

DRAFT: SWIFT Stability Derivatives and Dynamic Analysis

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Contents

1	Introduction	2
2	Nomenclature and Axes	2
3	Analysis	2
3.1	2D section computations	2
3.1.1	Hinge Moments	3
3.2	3D Computations	4
3.2.1	LinAir Method	4
3.2.2	XFLR5 Method	5
3.2.3	Comparison of methods	7
4	Dynamic Analysis - Work in Progress	7
5	Conclusion	8
A	XFLR5 look-up tables	9
A.1	$\delta_{f1} = 0$, $\delta_{f2} = 0$, $\delta_{a1} = 0$, $\delta_{a2} = 0$, $\beta = 0$ (flf2_0)	9
A.2	$\delta_{f1} = -20^\circ$, $\delta_{f2} = 0$, $\delta_{a1} = 0$, $\delta_{a2} = 0$, $\beta = 0$ (f1_-20)	9
A.3	$\delta_{f1} = +20^\circ$, $\delta_{f2} = 0$, $\delta_{a1} = 0$, $\delta_{a2} = 0$, $\beta = 0$ (f1_+20)	10
A.4	$\delta_{f1} = +30^\circ$, $\delta_{f2} = 0$, $\delta_{a1} = 0$, $\delta_{a2} = 0$, $\beta = 0$ (f1_+30)	10
A.5	$\delta_{f1} = 0$, $\delta_{f2} = -20^\circ$, $\delta_{a1} = 0$, $\delta_{a2} = 0$, $\beta = 0$ (f2_-20)	11
A.6	$\delta_{f1} = 0$, $\delta_{f2} = +20^\circ$, $\delta_{a1} = 0$, $\delta_{a2} = 0$, $\beta = 0$ (f2_+20)	11
A.7	$\delta_{f1} = 0$, $\delta_{f2} = +30^\circ$, $\delta_{a1} = 0$, $\delta_{a2} = 0$, $\beta = 0$ (f2_+30)	12
A.8	$\delta_{f1} = 0$, $\delta_{f2} = 0$, $\delta_{a1} = +20^\circ$, $\delta_{a2} = 0$, $\beta = 0$ (a1_+20)	12
A.9	$\delta_{f1} = 0$, $\delta_{f2} = 0$, $\delta_{a1} = 0$, $\delta_{a2} = +20^\circ$, $\beta = 0$ (a2_+20)	13
A.10	$\delta_{f1} = 0$, $\delta_{f2} = 0$, $\delta_{a1} = 0$, $\delta_{a2} = 0$, $\beta = -4^\circ$ (beta_4)	13
A.11	$\delta_{f1} = 0$, $\delta_{f2} = 0$, $\delta_{a1} = 0$, $\delta_{a2} = 0$, $\beta = -8^\circ$ (beta_8)	13
B	Matlab script for XFLR5 data	15
B.1	Comparison of Linearized data with Look-up tables	15
C	LinAir Input File and Results	20

1 Introduction

In this report, we summarize the approach use to derive the stability and control derivatives for the Swift UAV. We use two methods and cross-compare the results. Overall, we find good agreement between the two approaches which bolsters our confidence in them. The complete results and input files are given in the appendix.

2 Nomenclature and Axes

In this report we try to use the same notation and axes used in [1]. The non-dimensional coefficients are also the same as those given in Table 4.1 of [1]. All derivatives are by respect to radians unless otherwise stated. As for the reference geometry, we use the following values for surface area, span and M.A.C. These differ slightly from the Swift values due to simplifications in the model. However, we were consistent in using the same reference values in both LinAir and XFLR5 models.

- $M = 150 \text{ kg} = 330 \text{ lbs}$
- $x_{CG} = 1.2 \text{ m}$ behind Leading Edge of Wing
- $S = 12.1 \text{ m} = 39.4 \text{ ft}$
- $b = 13.1 \text{ m}^2 = 141 \text{ ft}^2$
- $\bar{c} = 1.06 \text{ m} = 3.47 \text{ ft}$

3 Analysis

3.1 2D section computations

Using the 3D CAD representation of the Swift airplane, we extracted 5 representative airfoil sections that we have used for analysis. Four of the sections were chosen at the control surface breaks in the spanwise direction for convenience, and the 5th one mid-span of the winglet.

We then used XFLR5 (a gui-interface for Xfoil, among other things) to compute the drag polars for the sections. These computations assumed viscous flow ¹, with $N_{crit}=13$ (sailplane) and forced transition at 25% of the chord (the Swift has a transition tape on its surface) and were done for a range of Reynolds Numbers. We also carried computations with the flaps deflected at different angles in order to find the effect on the section lift-coefficient, drag-coefficient and aerodynamic moment.

¹Xfoil uses the Integral Boundary Layer method

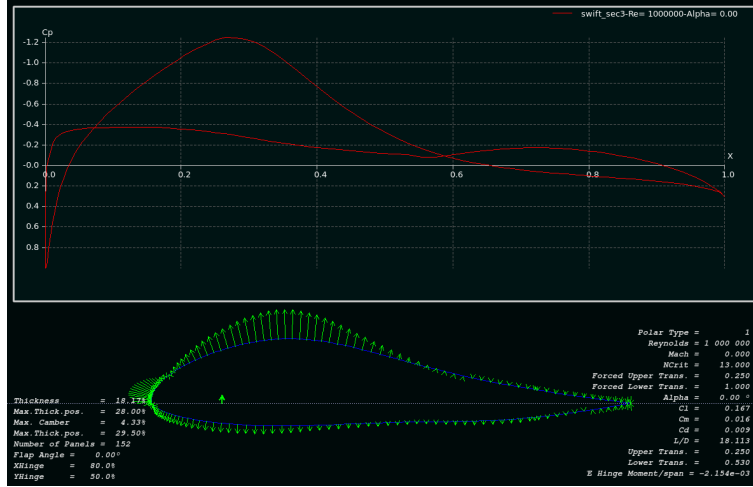


Figure 1: Sample Result from 2D section using XFOil

3.1.1 Hinge Moments

In order to size the actuators, hinge moments computations we necessary. Again, using Xfoil we computed the maximum expected hinge-moment coefficients. These were obtained by using up to 40° deflections for the flaps and 20° for the ailevons at angle of attacks past-stall (From [2] "Airfoil stall is accompanied by a rapid increase in hinge-moment coefficient. Air-flow separation over the flaps causes the hinge moment curves to become non linear and sometimes to reverse slop"). Using the surface area for each section, we converted these to moments using the worst case scenario of flying at the $V_{ne} = 120km/h$. It's worth mentioning that XFOil's hinge moments are normalized by respect to the Wing's chord $Hm = C_h q b_{flap} c_{airfoil}^2$ rather than flap chord as done in [1] $Hm = C_h q b_{flap} c_{flap}^2$. Using the correct coefficient, results were in good agreement with those computed using full CFD analysis as showed by the following table. The difference in results for ailevons is due to the fact that the CFD model used 30° deflections rather than 20°

Xfoil Results	Inner Flap	Outter Flap	Inner Ailevon	Outter Ailevon
Ch	0.46	0.46	0.2	0.2
Hinge-moment (lbs)	29.33	16.55	11.12	7.92
Actuator Force (lbs)	70.39	39.72	44.49	31.70
CFD Results				
Ch	0.376	0.395	0.381	0.410
Hinge-moment (lbs)	24.23	14.36	21.19	16.25
Actuator Force (lbs)	58.15	34.47	84.74	65.02

3.2 3D Computations

3.2.1 LinAir Method

We model the aircraft in LinAir, which solves an irrotational, inviscid, linearized flow around the airplane. The model we use is simplified in that we only make use of the root and tip sections. LinAir has the option of specifying 2D section properties, so we use the results obtained by XFOIL at a representative Reynolds Number. Unfortunately handling control derivatives is not easy in LinAir. The following table summarizes the derivatives, The input file is given in the appendix. Note that although LinAir reports the linearized drag-coefficient derivative around the current AoA, CD is not linear in AoA (i.e. CD_α is a strong function of α).

Derivatives @ $\alpha = -1.5$	CL 0.59	CD 0.023	Cm -0.005	Cy 0.0	Cn 0.0	Croll 0.0
Alpha	4.9998	0.2624	-0.7124	0.0000	0.0000	0.0000
Mach	0.0473	0.0026	-0.0028	0.0000	0.0000	0.0000
\hat{q}	6.2151	0.2421	-3.1388	0.0000	0.0000	0.0000
Beta	0.0000	0.0000	0.0000	-0.4297	0.04690	-0.1332
\hat{p}	0.0000	0.0000	0.0000	-0.1806	-0.0027	-0.6296
\hat{r}	0.0000	0.0000	0.0000	0.19370	-0.0302	0.16355

Table 1: LinAir Derivatives

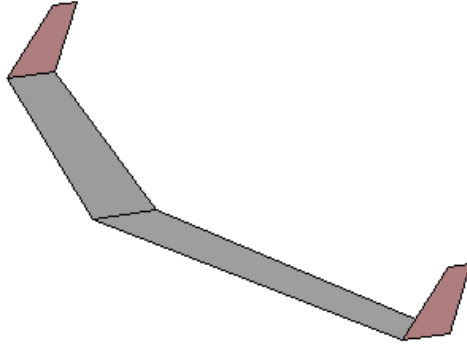


Figure 2: LinAir Geometry Snapshot

3.2.2 XFLR5 Method

XFLR5 also has an implementation of a Vortex-Lattice method similar to LinAir, but because it's able to compute the 2D section properties using Xfoil, it's relatively straightforward to add more spanwise 2D sections. Moreover, it is easy to deflect a section's trailing edge to model flap or ailevon deflections. However, the disadvantage is that it does not directly give the stability and control derivatives, nor does it handle roll, pitch and yaw rates (p, q and r) while LinAir does.

So our approach was to generate look-up tables of lift, drag and side force coefficients as well as pitch, roll and yaw moment coefficients. We then imported the data in Matlab, and assuming linear behaviour when appropriate (quadratic for drag) we used least-squares to approximate the derivatives. Let's take the lift-coefficient as an example, we know that in general

$$CL = CL_0 + CL_\alpha \alpha + CL_{\delta_f} \delta_f$$

So if we have a look-up from α and δ_f to CL , we can write this in vector form:

$$[CL]_i = [1 \ \alpha_i \ (\delta_f)_i] [CL_0 \ CL_\alpha \ CL_{\delta_f}]^T$$

If we stack all of the $[1 \ \alpha_i \ (\delta_f)_i]$ in a matrix, it is then possible to use least-squares to estimate the $[CL_0 \ CL_\alpha \ CL_{\delta_f}]$. A similar approach can be done for pitching moment, rolling moment, etc. It's worth mentioning that we assume longitudinal and lateral coefficients are decoupled (i.e. Rolling moment only depends on ailevon deflections and side-slip, and not angle of attack or flap deflections). Given that the vortex-lattice method is linear, we expect that linearizing the data should yield good results, and plots included in the appendix confirm this. The Matlab script used to extract these coefficients is also included in the appendix.

Table 2 summarizes some of the derivatives we extracted from the XFLR5 data. Flaps deflection downawrd is taken to be positive while positive ailevon deflections is taken to be such as positive rolling moment is produced (i.e. left ailevon down and right ailevon up). We have omitted the drag coefficient since it's not linear in AoA nor flap deflections over the entire range of AoA. If computation power for simulations is not an issue, we recommend using look-up tables. For analysis, we need to linearize it around trim conditions. It is also worth mentioning that all computations were only done up to beginning of stall. So if derivatives are used instead of look-up tables, one must be careful not to exceed the alpha limits, which actually depend on flap deflections (flaps increase lift-coefficient but decrease maximum AoA)

Derivatives	CL	Cm	Cy	Cn	Croll
@ $\alpha = 0$	0.6044	0.0077	0.0	0.0	0.0
Alpha	4.8594	-0.6834	-	-	-
δ_{flap1}	0.7795	0.0817	-	-	-
δ_{flap2}	0.5170	-0.1039	-	-	-
Beta	-	-	-0.3012	0.0031	-0.1322
$\delta_{ailevon1}$	-	-	0.0223	-0.0070	0.1999
$\delta_{ailevon1}$	-	-	0.0860	-0.0050	0.2078

Table 2: XFLR5 Derivatives

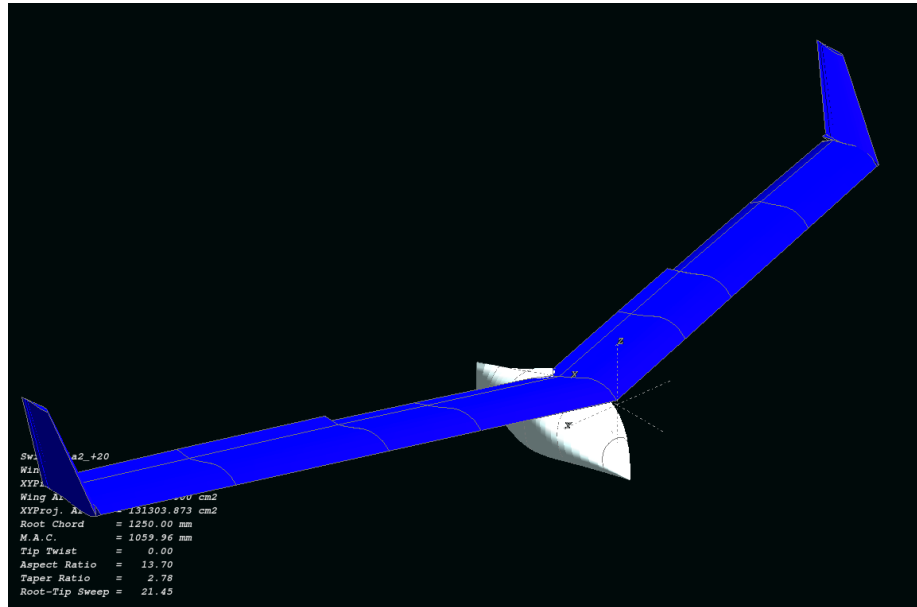


Figure 3: XFLR5 Geometry Snapshot (deflected ailevons)

3.2.3 Comparison of methods

As mentioned earlier, reference areas and lengths were chosen to match between the two models in order to facilitate comparison. Moreover, the point around which we linearize the data was chosen so that the lift coefficient matches (AoA of 0 in XFLR5 model and -1.5 in LinAir). Table 3 lists the results of the two methods next to each other.

Quantity	α	CD	CL	CL_α	Cm_α	Cy_β	Cn_β	Cl_β
Linair	-1.5	0.023	0.60	4.99	-0.71	-0.43	0.0031	-0.1332
XFLR5	0	0.022	0.59	4.86	-0.68	-0.30	0.0469	-0.1322

Table 3: LinAir - XFLR5 Comparisons

Clearly all the quantities match quite well, apart from the yawing moment. This turns out to be a limitation in XFLR5's implementation, and a report comparing calculations and experimental results concluded 'Yawing moment predictions give the correct trend - no more' [3]

Based on this comparison of results, we are left with the decision to choose between one of the models. LinAir provides us with the rate derivatives and does better in predicting yawing moment, but it uses a more simplified model and makes it hard to extract control derivatives. On the other hand, XFLR5 uses more spanwise sections with their drag polars, allows us to extract control derivatives but does not give rate derivatives and underpredicts the yawing moment. So rather than chose one of the models, we make the decision to use both: Given that the results are overall in good agreement, mixing both models should yield good results.

Our approach will be to use the look-up tables produced by XFLR5 for simulations and LinAir for dynamic analysis. The reason for this is that the look-up tables provide a simple way to account for non-linear effects (quadratic drag, forces due to control deflections and stall-limits), while the LinAir stability derivatives -augmented with the control derivatives- provide a simple way to linearize the model around an operating point and extract a state-space representation which can be used for control analysis and design.

Still need to find a concise way to represent CD as a function of CD_0 CD_α or CD_{CL} , CD_{f1} , , etc.

4 Dynamic Analysis - Work in Progress

Given the stability derivatives, construct the A and B matrices ... LinAir is capable of giving the roots (i.e. eigen values) but we want the zeros as well if we want to control So far, all of this has been dimensionless, We know need

to start talking about 'operating points', more urgently we need more accurate estimates MOMENTS OF INERTIA!!!

5 Conclusion

We used Xfoil to find 2D section properties for the Swift Uav, which was modeled in two vortex-lattice programs: LinAir and XFLR5. We compared the results of the two methods and found overall good agreement, which encouraged us in combining the results to obtain the complete stability and control derivatives for the airplane. ... more work to be done to find the state-space representation of the airplane!

References

- [1] Etkin B. Reid L., Dynamics of Flight: Stability and Control. 3rd Edition. 1996.
- [2] M. L. Spearman, Wind-tunnel investigation of control surface characteristics on NACA 0009 airfoil. Technical Note NACA-WR-L-47 November 1947
- [3] A. Deperrois, Comparison of Experimental Data to XFLR5 Results. <http://xflr5.sourceforge.net/xflr5.htm> [Retrieved November 2009]

A XFLR5 look-up tables

The following tables represent look-up tables for the Swift UAV in different configurations as a function of AoA. The last AoA given represents the limit of stall, and anything after it the wing has stalled (i.e. large increase in drag and drop in lift coefficient). The runs were done at constant lift by varying Qinf, so the 'freestream speed' line is not used.

It should be possible to interpolate between tables if done with care. For example, to find the lift coefficient with 10° of δ_{f1} and -5° of δ_{f2} , we would interpolate tables A.2 and A.5 relative to the zero-flap deflection case (A.1) to find the contribution of each flap to the increment in lift, then sum the two increments and add the contributions together. Although this is in a way already done when we extract the control derivatives.

It is important to remember that the Yawing Moment given by XFLR5 is not to be trusted. We recommend using the C_n coefficients given by LinAir instead

A.1 $\delta_{f1} = 0$, $\delta_{f2} = 0$, $\delta_{a1} = 0$, $\delta_{a2} = 0$, $\beta = 0$ (f1f2_0)

QFLR5_v.0001

Wing name : Swift_0
Wing polar name : T2-150.000 kg-VLM1-1200.00mm-proj_area
Freestream speed : 20.000 m/s

alpha	CL	ICd	PCd	TCd	CY	Cm	Rm	Ym	IYm	QInf	XCP
-5.500	0.128559	0.002816	0.009176	0.011992	0.000000	0.077399	-0.000000	-0.000000	-0.000000	37.7257	0.5528
-5.000	0.172023	0.003028	0.009242	0.012270	-0.000000	0.071109	-0.000000	-0.000000	-0.000000	32.6133	0.7546
-4.500	0.215476	0.003332	0.009374	0.012707	0.000000	0.064827	-0.000000	-0.000000	-0.000000	29.1399	0.8750
-4.000	0.258911	0.003730	0.009353	0.013083	0.000000	0.058564	-0.000000	-0.000000	-0.000000	26.5835	0.9551
-3.500	0.302320	0.004220	0.009399	0.013619	0.000000	0.052315	-0.000000	-0.000000	-0.000000	24.6011	1.0121
-3.000	0.345693	0.004802	0.009565	0.014367	0.000000	0.046080	-0.000000	0.000000	-0.000000	23.0061	1.0549
-2.500	0.389024	0.005477	0.009798	0.015275	0.000000	0.039861	-0.000000	0.000000	-0.000000	21.6870	1.0881
-2.000	0.432303	0.006243	0.010091	0.016334	0.000000	0.033659	-0.000000	0.000000	-0.000000	20.5728	1.1148
-1.500	0.475524	0.007101	0.010442	0.017543	0.000000	0.027477	-0.000000	0.000000	-0.000000	19.6156	1.1367
-1.000	0.518676	0.008050	0.010843	0.018893	-0.000000	0.021315	-0.000000	0.000000	0.000000	18.7819	1.1550
-0.500	0.561754	0.009090	0.011245	0.020334	0.000000	0.015181	-0.000000	0.000000	-0.000000	18.0474	1.1705
0.000	0.604748	0.010219	0.011614	0.021833	0.000000	0.009078	-0.000000	0.000000	0.000000	17.3941	1.1840
0.500	0.647651	0.011438	0.011945	0.023383	0.000000	0.003009	0.000000	0.000000	0.000000	16.8081	1.1957
1.000	0.690454	0.012746	0.012249	0.024995	0.000000	-0.003025	-0.000000	0.000000	-0.000000	16.2787	1.2061
1.500	0.733150	0.014141	0.012537	0.026678	0.000000	-0.009024	-0.000000	0.000000	0.000000	15.7976	1.2153
2.000	0.775730	0.015624	0.012806	0.028430	0.000000	-0.014987	0.000000	0.000000	-0.000000	15.3579	1.2236
2.500	0.818188	0.017192	0.013055	0.030247	0.000000	-0.020912	-0.000000	-0.000000	-0.000000	14.9542	1.2312
3.000	0.860515	0.018846	0.013256	0.032101	0.000000	-0.026792	-0.000000	-0.000000	-0.000000	14.5817	1.2381
3.500	0.902703	0.020583	0.013405	0.033988	-0.000000	-0.032626	-0.000000	-0.000000	0.000000	14.2369	1.2444
4.000	0.944745	0.022403	0.013513	0.035916	0.000000	-0.038411	-0.000000	-0.000000	0.000000	13.9165	1.2503
4.500	0.986633	0.024306	0.013593	0.037899	0.000000	-0.044148	-0.000000	-0.000000	-0.000000	13.6179	1.2558
5.000	1.028360	0.026288	0.013690	0.039978	-0.000000	-0.049836	-0.000000	-0.000000	0.000000	13.3388	1.2610
5.500	1.069918	0.028350	0.013825	0.042175	-0.000000	-0.055476	-0.000000	-0.000000	-0.000000	13.0772	1.2658
6.000	1.111299	0.030490	0.014004	0.044494	-0.000000	-0.061065	-0.000000	-0.000000	0.000000	12.8314	1.2704
6.500	1.152498	0.032706	0.014235	0.046940	0.000000	-0.066604	0.000000	-0.000000	-0.000000	12.5999	1.2748
7.000	1.193505	0.034996	0.014520	0.049516	0.000000	-0.072089	-0.000000	-0.000000	0.000000	12.3816	1.2790

A.2 $\delta_{f1} = -20^\circ$, $\delta_{f2} = 0$, $\delta_{a1} = 0$, $\delta_{a2} = 0$, $\beta = 0$ (f1_-20)

QFLR5_v.0001

Wing name : Swift_f1_-20
Wing polar name : T2-150.000 kg-VLM1-1200.00mm-proj_area
Freestream speed : 20.000 m/s

alpha	CL	ICd	PCd	TCd	CY	Cm	Rm	Ym	IYm	QInf	XCP
-2.500	0.104679	0.003661	0.011093	0.014754	0.000000	0.007099	-0.000000	0.000000	-0.000000	41.8080	1.1378
-2.000	0.148071	0.003937	0.011257	0.015194	-0.000000	0.000846	-0.000000	0.000000	-0.000000	35.1523	1.2021

-1.500	0.191445	0.004303	0.011337	0.015641	-0.000000	-0.005371	-0.000000	0.000000	0.000000	30.9148	1.2373
-1.000	0.234791	0.004760	0.011466	0.016227	-0.000000	-0.011560	-0.000000	0.000000	0.000000	27.9156	1.2595
-0.500	0.278103	0.005308	0.011717	0.017025	-0.000000	-0.017730	-0.000000	0.000000	0.000000	25.6499	1.2749
0.000	0.321372	0.005945	0.012200	0.018144	-0.000000	-0.023873	-0.000000	0.000000	-0.000000	23.8608	1.2863
0.500	0.364589	0.006671	0.012787	0.019458	0.000000	-0.029981	-0.000000	0.000000	0.000000	22.4020	1.2950
1.000	0.407748	0.007487	0.013323	0.020810	0.000000	-0.036050	-0.000000	-0.000000	0.000000	21.1832	1.3020
1.500	0.450839	0.008391	0.013768	0.022160	0.000000	-0.042076	-0.000000	-0.000000	-0.000000	20.1455	1.3078
2.000	0.493856	0.009384	0.014198	0.023582	-0.000000	-0.048066	-0.000000	0.000000	-0.000000	19.2481	1.3126
2.500	0.536790	0.010464	0.014597	0.025061	-0.000000	-0.054014	-0.000000	0.000000	0.000000	18.4623	1.3168
3.000	0.579633	0.011630	0.015021	0.026651	0.000000	-0.059916	-0.000000	0.000000	0.000000	17.7669	1.3205
3.500	0.622377	0.012883	0.015449	0.028331	-0.000000	-0.065768	-0.000000	0.000000	0.000000	17.1459	1.3238
4.000	0.665015	0.014220	0.015840	0.030060	0.000000	-0.071568	-0.000000	0.000000	0.000000	16.5872	1.3268
4.500	0.707539	0.015642	0.016106	0.031748	-0.000000	-0.077314	0.000000	0.000000	0.000000	16.0810	1.3296
5.000	0.749942	0.017147	0.016291	0.033437	0.000000	-0.083006	-0.000000	0.000000	-0.000000	15.6198	1.3321
5.500	0.792215	0.018734	0.016651	0.035385	0.000000	-0.088640	0.000000	0.000000	0.000000	15.1973	1.3345
6.000	0.834351	0.020402	0.016948	0.037350	-0.000000	-0.094213	-0.000000	0.000000	0.000000	14.8086	1.3368
6.500	0.876342	0.022151	0.017177	0.039327	0.000000	-0.099725	0.000000	0.000000	0.000000	14.4495	1.3390
7.000	0.918182	0.023977	0.017438	0.041415	0.000000	-0.105176	-0.000000	0.000000	0.000000	14.1164	1.3411
7.500	0.959863	0.025882	0.017752	0.043634	0.000000	-0.110566	-0.000000	0.000000	0.000000	13.8065	1.3432
8.000	1.001377	0.027862	0.018191	0.046053	0.000000	-0.115894	0.000000	0.000000	0.000000	13.5173	1.3452
8.500	1.042717	0.029918	0.018682	0.048600	-0.000000	-0.121159	0.000000	0.000000	-0.000000	13.2466	1.3471
9.000	1.083876	0.032046	0.019118	0.051164	0.000000	-0.126361	-0.000000	0.000000	-0.000000	12.9927	1.3491
9.500	1.124847	0.034246	0.019617	0.053863	0.000000	-0.131498	-0.000000	0.000000	-0.000000	12.7539	1.3510
10.000	1.165624	0.036517	0.020073	0.056590	0.000000	-0.136566	-0.000000	0.000000	-0.000000	12.5288	1.3529
10.500	1.206198	0.038855	0.020510	0.059365	0.000000	-0.141567	0.000000	0.000000	0.000000	12.3163	1.3549

A.3 $\delta_{f1} = +20^\circ$, $\delta_{f2} = 0$, $\delta_{a1} = 0$, $\delta_{a2} = 0$, $\beta = 0$ (f1_+20)

QFLR5_v.0001

Wing name : Swift_f1_+20
Wing polar name : T2-150.000 kg-VLM1-1200.00mm-proj_area
Freestream speed : 20.000 m/s

alpha	CL	ICd	PCd	TCd	CY	Cm	Rm	Ym	IYm	QInf	XCP
-8.000	0.196191	0.018157	0.012143	0.030300	0.000000	0.137161	-0.000000	-0.000000	-0.000000	30.5386	0.4156
-7.500	0.239454	0.018418	0.012091	0.030509	0.000000	0.130981	-0.000000	-0.000000	-0.000000	27.6425	0.5852
-7.000	0.282708	0.018769	0.011893	0.030662	-0.000000	0.124803	-0.000000	-0.000000	-0.000000	25.4401	0.7029
-6.500	0.325945	0.019209	0.011896	0.031105	0.000000	0.118617	-0.000000	-0.000000	-0.000000	23.6928	0.7893
-6.000	0.369157	0.019740	0.011947	0.031687	-0.000000	0.112433	-0.000000	-0.000000	-0.000000	22.2630	0.8555
-5.500	0.412336	0.020360	0.011996	0.032356	-0.000000	0.106256	-0.000000	-0.000000	-0.000000	21.0651	0.9079
-5.000	0.455473	0.021070	0.012109	0.033179	0.000000	0.100079	-0.000000	-0.000000	-0.000000	20.0427	0.9503
-4.500	0.498562	0.021869	0.012298	0.034167	0.000000	0.093903	-0.000000	-0.000000	0.000000	19.1571	0.9855
-4.000	0.541594	0.022757	0.012527	0.035285	0.000000	0.087737	-0.000000	-0.000000	-0.000000	18.3803	1.0150
-3.500	0.584560	0.023735	0.012800	0.036534	-0.000000	0.081580	-0.000000	-0.000000	0.000000	17.6919	1.0403
-3.000	0.627453	0.024800	0.013112	0.037912	-0.000000	0.075433	-0.000000	-0.000000	0.000000	17.0764	1.0622
-2.500	0.670265	0.025954	0.013459	0.039413	0.000000	0.069298	-0.000000	-0.000000	-0.000000	16.5221	1.0813
-2.000	0.712988	0.027194	0.013833	0.041027	0.000000	0.063178	-0.000000	-0.000000	-0.000000	16.0194	1.0982
-1.500	0.755614	0.028522	0.014194	0.042716	0.000000	0.057077	-0.000000	-0.000000	-0.000000	15.5610	1.1132
-1.000	0.798135	0.029935	0.014530	0.044465	0.000000	0.050999	-0.000000	-0.000000	-0.000000	15.1408	1.1267
-0.500	0.840543	0.031434	0.014846	0.046280	0.000000	0.044945	-0.000000	-0.000000	-0.000000	14.7539	1.1389
0.000	0.882831	0.033017	0.015138	0.048155	-0.000000	0.038917	0.000000	-0.000000	-0.000000	14.3963	1.1500
0.500	0.924990	0.034684	0.015404	0.050088	0.000000	0.032918	-0.000000	-0.000000	-0.000000	14.0644	1.1602
1.000	0.967014	0.036433	0.015656	0.052089	0.000000	0.026949	-0.000000	-0.000000	0.000000	13.7554	1.1695
1.500	1.008893	0.038264	0.015889	0.054153	0.000000	0.021011	-0.000000	-0.000000	0.000000	13.4668	1.1782
2.000	1.050622	0.040175	0.016118	0.056293	0.000000	0.015106	-0.000000	-0.000000	-0.000000	13.1967	1.1863
2.500	1.092191	0.042166	0.016353	0.058519	0.000000	0.009236	-0.000000	-0.000000	-0.000000	12.9431	1.1938
3.000	1.133595	0.044235	0.016611	0.060846	0.000000	0.003403	-0.000000	-0.000000	0.000000	12.7046	1.2009
3.500	1.174825	0.046380	0.016889	0.063269	0.000000	-0.002393	0.000000	-0.000000	0.000000	12.4796	1.2075

A.4 $\delta_{f1} = +30^\circ$, $\delta_{f2} = 0$, $\delta_{a1} = 0$, $\delta_{a2} = 0$, $\beta = 0$ (f1_+30)

QFLR5_v.0001

Wing name : Swift_f1_+30
Wing polar name : T2-150.000 kg-VLM1-1200.00mm-proj_area
Freestream speed : 20.000 m/s

alpha	CL	ICd	PCd	TCd	CY	Cm	Rm	Ym	IYm	QInf	XCP
-8.000	0.318264	0.031460	0.015438	0.046899	-0.000000	0.144297	-0.000000	-0.000000	-0.000000	23.9770	0.6753
-7.500	0.361158	0.031941	0.015466	0.047407	-0.000000	0.138154	-0.000000	-0.000000	-0.000000	22.5081	0.7667
-7.000	0.404026	0.032509	0.015539	0.048048	-0.000000	0.132004	-0.000000	-0.000000	-0.000000	21.2806	0.8208
-6.500	0.446860	0.033163	0.015613	0.048776	-0.000000	0.125855	-0.000000	-0.000000	0.000000	20.2350	0.8726
-6.000	0.489652	0.033904	0.015685	0.049590	-0.000000	0.119708	-0.000000	-0.000000	0.000000	19.3306	0.9154
-5.500	0.532393	0.034732	0.015775	0.050507	-0.000000	0.113565	-0.000000	-0.000000	0.000000	18.5384	0.9513
-5.000	0.575077	0.035646	0.015933	0.051579	-0.000000	0.107418	-0.000000	-0.000000	-0.000000	17.8372	0.9819
-4.500	0.617694	0.036646	0.016134	0.052779	-0.000000	0.101275	-0.000000	-0.000000	-0.000000	17.2108	1.0083
-4.000	0.660238	0.037731	0.016357	0.054087	-0.000000	0.095139	-0.000000	-0.000000	0.000000	16.6471	1.0314
-3.500	0.702700	0.038901	0.016617	0.055518	-0.000000	0.089011	-0.000000	-0.000000	0.000000	16.1363	1.0517

-3.000	0.745073	0.040156	0.016901	0.057057	-0.000000	0.082891	-0.000000	-0.000000	-0.000000	15.6707	1.0698
-2.500	0.787349	0.041494	0.017221	0.058716	-0.000000	0.076782	-0.000000	-0.000000	-0.000000	15.2442	1.0859
-2.000	0.829519	0.042916	0.017546	0.060463	-0.000000	0.070689	-0.000000	-0.000000	0.000000	14.8517	1.1005
-1.500	0.871577	0.044421	0.017873	0.062293	-0.000000	0.064613	-0.000000	-0.000000	0.000000	14.4889	1.1137
-1.000	0.913515	0.046007	0.018199	0.064206	0.000000	0.058558	-0.000000	-0.000000	-0.000000	14.1524	1.1258
-0.500	0.955324	0.047674	0.018511	0.066185	0.000000	0.052526	-0.000000	-0.000000	-0.000000	13.8393	1.1369
0.000	0.996998	0.049421	0.018824	0.068245	-0.000000	0.046517	-0.000000	-0.000000	-0.000000	13.5469	1.1471
0.500	1.038529	0.051247	0.019115	0.070362	-0.000000	0.040536	-0.000000	-0.000000	0.000000	13.2733	1.1566
1.000	1.079909	0.053151	0.019419	0.072570	0.000000	0.034581	-0.000000	-0.000000	-0.000000	13.0165	1.1654
1.500	1.121131	0.055131	0.019733	0.074864	0.000000	0.028656	-0.000000	-0.000000	-0.000000	12.7750	1.1737

A.5 $\delta_{f1} = 0$, $\delta_{f2} = -20^\circ$, $\delta_{a1} = 0$, $\delta_{a2} = 0$, $\beta = 0$ (f2_-20)

QFLR5_v.0001

Wing name : Swift_f2_-20
Wing polar name : T2-150.000 kg-VLM1-1200.00mm-proj_area
Freestream speed : 20.000 m/s

alpha	CL	ICd	PCd	TCd	CY	Cm	Rm	Ym	IYm	QInf	XCP
-3.500	0.133361	0.007269	0.010495	0.017764	-0.000000	0.086695	-0.000000	-0.000000	-0.000000	37.0402	0.4919
-3.000	0.176634	0.007508	0.010715	0.018223	-0.000000	0.080396	-0.000000	-0.000000	0.000000	32.1848	0.7034
-2.500	0.219888	0.007838	0.010920	0.018758	-0.000000	0.074110	-0.000000	0.000000	-0.000000	28.8461	0.8316
-2.000	0.263116	0.008259	0.010943	0.019202	0.000000	0.067853	-0.000000	-0.000000	-0.000000	26.3703	0.9177
-1.500	0.306310	0.008772	0.011148	0.019920	0.000000	0.061608	-0.000000	-0.000000	-0.000000	24.4404	0.9796
-1.000	0.349461	0.009375	0.011475	0.020851	-0.000000	0.055375	-0.000000	0.000000	-0.000000	22.8817	1.0262
-0.500	0.392562	0.010069	0.011877	0.021946	-0.000000	0.049155	-0.000000	0.000000	0.000000	21.5891	1.0627
0.000	0.435604	0.010853	0.012313	0.023167	0.000000	0.042956	-0.000000	0.000000	0.000000	20.4947	1.0920
0.500	0.478580	0.011727	0.012785	0.024512	-0.000000	0.036782	-0.000000	0.000000	0.000000	19.5529	1.1161
1.000	0.521481	0.012690	0.013264	0.025954	-0.000000	0.030638	-0.000000	0.000000	-0.000000	18.7314	1.1363
1.500	0.564299	0.013741	0.013759	0.027501	-0.000000	0.024524	-0.000000	0.000000	-0.000000	18.0067	1.1536
2.000	0.607027	0.014881	0.014255	0.029135	0.000000	0.018439	-0.000000	0.000000	-0.000000	17.3614	1.1685
2.500	0.649656	0.016107	0.014894	0.030701	-0.000000	0.012390	-0.000000	0.000000	-0.000000	16.7821	1.1815
3.000	0.692179	0.017420	0.014875	0.032294	0.000000	0.006379	-0.000000	0.000000	-0.000000	16.2584	1.1931
3.500	0.734589	0.018818	0.015221	0.034039	0.000000	0.000405	-0.000000	0.000000	-0.000000	15.7822	1.2034
4.000	0.776076	0.020300	0.015468	0.035768	0.000000	-0.005526	-0.000000	0.000000	-0.000000	15.3466	1.2126
4.500	0.819034	0.021866	0.015885	0.037751	0.000000	-0.011419	-0.000000	0.000000	-0.000000	14.9464	1.2211
5.000	0.861055	0.023514	0.016530	0.040045	0.000000	-0.017276	-0.000000	-0.000000	-0.000000	14.5772	1.2288
5.500	0.902931	0.025244	0.016970	0.042214	0.000000	-0.023078	-0.000000	-0.000000	-0.000000	14.2351	1.2359
6.000	0.944655	0.027054	0.017432	0.044485	0.000000	-0.028832	-0.000000	-0.000000	0.000000	13.9172	1.2424
6.500	0.986219	0.028942	0.017925	0.046867	0.000000	-0.034537	-0.000000	-0.000000	-0.000000	13.6208	1.2486
7.000	1.027616	0.030908	0.018441	0.049349	-0.000000	-0.040192	-0.000000	-0.000000	0.000000	13.3436	1.2543
7.500	1.068839	0.032950	0.018893	0.051844	0.000000	-0.045793	-0.000000	-0.000000	0.000000	13.0837	1.2598
8.000	1.109880	0.035067	0.019253	0.054320	0.000000	-0.051339	-0.000000	-0.000000	-0.000000	12.8396	1.2649
8.500	1.150733	0.037257	0.019571	0.056829	0.000000	-0.056830	-0.000000	-0.000000	0.000000	12.6096	1.2698

A.6 $\delta_{f1} = 0$, $\delta_{f2} = +20^\circ$, $\delta_{a1} = 0$, $\delta_{a2} = 0$, $\beta = 0$ (f2_+20)

QFLR5_v.0001

Wing name : Swift_f2_+20
Wing polar name : T2-150.000 kg-VLM1-1200.00mm-proj_area
Freestream speed : 20.000 m/s

alpha	CL	ICd	PCd	TCd	CY	Cm	Rm	Ym	IYm	QInf	XCP
-8.000	0.100117	0.010677	0.011414	0.022091	-0.000000	0.070122	-0.000000	0.000000	-0.000000	42.7497	0.4147
-7.500	0.143389	0.010806	0.010896	0.021702	-0.000000	0.063910	-0.000000	-0.000000	-0.000000	35.7216	0.6985
-7.000	0.186663	0.011026	0.011024	0.022050	-0.000000	0.057660	-0.000000	-0.000000	-0.000000	31.3082	0.8507
-6.500	0.229933	0.011336	0.010846	0.022182	-0.000000	0.051438	-0.000000	-0.000000	-0.000000	28.2090	0.9455
-6.000	0.273189	0.011736	0.010619	0.022355	0.000000	0.045232	-0.000000	-0.000000	-0.000000	25.8796	1.0103
-5.500	0.316424	0.012228	0.010683	0.022911	-0.000000	0.039025	-0.000000	0.000000	-0.000000	24.0466	1.0574
-5.000	0.359629	0.012809	0.010801	0.023610	-0.000000	0.032833	-0.000000	0.000000	-0.000000	22.5559	1.0932
-4.500	0.402797	0.013481	0.010976	0.024457	-0.000000	0.026652	-0.000000	0.000000	-0.000000	21.3130	1.1213
-4.000	0.445919	0.014242	0.011185	0.025428	0.000000	0.020491	-0.000000	0.000000	-0.000000	20.2563	1.1441
-3.500	0.488988	0.015094	0.011429	0.026523	-0.000000	0.014349	-0.000000	0.000000	0.000000	19.3437	1.1628
-3.000	0.531995	0.016035	0.011690	0.027725	-0.000000	0.008231	-0.000000	0.000000	0.000000	18.5453	1.1786
-2.500	0.574933	0.017065	0.011989	0.029053	-0.000000	0.002135	-0.000000	0.000000	-0.000000	17.8394	1.1921
-2.000	0.617793	0.018183	0.012326	0.030509	0.000000	-0.003937	-0.000000	0.000000	0.000000	17.2094	1.2038
-1.500	0.660568	0.019389	0.012679	0.032069	-0.000000	-0.009982	-0.000000	0.000000	-0.000000	16.6429	1.2140
-1.000	0.703249	0.020683	0.013015	0.033697	-0.000000	-0.015994	-0.000000	0.000000	-0.000000	16.1300	1.2231
-0.500	0.745828	0.022063	0.013330	0.035393	0.000000	-0.021972	-0.000000	0.000000	-0.000000	15.6628	1.2312
0.000	0.788299	0.023529	0.013628	0.037157	-0.000000	-0.027914	-0.000000	0.000000	0.000000	15.2350	1.2385
0.500	0.830652	0.025080	0.013900	0.038980	0.000000	-0.033819	-0.000000	0.000000	-0.000000	14.8415	1.2452
1.000	0.872881	0.026716	0.014150	0.040866	-0.000000	-0.039683	-0.000000	-0.000000	0.000000	14.4781	1.2513
1.500	0.914977	0.028434	0.014381	0.042815	-0.000000	-0.045506	-0.000000	-0.000000	0.000000	14.1411	1.2569
2.000	0.956933	0.030235	0.014583	0.044818	0.000000	-0.051286	-0.000000	-0.000000	0.000000	13.8276	1.2621
2.500	0.998742	0.032116	0.014750	0.046867	0.000000	-0.057018	-0.000000	-0.000000	-0.000000	13.5351	1.2670
3.000	1.040395	0.034078	0.014905	0.048982	-0.000000	-0.062703	-0.000000	-0.000000	0.000000	13.2614	1.2716
3.500	1.081886	0.036118	0.015063	0.051181	0.000000	-0.068339	-0.000000	-0.000000	0.000000	13.0046	1.2759

4.000	1.123206	0.038236	0.015251	0.053487	-0.000000	-0.073926	-0.000000	-0.000000	0.000000	12.7632	1.2800
4.500	1.164350	0.040430	0.015485	0.055914	0.000000	-0.079462	0.000000	-0.000000	0.000000	12.5356	1.2839
5.000	1.205308	0.042698	0.015775	0.058473	0.000000	-0.084949	-0.000000	-0.000000	0.000000	12.3208	1.2877

A.7 $\delta_{f1} = 0$, $\delta_{f2} = +30^\circ$, $\delta_{a1} = 0$, $\delta_{a2} = 0$, $\beta = 0$ (f2+30)

QFLR5_v.0001

Wing name : Swift_f2+30
Wing polar name : T2-150.000 kg-VLM1-1200.00mm-proj_area
Freestream speed : 20.000 m/s

alpha	CL	ICd	PCd	TCd	CY	Cm	Rm	Ym	IYm	QInf	XCP
-8.000	0.199272	0.020132	0.012887	0.033019	-0.000000	0.048475	-0.000000	-0.000000	-0.000000	30.3015	0.8999
-7.500	0.242314	0.020451	0.012886	0.033337	-0.000000	0.042279	-0.000000	-0.000000	-0.000000	27.4789	0.9815
-7.000	0.285345	0.020858	0.012870	0.033728	-0.000000	0.036094	-0.000000	-0.000000	-0.000000	25.3223	1.0384
-6.500	0.328357	0.021353	0.012930	0.034283	0.000000	0.029921	-0.000000	0.000000	-0.000000	23.6056	1.0804
-6.000	0.371341	0.021936	0.013022	0.034958	0.000000	0.023766	-0.000000	0.000000	-0.000000	22.1974	1.1127
-5.500	0.414290	0.022607	0.013123	0.035730	-0.000000	0.017629	-0.000000	0.000000	-0.000000	21.0153	1.1383
-5.000	0.457197	0.023366	0.013311	0.036676	0.000000	0.011503	-0.000000	0.000000	-0.000000	20.0049	1.1591
-4.500	0.500051	0.024212	0.013527	0.037739	-0.000000	0.005397	-0.000000	0.000000	-0.000000	19.1285	1.1764
-4.000	0.542847	0.025146	0.013771	0.038916	0.000000	-0.000686	-0.000000	0.000000	-0.000000	18.3590	1.1910
-3.500	0.585576	0.026166	0.014025	0.040191	0.000000	-0.006745	-0.000000	0.000000	-0.000000	17.6765	1.2035
-3.000	0.628230	0.027272	0.014308	0.041580	-0.000000	-0.012781	-0.000000	0.000000	-0.000000	17.0659	1.2144
-2.500	0.670802	0.028465	0.014608	0.043073	0.000000	-0.018790	-0.000000	0.000000	-0.000000	16.5155	1.2240
-2.000	0.713283	0.029743	0.014909	0.044652	0.000000	-0.024770	-0.000000	0.000000	-0.000000	16.0161	1.2325
-1.500	0.755655	0.031105	0.015201	0.046306	0.000000	-0.030716	-0.000000	0.000000	-0.000000	15.5605	1.2401
-1.000	0.797942	0.032651	0.015476	0.048027	-0.000000	-0.036628	-0.000000	0.000000	-0.000000	15.1427	1.2469
-0.500	0.840104	0.034061	0.015733	0.049814	-0.000000	-0.042503	-0.000000	0.000000	-0.000000	14.7578	1.2532
0.000	0.882146	0.035692	0.015976	0.051668	-0.000000	-0.048339	-0.000000	0.000000	-0.000000	14.4018	1.2590
0.500	0.924053	0.037385	0.016208	0.053594	0.000000	-0.054135	-0.000000	-0.000000	-0.000000	14.0714	1.2643
1.000	0.965333	0.039159	0.016428	0.055587	0.000000	-0.059889	-0.000000	-0.000000	-0.000000	13.7638	1.2692
1.500	1.007464	0.041012	0.016643	0.057655	0.000000	-0.065599	-0.000000	-0.000000	-0.000000	13.4764	1.2738
2.000	1.048944	0.042943	0.016854	0.059797	0.000000	-0.071264	-0.000000	-0.000000	-0.000000	13.2072	1.2782
2.500	1.090266	0.044952	0.017065	0.062017	0.000000	-0.076881	-0.000000	-0.000000	-0.000000	12.9546	1.2823
3.000	1.131418	0.047036	0.017290	0.064326	0.000000	-0.082448	-0.000000	-0.000000	-0.000000	12.7168	1.2862
3.500	1.172398	0.049195	0.017553	0.066748	0.000000	-0.087967	-0.000000	-0.000000	-0.000000	12.4925	1.2899
4.000	1.213198	0.051427	0.017862	0.069289	-0.000000	-0.093434	0.000000	-0.000000	0.000000	12.2807	1.2935

A.8 $\delta_{f1} = 0$, $\delta_{f2} = 0$, $\delta_{a1} = +20^\circ$, $\delta_{a2} = 0$, $\beta = 0$ (a1+20)

QFLR5_v.0001

Wing name : Swift_a1+20
Wing polar name : T2-150.000 kg-VLM1-1200.00mm-proj_area
Freestream speed : 20.000 m/s

alpha	CL	ICd	PCd	TCd	CY	Cm	Rm	Ym	IYm	QInf	XCP
-5.500	0.137520	0.013647	0.011244	0.024891	0.010945	0.073361	0.070242	0.000510	0.000189	36.4758	0.6045
-5.000	0.180646	0.013884	0.011406	0.025290	0.010705	0.067160	0.070247	0.000271	-0.000036	31.8254	0.7839
-4.500	0.223760	0.014211	0.011454	0.025665	0.010464	0.060979	0.070246	0.000053	-0.000262	28.5955	0.8941
-4.000	0.266854	0.014627	0.011505	0.026132	0.010222	0.054810	0.070241	-0.000191	-0.000488	26.1849	0.9688
-3.500	0.309920	0.015133	0.011675	0.026808	0.009977	0.048652	0.070231	-0.000447	-0.000714	24.2976	1.0227
-3.000	0.352951	0.015728	0.011963	0.027691	0.009731	0.042504	0.070217	-0.000684	-0.000939	22.7683	1.0635
-2.500	0.395937	0.016412	0.012261	0.028673	0.009484	0.036377	0.070198	-0.000923	-0.001165	21.4969	1.0955
-2.000	0.438872	0.017185	0.012563	0.029748	0.009236	0.030271	0.070174	-0.001165	-0.001391	20.4183	1.1213
-1.500	0.481747	0.018046	0.012908	0.030954	0.008986	0.024186	0.070146	-0.001401	-0.001616	19.4885	1.1425
-1.000	0.524554	0.018995	0.013300	0.032295	0.008734	0.018124	0.070113	-0.001628	-0.001840	18.6764	1.1603
-0.500	0.567285	0.020031	0.013725	0.033757	0.008482	0.012089	0.070076	-0.001839	-0.002064	17.9592	1.1756
0.000	0.609933	0.021155	0.014164	0.035318	0.008229	0.006082	0.070034	-0.002044	-0.002288	17.3200	1.1887
0.500	0.652489	0.022364	0.014611	0.036975	0.007975	0.000105	0.069988	-0.002238	-0.002510	16.7456	1.2003
1.000	0.694946	0.023659	0.015044	0.038703	0.007719	-0.005839	0.069937	-0.002431	-0.002731	16.2260	1.2105
1.500	0.737296	0.025038	0.015409	0.040447	0.007463	-0.011743	0.069881	-0.002633	-0.002952	15.7531	1.2196
2.000	0.779531	0.026501	0.015673	0.042175	0.007207	-0.017605	0.069821	-0.002854	-0.003171	15.3205	1.2278
2.500	0.821644	0.028048	0.015889	0.043937	0.006949	-0.023425	0.069756	-0.003078	-0.003389	14.9227	1.2353
3.000	0.863627	0.029676	0.016061	0.045737	0.006691	-0.029202	0.069687	-0.003302	-0.003605	14.5554	1.2422
3.500	0.905472	0.031385	0.016215	0.047600	0.006432	-0.034936	0.069613	-0.003522	-0.003820	14.2151	1.2485
4.000	0.947171	0.033174	0.016345	0.049519	0.006173	-0.040623	0.069534	-0.003747	-0.004033	13.8987	1.2543
4.500	0.988718	0.035042	0.016562	0.051603	0.005914	-0.046269	0.069451	-0.003955	-0.004245	13.6035	1.2598
5.000	1.030105	0.036987	0.016832	0.053819	0.005654	-0.051869	0.069364	-0.004160	-0.004454	13.3275	1.2649
5.500	1.071325	0.039008	0.017071	0.056079	0.005395	-0.057418	0.069271	-0.004384	-0.004662	13.0686	1.2697
6.000	1.112370	0.041104	0.017363	0.058467	0.005135	-0.062917	0.069175	-0.004610	-0.004867	12.8252	1.2743
6.500	1.153234	0.043273	0.017770	0.061043	0.004875	-0.068370	0.069073	-0.004824	-0.005070	12.5959	1.2787

A.9 $\delta_{f1} = 0$, $\delta_{f2} = 0$, $\delta_{a1} = 0$, $\delta_{a2} = +20^\circ$, $\beta = 0$ (a2_+20)

QFLR5_v.0001

Wing name : Swift_a2_+20
Wing polar name : T2-150.000 kg-VLM1-1200.00mm-proj_area
Freestream speed : 20.000 m/s

alpha	CL	ICd	PCd	TCd	CY	Cm	Rm	Ym	IYm	QInf	XCP
-5.000	0.177272	0.011795	0.010995	0.022790	0.032415	0.066859	0.072903	0.001886	0.001410	32.1268	0.7807
-4.500	0.220464	0.012156	0.011051	0.023207	0.032249	0.060698	0.072925	0.001582	0.001133	28.8084	0.8931
-4.000	0.263635	0.012607	0.010921	0.023527	0.032077	0.054566	0.072943	0.001237	0.000855	26.3443	0.9687
-3.500	0.306777	0.013147	0.011066	0.024213	0.031900	0.048425	0.072955	0.000938	0.000576	24.4218	1.0230
-3.000	0.349881	0.013777	0.011310	0.025087	0.031719	0.042298	0.072963	0.000631	0.000296	22.8680	1.0640
-2.500	0.392941	0.014496	0.011588	0.026084	0.031533	0.036190	0.072967	0.000317	0.000016	21.5787	1.0961
-2.000	0.435948	0.015304	0.011906	0.027210	0.031342	0.030102	0.072966	0.000009	-0.000265	20.4867	1.1218
-1.500	0.478894	0.016200	0.012265	0.028465	0.031147	0.024035	0.072960	-0.000290	-0.000546	19.5465	1.1431
-1.000	0.521770	0.017185	0.012652	0.029837	0.030947	0.017993	0.072950	-0.000580	-0.000827	18.7262	1.1609
-0.500	0.564570	0.018257	0.013064	0.031321	0.030743	0.011976	0.072935	-0.000860	-0.001108	18.0024	1.1761
0.000	0.607285	0.019416	0.013490	0.032905	0.030534	0.005985	0.072916	-0.001126	-0.001389	17.3577	1.1892
0.500	0.649908	0.020661	0.013914	0.034575	0.030321	0.000025	0.072893	-0.001382	-0.001670	16.7789	1.2007
1.000	0.692429	0.021991	0.014322	0.036313	0.030104	-0.005901	0.072865	-0.001629	-0.001950	16.2555	1.2108
1.500	0.734843	0.023406	0.014657	0.038063	0.029883	-0.011786	0.072832	-0.001890	-0.002230	15.7794	1.2199
2.000	0.777141	0.024905	0.014951	0.039856	0.029657	-0.017633	0.072796	-0.002154	-0.002508	15.3440	1.2281
2.500	0.819315	0.026487	0.015190	0.041677	0.029427	-0.023436	0.072755	-0.002419	-0.002786	14.9439	1.2355
3.000	0.861358	0.028151	0.015350	0.043501	0.029193	-0.029193	0.072709	-0.002701	-0.003063	14.5746	1.2423
3.500	0.903262	0.029896	0.015460	0.045355	0.028956	-0.034903	0.072659	-0.002984	-0.003338	14.2325	1.2486
4.000	0.945019	0.031720	0.015546	0.047266	0.028714	-0.040567	0.072605	-0.003264	-0.003612	13.9145	1.2544
4.500	0.986623	0.033623	0.015618	0.049241	0.028469	-0.046184	0.072546	-0.003548	-0.003885	13.6180	1.2598
5.000	1.028065	0.035603	0.015723	0.051326	0.028219	-0.051754	0.072483	-0.003832	-0.004156	13.3407	1.2649
5.500	1.069339	0.037659	0.015887	0.053546	0.027967	-0.057278	0.072416	-0.004113	-0.004425	13.0807	1.2698
6.000	1.110438	0.039790	0.016108	0.055898	0.027710	-0.062754	0.072344	-0.004394	-0.004692	12.8363	1.2743
6.500	1.151353	0.041994	0.016386	0.058380	0.027451	-0.068179	0.072269	-0.004673	-0.004957	12.6062	1.2787
7.000	1.192078	0.044270	0.016731	0.061001	0.027187	-0.073553	0.072189	-0.004952	-0.005220	12.3890	1.2828

A.10 $\delta_{f1} = 0$, $\delta_{f2} = 0$, $\delta_{a1} = 0$, $\delta_{a2} = 0$, $\beta = -4^\circ$ (beta_4)

QFLR5_v.0001

Wing name : Swift_0
Wing polar name : T2-150.000 kg-VLM1-1200.00mm-b4.0-proj_area
Freestream speed : 20.000 m/s

alpha	CL	ICd	PCd	TCd	CY	Cm	Rm	Ym	IYm	QInf	XCP
-5.500	0.130337	0.003298	0.009172	0.012469	0.022665	0.074541	0.003312	-0.000142	-0.000168	37.4675	0.5907
-5.000	0.173624	0.003511	0.009241	0.012753	0.022134	0.068414	0.003623	-0.000154	-0.000179	32.4626	0.7794
-4.500	0.216899	0.003818	0.009377	0.013195	0.021640	0.062294	0.003936	-0.000174	-0.000187	29.0442	0.8928
-4.000	0.260152	0.004218	0.009352	0.013570	0.021185	0.056195	0.004251	-0.000191	-0.000193	26.5201	0.9685
-3.500	0.303376	0.004711	0.009405	0.014116	0.020767	0.050111	0.004568	-0.000200	-0.000197	24.5583	1.0227
-3.000	0.346562	0.005297	0.009564	0.014861	0.020389	0.044041	0.004887	-0.000203	-0.000199	22.9772	1.0634
-2.500	0.389703	0.005975	0.009789	0.015764	0.020049	0.037988	0.005208	-0.000200	-0.000200	21.6681	1.0951
-2.000	0.432790	0.006745	0.010072	0.016817	0.019747	0.031954	0.005530	-0.000190	-0.000198	20.5613	1.1206
-1.500	0.475815	0.007606	0.010424	0.018030	0.019485	0.025937	0.005853	-0.000181	-0.000195	19.6096	1.1415
-1.000	0.518770	0.008560	0.010828	0.019388	0.019261	0.019941	0.006178	-0.000176	-0.000190	18.7802	1.1590
-0.500	0.561647	0.009603	0.011229	0.020832	0.019076	0.013973	0.006503	-0.000169	-0.000182	18.0491	1.1740
0.000	0.604438	0.010737	0.011594	0.022331	0.018931	0.008038	0.006829	-0.000159	-0.000173	17.3985	1.1869
0.500	0.647134	0.011960	0.011922	0.023882	0.018824	0.002136	0.007156	-0.000146	-0.000163	16.8148	1.1982
1.000	0.689729	0.013272	0.012232	0.025504	0.018756	-0.003732	0.007482	-0.000134	-0.000150	16.2873	1.2081
1.500	0.732214	0.014672	0.012531	0.027202	0.018728	-0.009565	0.007810	-0.000124	-0.000136	15.8077	1.2171
2.000	0.774581	0.016158	0.012807	0.028965	0.018738	-0.015362	0.008137	-0.000112	-0.000119	15.3693	1.2251
2.500	0.816822	0.017731	0.013054	0.030785	0.018788	-0.021120	0.008464	-0.000094	-0.000102	14.9666	1.2324
3.000	0.858930	0.019388	0.013258	0.032646	0.018876	-0.026834	0.008790	-0.000075	-0.000082	14.5952	1.2391
3.500	0.900897	0.021130	0.013412	0.034542	0.019004	-0.032501	0.009116	-0.000054	-0.000061	14.2512	1.2453
4.000	0.942715	0.022954	0.013520	0.036474	0.019171	-0.038121	0.009441	-0.000032	-0.000038	13.9315	1.2510
4.500	0.984377	0.024859	0.013602	0.038462	0.019376	-0.043692	0.009765	-0.000008	-0.000013	13.6335	1.2563
5.000	1.025875	0.026845	0.013691	0.040536	0.019621	-0.049215	0.010088	0.000018	0.000013	13.3549	1.2614
5.500	1.067201	0.028910	0.013815	0.042725	0.019905	-0.054689	0.010410	0.000045	0.000040	13.0938	1.2661
6.000	1.108349	0.031052	0.013989	0.045040	0.020227	-0.060114	0.010730	0.000073	0.000069	12.8484	1.2706
6.500	1.149312	0.033270	0.014210	0.047480	0.020588	-0.065488	0.011048	0.000102	0.000100	12.6174	1.2749

A.11 $\delta_{f1} = 0$, $\delta_{f2} = 0$, $\delta_{a1} = 0$, $\delta_{a2} = 0$, $\beta = -8^\circ$ (beta_8)

QFLR5_v.0001

Wing name : Swift_0
Wing polar name : T2-150.000 kg-VLM1-1200.00mm-b8.0-proj_area
Freestream speed : 20.000 m/s

alpha	CL	ICd	PCd	TCd	CY	Cm	Rm	Ym	IYm	QInf	XCP
-5.500	0.138405	0.005090	0.009180	0.014271	0.047836	0.069489	0.010471	-0.000517	-0.000567	36.3591	0.6800
-5.000	0.181136	0.005315	0.009287	0.014602	0.046843	0.064025	0.011125	-0.000539	-0.000583	31.7824	0.8337
-4.500	0.223849	0.005632	0.009405	0.015037	0.045921	0.058571	0.011783	-0.000564	-0.000595	28.5898	0.9288
-4.000	0.266536	0.006044	0.009372	0.015416	0.045072	0.053141	0.012445	-0.000585	-0.000602	26.2005	0.9934
-3.500	0.309189	0.006548	0.009428	0.015976	0.044294	0.047724	0.013110	-0.000593	-0.000604	24.3263	1.0402
-3.000	0.351799	0.007146	0.009567	0.016713	0.043590	0.042324	0.013779	-0.000591	-0.000602	22.8056	1.0757
-2.500	0.394358	0.007836	0.009767	0.017603	0.042958	0.036942	0.014449	-0.000575	-0.000595	21.5399	1.1037
-2.000	0.436859	0.008618	0.010050	0.018668	0.042400	0.031576	0.015123	-0.000566	-0.000584	20.4653	1.1262
-1.500	0.479293	0.009493	0.010413	0.019906	0.041914	0.026227	0.015798	-0.000538	-0.000569	19.5384	1.1449
-1.000	0.521651	0.010458	0.010804	0.021262	0.041502	0.020899	0.016474	-0.000519	-0.000549	18.7283	1.1606
-0.500	0.563927	0.011515	0.011196	0.022711	0.041164	0.015599	0.017152	-0.000497	-0.000524	18.0126	1.1740
0.000	0.606112	0.012661	0.011564	0.024225	0.040899	0.010330	0.017830	-0.000471	-0.000495	17.3745	1.1856
0.500	0.648198	0.013897	0.011911	0.025807	0.040707	0.005091	0.018509	-0.000445	-0.000462	16.8010	1.1959
1.000	0.690178	0.015221	0.012234	0.027455	0.040590	-0.000120	0.019188	-0.000421	-0.000423	16.2820	1.2050
1.500	0.732042	0.016632	0.012539	0.029171	0.040546	-0.005290	0.019867	-0.000383	-0.000381	15.8096	1.2131
2.000	0.773784	0.018130	0.012817	0.030948	0.040576	-0.010424	0.020545	-0.000338	-0.000334	15.3772	1.2205
2.500	0.815396	0.019714	0.013068	0.032782	0.040680	-0.015520	0.021223	-0.000283	-0.000282	14.9797	1.2272
3.000	0.856870	0.021383	0.013274	0.034657	0.040857	-0.020574	0.021898	-0.000224	-0.000227	14.6127	1.2334
3.500	0.898199	0.023134	0.013431	0.036565	0.041108	-0.025583	0.022572	-0.000159	-0.000166	14.2726	1.2391
4.000	0.939374	0.024968	0.013541	0.038509	0.041433	-0.030546	0.023244	-0.000090	-0.000102	13.9563	1.2444
4.500	0.980388	0.026863	0.013625	0.040507	0.041831	-0.035464	0.023914	-0.000020	-0.000033	13.6612	1.2494
5.000	1.021235	0.028877	0.013708	0.042585	0.042303	-0.040335	0.024580	0.000053	0.000040	13.3852	1.2541
5.500	1.061906	0.030949	0.013814	0.044763	0.042848	-0.045160	0.025244	0.000126	0.000118	13.1264	1.2586
6.000	1.102394	0.033098	0.013964	0.047062	0.043466	-0.049939	0.025903	0.000203	0.000199	12.8831	1.2629
6.500	1.142693	0.035322	0.014164	0.049486	0.044157	-0.054670	0.026559	0.000285	0.000285	12.6539	1.2669

B Matlab script for XFLR5 data

B.1 Comparison of Linearized data with Look-up tables

The following three graphs show lift-coefficient, pitching-moment and rolling-moments as a function of AoA for different flap and ailevon settings. The solid lines represent the data from XFLR5 while the 'x' points are the values interpolated using the derivatives extracted from the Matlab script.

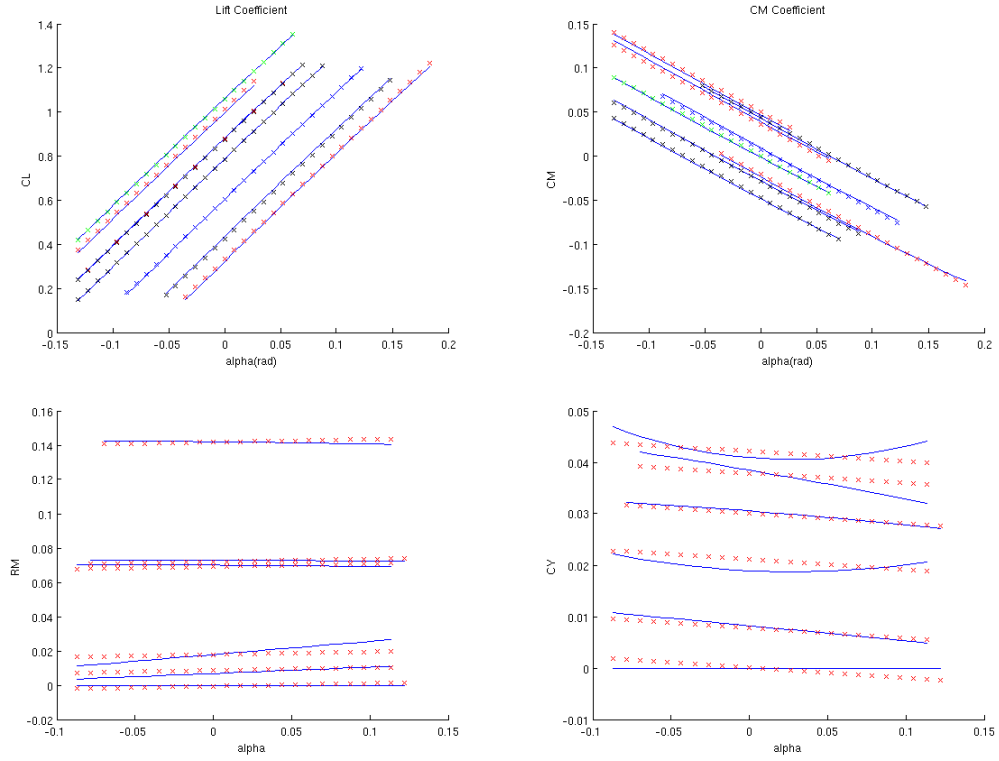


Figure 4: XFLR5 coefficients compared to results from derivative extraction


```

%post process

%Put in names of the data files
filenames = {'f1f2_0.txt','f1_-20.txt', 'f1_+20.txt','f1_+30.txt',...
             'f2_-20.txt', 'f2_+20.txt','f2_+30.txt',...
             'f1f2_20.txt', ...
             'a1_+20.txt', 'a2_+20.txt','a1a2_+20.txt',...
             'beta_4.txt', 'beta_8.txt' };
colors = {'bx','rx','ro','r+','kx','ko','k+','gx'};
%And the associated surface control variables
d_f1 = [0, -20, +20, + 30, 0 , 0, 0, +20, 0 , 0 , 0 , 0, 0]; %inner flap
d_f2 = [0, 0 , 0, 0, -20,+20,+30, +20, 0 , 0 , 0 , 0, 0]; %outter flap
d_a1 = [0, 0 , 0, 0, 0, 0, 0, 0, 0, +20, 0 ,+20, 0, 0]; %inner ailevon
d_a2 = [0, 0 , 0, 0, 0, 0, 0, 0, 0, 0, +20,+20, 0, 0]; %outter ailevon
beta = [0, 0 , 0, 0, 0, 0, 0, 0, 0, 0, 0, -4, -8]; %sideslip

%Parse in the data
nlon = 1:8;
nlat = [1,9:13];
for i = 1:13

    Configurations(i).d_con = ...
        deg2rad([(d_f1(i)), (d_f2(i)), (d_a1(i)), (d_a2(i)), (beta(i))]);

    polar = importdata(filenames{i},' ', 9); %skipping first 9 lines
    Configurations(i).alpha = deg2rad(polar.data(:,1)); %AoA
    Configurations(i).CL = polar.data(:,2); %Lift coefficient
    Configurations(i).CD = polar.data(:,5); %Drag coefficient
    Configurations(i).CY = polar.data(:,6); %Side force
    Configurations(i).CM = polar.data(:,7); %Pitching moment
    Configurations(i).RM = polar.data(:,8); %Rolling moment
    Configurations(i).YM = polar.data(:,9); %Yawing moment
end

%%
%Let's find longitudinal derivatives using least squares
CL_vec = []; CM_vec = []; CD_vec = [];
m = 0;
A = []; A_cd = [];
for i = nlon
    mi = length(Configurations(i).alpha);
    CL_vec = [CL_vec ; Configurations(i).CL];
    CM_vec = [CM_vec ; Configurations(i).CM];
    CD_vec = [CD_vec ; Configurations(i).CD];
    % CL0 * 1 + CLalpha * alpha + CLdf1 * d_f1 + .....
    % Cm0 * 1 + Cmalpha * alpha + Cmdf1 * d_f1 + ...
    A = [A ; [ones(mi,1), Configurations(i).alpha, ...
        repmat(Configurations(i).d_con(1:5),mi,1)]];

    % CD0 + CDCL1 * CL + CDCL2 * CL^2 + CDdf1*df1^2
    A_cd = [A_cd; [ones(mi,1), Configurations(i).CL, ...
        Configurations(i).CL.^2, ...
        repmat(Configurations(i).d_con(1:2),mi,1).^2]];
    m = m + mi;
end

```

```

%least squares
CLCM_der = pinv(A)*[CL_vec, CM_vec];
CD_der = pinv(A_cd) * CD_vec;

%Extracting the derivatives
CL_0 = CLCM_der(1,1);
CL_alpha = CLCM_der(2,1);
CL_df1 = CLCM_der(3,1);
CL_df2 = CLCM_der(4,1);

CM_0 = CLCM_der(1,2);
CM_alpha = CLCM_der(2,2);
CM_df1 = CLCM_der(3,2);
CM_df2 = CLCM_der(4,2);

CD_0 = CD_der(1);
CD_CL1 = CD_der(2);
CD_CL2 = CD_der(3);
CD_df1 = CD_der(4);
CD_df2 = CD_der(5);

fprintf('CL_0= %f , CL_alpha = %f, CL_df1=%f, CL_df2=%f\n',...
        CL_0,CL_alpha,CL_df1,CL_df2);
fprintf('CM_0= %f , CM_alpha = %f, CM_df1=%f, CM_df2=%f\n',...
        CM_0,CM_alpha,CM_df1,CM_df2);
fprintf('CD_0= %f , CD_CL1 = %f, CD_CL2=%f, CD_df1=%f, CD_df2=%f\n',...
        CD_0,CD_CL1,CD_CL2,CD_df1,CD_df2);

%%
%Let's find the lateral derivatives
CY_vec = []; RM_vec = []; YM_vec = [];
m = 0;
A = [];
for i = nlat
    mi = length(Configurations(i).alpha);
    CY_vec = [CY_vec ; Configurations(i).CY];
    RM_vec = [RM_vec ; Configurations(i).RM];
    YM_vec = [YM_vec ; Configurations(i).YM];
    %      CY_0*1 + CY_alpha*alpha + CY_da1*d_a1 + CY_da2*d_a2+ CY_beta*beta
    %      RM_0*1 + RM_alpha*alpha + RM_da1*d_a1 + RM_da2*d_a2+ RM_beta*beta
    %      YM_0*1 + YM_alpha*alpha + YM_da1*d_a1 + YM_da2*d_a2+ YM_beta*beta
    A = [A ; [ones(mi,1), repmat(Configurations(i).d_con(3:5),mi,1) ...
                                ,Configurations(i).alpha]];

    m = m + mi;
end

%Least-squares
CYRMYM_der = pinv(A)*[CY_vec, RM_vec, YM_vec];
%Extracting the right derivatives ...
CY_0 = CYRMYM_der(1,1);
CY_da1 = CYRMYM_der(2,1);
CY_da2 = CYRMYM_der(3,1);
CY_beta = CYRMYM_der(4,1);

```

```

CY_alpha = CYRMYM_der(5,1);

RM_0 = CYRMYM_der(1,2);
RM_da1 = CYRMYM_der(2,2);
RM_da2 = CYRMYM_der(3,2);
RM_beta = CYRMYM_der(4,2);
RM_alpha = CYRMYM_der(5,2);

YM_0 = CYRMYM_der(1,3);
YM_da1 = CYRMYM_der(2,3);
YM_da2 = CYRMYM_der(3,3);
YM_beta = CYRMYM_der(4,3);
YM_alpha = CYRMYM_der(5,3);

fprintf('CY_0= %f , CY_beta = %f,CY_alpha=%f, CY_da1=%f, CY_da2=%f\n',...
        CY_0,CY_beta,CY_alpha,CY_da1,CY_da2);
fprintf('RM_0= %f , RM_beta = %f,RM_alpha=%f, RM_da1=%f, RM_da2=%f\n',...
        RM_0,RM_beta,RM_alpha,RM_da1,RM_da2);
fprintf('YM_0= %f , YM_beta = %f,YM_alpha=%f, YM_da1=%f, YM_da2=%f\n',...
        YM_0,YM_beta,YM_alpha,YM_da1,YM_da2);

%%
%Plotting for good measure ...
colors = {'b','r','r','r','k','k','k','g'};

figure(); hold on;
for k = nlon
plot(Configurations(k).alpha,Configurations(k).CL,'b');
plot(Configurations(k).alpha,CL_0 + CL_alpha * Configurations(k).alpha ...
        + CL_df1 * Configurations(k).d_con(1)...
        + CL_df2 * Configurations(k).d_con(2),...
        [colors{k},'x']);
end
xlabel('alpha(rad)'); ylabel('CL'); title('Lift Coefficient');

%%

figure(); hold on;
for k = nlon
plot(Configurations(k).alpha,Configurations(k).CM,'b');
plot(Configurations(k).alpha,CM_0 + CM_alpha * Configurations(k).alpha ...
        + CM_df1 * Configurations(k).d_con(1)...
        + CM_df2 * Configurations(k).d_con(2),...
        [colors{k},'x']);
end
xlabel('alpha(rad)'); ylabel('CM'); title('CM Coefficient');

%%

figure(); hold on;
for k = nlon
plot(Configurations(k).CL,Configurations(k).CD,[colors{k},'--']);
plot(Configurations(k).CL,CD_0 + CD_CL1 * Configurations(k).CL ...
        + CD_CL2 * Configurations(k).CL.^2 ...
        + CD_df1 * Configurations(k).d_con(1)^2 ...
        + CD_df2 * Configurations(k).d_con(2)^2,...
        [colors{k},'x']);

```

```

end
xlabel('CL'); ylabel('CD')

%%
%Lateral derivatives
figure(); hold on;
for k = nlat
plot(Configurations(k).alpha,Configurations(k).CY,'b');
plot(Configurations(k).alpha,CY_0 + CY_beta * Configurations(k).d_con(5) ...
      + CY_da1 * Configurations(k).d_con(3)...
      + CY_da2 * Configurations(k).d_con(4)...
      + CY_alpha * Configurations(k).alpha , 'rx');

end
xlabel('alpha'); ylabel('CY');

%%

figure(); hold on;
for k = nlat
plot(Configurations(k).alpha,Configurations(k).RM,'b');
plot(Configurations(k).alpha,RM_0 + RM_beta * Configurations(k).d_con(5) ...
      + RM_da1 * Configurations(k).d_con(3)...
      + RM_da2 * Configurations(k).d_con(4)...
      + RM_alpha * Configurations(k).alpha , 'rx');

end
xlabel('alpha'); ylabel('RM');

%%

figure(); hold on;
for k = nlat
plot(Configurations(k).alpha,Configurations(k).YM,'b');
plot(Configurations(k).alpha,YM_0 + YM_beta * Configurations(k).d_con(5) ...
      + YM_da1 * Configurations(k).d_con(3)...
      + YM_da2 * Configurations(k).d_con(4)...
      + YM_alpha * Configurations(k).alpha , 'r--');

end
xlabel('alpha'); ylabel('YM');

```

C LinAir Input File and Results

Incomplete without moments of inertia ...