Some notes about

Comparing GU & Savier airfoil equipped half canard
In S4 wind tunnel (France)

Matthieu Scherrer

Adapted from Charlie Pujo & Nicolas Gorius' work

Contents

Chapter 1

Test conditions

1.1 S-4 Wind-tunnel

The S-4 wind tunnel used to be a commercial low speed wind tunnel until three years ago. Now property of ENSICA school since two years, it is used in a pedagogic way, for studies realized by student. But the measurement equipment is still the original high quality equipment.

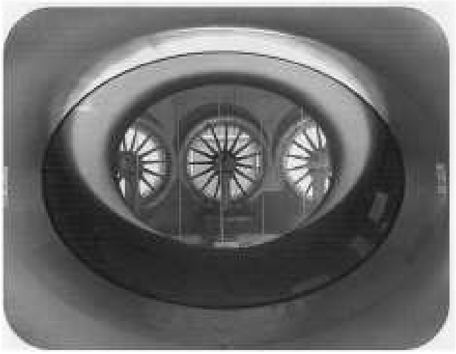


Figure 1.1: S4 wind tunnel elliptic test section.

The main data are :

- Elliptic free test section 2x3m.
- Speed between 10 and 40m/s.
- Canard mounted on three mast, with 6 axis measurement (only 3 used).
- Laser and UV light equipment for flow visualisation or measurement.
- Camera and light for filming each test.

1.2 The team

This study was conducted as a pedagogic project (”PIR”) for two French SUPAERO young students : Charlie Pujo and Nicolas Gorius. they produced a (French) report, highlighting some of the main points observe throughout this study.

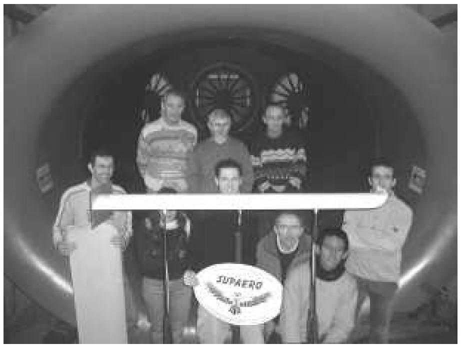


Figure 1.2: The full team within test section.

This project was initiated by Fabrice Claudel, helped by Patrick Lefebvre. The new canard was build according to Klaus Savier’s work and drawings.
The study was directed by Paul Claude Dufour and Matthieu Scherrer.

1.3 The tested canards

Full size half-canards were tested into the wind tunnel. A small flat plate was put to create a symmetry axis.

Both GU and Savier canards were similarly intalled in the wind tunnel.

The wind speed was set to the maximum available, that is 40m/s. this will gives correct values of Reynolds number for the low speed enveloppe of the VariEze, but too low for high speed.

1.4 Limitation : a comparison work

Here are some limitation about the work that was done.

- Only half a canard, without fuselage influence, was tested. The symmetry plane was not a perfect one.
- It was possible to measure and then subtract only a part of drag created by the fittings and attachment device.

As a consequence, the absolute value concerning C_{d0} and $C_{l_{max}}$ might not be accurate. But the fittings and attachment system were similar for both canard.
This work is then a ***Comparison*** of the two canards.

Chapter 2

Qualitative work : flow visualization

There were many way available to visualize the airflow over the canards. We tried characterize the canards with each of those.

NB : this was done partly in a pedagogical objective.

2.1 Wool string visualization

It was possible to move a wool string all aver the canard. Then functionning of the flap gap or wing tip vortex could be observed.

2.2 Laser flow visualization

Wing tip flow was through laser tomography. A laser beam was split into a plan, and smoke was send. Then the wing tip vortex could be studied.

There as no qualitative difference in aspect between the vortex of the two different canard.

2.3 Oil flow visualization

The oil flow visualization were the most interesting qualitative testing. It was possible to visualize and analyze the laminar to turbulent transition on the extrados, and the "quality" of this transition.
Shortly summed up, we may say :

	GU Canard	**Savier canard**
$C_l \simeq 0.5$, no flap defl.		
Position of transition	60-65%	40%
Laminar bubble	wide (10% of chord) & thick (oil)	short (3-4% of chord) & thin (no oil)
$C_l \simeq 1.2$, no flap defl.		
Position of transition	-	25%
Laminar bubble	-	disappearing

Intrados was not much observed.

It was tried to trip the laminar boundary layer to turbulent on the GU airfoil, to "kill" the laminar bubble. This does work with quite thick scotch tape.

Other visualization were made to observed the wing tip flow. The path of the vortex wing tip can be clearly seen.

2.4 Visualization report

Each visualization run was fully filmed.

A 3 minutes sequences was assembled by Charlie Pujo and Nicolas Gorius, and compressed as an *.AVI film. It represents the best visualization report. Indeed, photograph are too static to represents properly those visualisations.
This *.AVI film ($\simeq$ 50 Mo) might be available on the internet or on an ftp site (to be defined).

I will also issue a compilation of some of the photographs taken during those visualization trial.

Chapter 3

Quantitative work (1/2) : polar measurements

3.1 Data for comparing VariEze Canard equipped with GU and Savier airfoil

Here are displayed the results of measurement on the two canards. Three axis were measured :

- Lift force values.
- Drag force values.
- Pitching moment values, at 25% of chord (that aerodynamical center).

First are presented values for GU canard, and then for Savier canard. Finally comparison are made and some conclusion drawn.

3.1.1 Canard equipped with GU airfoil

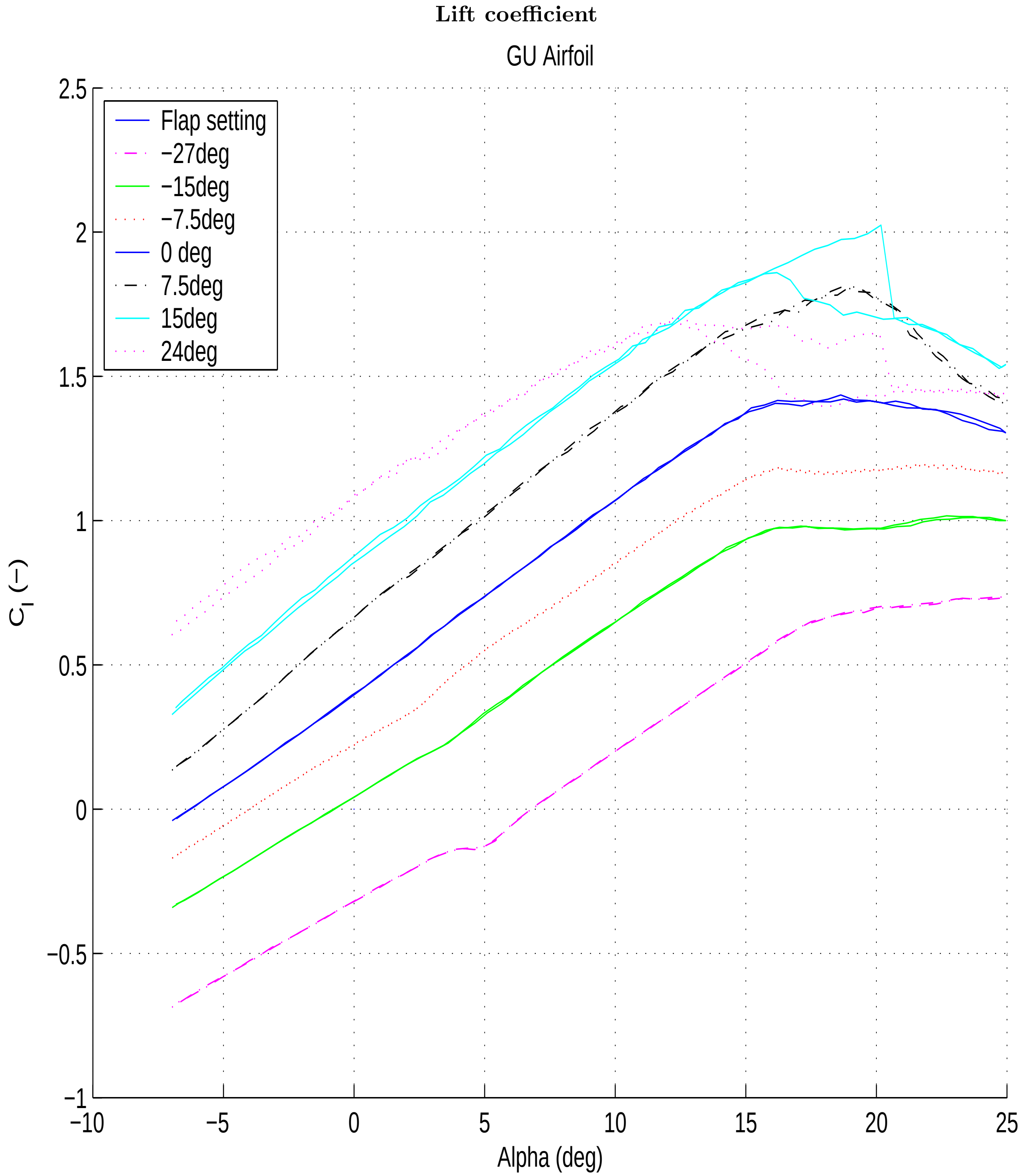


Figure 3.1: Lift coefficient vs incidence. Note the tricky hysteresis behavior for high flap deflection.

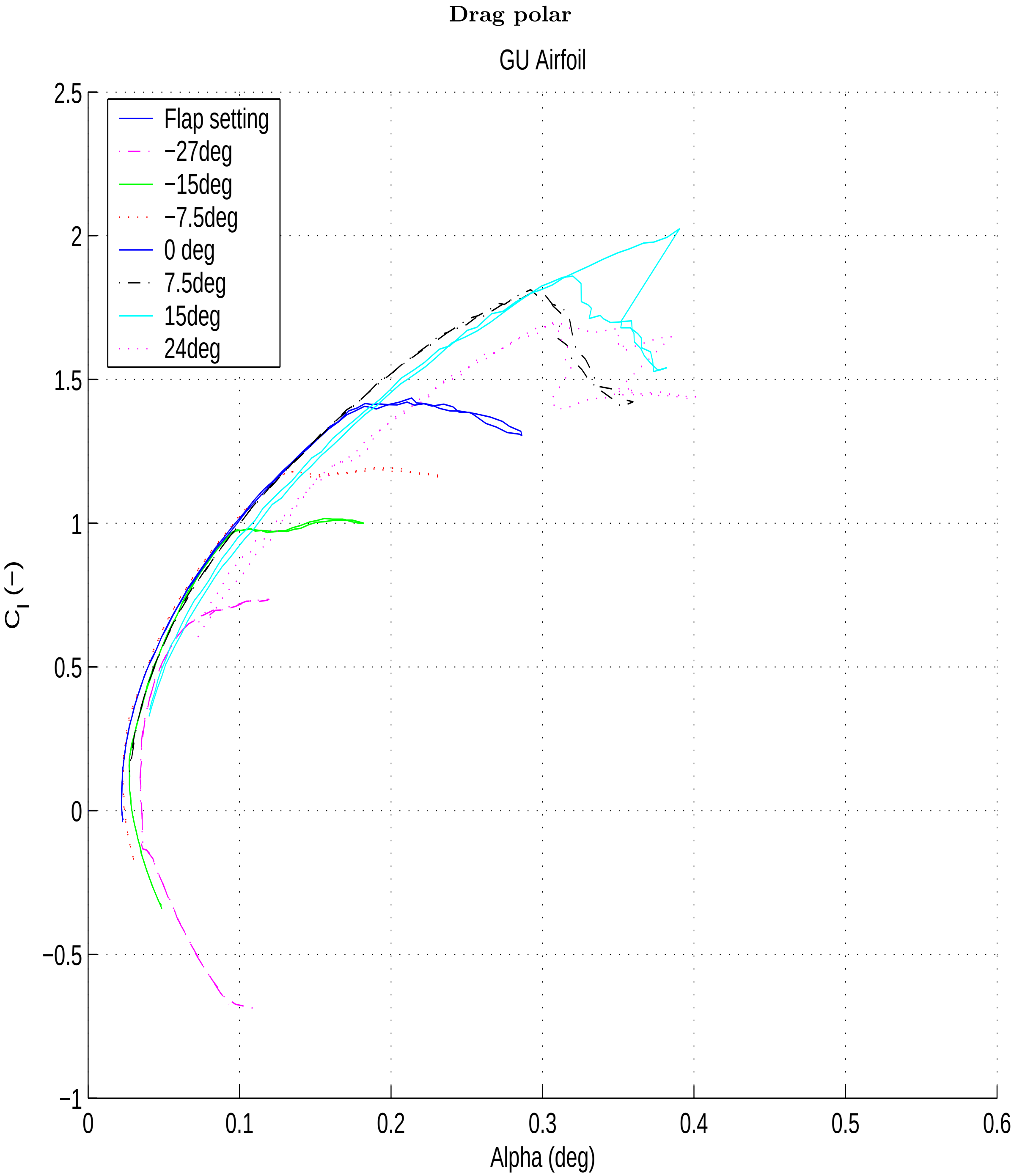


Figure 3.2: Lift coefficient vs drag coefficient.

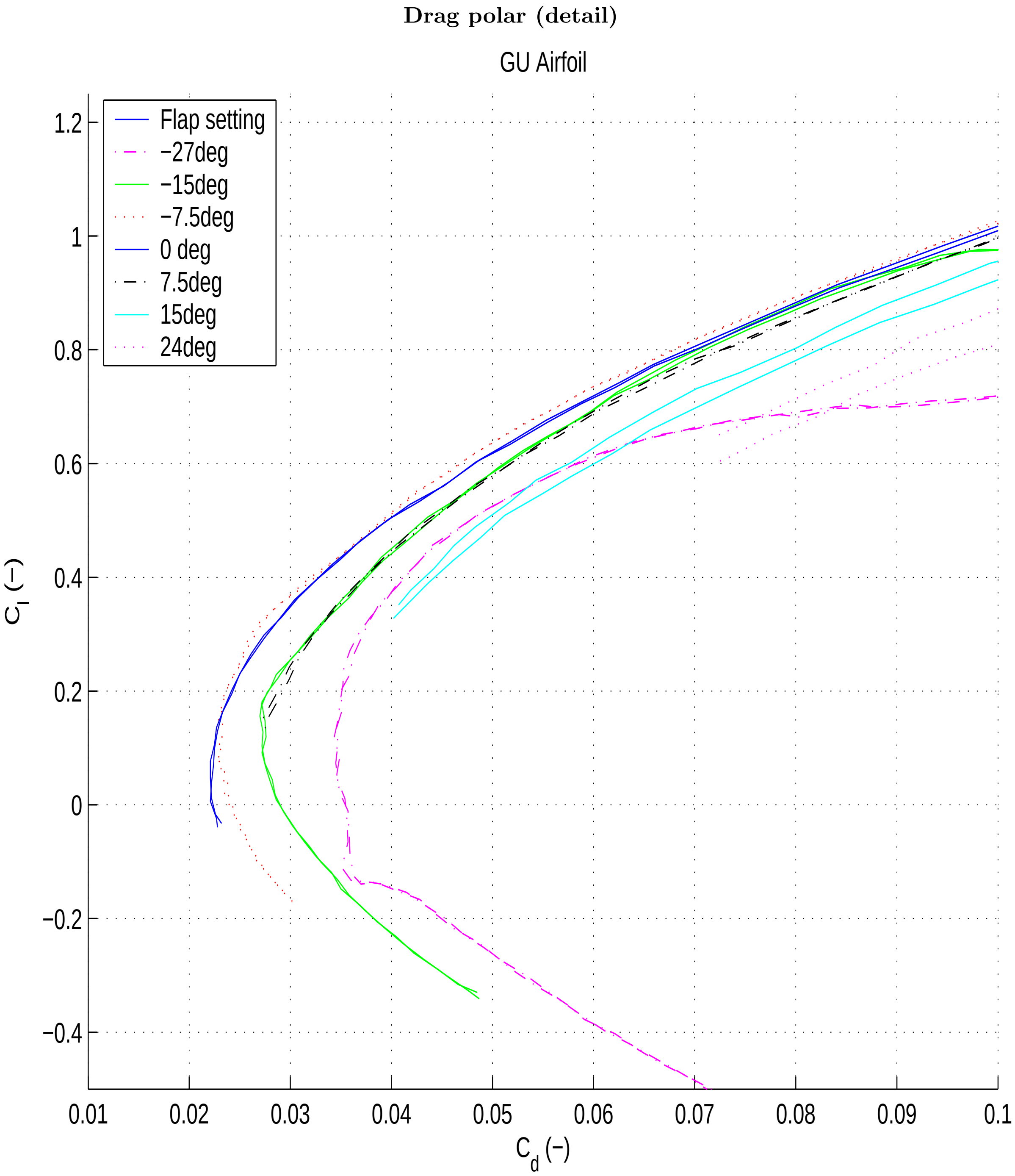


Figure 3.3: Lift coefficient vs drag coefficient, detailed around minimum drag.

Moment coefficient (at 25% chord)

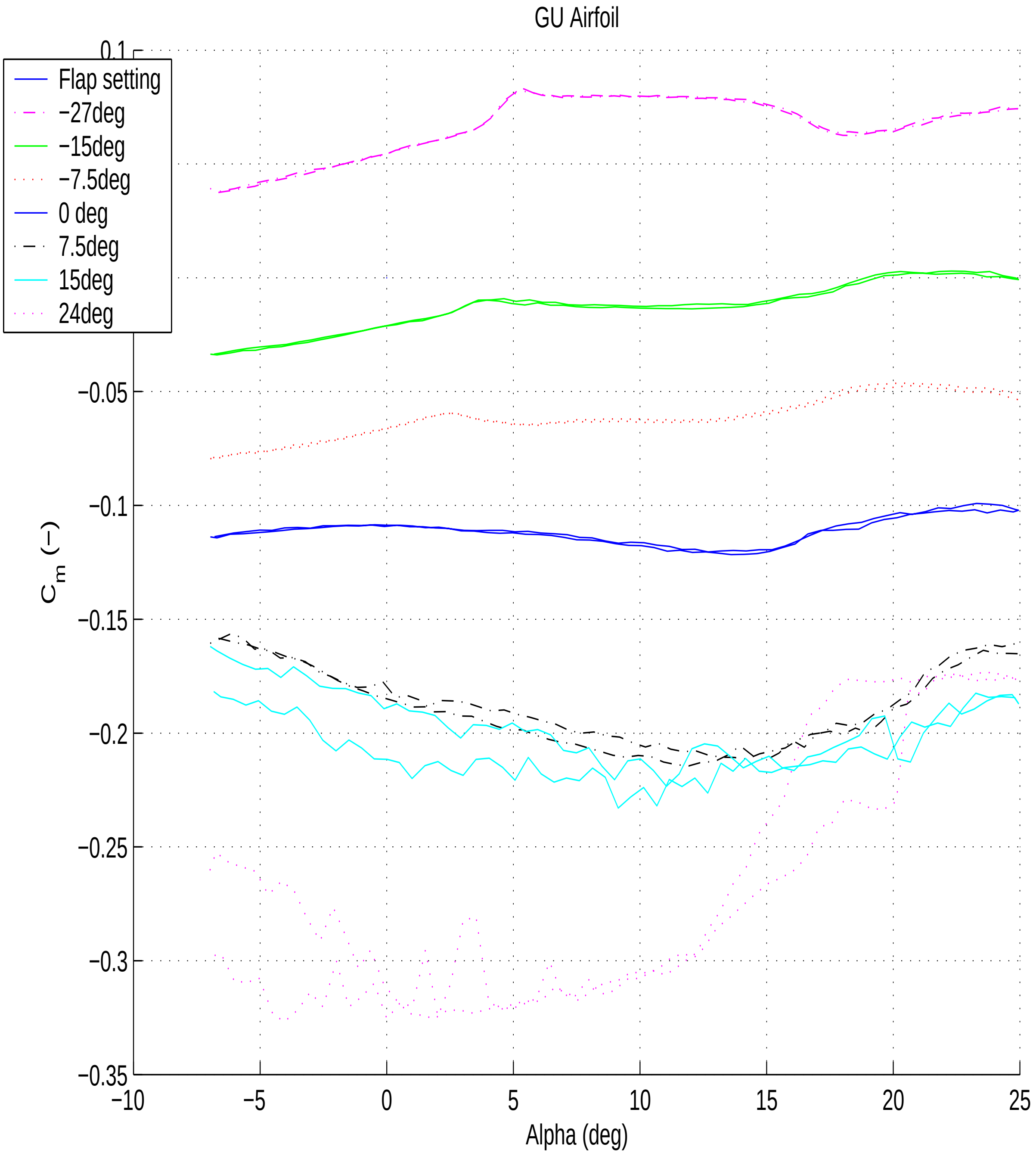


Figure 3.4: Moment coefficient vs incidence, detailed around minimum drag.

3.1.2 Canard equipped with Savier airfoil

Lift coefficient

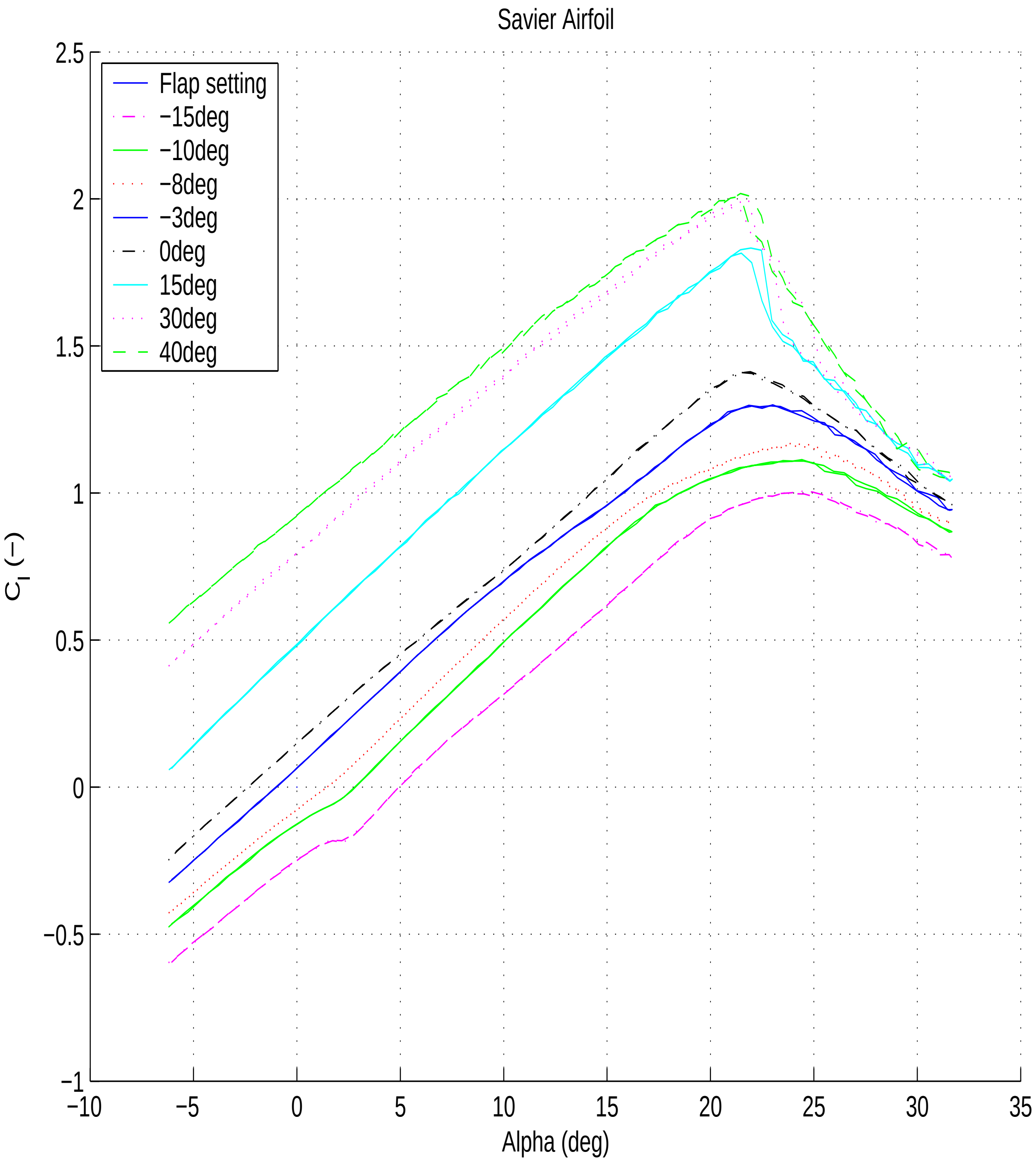


Figure 3.5: Lift coefficient vs incidence. Contrary to GU airfoil, there is no hysteresis behavior for high flap deflection.

Drag polar

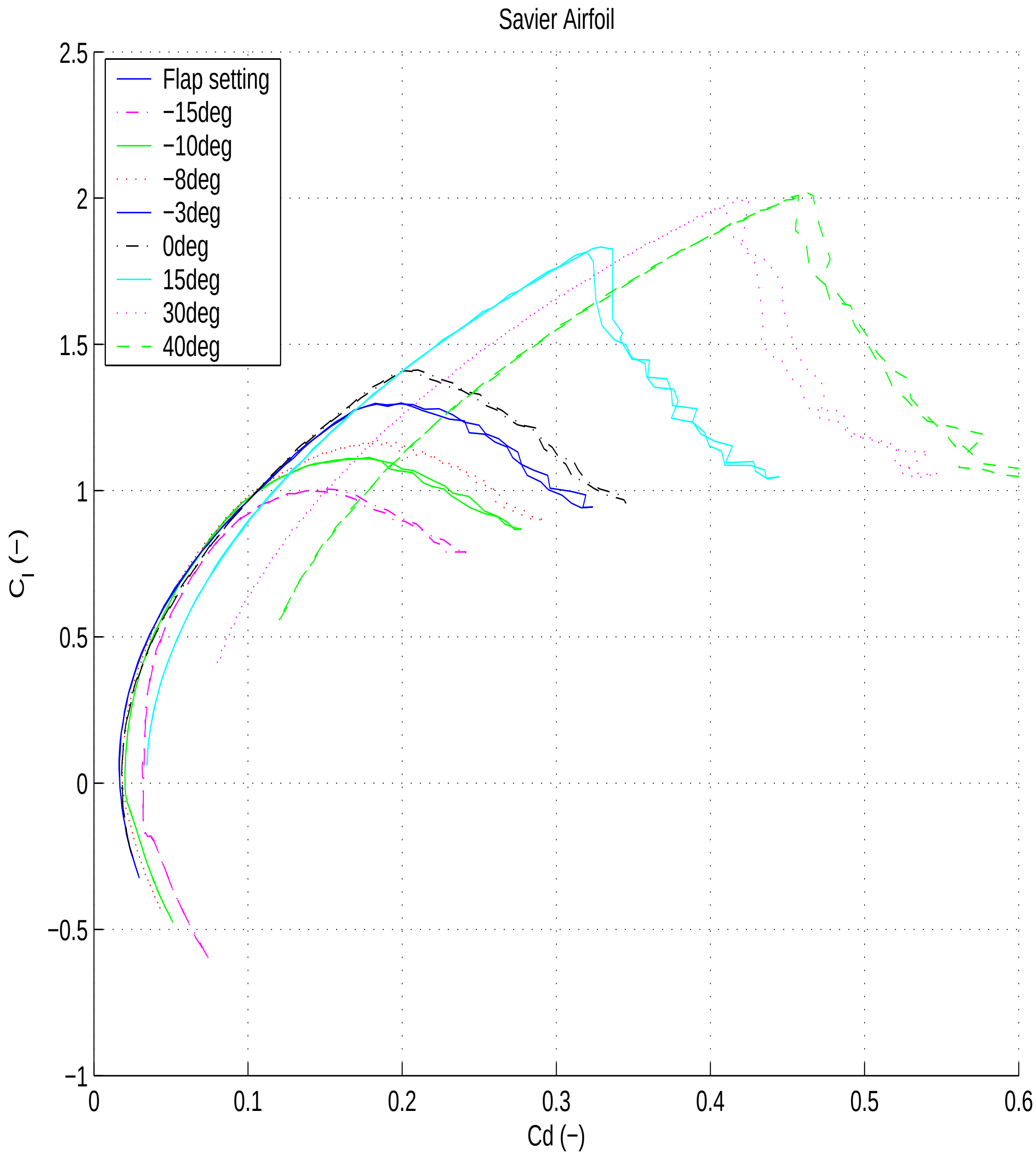


Figure 3.6: Lift coefficient vs drag coefficient.

Drag polar (detail)

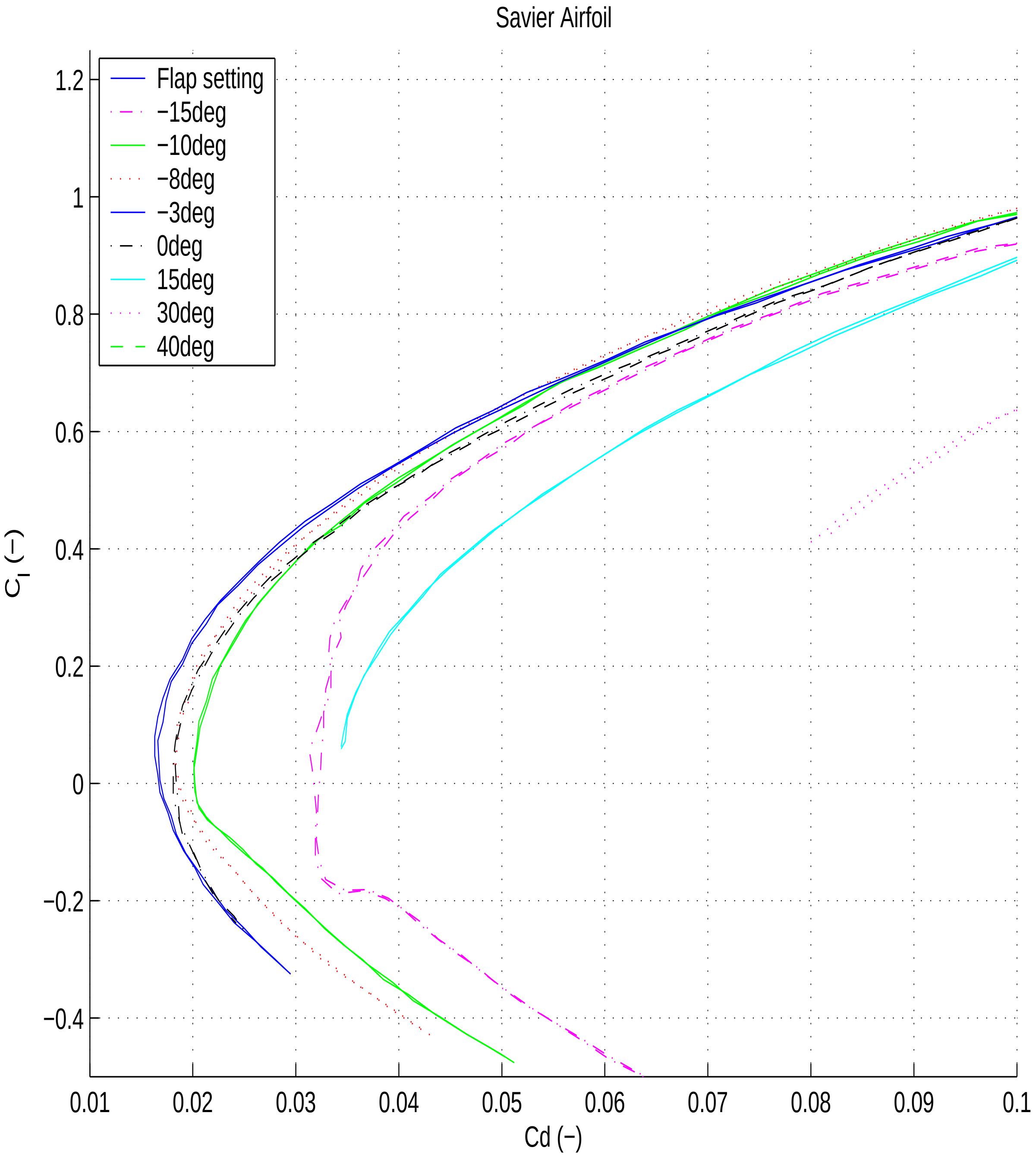


Figure 3.7: Lift coefficient vs drag coefficient, detailed around minimum drag.

Moment coefficient (at 25% chord)

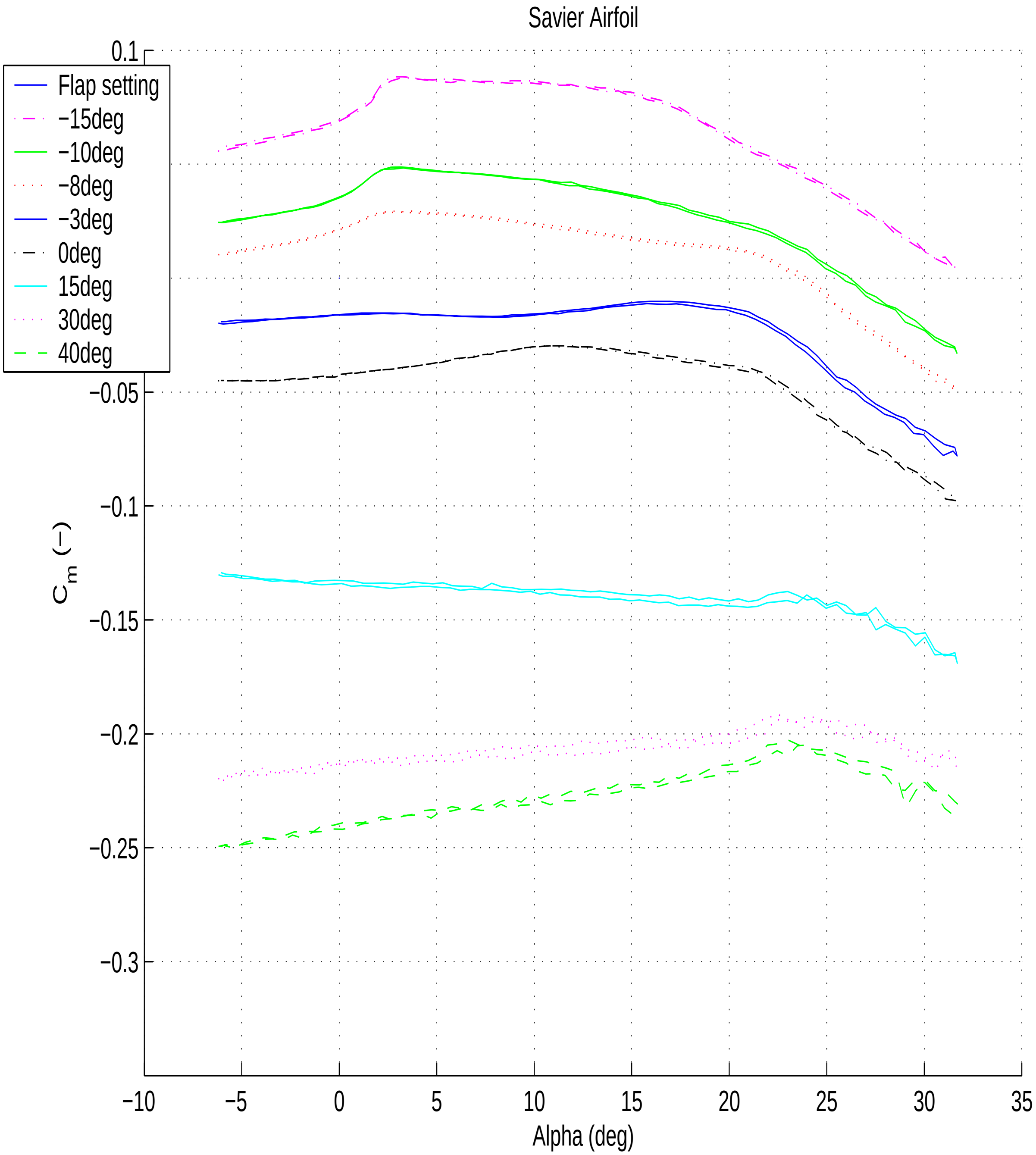


Figure 3.8: Moment coefficient vs incidence.

3.1.3 Comparison of canards equipped with GU and Savier airfoil

We shall now plot the C_l, C_d and C_m values on the same graphics.

Some results Here are the main results concerning lift :

- The Savier canard can reach the same C_l range as GU canard, including very high values for C_{lmax}.
- This C_l range is obtained for different flap setting and incidence for GU or Savier canard. Hence the importance of a correct setting of the rigging angle on the fuselage.
- The Savier has apparently no problem with hysteresis for high flap deflection, comparing to the GU. It can be hoped that Savier canard might not present tricky behavior with high loading as GU sometime does.

Then some results concerning drag :

- The Savier canard has a lower minimum drag coefficient than GU canard. This corresponds to lower C_d at low loads, that is high speed configuration.
- Minimum drag for the Savier canard is reached for -3^o flap defelction
- The polar for Savier canard is more "rounded" and "closed" than for GU, than is C_d gets higher for the Savier than for the GU when its load gets higher.

My two cents about this : my impression is that Savier canard is more adapted to high speed, even if less "laminar", and then would have less C_{lmax} with no flap deflection.
But thanks to a carefully design slat, it can reach as high C_{lmax} as GU canard , while being more performing for high speed.

Lift coefficient

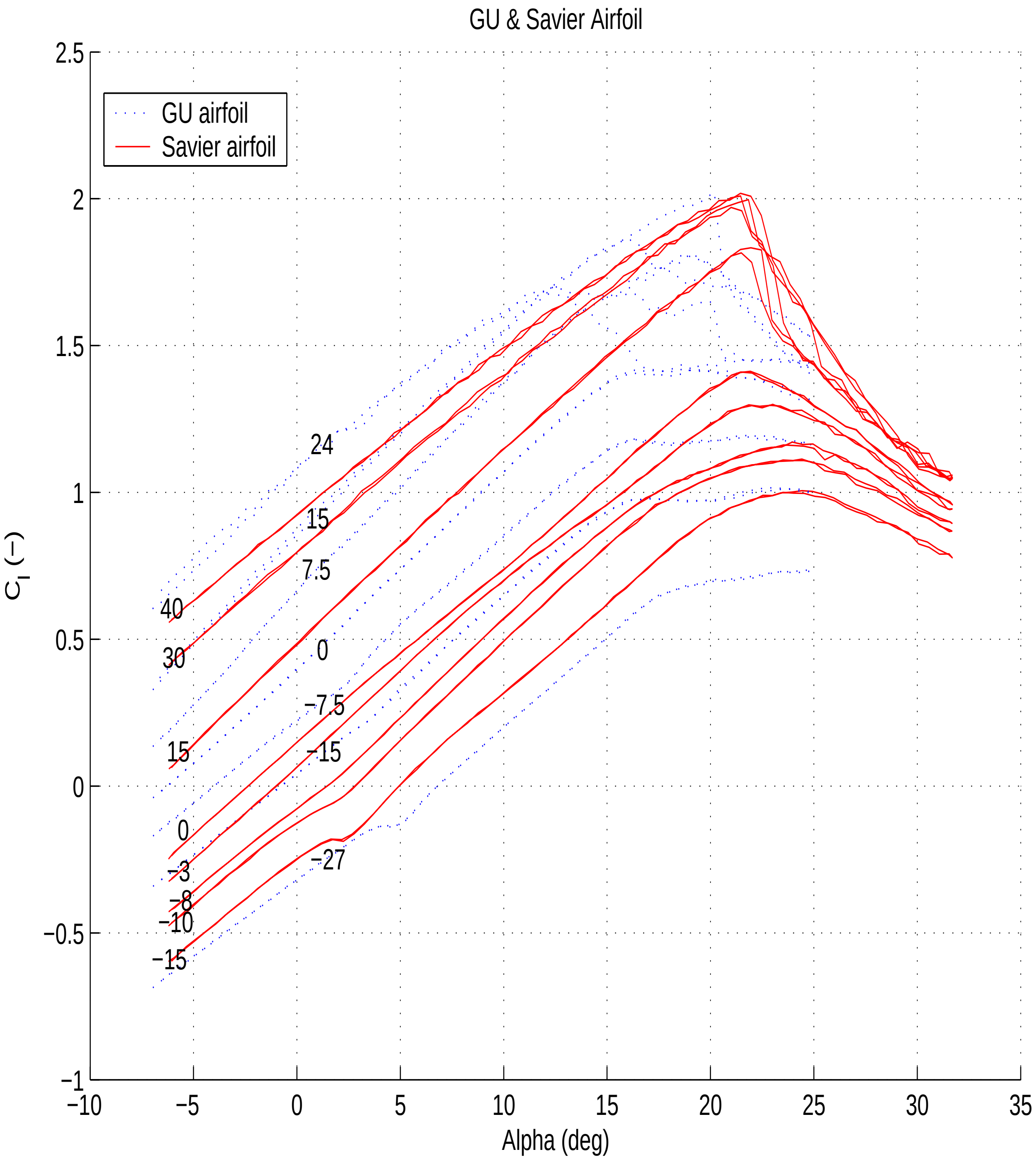


Figure 3.9: Lift coefficient vs incidence. Contrary to GU, Savier airfoil has no hysteresis behavior for high flap deflection. C_l slope is more regular for Savier than for GU.

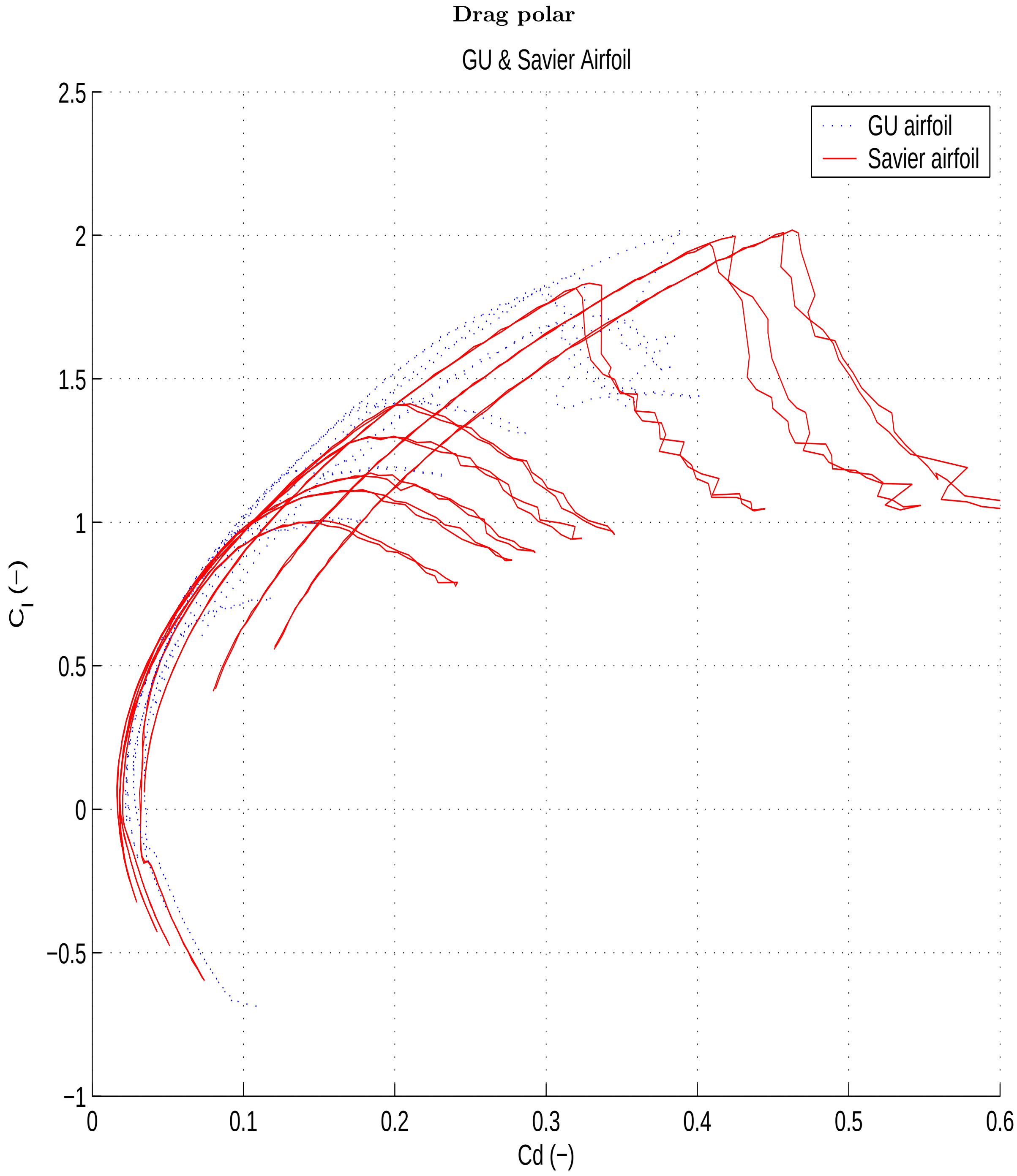


Figure 3.10: Lift coefficient vs drag coefficient. Effect of flap deflection may seem higher for Savier airfoil.

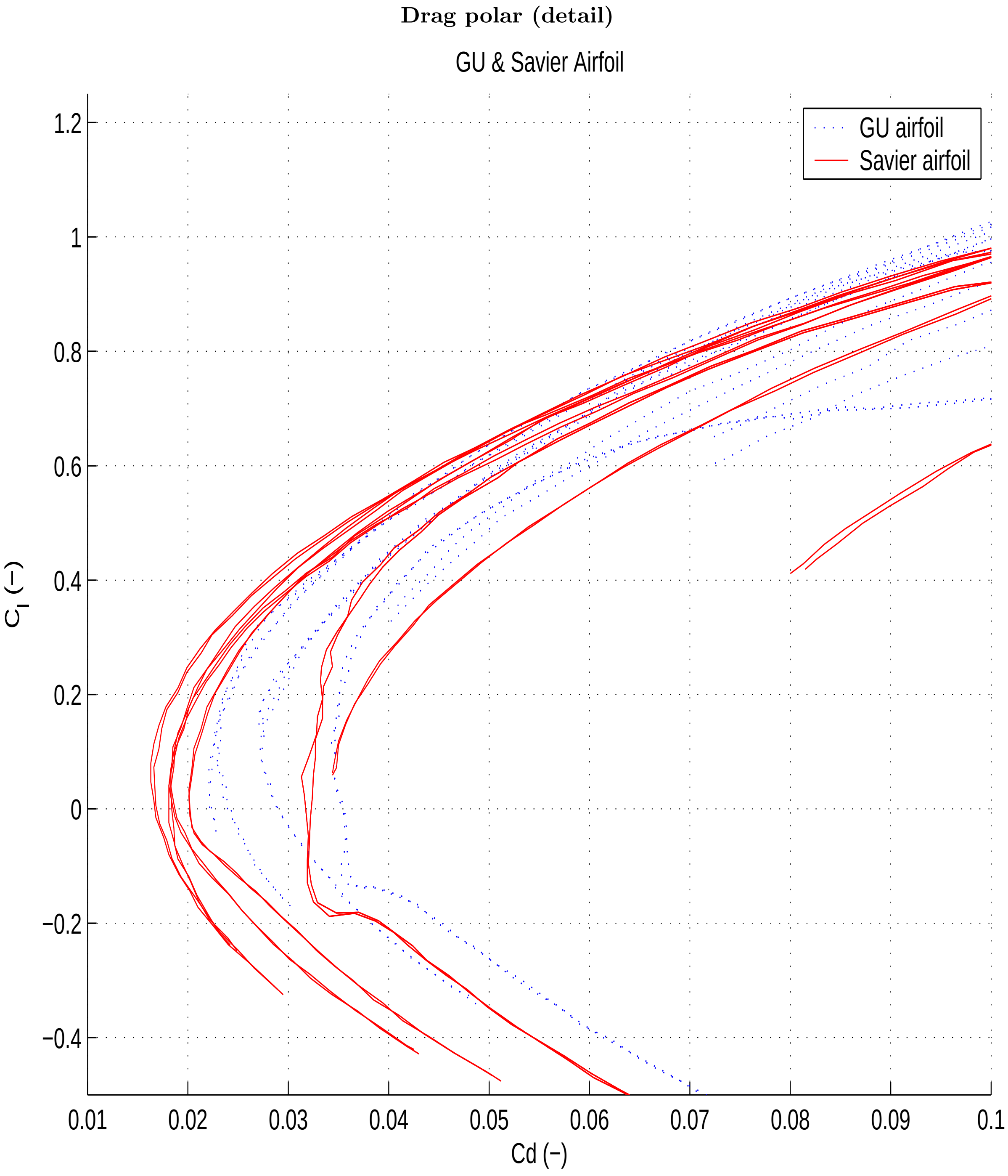


Figure 3.11: Lift coefficient vs drag coefficient, detailed around minimum drag. Minimum drag is smaller for Savier than for GU airfoil.

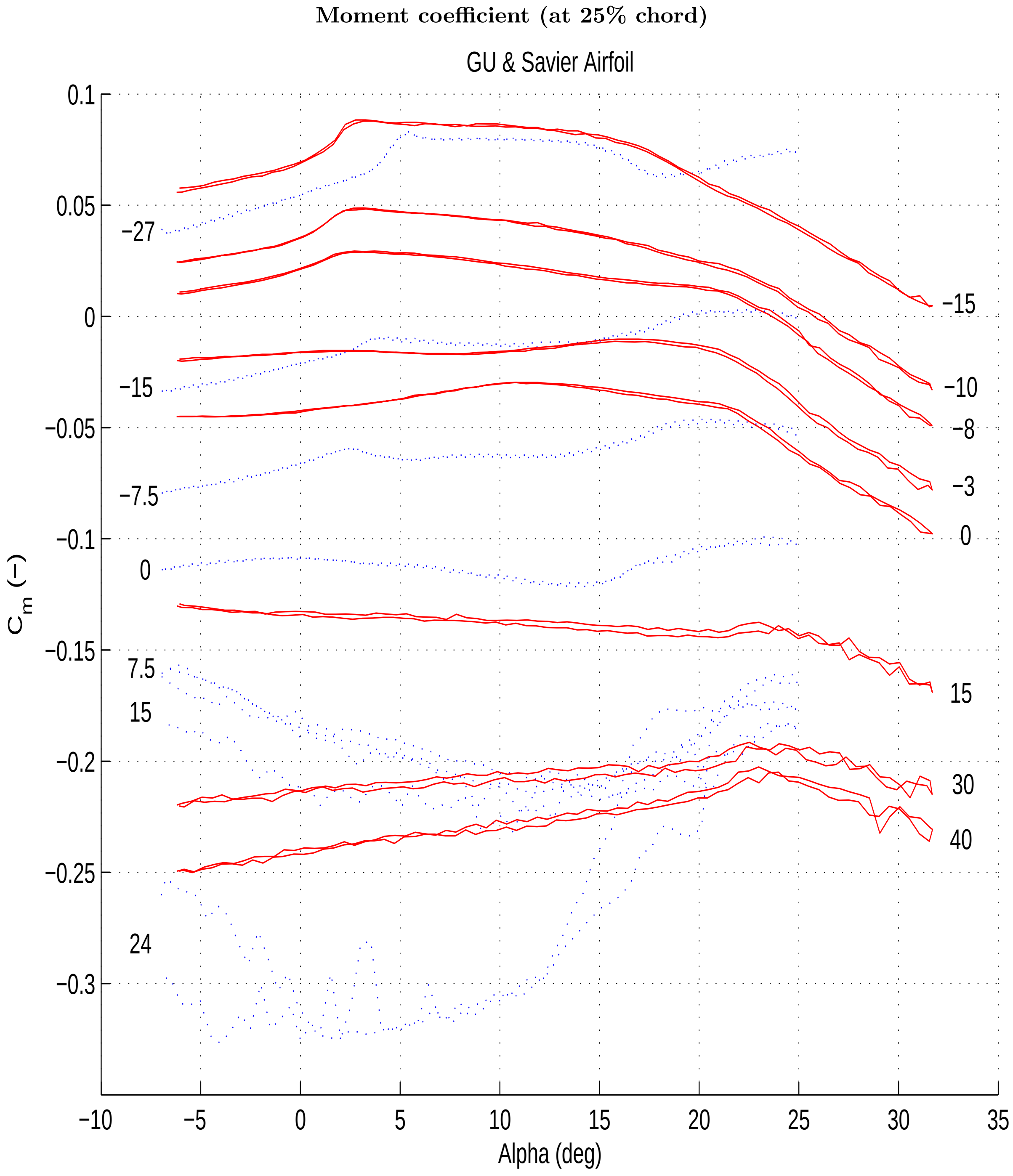


Figure 3.12: Moment coefficient vs incidence. Absolute values of C_{m0} are smaller for Savier than for GU airfoil.

3.2 3D visualisation of lift coefficient

3.2.1 Canard equipped with GU airfoil

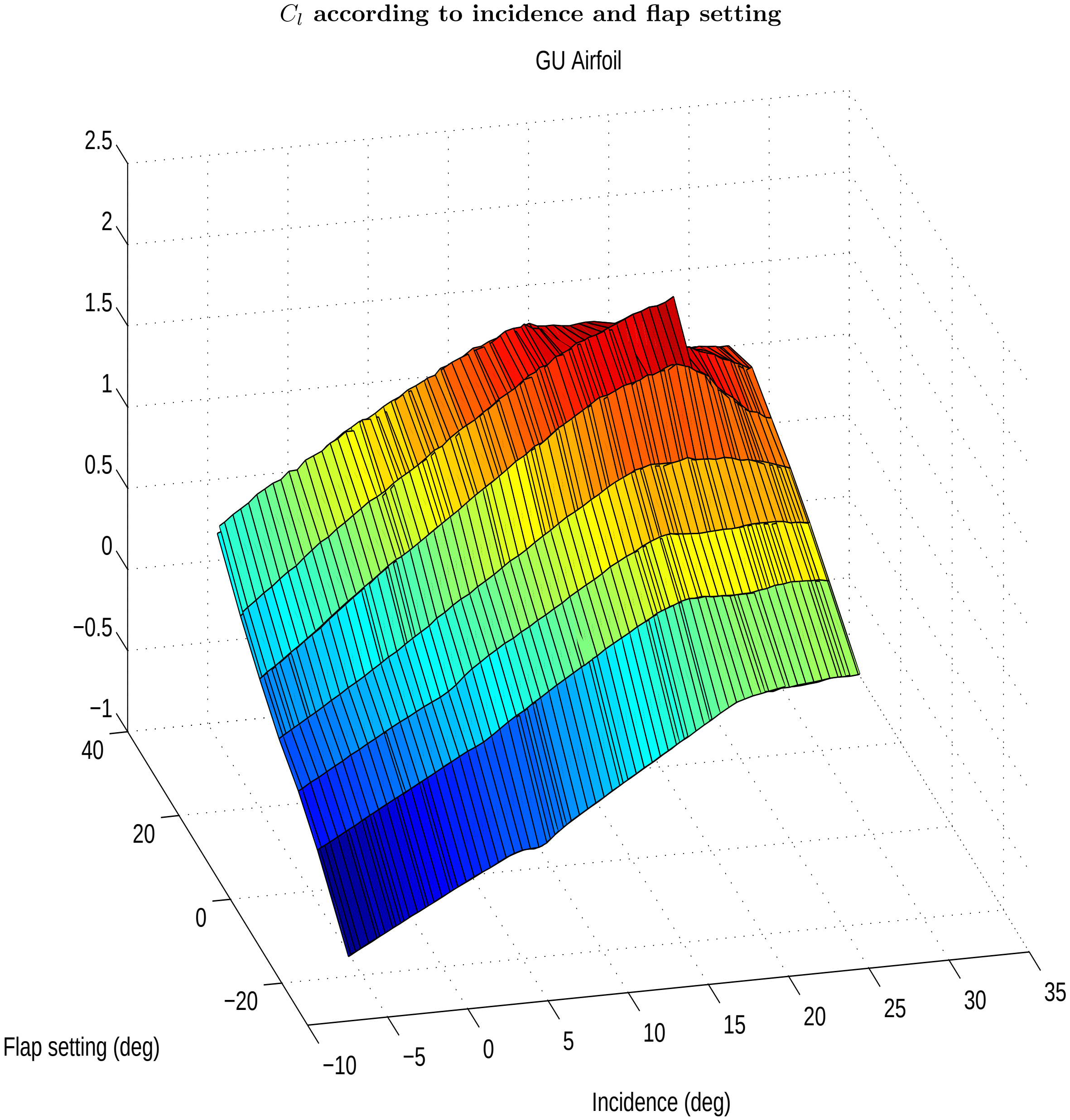


Figure 3.13: Lift coefficient as a function of both incidence and flap setting. Tri-dimensionnal view.

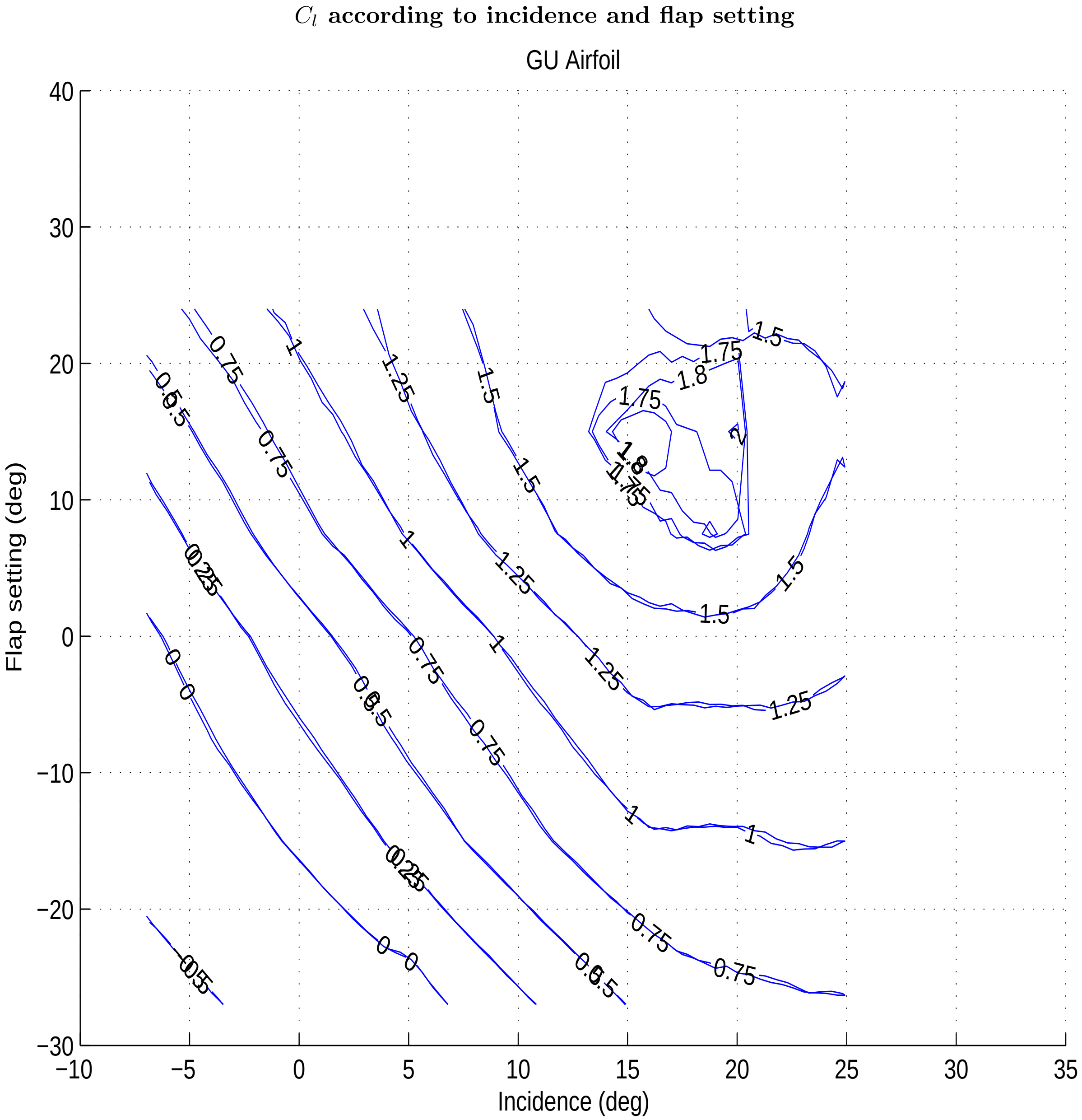


Figure 3.14: Lift coefficient as a function of both incidence and flap setting. Levels view.

3.2.2 Canard equipped with Savier airfoil

C_l according to incidence and flap setting

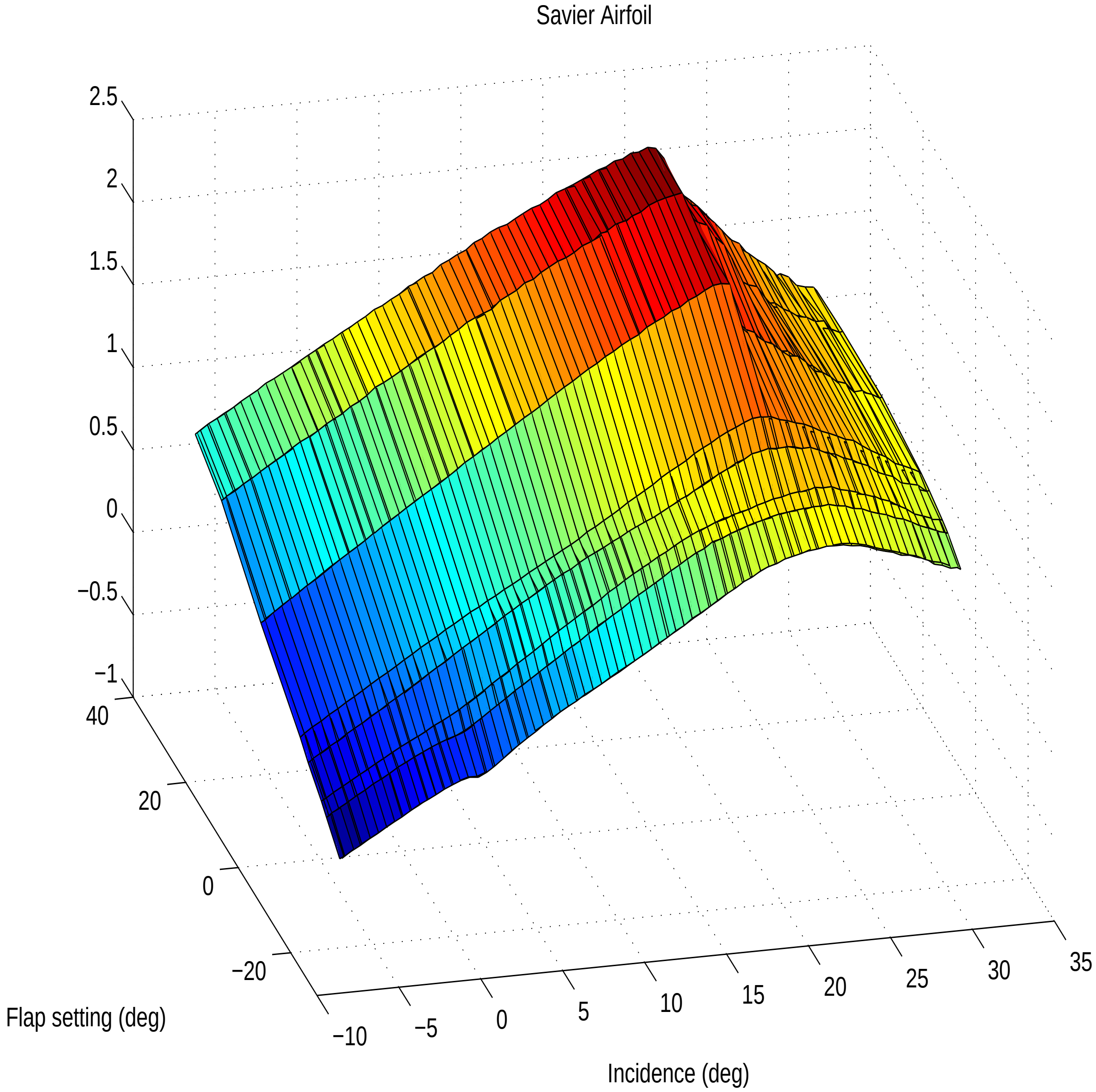


Figure 3.15: Lift coefficient as a function of both incidence and flap setting. Tri-dimensionnal view.

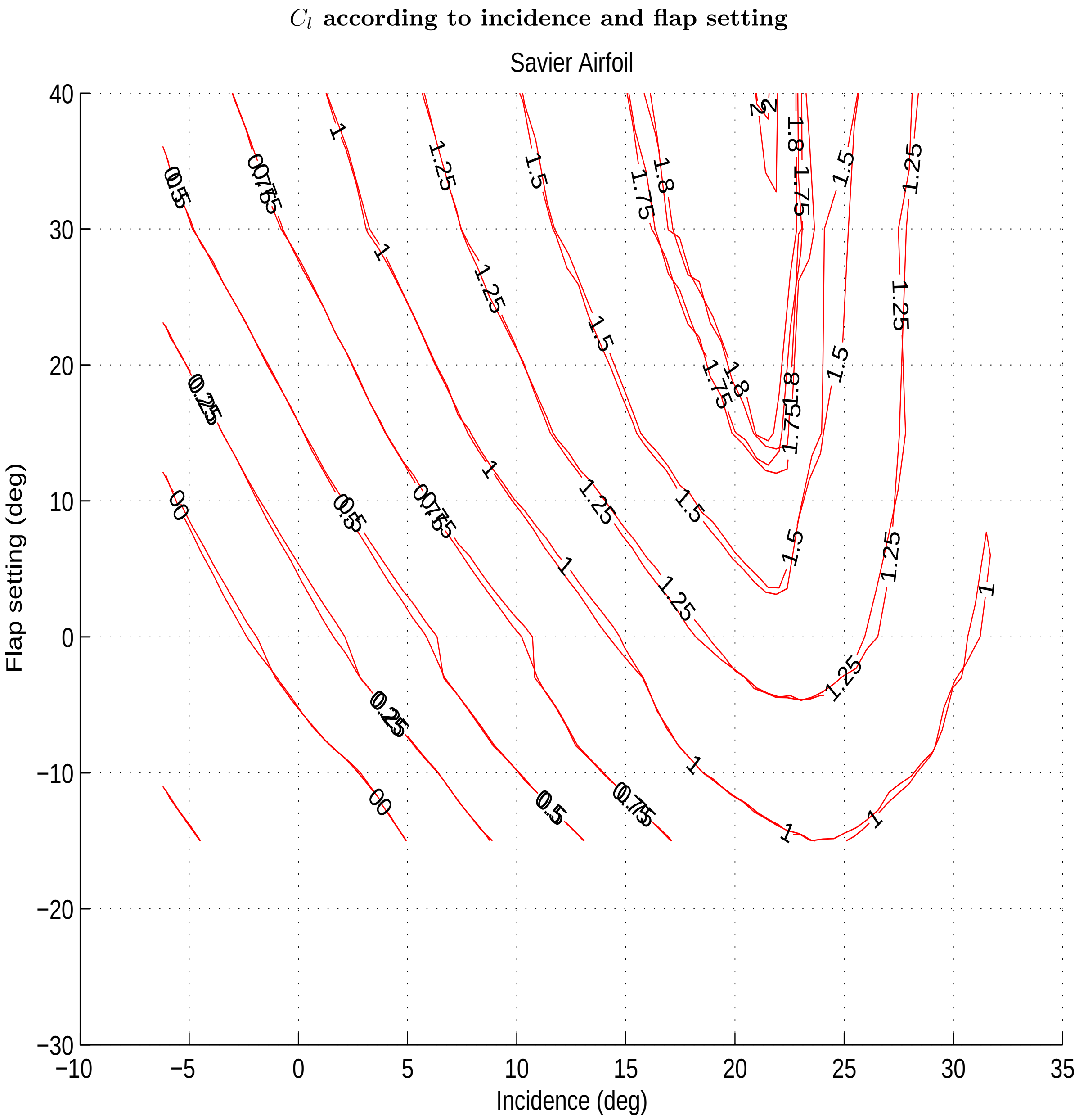


Figure 3.16: Lift coefficient as a function of both incidence and flap setting. Levels view.

3.3 Effect of wetted surface (”rain”) and transition on canard equipped with Savier Airfoil

Artificial transition was created by carborandum located at 5% chord.

Wetted surface referred to measurements with visualization oil on the canard.

One conclusion is that if transition occurred early, performance is really affected. But it seems Savier airfoil is resistant to wetted surface, since wetted surface did not seem to create transition. This point should be detailed further.

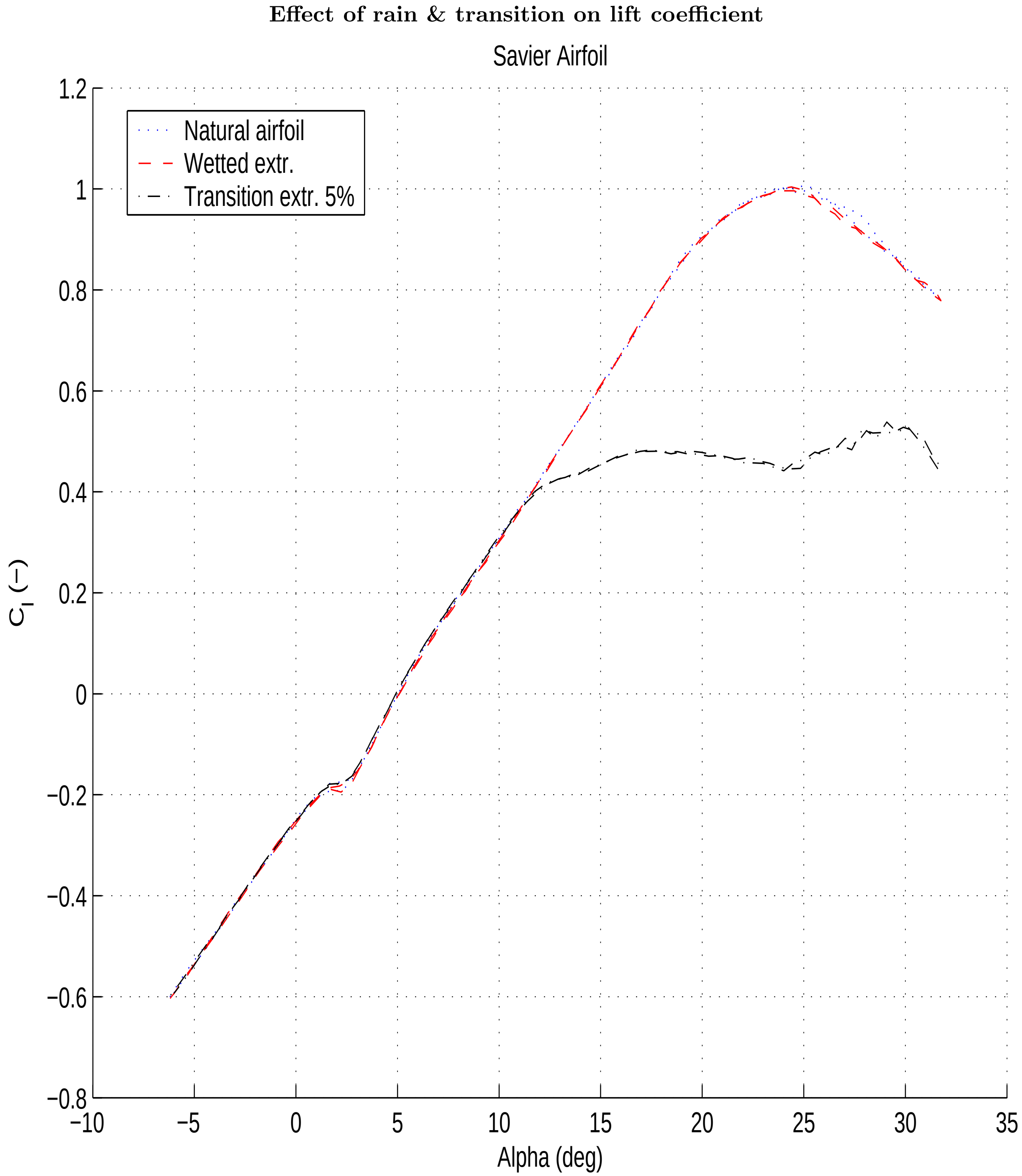


Figure 3.17: Lift coefficient vs incidence. Savier airfoil seems to be not really hurt by wetted surface, whereas genuine transition reduced greatly maximum lift.

Effect of rain & transition on drag polar

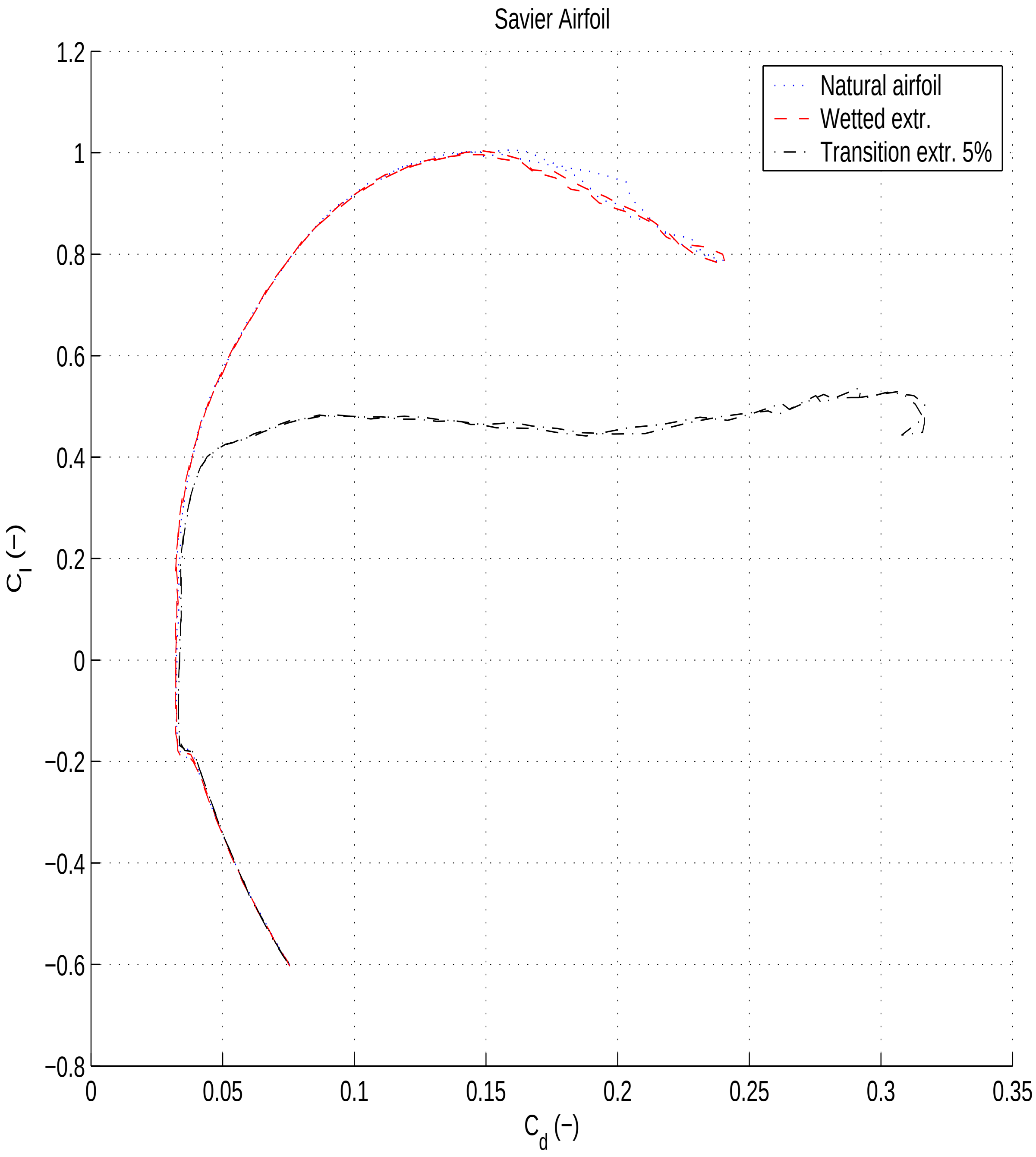


Figure 3.18: Lift coefficient vs drag coefficient.

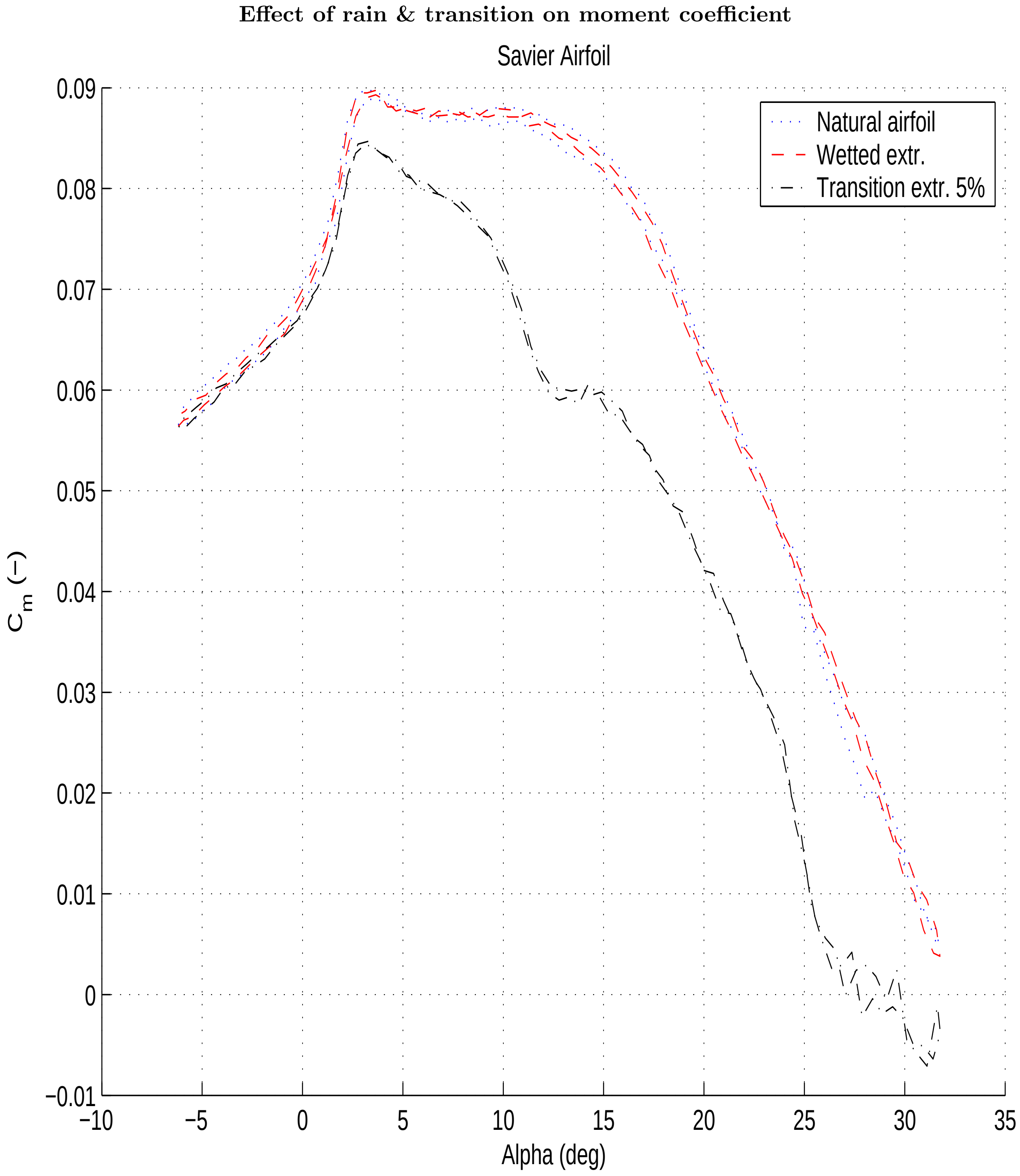


Figure 3.19: Moment coefficient vs incidence.

Chapter 4

Quantitative work (2/2) : extrapolation from polar measurements

From "raw data", some calculation work can be done for extrapolating some complementary data.

At first, the part of the airfoil within drag can be extracted.

Then, we can look carefully the wind tunnel data on each functioning point that is encountered in steady flight.

4.1 Extrapolated data for airfoils alone

In short, drag measured for the half canard can be split into :

- "Mounting" drag C_{dMount}, that is drag causes by the fitting device into the wind tunnel.
- Airfoil drag C_{dAirf}
- Induced drag C_{di}

$$C_d = C_{dMount} + C_{dAirf} + C_{di} \tag{4.1}$$

Assuming the left plate is a correct plan of symmetry, we can say that the effective aspect ratio is about $\lambda = 5$. This is coherent with the C_l slope measured. Then the induced drag can be expressed as $C_{di} = \frac{1}{\pi\lambda}{C_l}^2$, and subtracted from the total drag coefficient.

Then we can compare airfoil, since "Mounting" drag C_{dMount} is comparable for both half canards.

NB : so keep in mind that the minimum drag values C_{d0} plotted contains C_{dMount}, that is fittings and attachment system. So that they are not genuine "airfoil C_{d0}".

Drag polars

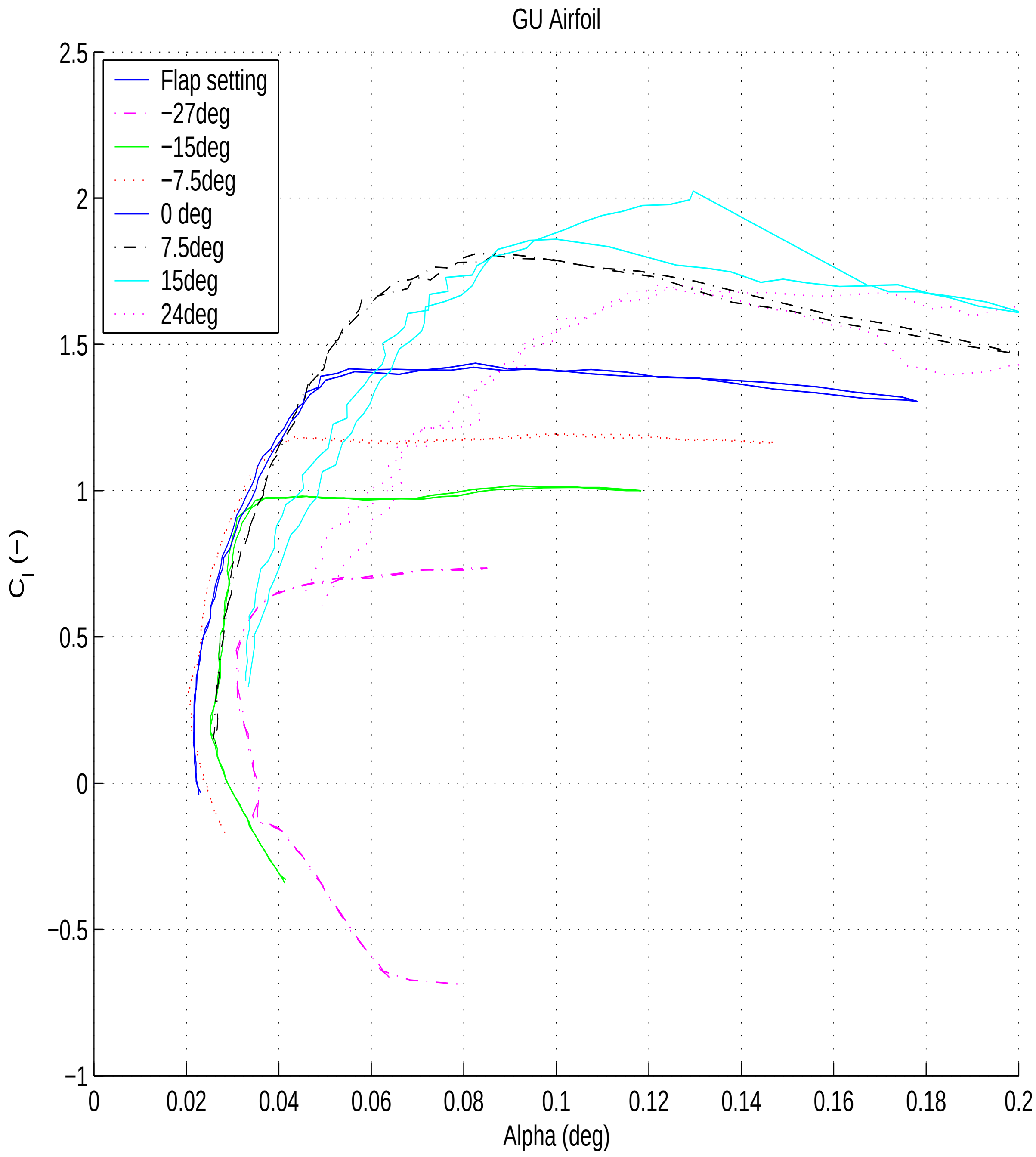


Figure 4.1: Lift coefficient vs drag coefficient, for airfoil only.

Drag polars

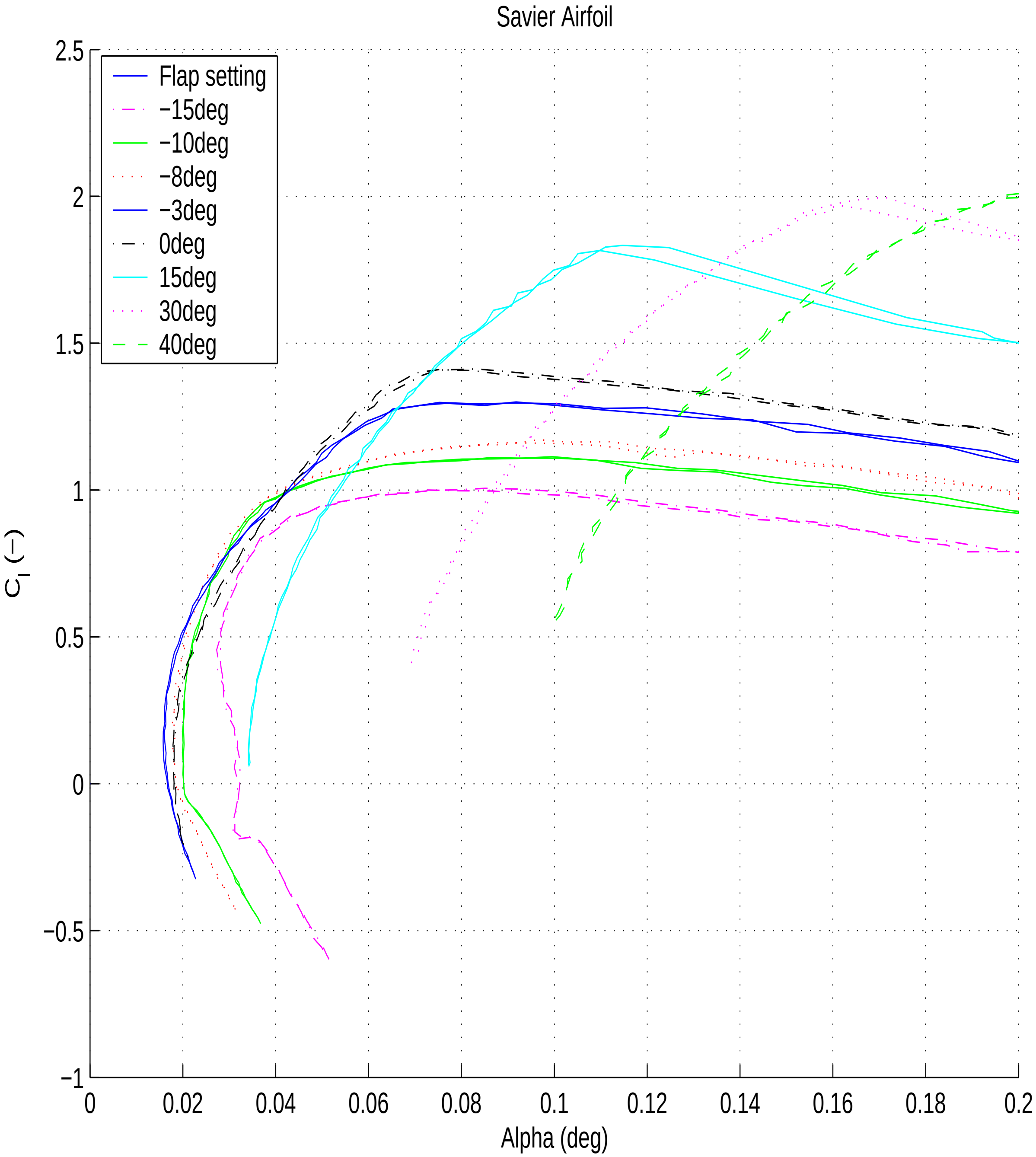


Figure 4.2: Lift coefficient vs drag coefficient, for airfoil only.

Drag polars comparison

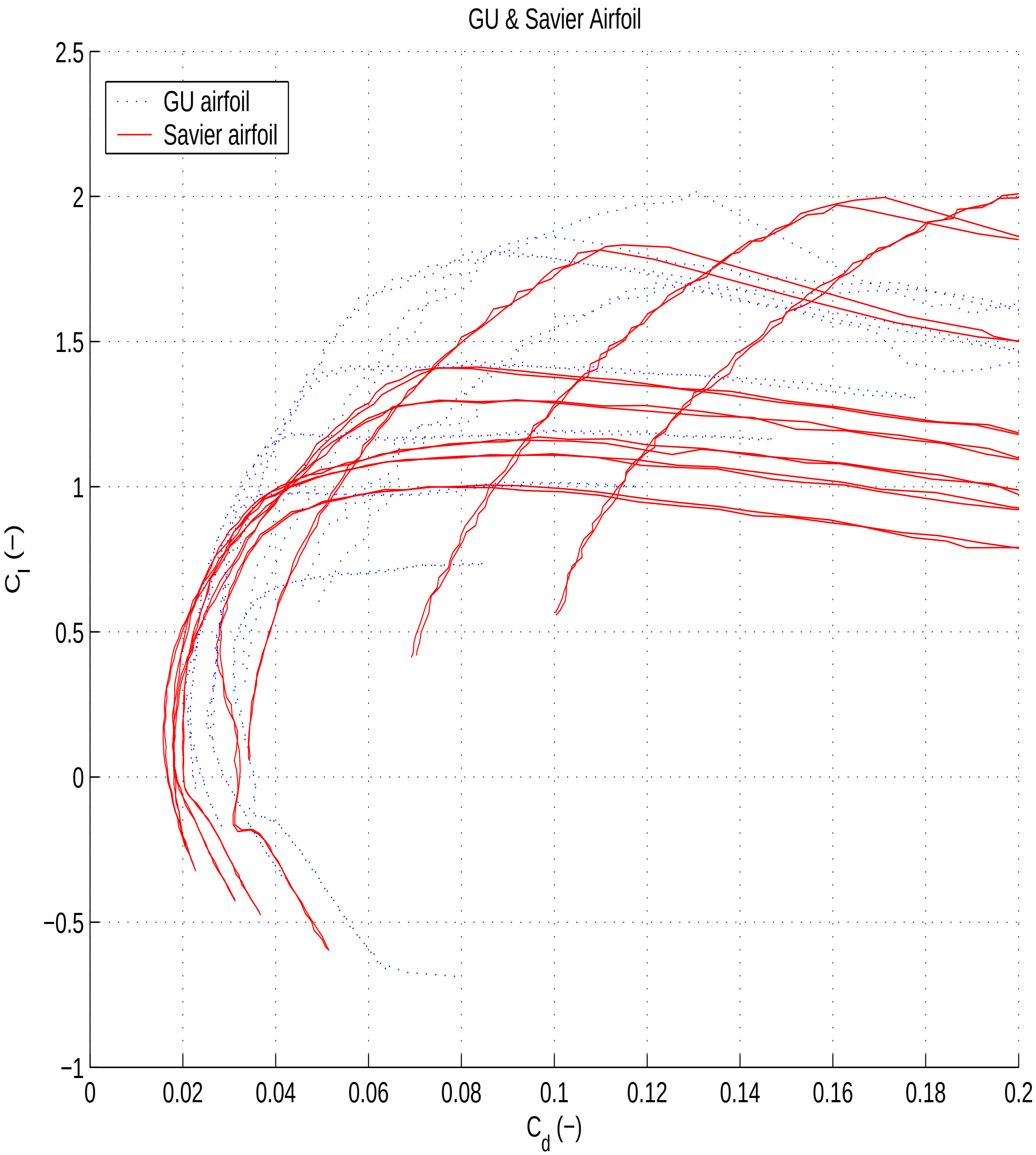


Figure 4.3: Comparison of drag polars for airfoils only. Savier Airfoil has a less laminar behavior (more "rounded polar"), but lower C_{dmin}.

4.2 Data adapted to flight condition

An attempt to get the effective "in flight parameters" over the canards was made. Every parameter were not known, but this is a good start for the comparison of both canard.
Indeed, wind tunnel data have to be treated to be used with the different parameters

- Measurement of flap deflection and fuselage attitude was installed into three aircraft (F-PYHR (Savier canard), F-PYOP (GU Canard), F-PYSM (GU Canard)).
- Similar measurements were made on the three aircraft to reduce scatter effect.
- Measurements were made for aircraft wing-loadings close to each other.
- Data were collected at first on a steady, constant attitude path, for basic values of incidence and flap deflection. Then some measurements were also made with constant bank and altitude, for higher load on the canard.
- From measurements, calculations were made to get the effective aerodynamic incidence on the canard, influenced by the wing.
- Some interpolations of the wind tunnel results were made to get the exact functioning parameters of the canards within the collected data.

We should keep in mind the following points :

- A weak point of this study is that we could not get precise CG location for each aircraft. CG location influences canard load, hence its performance. We supposed that empty CG location were comparable on the different aircraft, according to the building plan.
- It is a pity we could not make the measurements of both canards on the same aircraft. This will be soon possible on F-PYIB (Savier & GU canard) which is currently grounded, and this study will be released.
- Reynolds number for wind tunnel data corresponds to low speed.

Some results

- If you look only on the effective drag polar for the canard of trimmed aircraft, Savier Canard has a lower drag coefficient only for low C_l values.
- If you plot C_d as a function of speed of the trimmed aircraft, Savier Canard has lower drag coefficient for a larger speed domain.
- If you plot value of the drag force, as a function of speed of the trimmed aircraft, Savier Canard saves really quite a lot drag at high speed. This is caused partly to the magnifying effect of V^2 value.

4.2.1 Result of in flight measurements

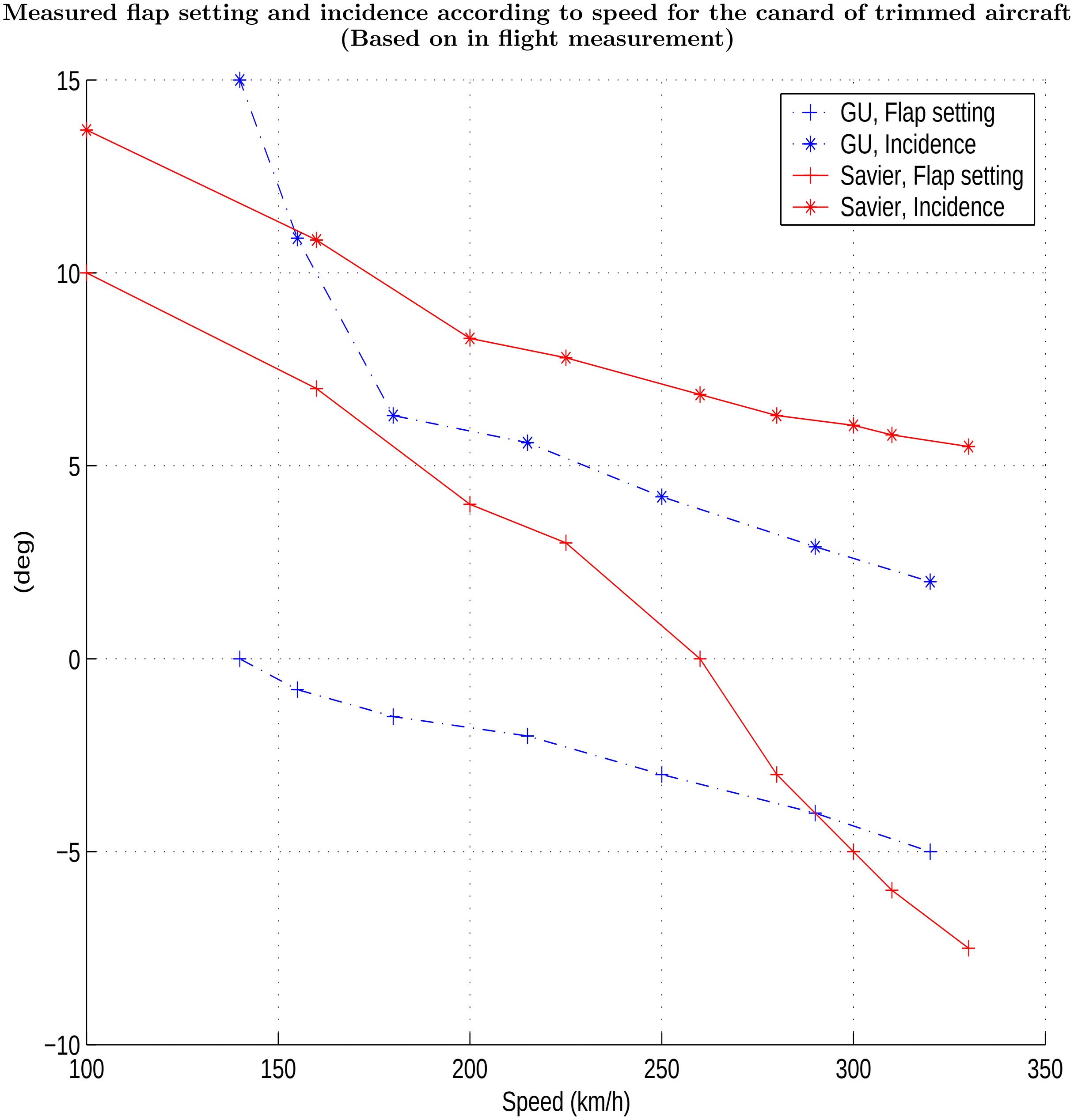


Figure 4.4: Measured flap setting and incidence on aircraft equipped with both canard. Flap setting was directly measured, whereas incidence was calculated from fuselage attitude, including deflection and rigging angle of the canard.

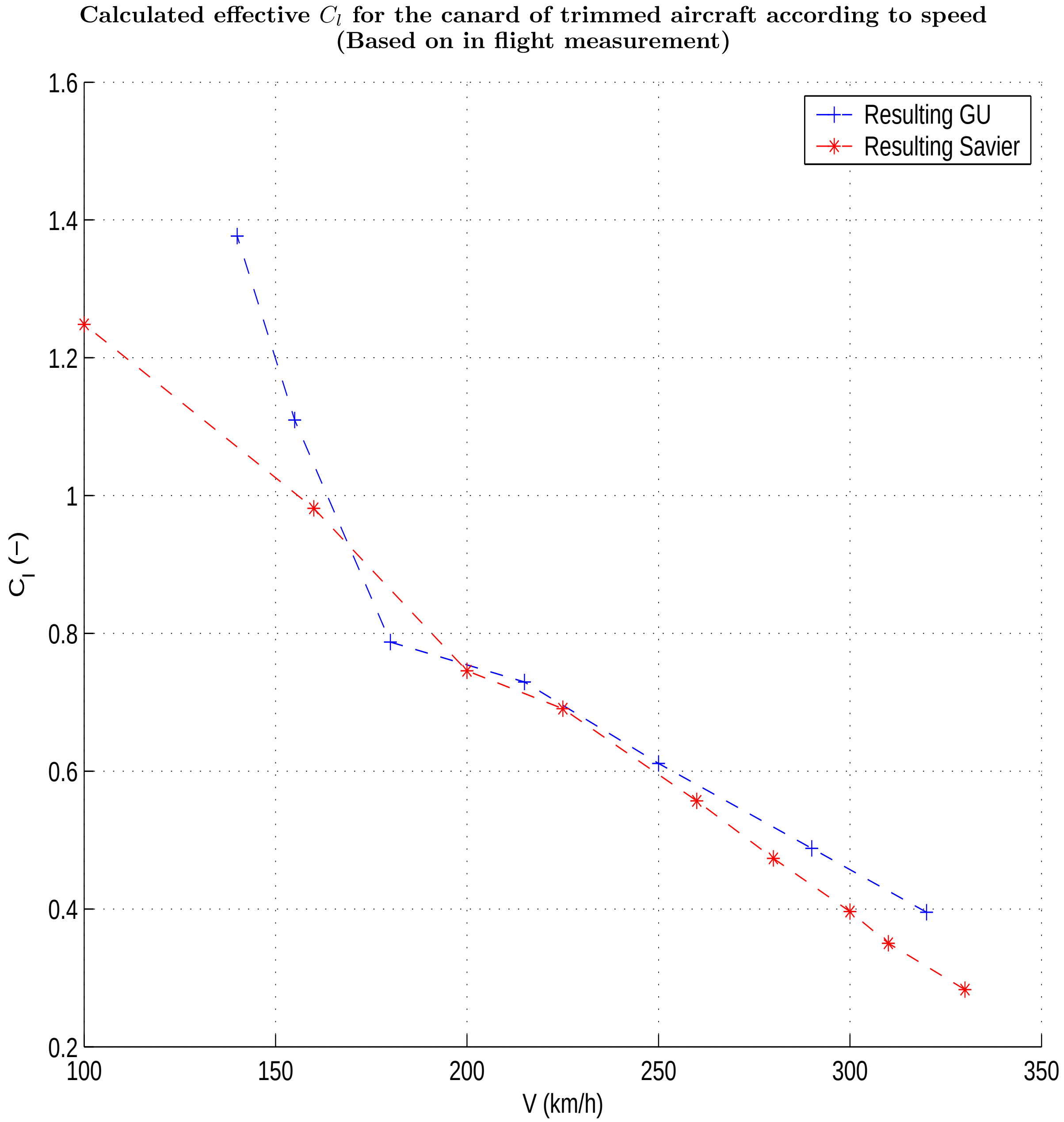
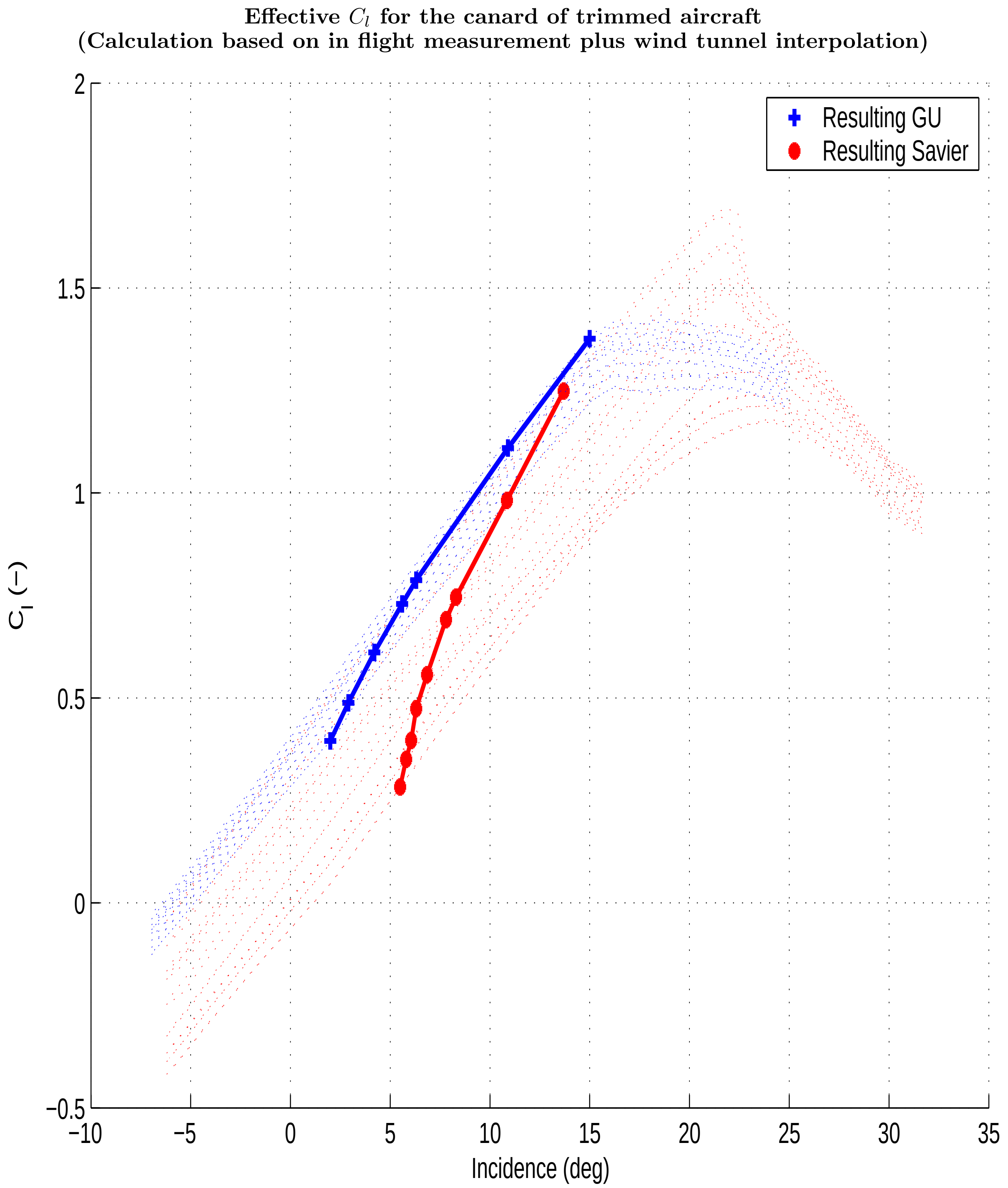


Figure 4.5: C_l **for trimmed aircraft vs speed, on aircraft equipped with both canard.**

4.2.2 Comparison of GU and Savier airfoil



Effective C_l for the canard of trimmed aircraft
(Calculation based on in flight measurement plus wind tunnel interpolation)

Figure 4.6: C_l **for trimmed aircraft vs incidence and flap setting, as put on the wind tunnel measurement.**

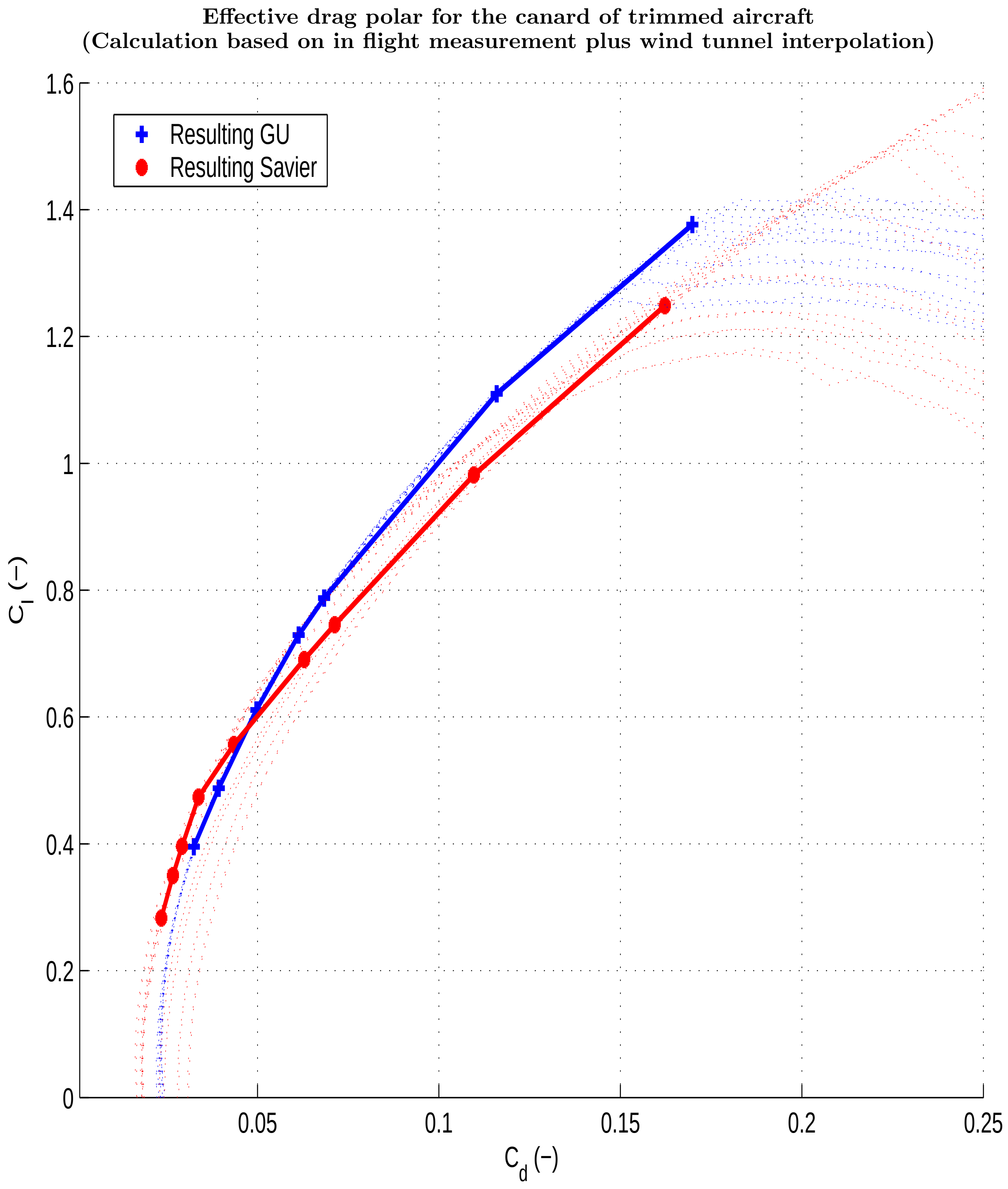


Figure 4.7: C_l vs C_d for the canard of trimmed aircraft, interpolated from wind tunnel measurement.

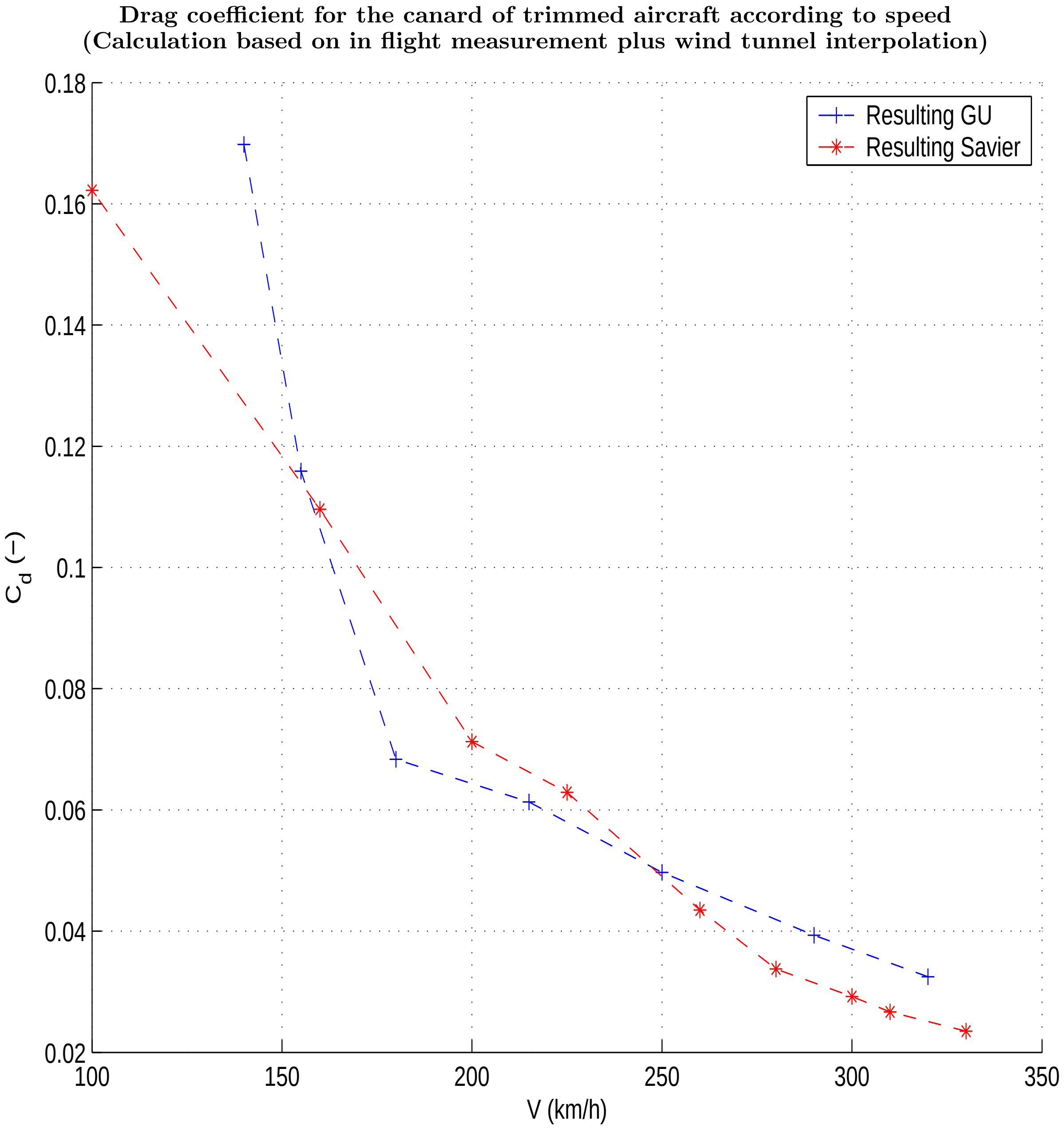


Figure 4.8: C_d for the canard of trimmed aircraft vs speed, interpolated from wind tunnel measurement. Savier airfoil equipped canard has higher drag coefficient for intermediate speed, whereas at low and high speed C_d is lower.

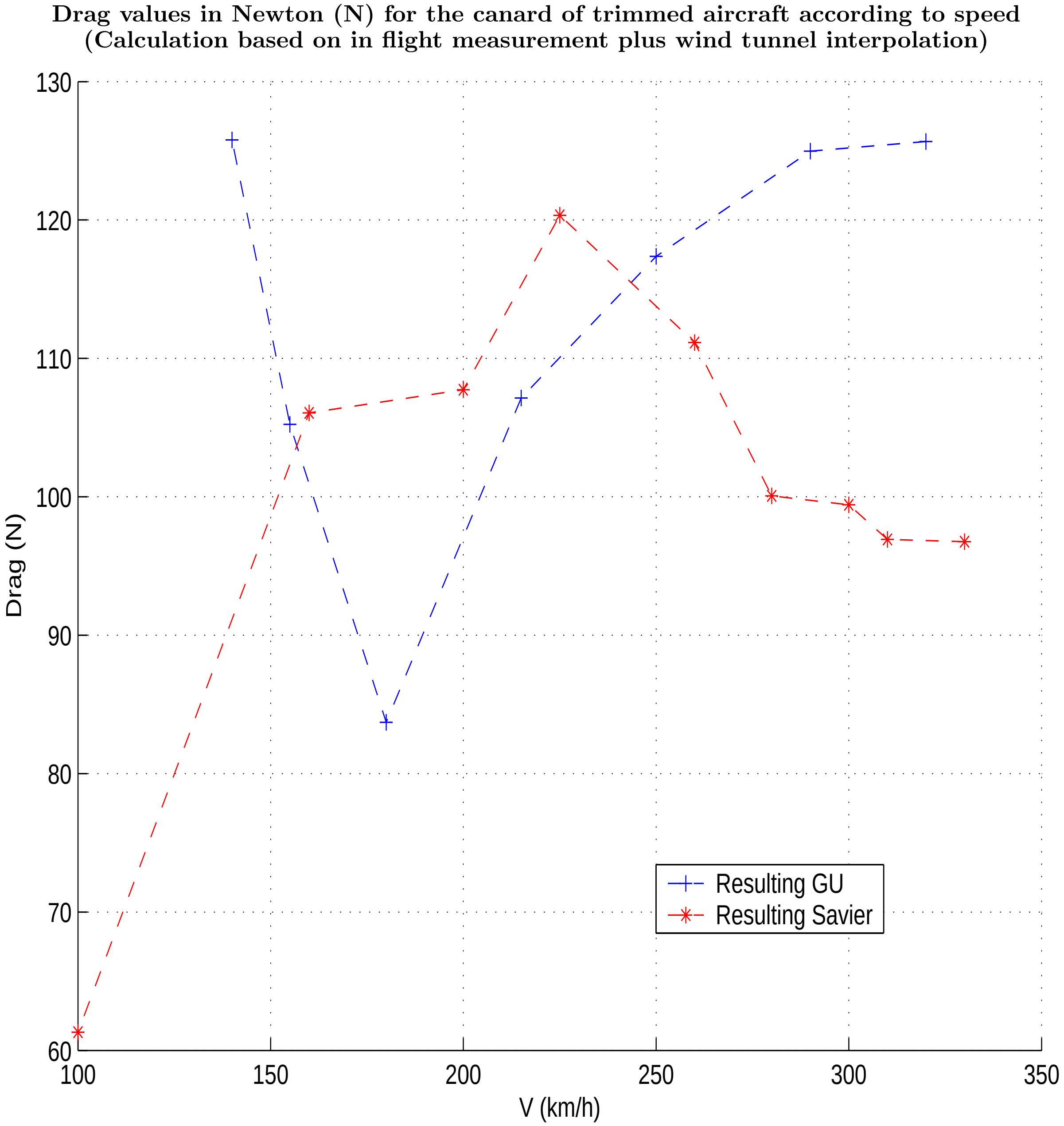


Figure 4.9: Drag values in Newton (N) for the canard of trimmed aircraft vs speed, interpolated from wind tunnel measurement. Drag value is $1/4$ lower for the Savier Canard at high speed.

Chapter 5

Conclusion

This paper has presented the measurements made in a pedagogical project, performed by french students.
In this summary, experimental parameters were described. Then presentation of "raw data" were performed.
Some extrapolation were also made to use the raw data in "in flight conditions".
From those data, others work could be done.

The measurement chain was top quality, and we are confident about the measurements that were made. We are really happy to have benefit from S-4 wind tunnel.
The main regret we have is that the wind tunnel could not produce more than 40m/s. It would have been nice to measure hinge moment on the flap, since reduction allowed by Savier Canard is a key point observed in flight.

We hope this work will help being confident about the Savier Canard.