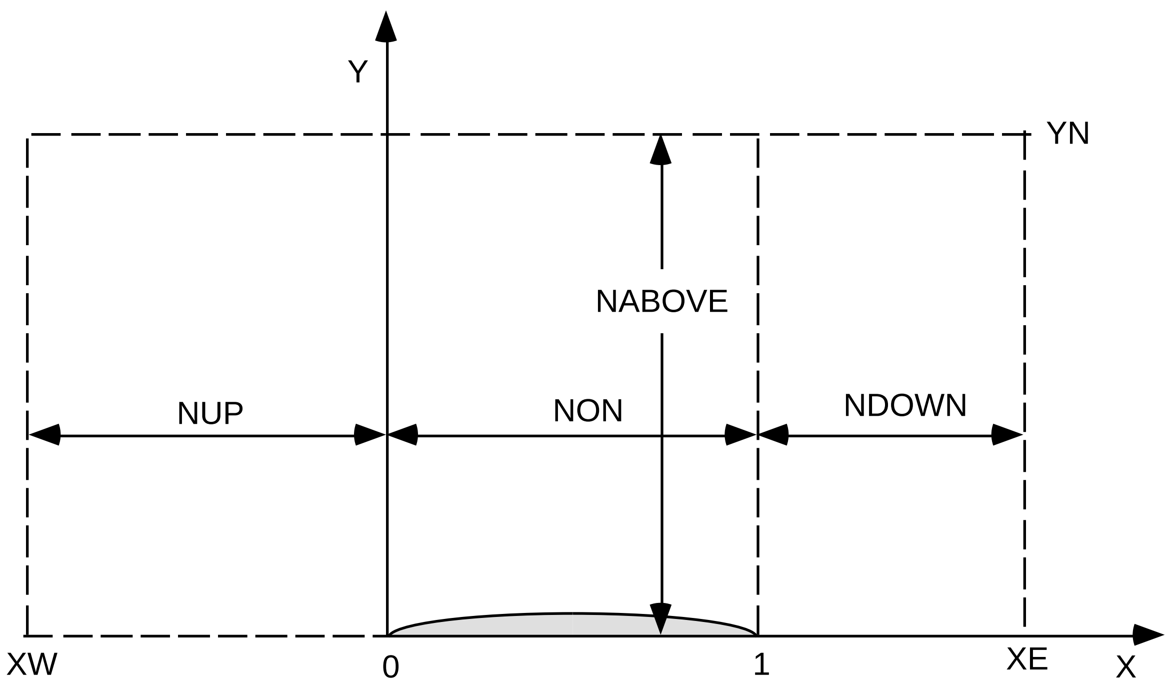
G.4 TRANFOIL/TSFOIL2

These programs solve the transonic small disturbance equation. The disk contains the source codes, sample input, and sample output.

TSDE is from Moran's book. This program uses SLOR to solve the algebraic equations using an evenly spaced grid for flow over a biconvex airfoil at zero angle of attack at a specified Mach number and thickness ratio.

The input values are essentially the same as those used in program THINAIR, and are defined in the following figure. Make sure that the value of XW is negative, and that the order of input requested by the program is followed. Unlike THINAIR, where this was the source of most problems encountered running the code, TSDE may diverge if the value of the relaxation factor is too high, or the Mach number is too close to one. The user also specifies the Mach number, thickness ratio, number of iterations, `MAXTRY`, and the relaxation factors for locally subsonic flow (`RLXSUB` > 1), and supersonic flow (`RLXSUP` < 1).

The airfoil is defined from $x = 0$ to $x = 1$ on $y = 0$. At the farfield boundaries the potential is set to zero. On the plane of symmetry, $y = 0$, the normal velocity is set to zero.



The maximum number of x grid points is 80. However, the program automatically adds points around the boundary, so the user is prevented from exceeding 77. Similarly, the maximum number of y points is 38. The convergence criteria is set internally. The iteration history is output every ten iterations, and includes the number of supersonic points in the flowfield, `NUMSUP`.

Sample execution:

```
  MORAN:  PROGRAM TSDE

INPUT DX,DY: .05,.05

INPUT XW,XE,YN: -1,2,1.8

  NX= 62   NY= 38   ILE= 22   ITE= 42

INPUT MACH, TAU: .82,.1

INPUT MAXTRY, RLXSUB, RLXSUP: 1000,1.8,1.0

 TRIAL  RMS CHANGE  CHANGE RATIO   XMAX     YMAX   MAX CHANGE  NUMSUP
  10     0.330E-02     0.9638    -0.2500   0.1000   0.227E-01    9
  20     0.152E-02     0.9497    -0.5500   0.1000   0.657E-02   16
  30     0.828E-03     0.9530     0.7500   0.0500   0.220E-02   19
  40     0.647E-03     0.9849     0.7500   0.0500   0.167E-02   21
  50     0.582E-03     0.9936     0.7500   0.0500   0.143E-02   22
  60     0.544E-03     0.9942     0.7500   0.0500   0.114E-02   22
  70     0.515E-03     0.9950     0.7500   0.0500   0.998E-03   23
  80     0.490E-03     0.9949     0.7500   0.0500   0.891E-03   23
  90     0.466E-03     0.9948     0.7500   0.0500   0.813E-03   23
 100     0.442E-03     0.9947     0.7500   0.0500   0.753E-03   24
.
.
.
 900     0.539E-05     0.9945     0.8000   0.0500   0.953E-05   34
 910     0.510E-05     0.9943     0.8000   0.0500   0.893E-05   34
 920     0.483E-05     0.9944     0.8000   0.0500   0.845E-05   34
 930     0.457E-05     0.9943     0.8000   0.0500   0.807E-05   34
 940     0.433E-05     0.9943     0.8000   0.0500   0.762E-05   34
 950     0.410E-05     0.9944     0.8000   0.0500   0.716E-05   34
 960     0.388E-05     0.9947     0.8000   0.0500   0.679E-05   34
 970     0.367E-05     0.9941     0.8000   0.0500   0.660E-05   34
 980     0.348E-05     0.9950     0.8000   0.0500   0.613E-05   34
 990     0.329E-05     0.9945     0.8000   0.0500   0.582E-05   34
1000     0.311E-05     0.9945     0.8000   0.0500   0.553E-05   34
```

```
     PRESSURE DISTRIBUTION ON AIRFOIL

        I        X          CP

       23     0.02500     0.23445
       24     0.07500     0.05530
       25     0.12500    -0.07965
       26     0.17500    -0.18781
       27     0.22500    -0.27958
       28     0.27500    -0.36014
       29     0.32500    -0.45224
       30     0.37500    -0.52386
       31     0.42500    -0.58545
       32     0.47500    -0.64134
       33     0.52500    -0.69270
       34     0.57500    -0.73978
       35     0.62500    -0.78178
       36     0.67500    -0.81499
       37     0.72500    -0.80487
       38     0.77500    -0.27178
       39     0.82500    -0.07417
       40     0.87500    -0.02823
       41     0.92500     0.08152
       42     0.97500     0.24863

   INPUT MAXTRY, RLXSUB, RLXSUP: 0,0,0

   STOP
```

TSFOIL2 is also a solution of the transonic small disturbance theory. It was written by Earll Murman, Frank Bailey and Margaret Johnson.[1] However, it has significantly more capability than TSDE. It is also bigger. It may not run on all personal computers. For comparison, consider:

TSDE	TSFOIL2
• 80 col. output	• 133 col. output
• non-lifting biconvex sections	• arbitrary airfoils
• evenly spaced grid points	• unevenly spaced grid points
• interactive input and execution	• input file using NAMELIST

The input to the program is descrbed in subroutine READIN, which asks the user for the name of the input file. The following description is from READIN. Note the default values. Two input data sets are included to illustrate the procedure. TSFOIL was documented in NASA CR 3064, by Stephen S. Stahara, “Operational Manual for Two-Dimensional Transonic Code TSFOIL, Decf. 1978.

1. 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.

```
INPUT EXPLANATION

      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. MULTIPLE CASES
           MAY BE RUN WITH THIS PROGRAM AND THE DATA FOR EACH CASE
           MUST START WITH THIS CARD. THE LAST CARD OF THE INPUT MUST
           BE A CARD WITH THE WORD ?FINISHED? IN THE FIRST 8 COLUMNS.

      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 PREVIOUS CASE
           (OR DEFAULT) MUST BE INCLUDED, ALTHOUGH AT LEAST ONE VALUE
           MUST BE INPUT BY NAMELIST FOR EACH CASE.
                   * (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.
      EMACH  (F) FREESTREAM MACH NUMBER.                               .75
                  NOTE****EMACH MAY NOT BE = 1.0
      DELTA  (F) BODY THICKNESS RATIO.                                .115
      ALPHA  (F) ANGLE OF ATTACK (DEGREES IF PHYS=T)                   .12
      AK     (F) TRANSONIC SIMILARITY PARAMETER.                       0.0
                  (INPUT REQUIRED ONLY IF PHYS = .F. )
      GAM    (F) RATIO OF SPECIFIC HEATS.                              1.4
      SIMDEF (I) SIMILARITY DEFINITION.                                 3
                  =1 COLE
                  =2 SPREITER
                  =3 KRUPP
                  =4 USER
      PRTFLO (I)  OPTION FOR PRINT OF FINAL FLOW FIELD.                 1
                  =1  NO FLOW FIELD PRINT.
                  =2  ALL J LINES PRINTED.
                  =3 PRINT 3 J LINES AROUND MAXIMUM ERROR
      PSTART (I) OPTION FOR INITIALIZING P ARRAY.                       1
                  =1 SET TO ZERO.
                  =2 READ P FROM UNIT 7
                  =3 USE P IN CORE (PREVIOUS CASE).
```

```
                                                              DEFAULT
                                                               VALUE
PSAVE  (L) OPTION FOR SAVING RESTART BLOCK OF                   .F.
            VALUES ON UNIT 3.
            =.TRUE. SAVE FOR RESTART.
            =.FALSE. DO NOT SAVE.
FCR    (L) FULLY CONSERVATIVE RELAXATION OPTION                 .T.
            =.TRUE. DIFFERENCE EQUATIONS ARE
            FULLY CONSERVATIVE FORM.
            =.FALSE. DIFFERENCE EQUATIONS NOT
            CONSERVATIVE AT SHOCK WAVES.
KUTTA  (L) KUTTA CONDITION OPTION.                              .T.
            =.TRUE. KUTTA CONDITION IS ENFORCED
            =.FALSE. LIFT COEFFICIENT SPECIFIED BY USER.
CLSET  (F) LIFT COEFFICIENT, USED IF KUTTA                      .0
            IS FALSE.
BCFOIL (I) OPTION FOR FOIL OR BODY GEOMETRY.                     3
            =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
BCTYPE (I) DESCRIBES THE TYPE OF FLOW TO BE COMPUTED.            1
            =1 FREE AIR.
            =2 SOLID WALL.
            =3 FREE JET.
            =4 SLOTTED WALL.
            =5 POROUS WALL.
F      (F) TUNNEL SLOT PARAMETER.                               0.
H      (F) TUNNEL HALF HEIGHT/CHORD RATIO.                      0.
POR    (F) WALL POROSITY FACTOR.                                .0
PHYS   (L) TYPE OF SCALING TO USE FOR I/O.                      .T.
            =.TRUE.  PHYSICALLY SCALED VALUES.
            =.FALSE. TRANSONICALLY SCALED VALUES
                     FOR PHYS = .F., ALSO INPUT VALUE FOR AK.
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.                  2
            = 0  INPUT MESH IS USED TO CONVERGENCE.
            = 1  INPUT MESH MAY BE CUT ONCE.
            = 2  INPUT MESH MAY BE CUT TWICE.
WE      (F)  3 VALUES FOR RELAXATION FACTOR FOR                 1.8
            ELIPTIC PTS. 1-ST FOR COARSE MESH,                  1.9
            2-ND FOR MED. MESH AND 3-RD FOR                    1.95
            FINE MESH. DEFAULT VALUES ARE SUGGESTED
            VALUES, IN ORDER. IF SPECIFIED IN INPUT
            ALL THREE VALUES MUST BE GIVEN.
WCIRC  (F) RELAXATION FACTOR FOR CIRCULATION.                   1.0
MAXIT  (I) MAXIMUM NUMBER OF ITERATION CYCLE ALLOWED.           500
```

```
                                                                    DEFAULT
                                                                     VALUE

      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                     10
                  LINE IN MESH WHERE ERROR IS LARGEST.
                  I.E. IPRTER=10 , LINE WILL BE PRINTED
                  EVERY 10-TH ITERATION
      NWDGE  (I) CONTROL FOR VISCOUS WEDGE INCLUSION                    0
                  = 0  NO WEDGE
                  = 1  MURMAN BUMP
                  = 2  YOSHIHARA WEDGE
      REYNLD (E) REYNOLDS NUMBER BASED ON CHORD.                    4.0E+6
                  USED WHEN NWDGE = 1
      WCONST (F) WEDGE CONSTANT. USED WHEN NWDGE=1                    4.0
      IFLAP  (I) CONTROL FOR FLAP DEFLECTION.                           0
                  FLAP INCLUDED WHEN IFLAP .NE. 0
      DELFLP (F) FLAP DEFLECTION ANGLE.                               5.0
                  POSITIVE DEGREES T.E. DOWN
      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 two sample inputs for TSFOIL2:

This dataset provides the solution to the biconvex airfoil (BCFOIL=2) that corresponds to the solution provided by TSDE:

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

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

These files are contained on the disk as bicon.inp and N2412.inp. The corresponding output is contained in the files bicon.out and n2412.out.