

TSFOIL2 Manual

TSFOIL2 is a solution of the transonic small disturbance theory equations. It will run on PCs or a MAC and provides useful results, although Euler solutions are preferred if you have access to that level of code. The method obtains the solution by solving a set of coupled nonlinear algebraic equations. As such, the process does not necessarily converge, and the convergence history must be examined before accepting the results as valid. It is entirely possible to specify a Mach number and angle of attack which causes the iterative process to diverge. The program typically computes the solution on a sequence of progressively finer meshes. It is the convergence history on the final mesh that is important. The references given below should be studied to obtain a full understanding of the theory and use of the code. Figure 1 shows the agreement obtained between TSFOIL2 and a full potential code, FLO36.

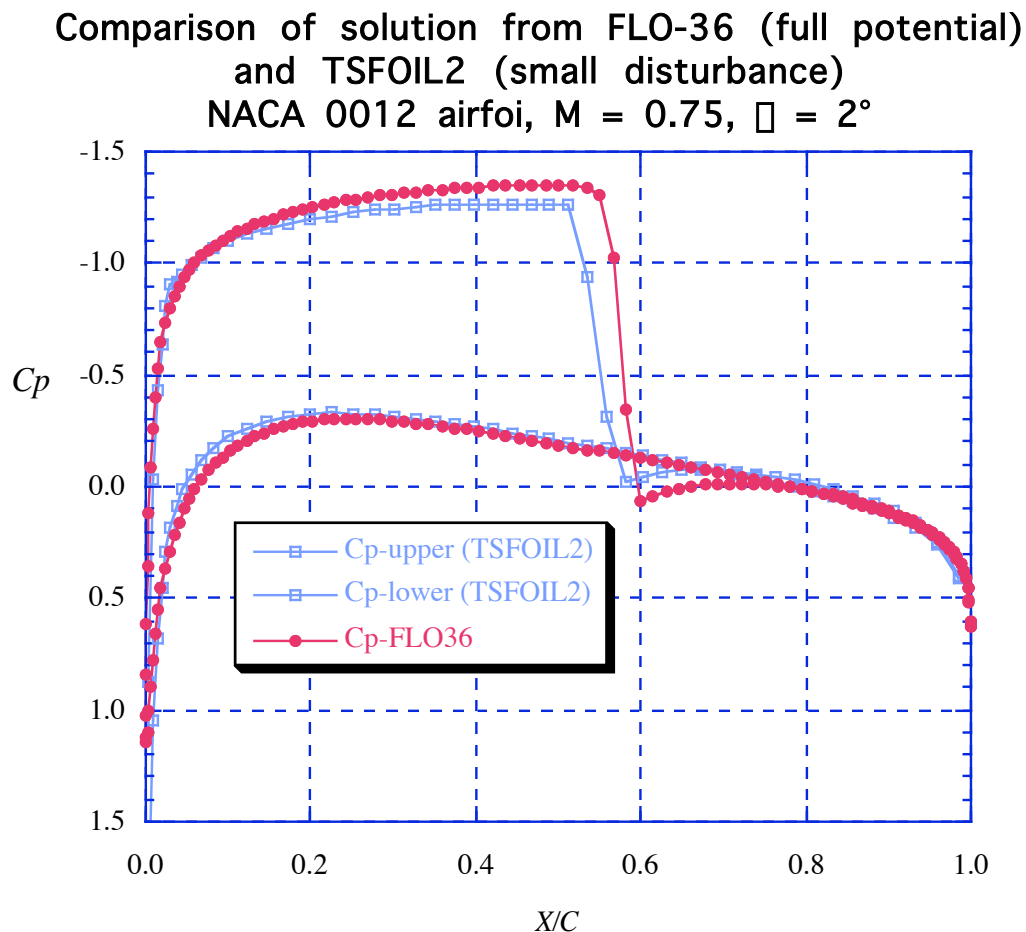


Figure 1. Agreement between small disturbance theory and full potential theory for a typical transonic test case.

References

Murman, E.M., Bailey, F.R., and Johnson, M.L., "TSFOIL — A Computer Code for Two-Dimensional Transonic Calculations, Including Wind-Tunnel Wall Effects and Wave Drag Evaluation," NASA SP-347, March 1975.

Stephen S. Stahara, "Operational Manual for Two-Dimensional Transonic Code TSFOIL," NASA CR 3064, Dec. 1978.

Some of the aspects of the code which may make it a little unusual to run on a PC are the use of 133 column output and an input file that uses NAMELIST. Minor modifications to the code have been made to make it easier to use on a PC.

The input to the program is primarily described in the comments to subroutine READIN, which first prompts the user for the name of the input file. The input description contained here is from READIN. Note the default values. However, *it is very important to use the AMESH = T option in order to obtain converged results.* Several input data sets are included to illustrate the input procedure. In particular, the option to use the Jameson input is illustrated because that is the format that is most easily used for the analysis of arbitrary airfoils.

From Subroutine READIN:

INPUT EXPLANATION

Almost ALL INPUT IS READ IN THIS SUBROUTINE. THE ORDER IS AS DESCRIBED BELOW.

1.) ONE CARD OF TITLE INFORMATION. AN ?A? (ALPHANUMERIC) FORMAT IS USED TO READ AND WRITE THIS INFORMATION.

2.) NAMELIST CONTAINING THESE PARAMETERS IS NOW READ. (SEE FORTRAN MANUAL FOR DESCRIPTION OF NAMELIST INPUT). THE BLOCK DATA SUBROUTINE SETS A DEFAULT VALUE, AS NOTED BELOW, FOR ALL OF THESE PARAMETERS. ONLY THE VALUES WHICH ARE DIFFERENT FROM THE DEFAULT CASE MUST BE INCLUDED, ALTHOUGH AT LEAST ONE VALUE MUST BE INPUT BY NAMELIST FOR EACH CASE. (today this may not be true)

- * (F) = FLOATING POINT *
- * (I) = INTEGER *
- * (L) = LOGICAL *
- * (E) = EXPONENTIAL *

DEFAULT
VALUE

AMESH (L) OPTION FOR ANALYTICAL MESH CALC.

.F.

- .TRUE. X AND Y MESH VALUES ARE COMPUTED WHEN AMESH = T, IMAXI AND JMAXI SHOULD ALSO BE SUPPLIED. IMAXI AN ODD NO. AND JMAXI AN EVEN NO. (81 AND 40 HAVE BEEN USED).
- .FALSE. X AND Y POINTS ARE THE DEFAULT VALUES OR THE VALUES SUPPLIED BY THE USER THRU NAMELIST.

		DEFAULT VALUE
EMACH	(F) FREESTREAM MACH NUMBER. NOTE****EMACH MAY NOT BE = 1.0	.75
DELTA	(F) BODY THICKNESS RATIO.	.115
ALPHA	(F) ANGLE OF ATTACK (DEGREES IF PHYS=T)	.12
AK	(F) TRANSONIC SIMILARITY PARAMETER. (INPUT REQUIRED ONLY IF PHYS = .F.)	0.0
GAM	(F) RATIO OF SPECIFIC HEATS.	1.4
SIMDEF	(I) SIMILARITY DEFINITION. =1 COLE =2 SPREITER =3 KRUPP =4 USER	3
PRTFLO	(I) OPTION FOR PRINT OF FINAL FLOW FIELD. =1 NO FLOW FIELD PRINT. =2 ALL J LINES PRINTED. =3 PRINT 3 J LINES AROUND MAXIMUM ERROR	1
PSTART	(I) OPTION FOR INITIALIZING P ARRAY. =1 SET TO ZERO. =2 READ P FROM UNIT 7 =3 USE P IN CORE (PREVIOUS CASE).	1
PSAVE	(L) OPTION FOR SAVING RESTART BLOCK OF VALUES ON UNIT 3. =.TRUE. SAVE FOR RESTART. =.FALSE. DO NOT SAVE.	.F.
FCR	(L) FULLY CONSERVATIVE RELAXATION OPTION =.TRUE. DIFFERENCE EQUATIONS ARE FULLY CONSERVATIVE FORM. =.FALSE. DIFFERENCE EQUATIONS NOT CONSERVATIVE AT SHOCK WAVES.	.T.
KUTTA	(L) KUTTA CONDITION OPTION. =.TRUE. KUTTA CONDITION IS ENFORCED =.FALSE. LIFT COEFFICIENT SPECIFIED BY USER.	.T.
CLSET	(F) LIFT COEFFICIENT, USED IF KUTTA IS FALSE.	.0
BCFOIL	(I) OPTION FOR FOIL OR BODY GEOMETRY. =1 NACA00XX =2 PARABOLIC ARC. =3 ORDINATES (READ LATER IN NAMELIST IF DIFFERENT FROM DEFAULT VALUES WHICH ARE FOR THE KORN AIRFOIL). =4 JAMESON'S AIRFOIL INPUT FORMAT =5 Diamond Airfoil	3
BCTYPE	(I) DESCRIBES THE TYPE OF FLOW TO BE COMPUTED. =1 FREE AIR. =2 SOLID WALL. =3 FREE JET. =4 SLOTTED WALL. =5 POROUS WALL.	1
F	(F) TUNNEL SLOT PARAMETER.	0.
H	(F) TUNNEL HALF HEIGHT/CHORD RATIO.	0.
POR	(F) WALL POROSITY FACTOR.	.0

		DEFAULT VALUE
PHYS	(L) TYPE OF SCALING TO USE FOR I/O. = .TRUE. PHYSICALLY SCALED VALUES. = .FALSE. TRANSONICALLY SCALED VALUES FOR PHYS = .F., ALSO INPUT VALUE FOR AK.	.T.
IMAXI	(I) NUMBER OF X-MESH POINTS(.LE. 100)	77
JMAXI	(I) NUMBER OF Y-MESH POINTS(.LE. 100)	56
IMIN	(I) X MESH POINT WHERE CALC IS TO START	1
JMIN	(I) Y MESH POINT WHERE CALC IS TO START	1
ICUT	(I) CONTROL FOR MESH CUT AND REFINEMENT. = 0 INPUT MESH IS USED TO CONVERGENCE. = 1 INPUT MESH MAY BE CUT ONCE. = 2 INPUT MESH MAY BE CUT TWICE.	2
WE	(F) 3 VALUES FOR RELAXATION FACTOR FOR ELIPTIC PTS. 1-ST FOR COARSE MESH, 2-ND FOR MED. MESH AND 3-RD FOR FINE MESH. DEFAULT VALUES ARE SUGGESTED VALUES, IN ORDER. IF SPECIFIED IN INPUT ALL THREE VALUES MUST BE GIVEN.	1.8 1.9 1.95
WCIRC	(F) RELAXATION FACTOR FOR CIRCULATION.	1.0
MAXIT	(I) MAXIMUM NUMBER OF ITERATION CYCLE ALLOWED.	500
CVERGE	(F) CONVERGENCE CRITERION FOR RESIDUALS OF P.	.00001
DVERGE	(F) DIVERGENCE CRITERION FOR RESIDUALS OF P.	10.
RIGF	(F) REIGLES RULE FOR BODY SLOPE.	0.0
EPS	(F) COEFFICIENT OF PXT	.2
IPRTER	(I) CONTROL FOR FREQUENCY OF PRINT OF LINE IN MESH WHERE ERROR IS LARGEST. I.E. IPRTER=10 , LINE WILL BE PRINTED EVERY 10-TH ITERATION	10
NWDGE	(I) CONTROL FOR VISCOUS WEDGE INCLUSION = 0 NO WEDGE = 1 MURMAN BUMP = 2 YOSHIHARA WEDGE	0
REYNLD	(E) REYNOLDS NUMBER BASED ON CHORD. USED WHEN NWDGE = 1	4.0E+6
WCONST	(F) WEDGE CONSTANT. USED WHEN NWDGE=1	4.0
IFLAP	(I) CONTROL FOR FLAP DEFLECTION. FLAP INCLUDED WHEN IFLAP .NE. 0	0
DELFLP	(F) FLAP DEFLECTION ANGLE. POSITIVE DEGREES T.E. DOWN	5.0
FLPLOC	(F) LOCATION OF FLAP H.L., X/C	0.77
** NOTE**WHEN ARRAYS ARE READ BY NAMELIST THE FULL ARRAY MUST BE SET, I.E. IF ALL VALUES ARE NOT REQUIRED THE ARRAY MAY BE FILLED USING MULTIPLE ZEROS. (N*0.0)		
XU	(F) ARRAY - X VALUES FOR UPPER BODY. USED IF BCFOIL = 3. KORN AIRFOIL USING ALL 100 PTS.(UPPER) AND 75 (LOWER) IS DEFAULT.	
XL	(F) ARRAY - X VALUES FOR LOWER BODY.	
YU	(F) ARRAY - Y VALUES FOR UPPER BODY.	
YL	(F) ARRAY - Y VALUES FOR LOWER BODY.	
NU	(I) NUMBER OF POINTS TO USE FOR UPPER BODY	100
NL	(I) NUMBER OF POINTS TO USE FOR LOWER BODY	75

** NOTE THIS PROGRAM USES A MESH REFINEMENT METHOD FOR DECREASING COMPUTER TIME. FOLLOW THE RULES BELOW FOR CONSTRUCTING THE X AND Y MESH TO TAKE FULL ADVANTAGE OF THIS FEATURE.

IMAXI - ITE SHOULD BE A MULTIPLE OF 4.
 ITE - IMIN SHOULD BE A MULTIPLE OF 4.
 JMAXI - JUP + 1 SHOULD BE A MULTIPLE OF 4
 JLOW - JMIN + 1 SHOULD BE A MULTIPLE OF 4
 (WHERE JLOW IS LAST POINT BELOW SLIT AND
 JUP IS FIRST POINT ABOVE SLIT.)

WHERE ITE = I FOR X = 1.0 (OR POINT ON BODY CLOSEST TO X = 1.0).
 SUBROUTINE CKMESH INSPECTS THE X AND Y MESHES TO SEE IF THIS IS TRUE AND, IF NOT, WILL MODIFY INPUT MESH IN SOME CASES.

XIN (F) ARRAY - X MESH POINTS. LIMIT 100 PTS.

YIN (F) ARRAY - Y MESH POINTS. LIMIT 100 PTS.

X AND Y MESH DEFAULT VALUES ARE KRUPP BASIC GRID.

The following are sample inputs for TSFOIL2:

bicon.inp

```
TEST OF TSFOIL2, 10% thick biconvex airfoil
$INP
ALPHA=0.0,DELTA=0.10,EMACH=0.82
BCFOIL=2,MAXIT=1500
$END
```

n2412.inp

This dataset was used to obtain the solution for the flow over an NACA 2412 airfoil at zero alpha and a Mach number of 0.75.

```
TEST OF DATA POINT INPUT CASE , NACA2412
$INP
ALPHA=0.0,DELTA=0.12,EMACH=0.75
BCFOIL=3,NU=21,NL=26,MAXIT=1500
XU = 0.00000,
      0.04738, 0.09730, 0.14745, 0.19772,
      0.24805, 0.29842, 0.34882, 0.39923, 0.44963,
      0.50000, 0.55032, 0.60059, 0.65078, 0.70090,
      0.75094, 0.80089, 0.85076, 0.90055, 0.95027,1.0,
YU = 0.00000,
      0.03430, 0.04896, 0.05959, 0.06760,
      0.07363, 0.07786, 0.08037, 0.08123, 0.07988,
      0.07686, 0.07246, 0.06690, 0.06033, 0.05293,
      0.04483, 0.03619, 0.02722, 0.01818, 0.00919,0.0 ,
XL = 0.00000, 0.00662, 0.00931, 0.01455, 0.02736,
      0.05262, 0.07771, 0.10270, 0.15255, 0.20228,
      0.25195, 0.30158, 0.35118, 0.40077, 0.45037,
      0.50000, 0.54968, 0.59941, 0.64922, 0.69910,
      0.74906, 0.79911, 0.84924, 0.89945, 0.94973,1.0 ,
YL = 0.00000,-0.00864,-0.01025,-0.01262,-0.01649,
      -0.02166,-0.02535,-0.02828,-0.03267,-0.03576,
      -0.03783,-0.03898,-0.03917,-0.03839,-0.03608,
      -0.03274,-0.02866,-0.02406,-0.01913,-0.01405,
      -0.00903,-0.00435,-0.00038, 0.00250, 0.00345,0.0 ,
$END
```

N0012.inp

This dataset was used to obtain the results presented in Figure 1.

```
NACA 0012
$INP
  ALPHA=2.0, DELTA=0.12, EMACH=0.75, AMESH=T,
  BCFOIL=1, MAXIT=1500
$END
```

SC20610.inp

This dataset illustrates the use of the Jameson type input. Note that the airfoil is defined with another title card, and then a card in 3F10 format with the symmetry clue and the number of upper and lower surface coordinates to be read in. If the symmetry clue is zero, the airfoil is defined by both upper and lower surfaces. If the symmetry clue is not zero, then the airfoil is assumed to be symmetric, and only the upper surface definition is needed. Before a surface is read in, there is a title card. This could be either UPPER SURFACE and LOWER SURFACE, or X/C Y/C. The program simply reads a dummy card.

```
TEST OF DATA POINT INPUT CASE , NASA SC(2)-0610
$INP
ALPHA=0.0, DELTA=0.10, EMACH=0.74, WE=1.8, 1.8, 1.7, EPS=0.2, AMESH=T,
RIGF=0.0, CVERGE=0.000001, BCFOIL=4, MAXIT=800
$END
SUPERCRITICAL AIRFOIL SC(2)-0410      Entered by Han S Woo
  0.0      100.00000 100.00000
UPPER SURFACE
  0.00000  0.00000
  0.00200  0.00760
  0.00500  0.01160
  0.01000  0.01550
  0.02000  0.02060
  0.03000  0.02410
  0.04000  0.02680
  0.05000  0.02900
  0.06000  0.03090
  0.07000  0.03260
  0.08000  0.03410
  0.09000  0.03550
  0.10000  0.03670
  0.11000  0.03780
  0.12000  0.03890
  0.13000  0.03990
  0.14000  0.04080
  0.15000  0.04170
  0.16000  0.04250
  0.17000  0.04320
  0.18000  0.04390
  0.19000  0.04450
  0.20000  0.04510
  0.22000  0.04610
  0.23000  0.04660
  0.24000  0.04700
  0.25000  0.04740
  0.26000  0.04780
  0.27000  0.04810
  0.28000  0.04840
  0.29000  0.04870
```

0.30000	0.04890
0.32000	0.04930
0.33000	0.04950
0.34000	0.04960
0.35000	0.04970
0.36000	0.04980
0.37000	0.04990
0.38000	0.05000
0.39000	0.05000
0.40000	0.05000
0.42000	0.05000
0.43000	0.04990
0.44000	0.04980
0.45000	0.04970
0.46000	0.04960
0.47000	0.04940
0.48000	0.04920
0.49000	0.04900
0.50000	0.04880
0.51000	0.04860
0.52000	0.04830
0.53000	0.04800
0.54000	0.04770
0.55000	0.04740
0.56000	0.04700
0.57000	0.04660
0.58000	0.04620
0.59000	0.04580
0.60000	0.04530
0.61000	0.04480
0.62000	0.04430
0.63000	0.04380
0.64000	0.04320
0.65000	0.04260
0.66000	0.04190
0.67000	0.04120
0.68000	0.04050
0.69000	0.03970
0.70000	0.03890
0.71000	0.03810
0.72000	0.03720
0.73000	0.03630
0.74000	0.03530
0.75000	0.03430
0.76000	0.03320
0.77000	0.03210
0.78000	0.03090
0.79000	0.02970
0.80000	0.02850
0.81000	0.02720
0.82000	0.02590
0.83000	0.02450
0.84000	0.02310
0.85000	0.02160
0.86000	0.02010
0.87000	0.01850
0.88000	0.01690
0.89000	0.01530

0.90000	0.01360
0.91000	0.01190
0.92000	0.01010
0.93000	0.00830
0.94000	0.00640
0.95000	0.00450
0.96000	0.00250
0.97000	0.00040
0.98000	-0.00180
0.99000	-0.00420
1.00000	-0.00670
LOWER SURFACE	
0.00000	0.00000
0.00200	-0.00760
0.00500	-0.01160
0.01000	-0.01550
0.02000	-0.02060
0.03000	-0.02410
0.04000	-0.02680
0.05000	-0.02900
0.06000	-0.03090
0.07000	-0.03260
0.08000	-0.03410
0.09000	-0.03550
0.10000	-0.03670
0.11000	-0.03790
0.12000	-0.03900
0.13000	-0.04000
0.14000	-0.04090
0.15000	-0.04180
0.16000	-0.04260
0.17000	-0.04330
0.18000	-0.04400
0.19000	-0.04460
0.20000	-0.04520
0.22000	-0.04630
0.23000	-0.04680
0.24000	-0.04720
0.25000	-0.04760
0.26000	-0.04800
0.27000	-0.04830
0.28000	-0.04860
0.29000	-0.04890
0.30000	-0.04910
0.32000	-0.04950
0.33000	-0.04960
0.34000	-0.04960
0.35000	-0.04980
0.36000	-0.04980
0.37000	-0.04980
0.38000	-0.04980
0.39000	-0.04970
0.40000	-0.04960
0.42000	-0.04930
0.43000	-0.04910
0.44000	-0.04890
0.45000	-0.04860
0.46000	-0.04830

0.47000	-0.04790
0.48000	-0.04750
0.49000	-0.04700
0.50000	-0.04650
0.51000	-0.04590
0.52000	-0.04530
0.53000	-0.04460
0.54000	-0.04390
0.55000	-0.04310
0.56000	-0.04220
0.57000	-0.04120
0.58000	-0.04010
0.59000	-0.03900
0.60000	-0.03780
0.61000	-0.03660
0.62000	-0.03530
0.63000	-0.03400
0.64000	-0.03270
0.65000	-0.03130
0.66000	-0.02990
0.67000	-0.02840
0.68000	-0.02690
0.69000	-0.02540
0.70000	-0.02380
0.71000	-0.02220
0.72000	-0.02060
0.73000	-0.01900
0.74000	-0.01740
0.75000	-0.01580
0.76000	-0.01420
0.77000	-0.01260
0.78000	-0.01110
0.79000	-0.00960
0.80000	-0.00810
0.81000	-0.00680
0.82000	-0.00560
0.83000	-0.00450
0.84000	-0.00350
0.85000	-0.00260
0.86000	-0.00180
0.87000	-0.00120
0.88000	-0.00070
0.89000	-0.00040
0.90000	-0.00030
0.91000	-0.00040
0.92000	-0.00070
0.93000	-0.00120
0.94000	-0.00200
0.95000	-0.00300
0.96000	-0.00420
0.97000	-0.00560
0.98000	-0.00730
0.99000	-0.00930
1.00000	-0.01160

These input files are all on the web. The corresponding output files are also on the web, with the same names as the inputs, except the extension is .out.

The Output

The output file is fairly lengthy. It starts with an echo of the input. This allows you to check that your input data set was read in correctly. The program then shows the airfoil geometry interpolated to the grid. As a thin airfoil theory method, the important information is the airfoil slope, DY/DX , on both the upper and lower surfaces. Look at these to make sure that the values are reasonably smooth.

The program then computes the solution on a sequence of meshes. On each mesh the output starts by giving the value of the over relaxation factor, WE , and the coefficient of the artificial time parameter, EPS , as well as the maximum number iterations allowed on this mesh, $MAXIT$. The next section of the output is the convergence history for this grid. The residual, $BIGRL$, and the maximum correction, $ERROR$, should decrease by several orders of magnitude, but this might not happen on the initial grids. If the values don't decrease significantly on the final mesh, a useful solution has probably not been obtained. You should also look at the change in lift, CL and pitching moment, CM . $IERR$, $JERR$, and IRL , JRL are the grid locations where the values of $ERROR$ and $BIGRL$ are located on the grid. The iteration history continues until the maximum number of iterations allowed is reached, or the values of $ERROR$ or $BIGRL$ have decreased to the value of the convergence criteria set by the user. The values of the computed CL and CM are given, together with CP^* , the value of the critical pressure coefficient ($M = 1$).

In the next section of the output the program displays the values of the pressure coefficient and Mach number on the airfoil plane. This includes the flowfield upstream and downstream of the airfoil. A so-called "print plot" attempts to provide the user with an idea of the computed pressure distribution. This is a remnant of the days when automatic plotting was not routinely available. After the final grid solution is computed, print plots showing where the flow is supersonic, and the values of the Mach number are given. Finally, additional output is given providing an estimate of the wave drag.

Note: This program could actually be considered a "CFD" code, and requires much more skill to use than the codes that work by solving a linear system of equations. An informed user needs to study the references cited above to understand how the code works and how to understand the input and output. Basic information on solutions using iterative methods of the type this program uses can be found in Chapter 8 of the Applied Computational Aerodynamics notes available on the web.