CAP-TSD ANALYSIS OF THE F-15 AIRCRAFT

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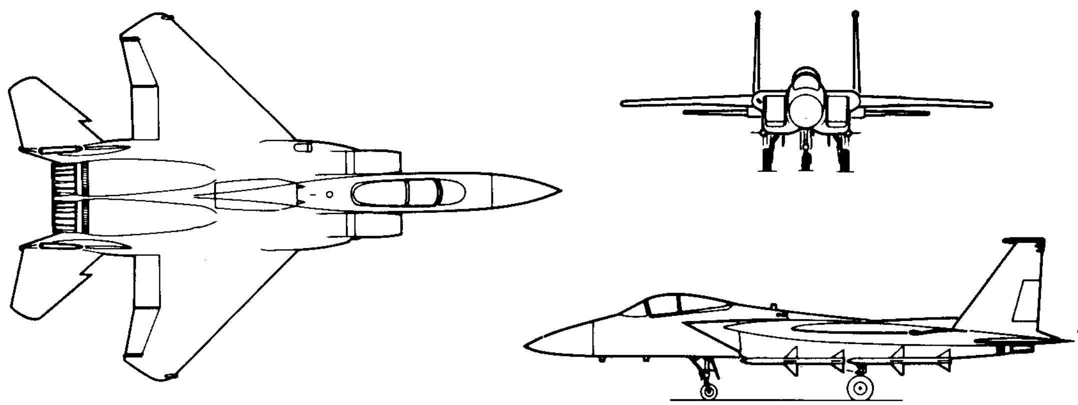
The CAP-TSD analysis of the F-15 fighter aircraft is the result of a cooperative program between NASA Langley Research Center and McDonnell Aircraft Company (MCAIR). We are grateful to Dr. John Edwards and his Unsteady Aerodynamic Branch for allowing MCAIR the use of CAP-TSD and providing the VPS-32 super computer resources. A special thanks is given to Jack Batina, Bob Bennett, and Dave Seidel for all of their help in setting up the CAP-TSD model of the F-15.

The F-15 is a twin engine high performance fighter aircraft and is shown in the three view drawing of Figure 1. The large wing area allows for a low wing loading in cruise flight. Figure 2 also shows some of the wing and stabilator geometry characteristics.

F-15 Geometry



	Wing	Stabilator
Aspect Ratio:	3.01	2.05
Taper Ratio:	0.25	0.34
Sweep (LE):	45°	50°
Dihedral:	−1°	0°

Figure 1

Figure 2 shows the airfoil sections of the F-15 wing. The wing root is a 6 percent thick symmetric airfoil. The wing decreases in thickness towards the tip, which is a 3 percent highly cambered airfoil. The F-15 wing has conical camber outboard of the 20 percent semi-span location.

F-15 Wing and Airfoil Shapes

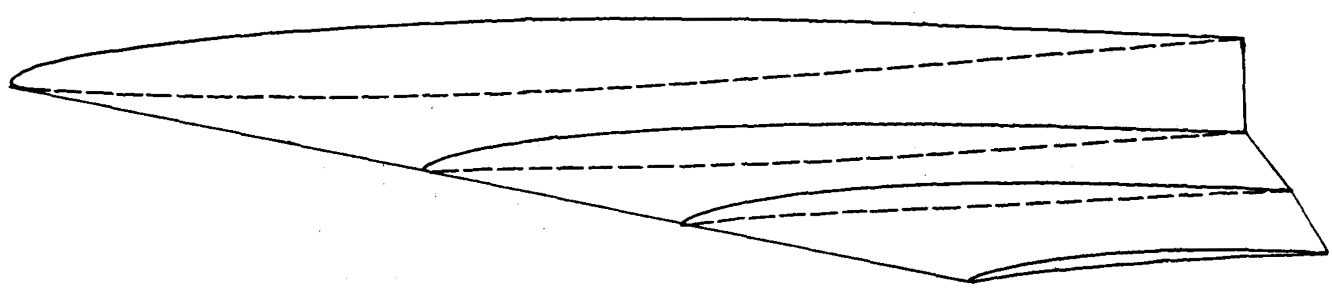


Figure 2

A 4.7 percent rigid model of the F-15 was tested in the MCAIR Polysonic Wind Tunnel in January of 1971. Wing pressures were measured at four span stations. The semi-span stations were located at 36.2, 58.7, 77.0 and 86.2 percent. Nominally, there were 16 upper surface pressure taps and 7 lower surface pressure taps. All data shown are for undeflected ailerons and flaps. The forward fuselage had 70 pressure taps located at 10 fuselage stations as shown in Figure 3. The fuselage taps were located at fuselage rotation angles of 0 (top), 44, 68, 90, 114, 138 and 180 (bottom) degrees.

F-15 4.7% SCALE MODEL

Wing and Fuselage Pressure Tap Location

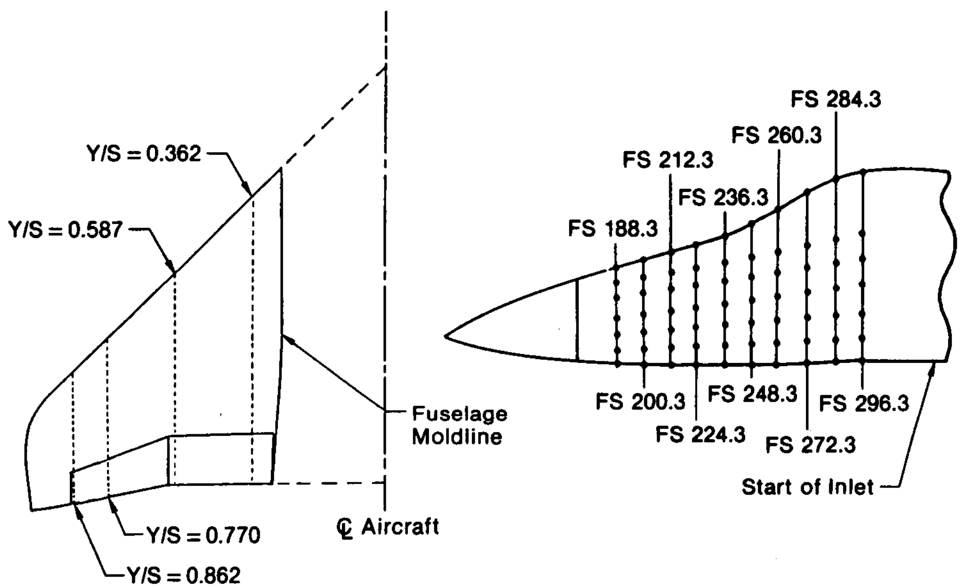


Figure 3

F-15 CAP-TSD runs were made for the angle-of-attack and Mach range shown in Figure 4. The Mach number ranged from subsonic, through the transonic to the supersonic range. The angle-of-attack ranged from 0 to about 5 degrees. The F-15 CAP-TSD model includes the wing, wing-glove, stabilator, flow through inlets and fuselage body. Various pressures from these runs will be compared with test data. Also, two wing alone cases will be shown to highlight the fuselage effects.

F-15 CAP-TSD STEADY RUNS

Mach 0.80	Mach 0.90	Mach 0.95	Mach 1.208
$\alpha = 0.08°$	$\alpha = 0.08°$	$\alpha = 0.08°$	$\alpha = 0.08°$
$= 2.46°$	$= 2.46°$ *	$= 2.58°$	$= 2.70°$ *
$= 4.84°$	$= 4.84°$		

F-15 CAP-TSD Model Includes:

- Wing, Wing-Glove, Stabilator, Flow Through Inlets, Fuselage Body

*Runs were also made for wing alone case.

Figure 4

Figure 5 is a picture of the CAP-TSD X-Y grid for the F-15 complete aircraft configuration. There are 150 X grid points, 32 Y grid points and 72 Z grid points. Thus, the total number of grid points is 345,600. There are 22 Eta grid points along the wing span and 50 grid points along the wing chord. The stabilator has 15 Eta grid points and 23 chordwise points.

F-15 CAP-TSD GRID

$n_x = 150 \quad n_y = 32 \quad n_z = 72$

Total Number of Grid Points = 345,600

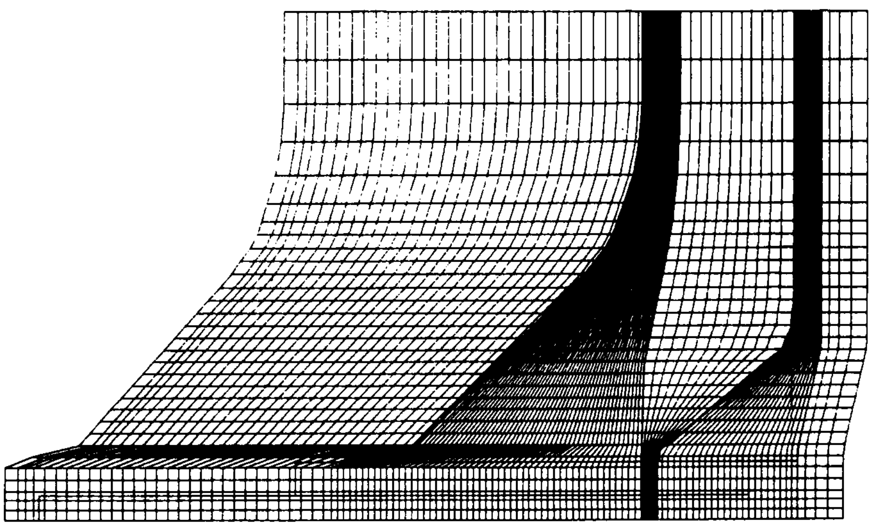


Figure 5

The first CAP-TSD results to be shown will be for the F-15 forward fuselage section. Figure 6 shows the pressure coefficients for the top and bottom of the fuselage versus fuselage station. For M = 0.9 and an angle-of-attack of 0.08 degrees, the CAP-TSD lower surface pressures agree well with the wind tunnel data. The upper surface CAP-TSD pressures agree qualitatively with the data. However, CAP-TSD shows the compression over the canopy starting a little sooner than the test data at a fuselage station of 225 inches. CAP-TSD predicts more compression than the data shows. In the area where the flow expands over the canopy, Fuselage station 250 inches, the agreement is better. Refer to Figure 3 for a side view of the canopy. It is felt that more grid points along the fuselage will improve the CAP-TSD correlation of the upper surface pressure.

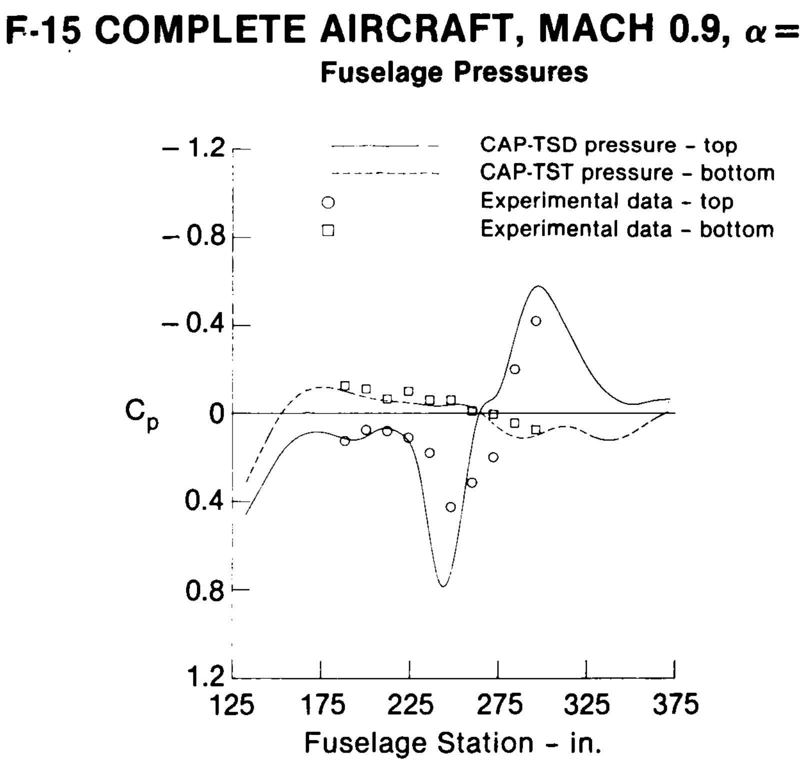


Figure 6

The F-15 fuselage pressures for a supersonic case are shown in Figure 7. The lower surface pressures show good correlation between CAP-TSD results and the test data. The upper surface pressures show a more severe compression than the data. However, the overall comparison is encouraging.

F-15 COMPLETE AIRCRAFT, MACH 1.208, $\alpha = 0.08°$

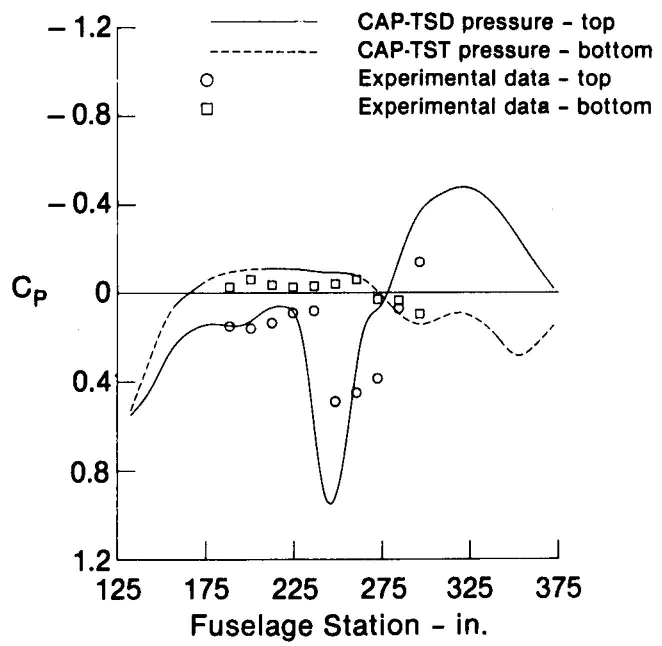


Figure 7

Figures 8-10 are comparisons of CAP-TSD results and measured data for the outer most wing pressures. The Mach number is 0.81 and the angles-of-attack are 0.08, 2.46 and 4.84 degrees. These three figures show the effects that increasing angle-of-attack has on the wing flow. It should be noted that the airfoil shape at this outboard section is highly cambered. (Refer to Figure 2.) Figure 8 shows very good agreement between CAP-TSD results and wind tunnel pressures.

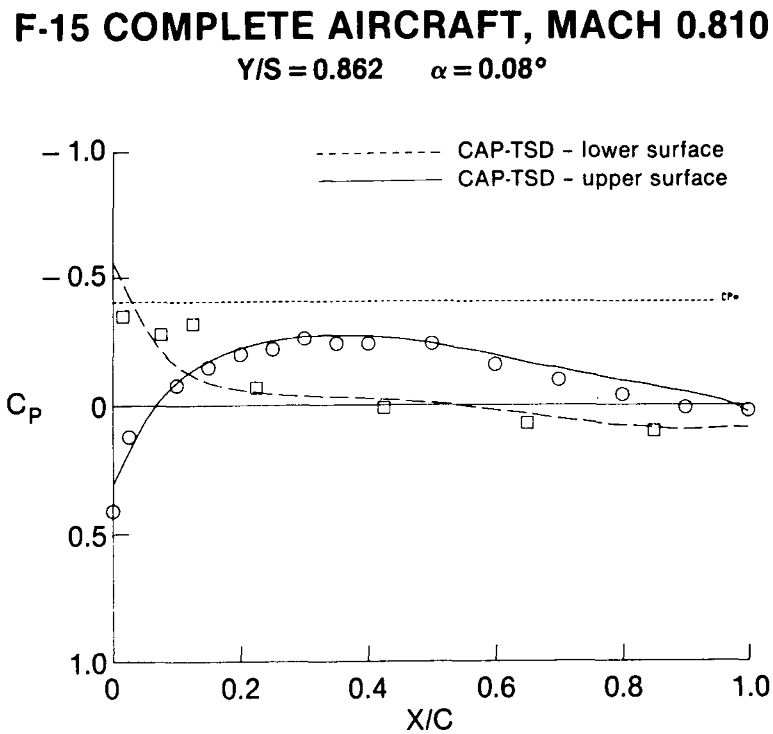


Figure 8

Figure 9 is the comparison of experimental wing pressures with CAP-TSD results for M = 0.81, alpha = 2.46 degree at an 86 percent semi-span location. The flow on the upper surface is barely supersonic at X/C = 0.2. Agreement between CAP-TSD and experiment is very good.

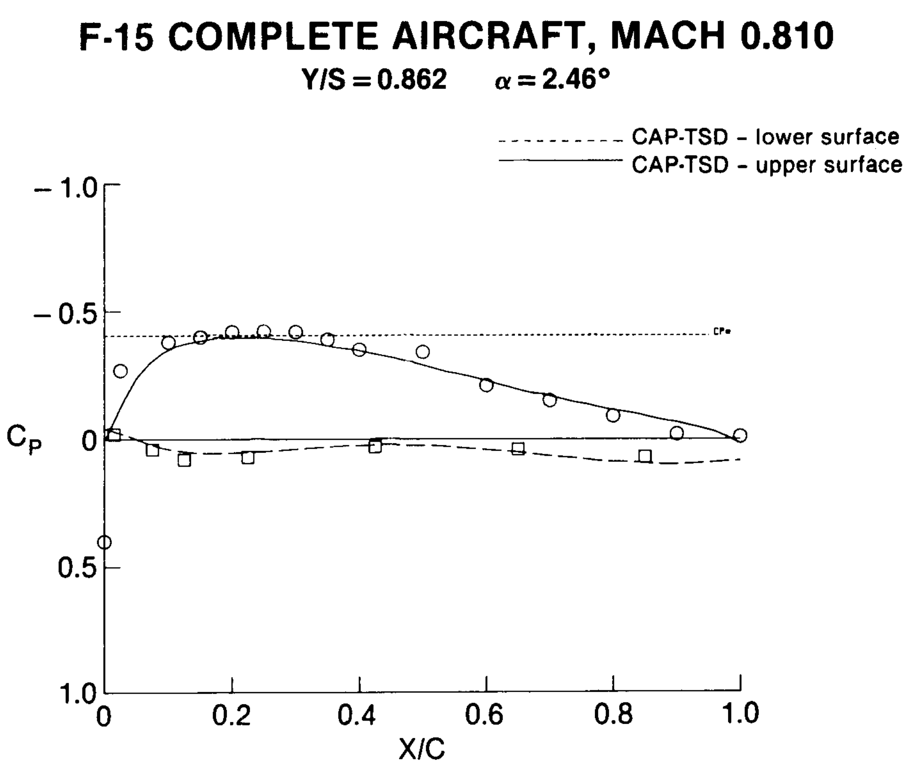


Figure 9

The F-15 outer wing pressure comparison for M = 0.81, alpha = 4.84 degree is shown in Figure 10. The lower surface pressures as predicted by CAP-TSD agree well with the experimental data. The upper surface CAP-TSD pressures are not quite showing the degree of suction suggested by the test data.

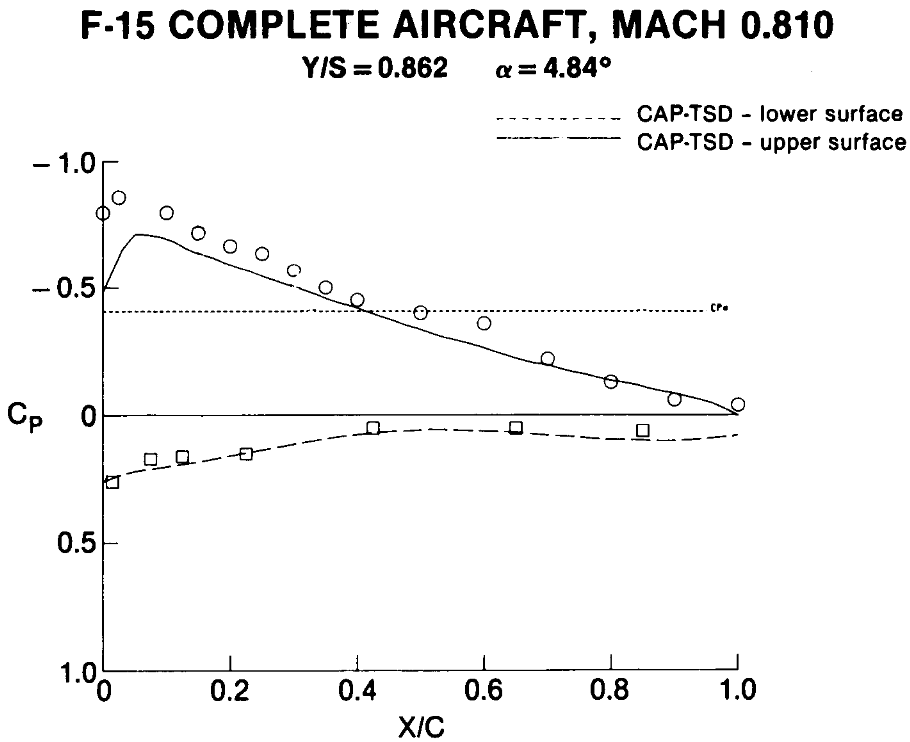


Figure 10

Some representative Mach 0.9 cases are shown in Figures 11 and 12. Figure 11 shows data for the wing pressure at a 77.8 percent semi-span location for an angle-of-attack of 0.08 degrees. The upper surface pressures are in good agreement between CAP-TSD results and wind tunnel data. The lower surface pressures also agree well, with a slight discrepancy at $0.1 \leq X/C < 0.2$. This is an area of extreme lower surface camber and rapid change in airfoil slopes.

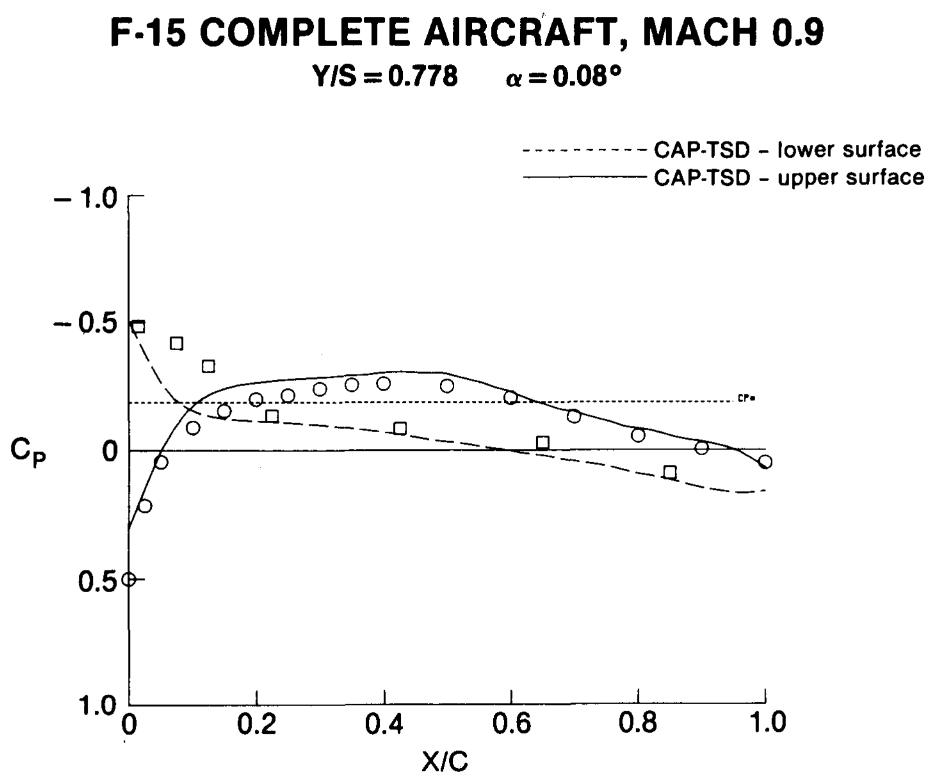


Figure 11

Figure 12 shows results for the inboard wing pressures for M = 0.9 and alpha of 2.46 degrees. The figure compares CAP-TSD wing alone results with the CAP-TSD complete fuselage model results and wind tunnel data. It is apparent that the modeling of the fuselage improves the upper surface pressures over the last 60 percent of the wing chord. The fuselage effects also increase the upper surface leading edge suction.

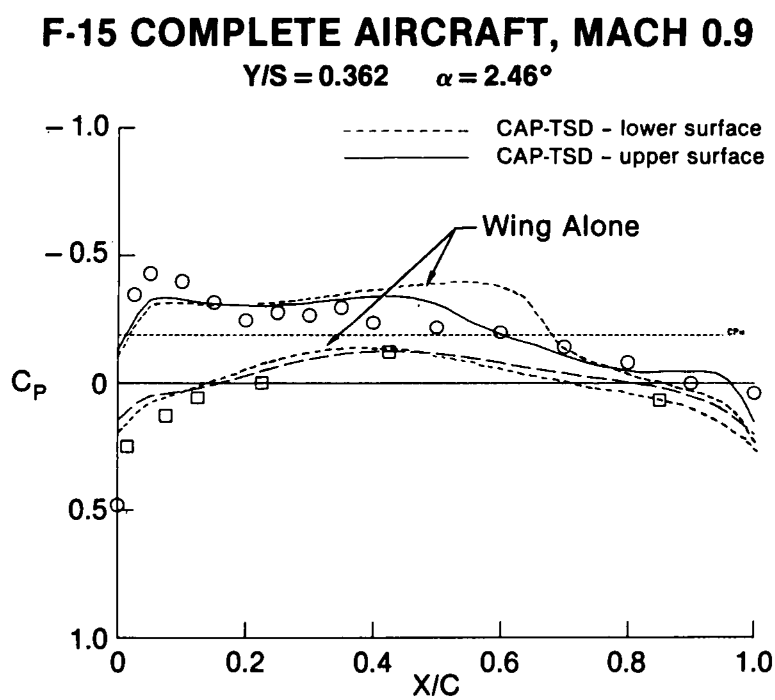


Figure 12

Figures 13 and 14 show some of the wing pressure results for the Mach = 0.95 case. Figure 13 is a comparison of the F-15 wing pressures with those predicted by CAP-TSD at a semi-span location of 77 percent and alpha = 0.08 degrees. Both the experimental data and CAP-TSD results show a strong upper surface shock at 75% local chord location. The agreement between the test data and CAP-TSD pressures is excellent for both the upper and lower surfaces.

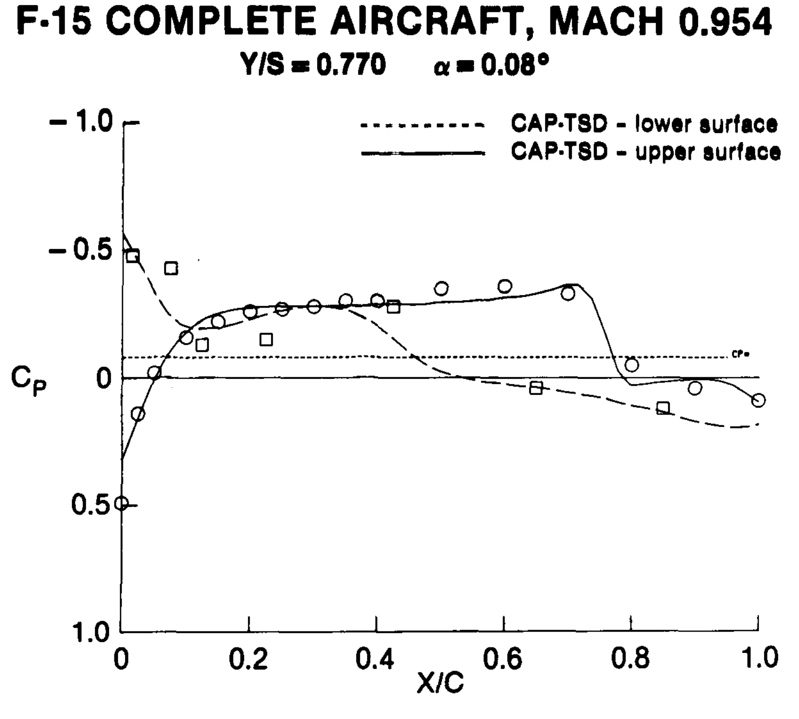


Figure 13

Figure 14 shows the wing pressures for the same Mach number and semi-span as reported in Figure 13, but for an increased angle-of-attack of 2.58 degrees. The lower surface measured pressures are in good agreement with CAP-TSD results. The upper surface CAP-TSD pressures are slightly below the test data, with the predicted shock being slightly forward of the position shown by the test data.

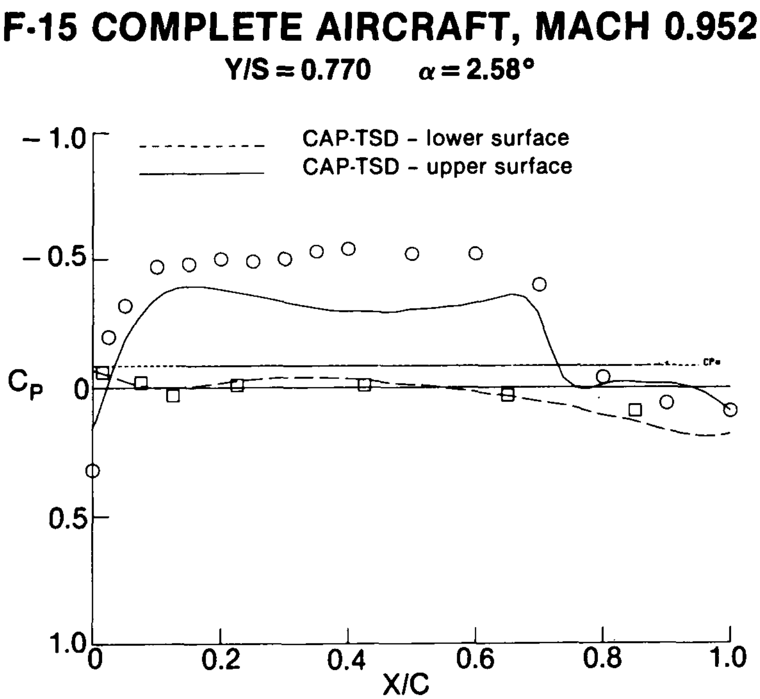


Figure 14

Some representative supersonic, Mach = 1.208, cases are shown in Figures 15 thru 17. Figure 15 is the CAP-TSD results for the complete F-15 compared to wind tunnel data at the 58.7 percent semi span and alpha of 0.08 degrees. Generally the agreement between theory and test is excellent for both upper and lower surface.

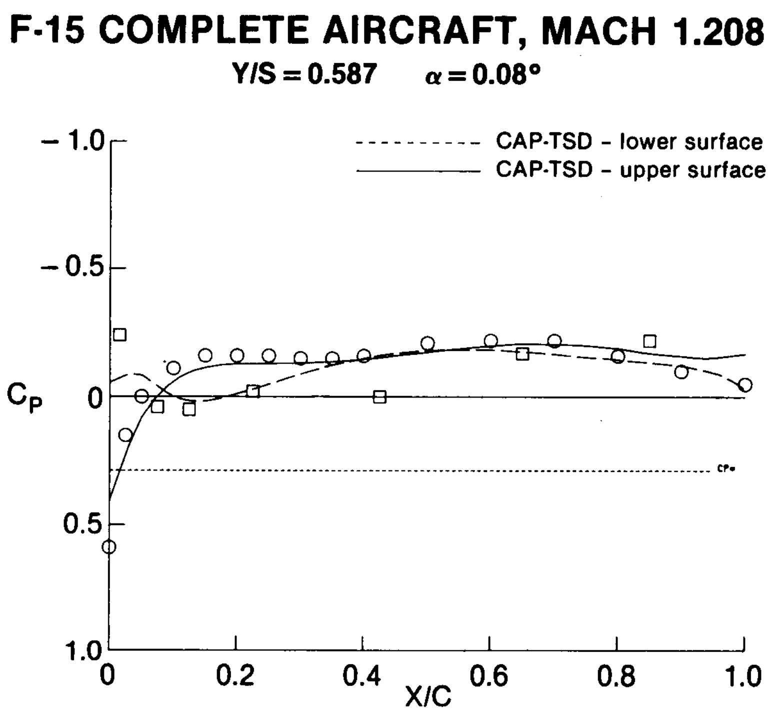


Figure 15

The wing pressures for the same supersonic case as Figure 15 but at a more outboard semi-span location of 86.2 percent are shown in Figure 16. The upper surface experimental pressures are in very good agreement with CAP-TSD results. The lower surface CAP-TSD results also agree very well with experiment and show the effects of the lower surface camber in the leading edge area.

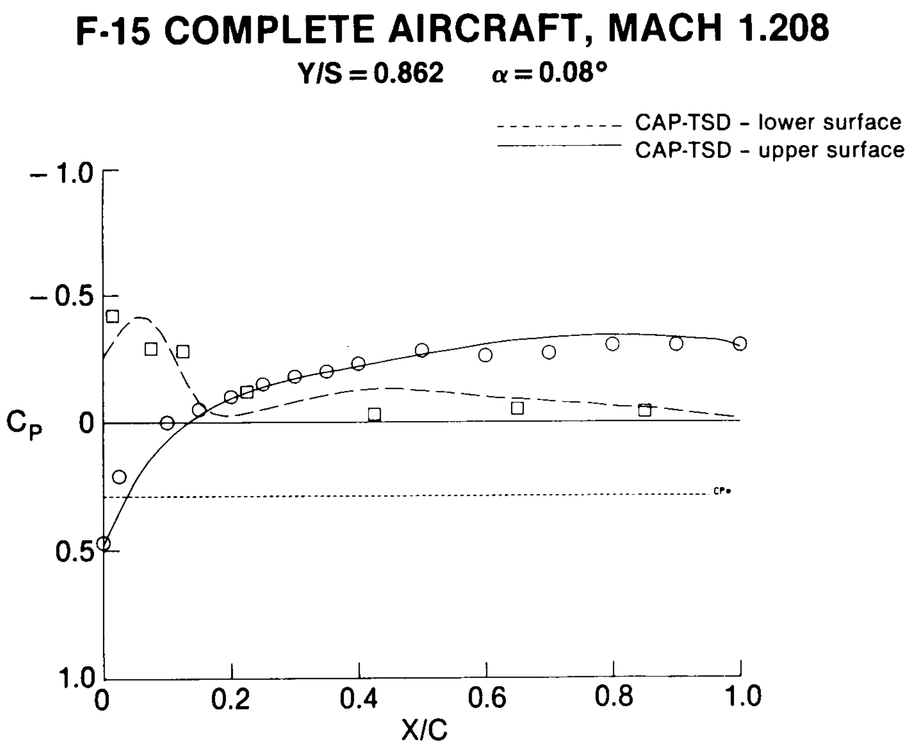


Figure 16

Figure 17 is the inboard wing pressures for a Mach of 1.208 and an alpha of 2.70 degrees. This figure compares CAP-TSD complete fuselage wing pressures with CAP-TSD wing alone results and wind tunnel data. The fuselage effects improve the correlation for the upper surface pressures. The largest improvement is over the last 40% of the local chord on the upper surface.

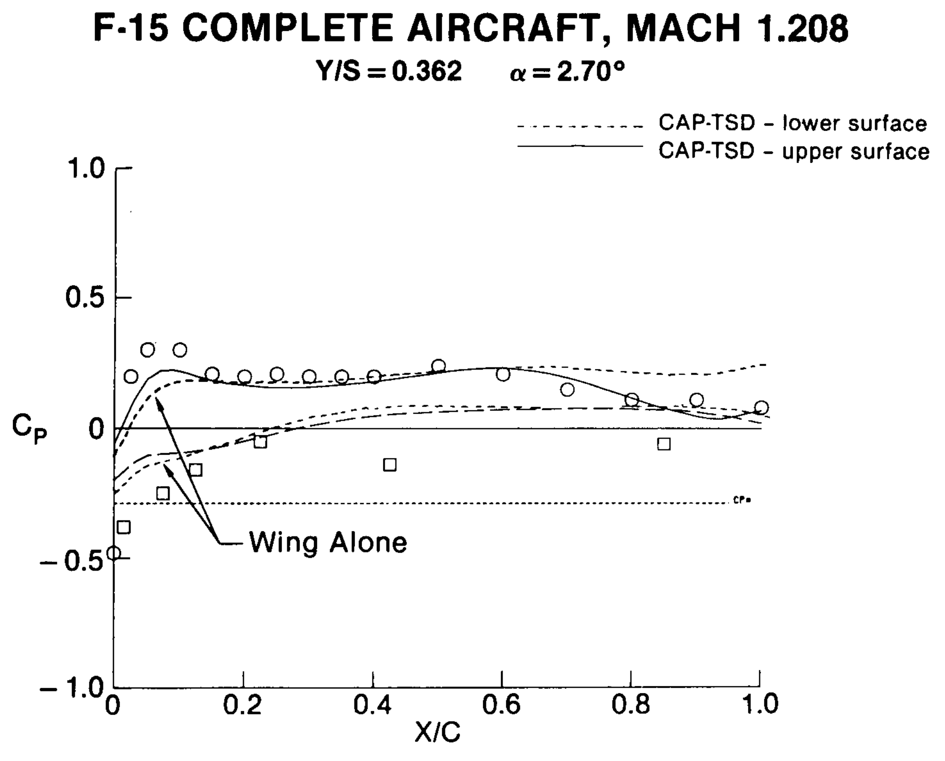


Figure 17

In summary, the F-15 fighter aircraft was modeled using CAP-TSD. The complete aircraft was model including the wing, stabilator, flow through inlets, and fuselage body. CAP-TSD was used to make static pressure runs for Mach numbers of 0.8, 0.9, 0.95 and 1.2. The angle-of-attack for these runs ranged from 0 to 5 degrees.

The CAP-TSD program showed good agreement between the computed fuselage and wing pressures and the measured wind tunnel pressures. Including the fuselage and inlets in the CAP-TSD analysis is important and improves the correlation of wing pressures with test data (Figure 18).

SUMMARY/CONCLUSIONS

- CAP-TSD Used to Model F-15, Model Includes:
  - Wing, Stabilator, Inlets, and Fuselage Body
- Static Runs Made for Following Conditions:
  - Mach Range - 0.8 to 1.2
  - Alpha Range - 0 to 5 deg
- CAP-TSD Generally Showed Good Agreement With Test Data
- Fuselage Effects Are Important in Modeling the F-15

Figure 18