Airplane	Daher Socata TBM-700A
ADS	V433

Introduction

The goal of the validation process is to determine the accuracy of the ADS's algorithms to model an airplane of a given configuration. Validation consists in comparing the results of a series of measurements made during flight tests (FT) on a particular aircraft with the results of modelling carried out with the ADS software on the same aircraft (ADS). If no flight test results are available, the data are taken from the flight manual (FM) and from the Type Certificate Data Sheet (TCDS)

The algorithms used to compute the aerodynamic, weight and balance, stability and performance are described at the end of this report.

Figure 1 – Daher Socata TBM-700A

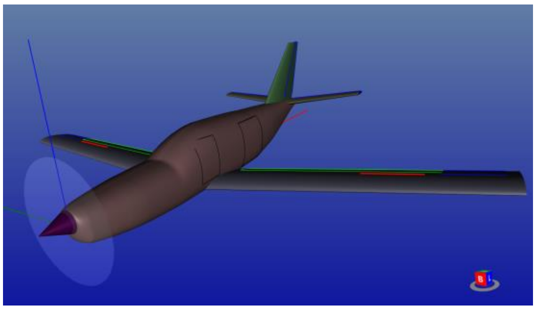

Figure 2 – Daher Socata TBM-700A 3D model

Methodology

The analysis takes place in 3 steps:

- Step 1: make the reverse engineering of the aircraft
- Step 2: calculate the performance of the aircraft for different flight conditions
- Step 3: present and comment the results

List of assumptions

- Wing incidence 2°
- Wing Center of Gravity (CG) 40%
- Wing airfoil: NLF(1)0416
- Airplane CG position 30%

List of references

- Pilot's Information Manual Daher Socata TBM-700 Versions A and B (2010)
- EASA Type Certificate for Daher Socata TBM-700

Reverse Engineering

The reverse analysis consists to generate the 3D-Model of the aircraft and to specify its characteristics and performance. The aircraft will then be analyzed in detail in order to determine its mass efficiency and its aerodynamic efficiency for different flight conditions. A large number of statistics data will be generated.

Results

Drag efficiency

From the reverse engineering, the equivalent friction drag coefficient (Cfe) and the interference drag coefficient (Cd_{int}) have been computed for different altitudes (Alt) and power settings (PS), as shown in Table 1.

Table 1 – Flight parameters for cruise condition

PS [%]	Alt [m]	V_{cr}[km/h]	**Cfe**	**Cd_{int}**
100	1524	444	**0.00424**	**8.6**
100	3048	467	**0.00425**	**6.8**
100	4572	491	**0.00431**	**6.1**
100	6096	517	**0.00447**	**7.5**
97	7620	539	**0.00452**	**6.8**
90	8230	531	**0.00463**	**9.1**
78	9144	522	**0.00452**	**7.6**

Lift efficiency

The lift efficiency is the ratio between the maximum lift coefficient (Cl_{Mx}) computed from the stall speed performance flaps up and the maximum lift coefficient computed from the theory taking into account the wing geometry. The high lift device efficiency is the ratio between the maximum lift increment (ΔCl_{Mx}) computed from the stall speed performance flaps down and the maximum lift increment computed from the theory taking into account the flap type and geometry. Lower than 1 means that the theory overestimates the value.

Table 2 – Lift efficiency

	FM	ADS	**η [%]**
Cl_{Mx}	1.72	1.70	**102.2**
ΔCl_{Mx}	0.96	1.04	**92.5**

Mass efficiency

The mass efficiency (MCF) is the ratio between the empty weight given by the manufacturer and the empty weight computed from the theory taking into account the geometry of every components of the aircraft. The theory makes the assumption that the aircraft is build with light alloy. The MCF takes into account the material but also the ability of the manufacturer to build a light structure, or not. MCF higher than 1 means that the aircraft is heavier than it should be if built with light alloy and optimized in weight.

Table 3 – Mass efficiency

MCF	**1.212**

Performance Analysis

The performance analysis consists to compute the performance of the aircraft for a specific flight condition. A flight condition is defined by the flight weight, the flight altitude, the power setting and the CG position. The total zero lift drag is computed from the interference drag coefficient which is supposed to be the same (6.1) for every flight conditions (Cruise, Takeoff (TO), Landing (Ld), Maximum Rate of Climb (RC_{Mx})).

Stall

The stall speeds (V_s) are calculated by ADS and compared with the stall speeds given in the flight manual for a specific flight condition. The stall speeds with flaps up and down computed by ADS and given by the flight manual are presented in A first fudge factor (FFClMx) is used for the flaps up flight condition to taking into account that the maximum lift coefficient of the lift curve generated by XFoil is most of the time overestimated. The second fudge factor (FFΔClMx) is used for the flaps down condition to adjust the maximum lift increment due to the flap deflection. The magnitude of both fudge factors is determined from reverse engineering and is considered to be 1.022 for the first one and 0.925 for the second in the current airplane.

Table *4*.

A first fudge factor (FF_{ClMx}) is used for the flaps up flight condition to taking into account that the maximum lift coefficient of the lift curve generated by XFoil is most of the time overestimated. The second fudge factor ($FF\Delta_{ClMx}$) is used for the flaps down condition to adjust the maximum lift increment due to the flap deflection. The magnitude of both fudge factors is determined from reverse engineering and is considered to be 1.022 for the first one and 0.925 for the second in the current airplane.

Table 4 – V_s @ 2984kg, CG @ 30% MAC, Alt @ SL, FF_{ClMx}=1.022 and $FF\Delta_{ClMx}$ =0.925

	FM	ADS	**Δ [%]**
$V_{s\ flaps\ up}$ [km/h]	141	141	**0**
$V_{s\ flaps\ down\ 100\%}$ [km/h]	113	114	**0.9**

Takeoff

The takeoff is calculated according to the runway slope and surface, headwind speed (HW), flap deflection (Flap dflct), CG position, flight weight and rotation time (Rot. T). The takeoff distance computed by ADS and given by the flight manual are presented in Table 5 for an asphalt runway.

Table 5 – Takeoff Distance considering a constant Rot. T

						FM	ADS	Δ
Rwy alt [m]	Mass [kg]	Flap dflct [º]	HW [km/h]	V_{LO} [km/h]	Rot. T [s]	TO Run [m]	TO Run [m]	TO Run [%]
0	2984	10	0	156	1	420	434	3.3
0	2984	10	22	156	1	370	383	3.5
0	2500	10	0	143	1	310	305	-1.6
0	2500	10	22	143	1	273	267	-2.2
1219	2984	10	0	166	1	530	520	-1.9
1219	2984	10	22	166	1	466	461	-1.1
1219	2500	10	0	152	1	390	364	-6.7
1219	2500	10	22	152	1	343	320	-6.7

The deviation is higher for a lighter flight weight at 914m and it increases with headwind for both flight weights at sea level. The rotation time should be within a range of values (1s to 3s) according to the literature and should be adjusted for a given aircraft in order to obtain a good accuracy in the takeoff distance. The maximum deviation is less than 7%.

Maximum Rate of Climb

The RC_{Mx} and its associated flight speed (V_y), are presented in Table 6 for a flight weight of 2984kg and in Table 7**Erreur ! Source du renvoi introuvable.** for a flight weight of 2500kg.

Table 6 – RC_{Mx} @ 2984kg, CG @ 30% MAC, Alt @SL

	FM	ADS	**Δ [%]**
V_y [km/h]	241	223	**-7.5**
RC [m/s]	9.53	9.47	**-0.6**

Table 7 – RC_{Mx} @ 2500kg, CG @ 30% MAC, Alt @SL

	FM	ADS	**Δ [%]**
V_y [km/h]	241	220	**-8.7**
RC [m/s]	12.09	12.02	**-0.6**

Cruise Speed

The computed cruise speed (ADS) for different altitudes and power settings is presented in Table 8.

Table 8 – V_{cr} @ 2800kg, CG @ 30% MAC

		FM	ADS	**Δ**
Alt [m]	PS [%]	V_{cr} [km/h]	V_{cr} [km/h]	**[%]**
1524	100	444	434	**-2.3**
3048	100	467	452	**-3.2**
4572	100	491	482	**-1.8**
6096	100	517	502	**-2.9**
7620	97	539	521	**-3.3**
8230	90	531	517	**-2.6**
9144	78	522	511	**-2.1**

Both computed values (ADS) and values taken from the flight manual (FM) are presented in Figure 3. The maximum deviation is less than 3.5%.

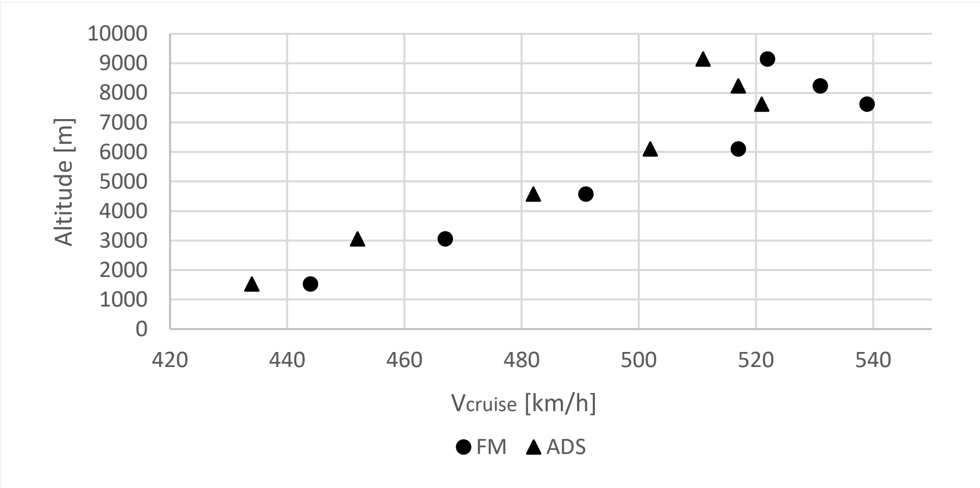

Figure 3 – Cruise speed (taken from FM and computed with ADS)

Landing

The landing distance depends on the runway surface, touchdown speed (V_{TD}) and flare time (Flr. T). The RFC (Rolling Friction Coefficient, brakes on) controls the brake action during the landing. This parameter can have a range of values [0.15 - 0.50] according to the runway surface and the pilot action on the brakes. The flare time is the time required for the aircraft to be rolling on the runway with all wheels on the surface. It starts when the main wheels hit the ground and ends as soon as the nosewheel touches the runway. The landing distance is calculated according to the runway slope and surface, headwind speed, flap deflection, CG position, flight weight and for a RFC equal to 0.15 which represents the friction coefficient on a concrete runway and low action of the pilot on the brakes. The conditions used to obtain the landing distance are presented in Table 9.

Table 9 – Landing distance considering a constant RFC=0.15

							FM	ADS	Δ
Rwy Alt [m]	Mass[kg]	Flap dflct [º]	HW [km/h]	V_{TD} [km/h]	Flr T[s]	RFC	Ld run [m]	Ld run [m]	Ld Run [%]
0	1650	42	0	141	1	0.29	310	310	0.00
0	1650	42	24	141	1	0.29	270	270	0.00
1219	1650	42	0	150	1	0.29	350	348	-0.57
1219	1650	42	24	150	1	0.29	300	307	2.33
0	1400	42	0	127	1	0.29	260	255	-1.92
0	1400	42	24	127	1	0.29	220	218	-0.91
1219	1400	42	0	135	1	0.29	295	286	-3.05
1219	1400	42	24	135	1	0.29	250	247	-1.20

The deviation is influenced by the headwind and the altitude, as shown in Figure 4**Erreur ! Source du renvoi introuvable.** for a flight weight of 2835kg and in Figure 5 for a flight weight of 2300kg. For a constant flap setting the deviation depends on the altitude, it increases with headwind in both flight weights when the altitude is 1219m and reduces with headwind when the altitude is equal to sea level. The maximum deviation is 5%.

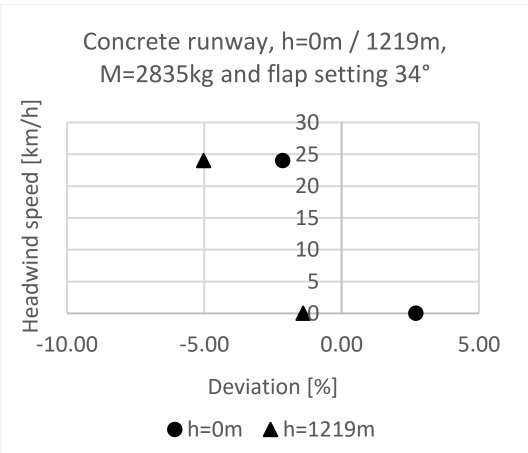

Figure 4 – Deviation in function of headwind and altitude

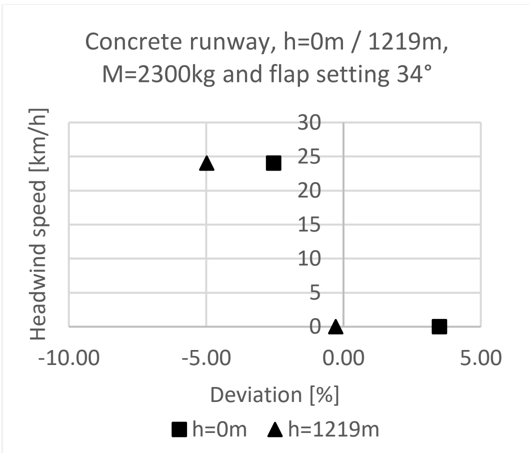

Figure 5 – Altitude and headwind versus deviation

Comments

The maximum lift is computed from the lift distribution over the lifting surface using the lifting line theory. The lift increment due to flap deflection is computed from the flap type and geometry

The total drag is computed making the sum of the drag of each component of the Aircraft, including the interference drag.

The empty weight is computed making the sum of the weight of each component of the aircraft. The weight of each component is computed from its geometry. A fudge factor may be used to take into account the material and the skills of the manufacturer.

The Center of Gravity position of the aircraft is computed from the mass and position of each component. The center of gravity is computed for different loading configuration. The CG range is computed to ensure stability and maneuverability.

The engine performance are computed from an engine database taking into account the flight conditions

The takeoff run is the distance between the brake release point and the point where the speed is equal to the liftoff speed and the plane lifts off. The mean acceleration is computed at several speeds, between these two limits, taking into account the engine thrust, the total drag, the wheel friction and the slope of the runway. The length of each segment is computed from the mean acceleration and the speed. The total distance is the sum of the distances travelled in each segment.

The rate of climb is computed at a given speed taking into account the engine thrust and the total drag of the airplane. The engine thrust is computed from the engine nominal power and takes into account the effects of altitude, the propeller efficiency and the installation efficiency. The total drag is the sum of the zero lift drag, induced drag and trim drag. The zero lift drag is computed by summing the drag of each component of the aircraft, including the interference drag.

The cruising speed is computed for a given flight condition taking into account the power setting, the flight weight, the center of gravity position and the flight altitude.

The stall speed is computed flaps up and flaps down taking into account the lift distribution on the wing. The stall is reached when one local lift coefficient reaches its maximum value. The lift distribution is computed from the lifting line theory and takes into account the airfoil profiles and the planform of the lifting surface. The aerodynamic data of each airfoil profile have been computed with XFoil.

Not included in this report but processed by ADS:

- Static stability
- Dynamic stability (free response (eigenmode), step response, harmonic response)
- Cost analysis (R&D, Operating, Breakeven, Market price)
- Optimization (performance, cost, shape)
- Sizing and location of each component/system
- Checking for interference between components

Sources

The ADSV4 computation engine is a compilation of the best algorithms, chosen for their excellent accuracy / time-to-compute ratio. The algorithms are extracted from academic & scientific publications and reference books such as USAF DATCOM, Roskam, Raymer, Torenbeek… Technical notes written by OAD complete them and are directly accessible via the software's interface

List of Symbols

ADS	Result computed by ADS	
Cd_{int}	Airplane equivalent interference drag coefficient	
Cfe	Airplane friction coefficient	
CG	Center of Gravity	% MAC
Cl_{Mx}	Maximum lift coefficient	
FF_{ClMx}	Fudge factor maximum lift coefficient	
$FF\Delta_{ClMx}$	Fudge factor maximum lift increment	
Flap dflct	Flap deflection	°
Flr. T	Landing flare time	s
FM	Value taken from the Flight Manual	
HW	Headwind speed	km/h
Ld_{Run}	Landing run	m
MCF	Mass efficiency	
PS	Engine Power Setting	%
RC_{Mx}	Maximum Rate of Climb	m/s
RCF	Rolling friction coefficient	
Rot. T	Rotation time during takeoff	s
Rwy Alt	Runway altitude	m
TO_{Run}	Takeoff run	m
V_{cr}	Cruise Speed	km/h
V_{LO}	Liftoff Speed	km/h
V_S	Stall Speed	km/h
V_{TD}	Touchdown Speed	km/h
V_Y	Speed for best rate of climb	km/h
Δ	(ADS-FM)/FM	%
ΔCl_{Mx}	Maximum lift increment	