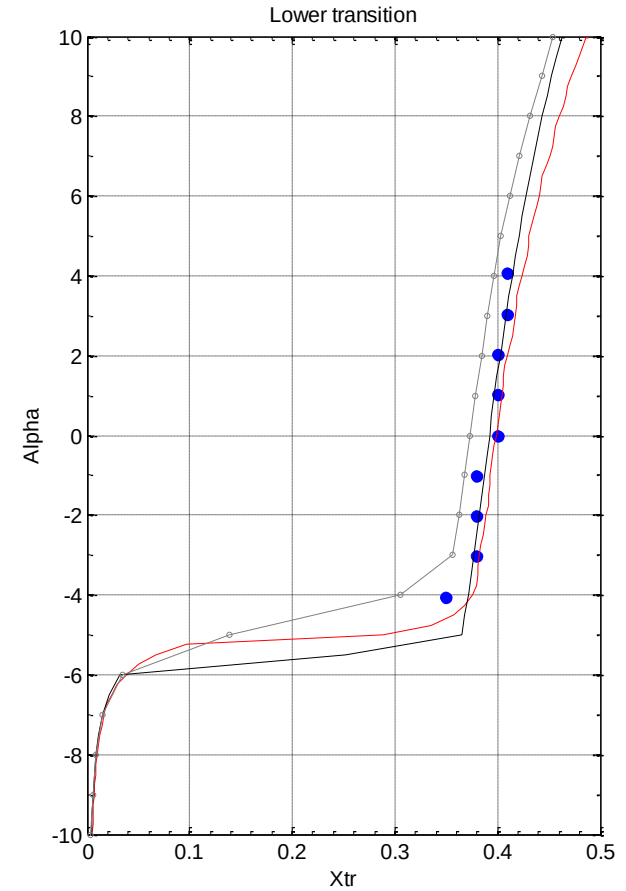
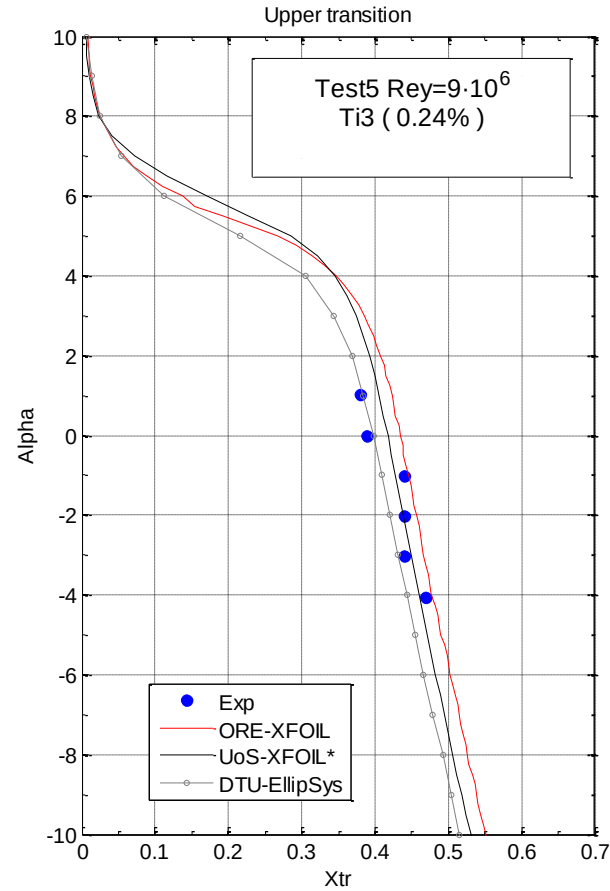
Re effects in Cl/Cd trends



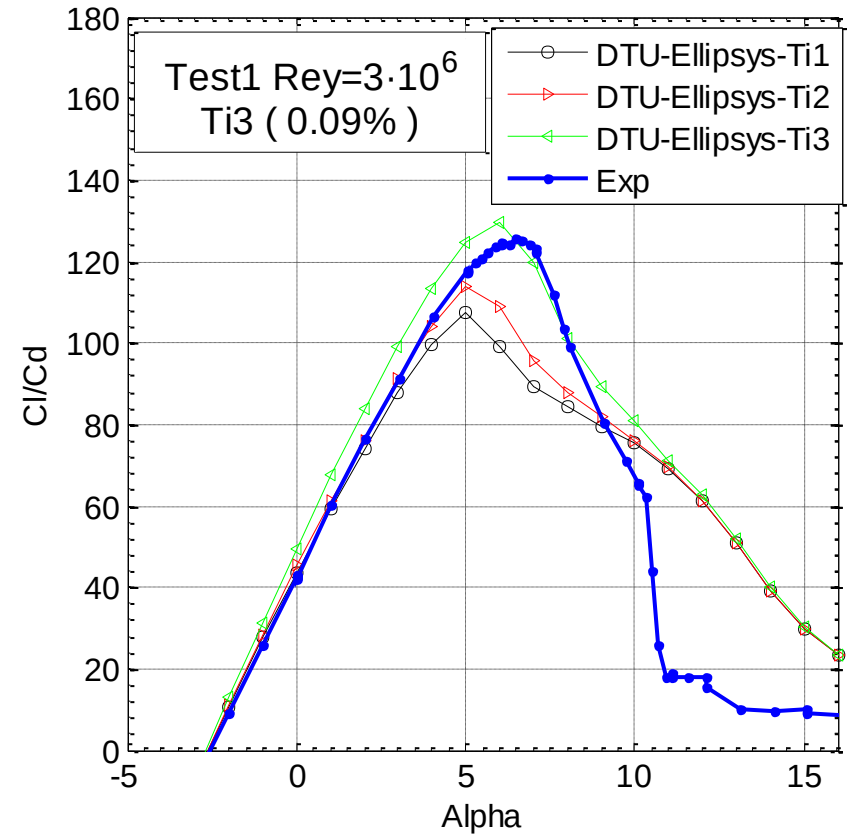
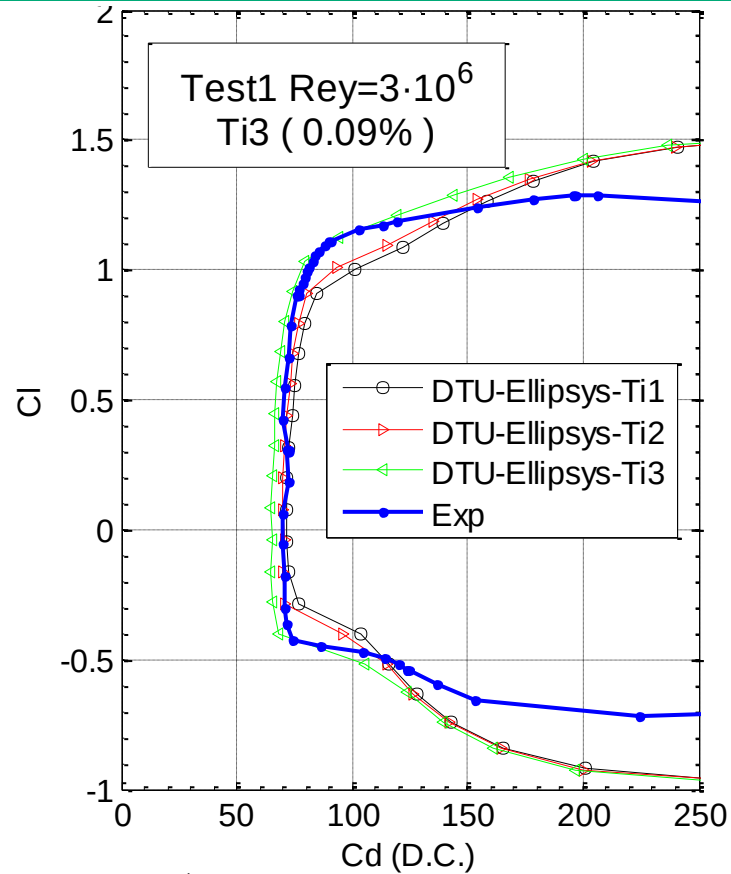
Transition locations



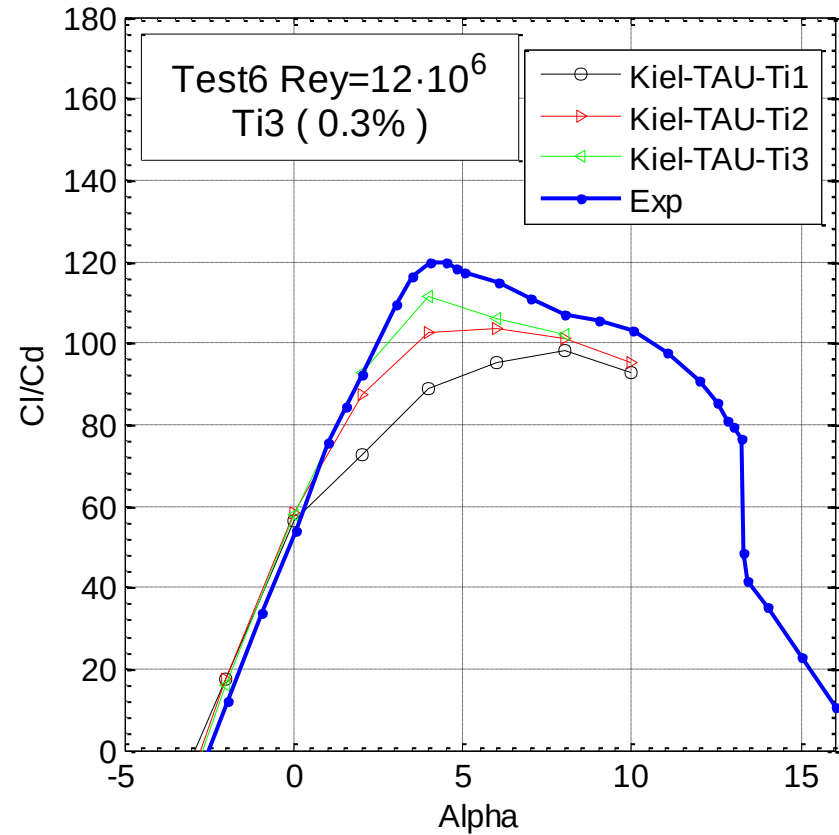
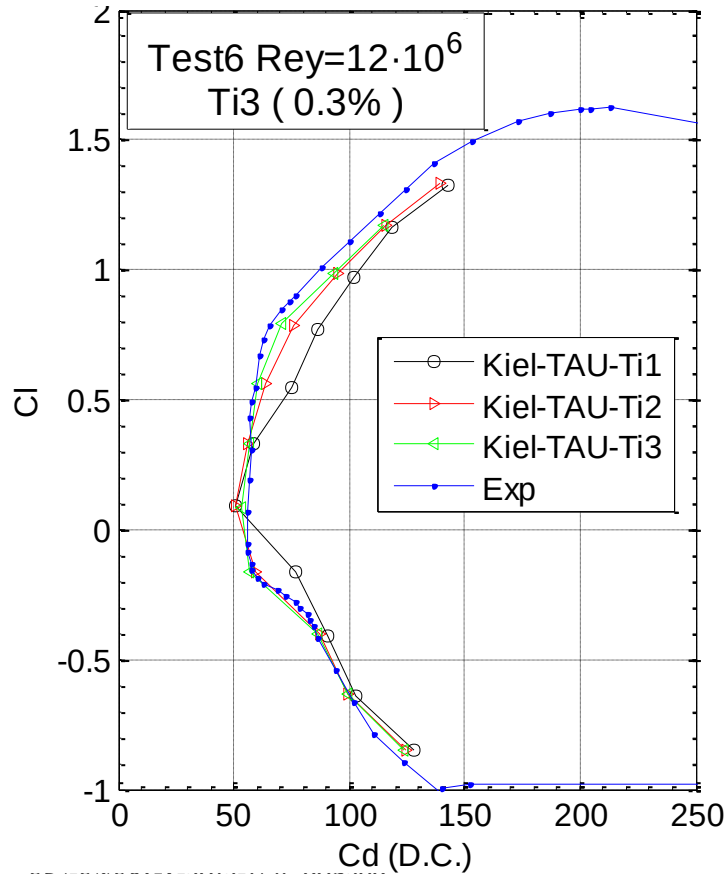
Transition locations



Effect of inflow turbulence intensity



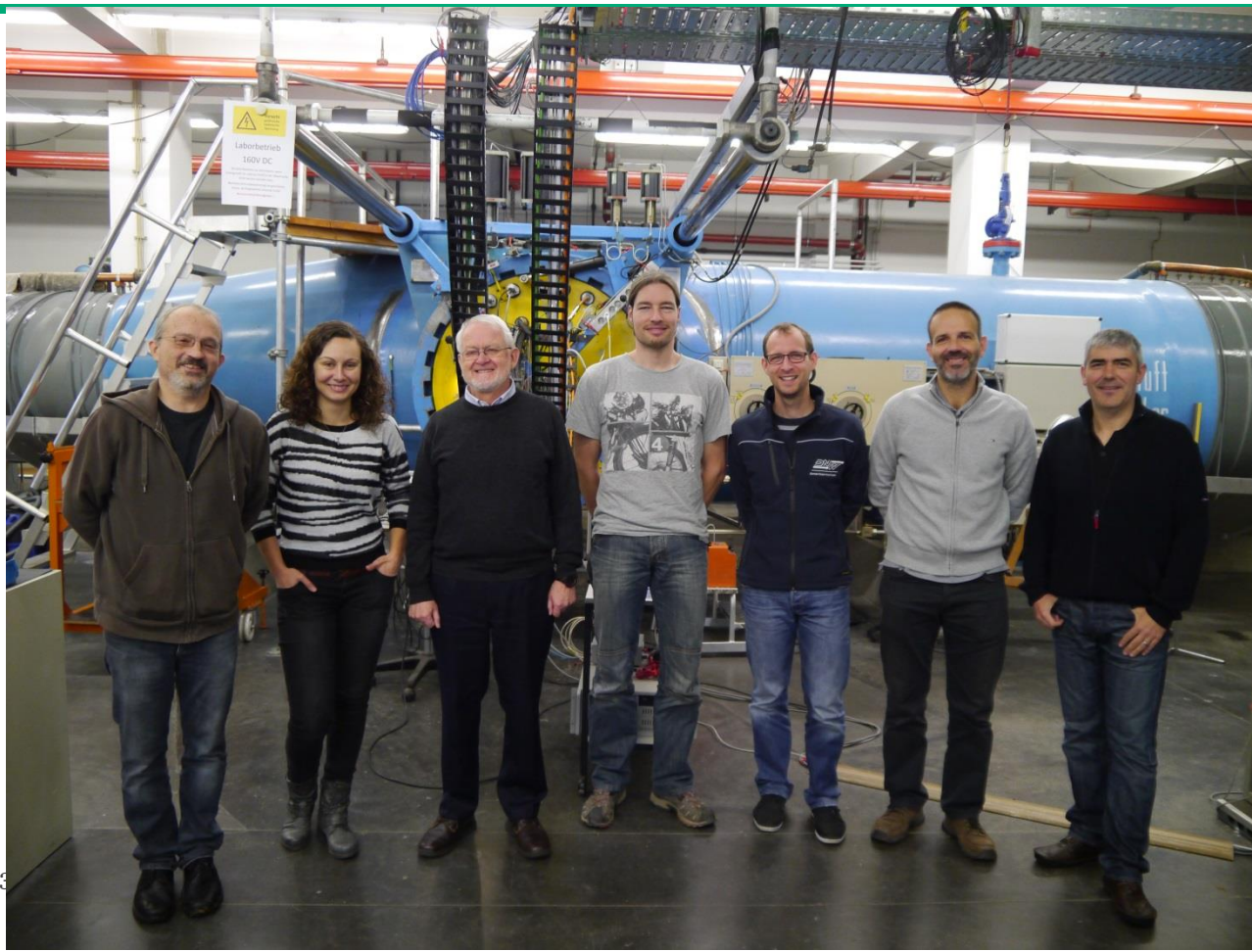
Effect of inflow turbulence intensity



Conclusions

- All codes are able to predict the linear lift region quite well however, the maximum lift and the maximum lift angle are always overpredicted.
- Low drag region is predicted well with eN transition model in general, except the corners. Better agreement can be obtained by using more accurate inflow turbulence and choosing more angle of attack values to capture the corners.
- Turbulent drag is over predicted mostly except EllipSys and XFOIL codes where it is underpredicted.
- Cl/Cd is well predicted with EllipSys and TAU, but not with the other codes. Panel codes can reproduce the general behaviour but always overpredict the absolute values.
- Reynolds number effects in Cl/Cd max, Cd min and Cl_{max} are well predicted with eN transition model, even if the absolute values are different.
- Mapflow's transition model predictions become more accurate in higher Re numbers. But the trends are captured wrong.
- eN transtion model is able to predict Re effects quite well.

WIND TUNNEL TEAM



Coordinator:



Partners in alphabetical order:





Thank you for your attention

This project has received funding from the European Union's Seventh Programme for research, technological development and demonstration under grand agreement No FP7-ENERGY-2013-1/n° 608396 .

