Generating control and stability derivatives of Yardstik Model using Tornado software

27th Jan 2007 by Paw Yew Chai

The control and stability derivatives of Yardstik to be used for simulation are generated using the Tornado software. Tornado is a 3-D vortex lattice program written in Matlab environment which makes use of the vortex lattice method for obtaining the forces and moment acting on the aerodynamic surfaces [2].

From these forces and moment generated, we are able to obtain the stability and control derivatives with respect to different trim points in the angle of attack, angle of sideslip, angular rates and control surfaces deflection [1].

1. Aircraft Geometry setup in Tornado

We must first generate the Yardstik aircraft Geometry into the Tornado, by creating different panels to model the aircraft geometry. In this modeling, we only model the surfaces that generated aerodynamic forces, which are the:

1. Wing
2. Horizontal tail
3. Vertical tail
4. Rudder control surface
5. Elevator control surface

Figure 1 shows the 3-D mesh of the Yardstik model in the Tornado. The Yardstik has 8 degrees dihedral on its wings and the wings are mounted at positive angle of attack with the fuselage reference line (FRL). These details are modeled in the Tornado model.

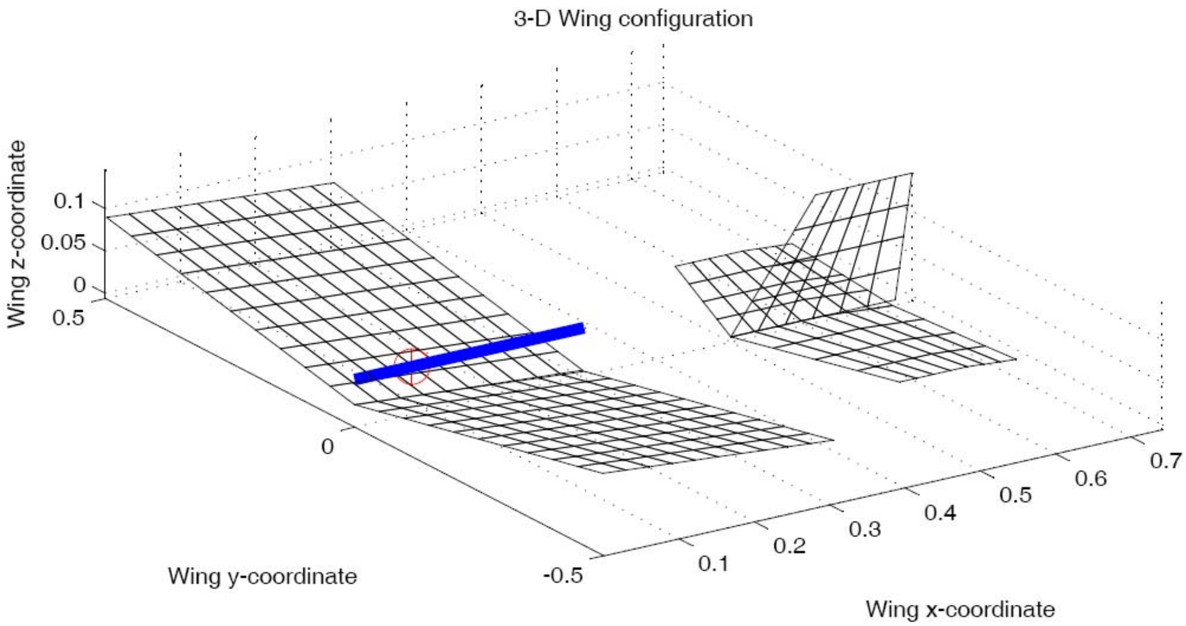

Figure 1. 3-D mesh of the Geometry of Yardstik model in Tornado

2. Trim condition for analysis.

The trim condition that we are using for the analysis and extracting the stability and control derivatives are based on the experience from flight testing the Yardstik aircraft that has been instrumented. The following is the trim condition that is used:

Alpha	2 deg
Beta	0 deg
Airspeed	8 m/s
p	0 deg/sec
q	0 deg/sec
r	0 deg/sec
Rudder	0 deg
Elevator	4 degrees (positive)

3. Result

Figure 2 shows the pressure coefficient plot for the run with the trim condition that is in the previous section.

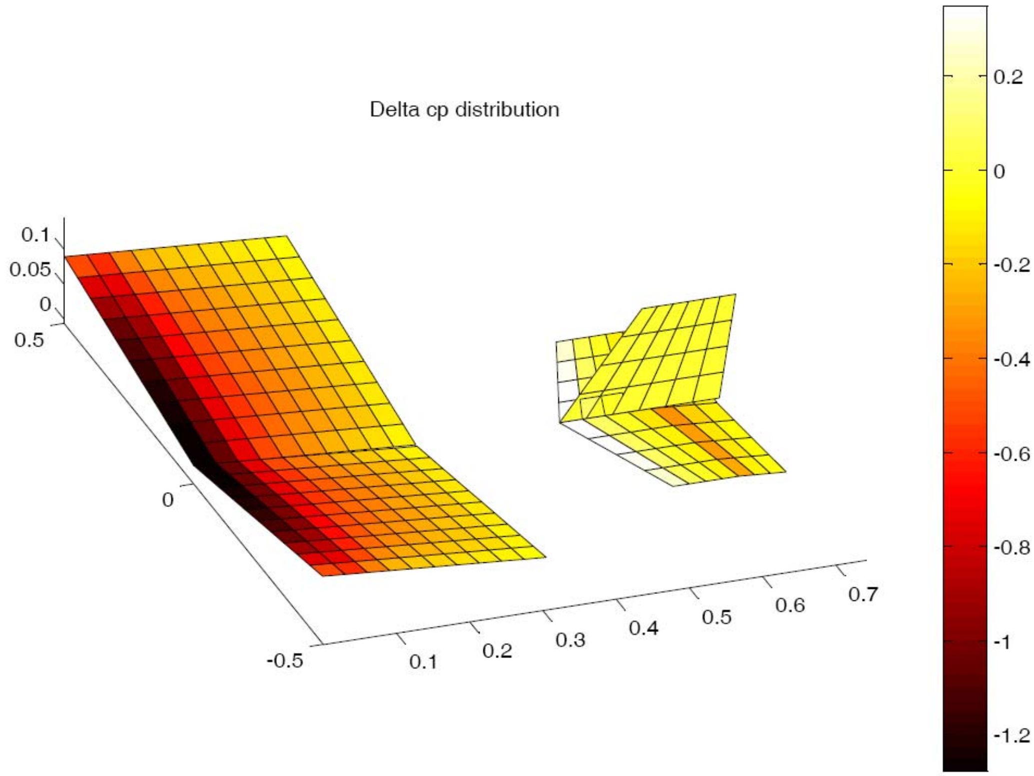

Figure 2 Plot of the pressure coefficient distribution

3.1 Result for coefficients for forces and moments

Tornado Computation Results

JID:	111	Downwash matrix condition:	32.3875		
Reference area:	0.30713				
Reference chord:	0.305	Reference point pos:	0.07625	0	0.050037
Reference span:	1.007				

Net Wind Forces: (N)		Net Body Forces: (N)		Net Body Moments: (Nm)	
Drag:	0.24152	X:	0.050058	Roll:	0.00021995
Side:	0.0027074	Y:	0.0027074	Pitch:	-0.15295
Lift:	5.482	Z:	5.4871	Yaw:	0.0014811

CL	0.45532	CZ	0.45575	Cm	-0.041651
CD	0.020061	CX	0.0041578	Cn	0.00012216
CY	0.00022488	CC	0.00022488	Cl	1.8142e-005

STATE:

alpha:	2	P:	0		0
beta:	0	Q:	0	Rudder setting [deg]:	0
Airspeed:	8	R:	0		4
Density:	1.225				

From the result above, we can see that the lift generated is about 5.5 N and this is almost equal to the weight of the instrumented Yardstik aircraft, which is 0.56 kg. Hence, this result seems to be reasonable for the trim flight condition where the weight is equal to the lift generated.

3.2 Result for control and stability derivatives

TORNADO CALCULATION RESULTS, Central difference

JID:	111				
Reference area:	0.30713	Alpha:	2	P:	0
Reference chord:	0.305	Beta:	0	Q:	0
Reference span:	1.007	Airspeed:	8	R:	0

CL derivatives :		CD derivatives :		CY derivatives :	
CL-alfa	3.9398	CD-alfa	0.34011	CY-alfa	0.040354
CL-beta	0.00064819	CD-beta	-0.0010522	CY-beta	6.391
CL-P	-0.0013392	CD-P	0.00026054	CY-P	-3.132
CL-Q	23.9894	CD-Q	1.4945	CY-Q	1.7057
CL-R	0.015582	CD-R	-0.011333	CY-R	89.1406

Roll derivatives :		Pitch derivatives :		Yaw derivatives :	
Cl-alfa	0.0038387	Cm-alfa	-0.98096	Cn-alfa	0.02198
Cl-beta	0.56558	Cm-beta	-0.0016133	Cn-beta	3.5168
Cl-P	-0.57427	Cm-P	0.002654	Cn-P	-1.8176
Cl-Q	0.15552	Cm-Q	-27.0261	Cn-Q	0.93269
Cl-R	7.0487	Cm-R	-0.034846	Cn-R	48.6573

References:

[1] Tomas Melin, "***User's guide and reference manual for Tornado***", Royal Institute of Technology (KTH) Department of Aeronautics, 2000.

[2] Tomas Melin, "***A Vortex Lattice MATLAB Implementation for Linear Aerodynamic Wing Applications***", Royal Institute of Technology (KTH) Department of Aeronautics, 2000.