AEM 495 MEMO

Subject:	Preliminary aerodynamics analysis of an unofficial Cessna Citation geometry		
TO:	AEM 495 Students	**Date:**	1 Sept 2014
CC:		**Memo:**	AEM495-14-M02
		From:	Charles O'Neill
REF:	Citation2-v4.CATPart	**Ext:**	8-5161

Summary:

The reverse engineered Cessna Citation 2 geometry is neither suited for a low speed or high speed wind tunnel test. It is recommended that a CAD redesign be conducted before additional testing and expense.

The aircraft exhibited significant aerodynamic problems.

1. The current wing airfoil produces excessive shocks and reduced stability; a supercritical airfoil is suggested.
2. A redesign of the wing root will be necessary. The local flow exhibits excessive stagnation point movement and poor separation performance. Separation currently negatively affects the engine inlet and fan-face flow.
3. The loft in the canopy area contains a non-tangential surface match. A local shock and separation is present at higher Mach numbers.
4. The pylon connecting the engine nacelle and aft fuselage is poorly matched to the local streamlines. Shocks and separation are present at cruise conditions. The pylon should be reshaped.
5. In general over the tested conditions, the pressure contours and streamlines are not particularly smooth. The aerodynamic efficiency appears fairly poor.

Discussion:

This memo concerns a reverse engineered CAD model of the Cessna Citation 2. The objective of this memo is to provide a quick evaluation of the model with respect to the aerodynamics.

The model was supplied in a .STEP format by GrabCAD.com. It should be noted that the loft geometry presented is **not** an official Cessna geometry; the geometry was solely determined by reverse engineering. The as-supplied model required moderate loft-cleanup and surface trimming with CATIA. The cleaned model is illustrated in Figure 1. The forward hatch area was particularly difficult as the original model attempted to represent the hatch gaps with a tangential double fillet.

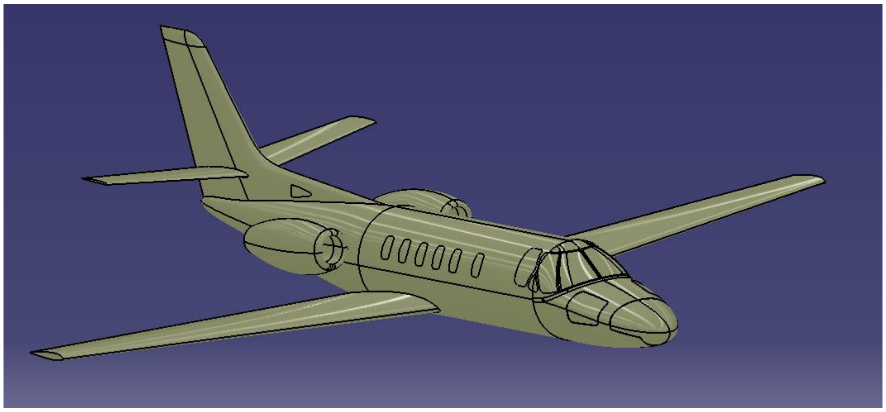

Figure 1: Citation CAD model (full aircraft)

A significant loft issue in the canopy area was spotted with zebra lighting (see Figure 2) at the intersection of the cylindrical fuselage and the complex canopy surface. From the zebra lighting, this region does **not** appear to be either tangentially or curvature constrained. **This canopy loft issue will appear as a local accelerated flow region with detrimental downstream separation**. A comparison with the actual Citation surface reveals that the current CAD model poorly represents reality.

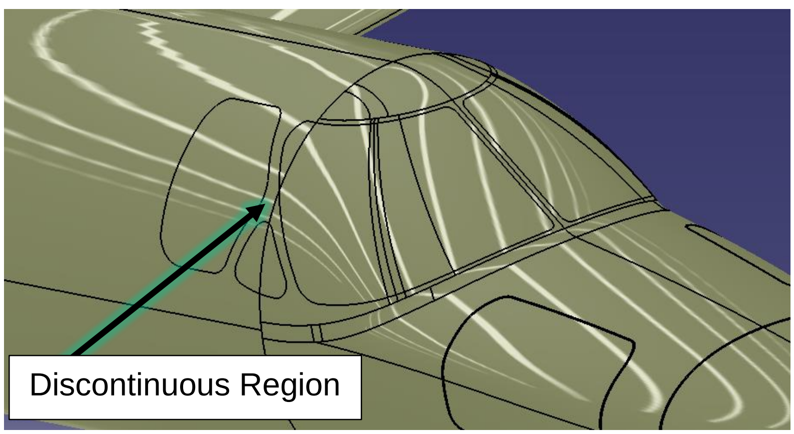

Figure 2: Canopy Loft Issue

An aerodynamics analysis was conducted with the FUN3D turbulent CFD code at Mach 0.40 and Mach 0.80 at approximately a 1/10th subscale Reynolds number. The SA turbulence model with the default parameters was used. The grid, including the BL anisotropic grid, was generated in Pointwise as a half geometry from a CATIA generated .STEP file of surface geometry.

Geometric and aerodynamic analysis gives the following characteristics.

Wing Span [ft]	50.63
Wing Area [sq-ft]	334.2
MAC [in]	77.955
MAC Location	
FS267.24, BL151.89, WL1.53	

	Mach 0.40	Mach 0.80
CLa	0.085	0.105
CD_0	223 counts	369 counts
NP	44% MAC	36% MAC
CLmax (flaps up)	1.4	

Low Speed Tests

The aircraft already shows undesirable characteristics at Mach 0.40. Figure 3 shows the streamlines at 0 and 10 degrees angle of attack. Overall, the flow is attached at 0 AOA. The wing-fuselage intersection has significant issues with local flow (e.g. the stagnation point at the root is several inches along the upper wing surface); **a wing glove is needed**. The previously mentioned canopy loft issue appears as a faint blue area in the pressure contour; no separation appeared at Mach 0.40.

At 10 degrees AOA, a separated region appears in the wing root area. Unfortunately, this separation is likely to have a strong negative impact on the jet intake. At higher power settings and higher AOAs, strong separation will likely be entrained by the intake. Again, a **careful redesign of the wing root region** will be required.

Mach 0.40, 0 AOA　　　　Mach 0.40, 10 AOA

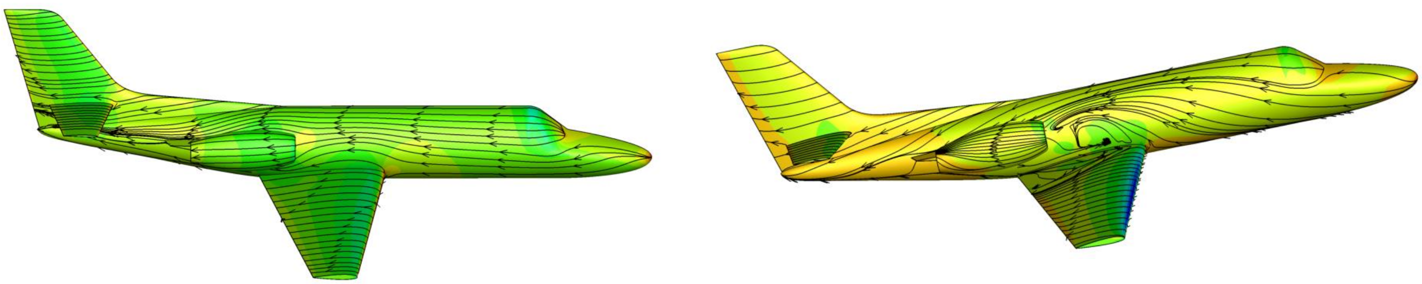

Figure 3: Mach 0.40 Streamlines

The pylon region connecting the engine nacelle and the aft fuselage also exhibited poor aerodynamic behavior. Figure 4 shows the streamlines and pressure contours on the aft fuselage in the pylon region at Mach 0.40 and 0 AOA. The pylon is situated in a downwash region of the aft wing, resulting in an excessive suction peak on the lower surface. At other conditions, a shock appeared in this area. **The pylon must be redesigned**.

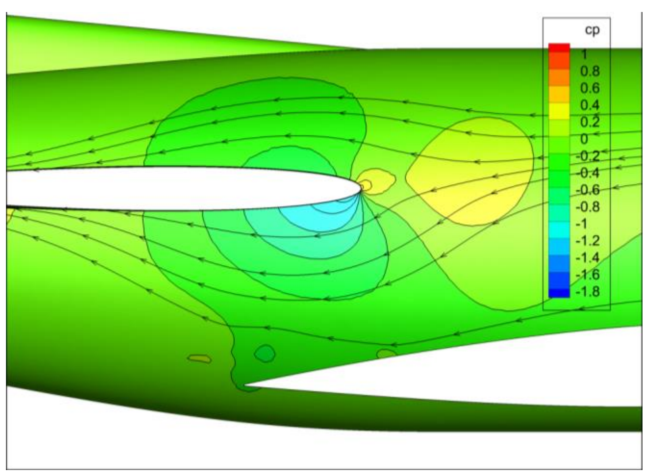

Figure 4: Pylon Streamlines and Pressures (Mach 0.40, 0 AOA)

In general, the low speed aerodynamics of this reverse-engineered Citation model are not satisfactory. A low speed wind-tunnel test of the existing geometry is strongly not advised.

High Speed Tests

Testing at Mach 0.80 brought out additional aerodynamic issues. At 0 AOA, a strong shock is seen on the wing, upper pylon, upper canopy, and lower horizontal. See Figure 5 for streamlines and pressure contours at Mach 0.80 and 0 AOA. The upper canopy region is particularly bad. The adverse pressure gradient (i.e. shock) associated with the non-tangential surface produces a strong separation region. This local shock and separation will produce excessive noise and vibration on the aircraft.

As expected given the classical airfoil, the neutral point moves forward approximately 8% between Mach 0.40 and Mach 0.80. Given that the Citation 2's tail volume is relatively small, the pylon and nacelle appear to be significant contributors to the 10% aft shift in the NP when compared to wing-only theory (i.e. quarter chord).

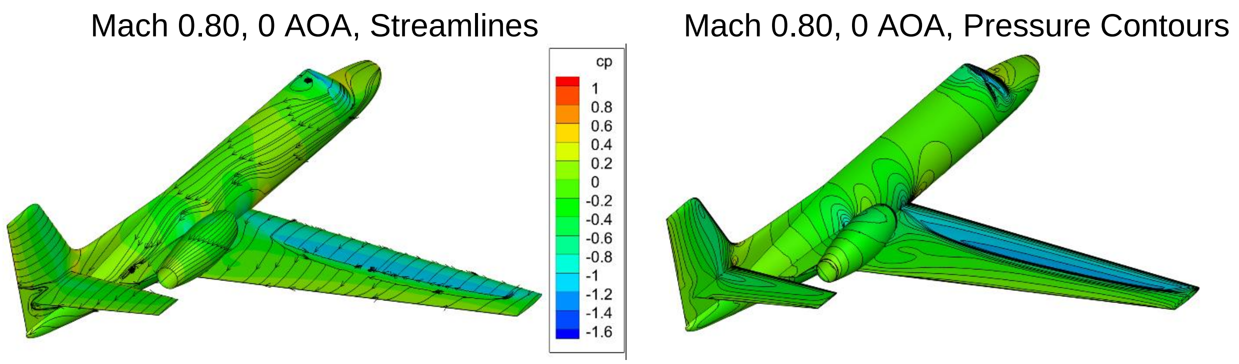

Figure 5: Mach 0.80 0 AOA Streamlines and Cp Contours

The wing pressure contours indicate that the airfoil cross sections are likely from the classical NACA series. **These current airfoils are potentially unsatisfactory for high subsonic transport aircraft**. Also, these airfoils appear to contribute to the detrimental degradation in the pitch stability in the Mach 0.70 to Mach 0.90 range.

The current aircraft geometry is neither suited for a low speed nor a high speed wind tunnel test. It is recommended that a CAD redesign be conducted before additional testing or expense.

This test should reinforce to the reader that a casual CAD reverse engineering design of existing aircraft has **significant** risks. The actual Cessna Citation required multiple aerodynamic design iterations to prevent or mitigate the issues presented in this memo.

Further Information

If further information is needed regarding this project's analysis, contact Charles O'Neill at 8-5161 or croneill@eng.ua.edu.