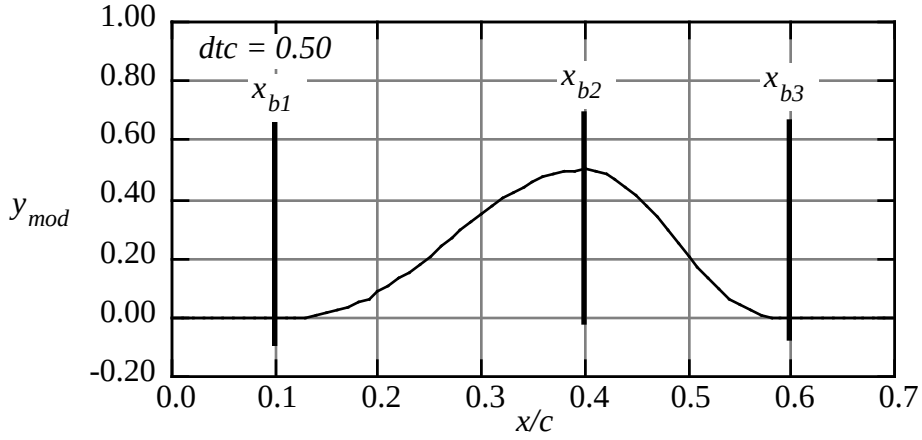
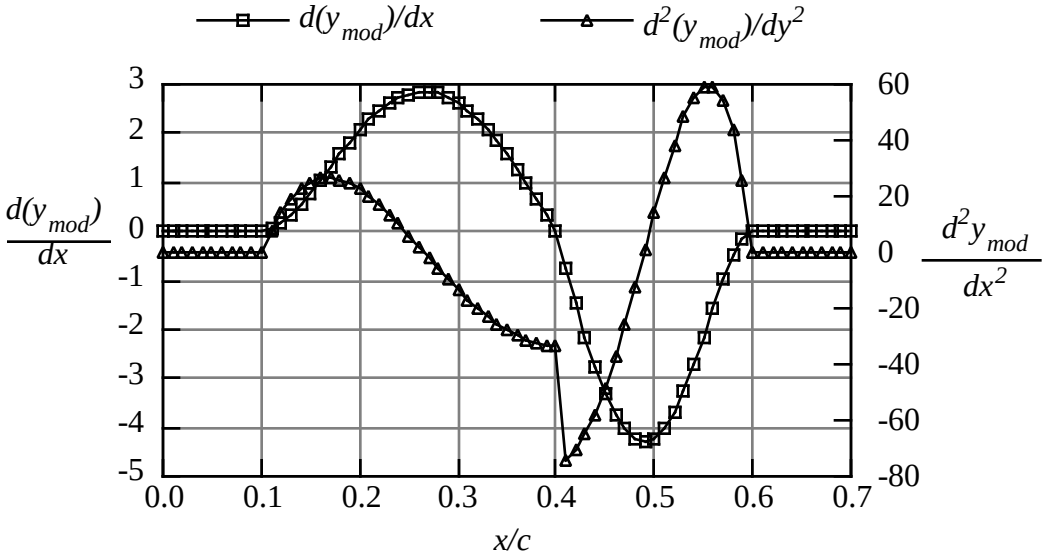
E.5 BUMP

This subroutine illustrates a means of making smooth changes to airfoil shapes. It is included in PANELv2. It is designed to place a "bump" on the airfoil contour. The shape change starts gradually with zero curvature at point x_{b_1}. The bump is setup to be asymmetric about the bump midpoint, x_{b_2}, and to blend back into the baseline shape with zero curvature at point x_{b_3}. However, if an asymmetric bump is used, the curvature will be discontinuous at the bump maximum. The following plot defines the nomenclature, as well as plotting the output of the sample main program presented below.



The related slope and curvature are given in the next graph.



The equation of the bump is:

$$y_{mod} = -64\left(\Delta\frac{t}{c}\right)x_d^3(x_d-1)^3$$

$$\frac{dy_{mod}}{dx_d} = -64\left(\Delta\frac{t}{c}\right)3x_d^2(x_d-1)^2(2x_d-1)$$

$$\frac{d^2y_{mod}}{dx_d^2} = -64\left(\Delta\frac{t}{c}\right)6x_d(x_d-1)\left(5x_d^2-5x_d+1\right)$$

where

$$x_d = \frac{(x-x_1)}{2(x_2-x_1)} \qquad x_1 < x < x_2$$

or

$$x_d = \frac{(x+x_3-2x_2)}{2(x_3-x_2)} \qquad x_2 < x < x_3$$

This function is often called a “cubic bump” although it is clearly a sixth order polynomial. The user should examine the subroutine to understand the transformation between the local variable x_d and the global variable x_{in}.

Listing of subroutine bump.f:

```
      subroutine bump(xb1,xb2,xb3,dtc,xmax,xin,ymod,ymodp,ymodpp)
c
c     so-called cubic bump function
c
c     used to make mods to aero surfaces
c
c     W.H. Mason, December 1989
c
c     xb1    - start of bump (dimensional)
c     xb2    - location of maximum bump height (dimensional)
c     xb3    - end of bump (dimensional)
c
c     dtc    - magnitude of bump
c     xmax   - reference length of geometry
c
c     xin    - input location to get bump value
c     ymod   - bump height
c     ymodp  - first derivative of bump wrt xin
c     ymodpp - second derivative of bump wrt xin

      x      = xin/xmax
      x1     = xb1/xmax
      x2     = xb2/xmax
      x3     = xb3/xmax
```

```
      xd     = 0.0
      dxddx  = 0.0
      if ( x .ge. x1 .and. x .le. x2) then

               xd = (x - x1)/2.0/(x2 - x1)
               dxddx = 1./2./(x2 - x1)
               endif

      if ( x .gt. x2 .and. x .le. x3) then

               xd = (x + x3 - 2.0*x2)/2.0/(x3 - x2)
               dxddx = 1./2./(x3 - x2)
               endif

      ymod   = -64.*dtc*xd**3*(xd - 1.0)**3

      ymodp  = -64.*dtc*3.0*dxddx*xd**2*
     1          (xd - 1.0)**2*(2.0*xd - 1.0)
      ymodpp = -64.*dtc*6.0*dxddx**2*xd*(xd - 1.0)*
     1          (5.0*xd**2 - 5.0*xd + 1.0)

      return
      end
```

This is a sample main program that can be used to check subroutine bump.

```
c
c     example of use of bump function
c     this is one way to modify an airfoil
c     w.h. mason, Feb. 12, 1994

c     set input parameters

      xb1    = 0.1
      xb2    = 0.4
      xb3    = 0.6

      dtc    = 0.50

      xmax   = 1.0

      write(6, 90) xb1,xb2,xb3,dtc
   90 format(/3x,'bump example'//
     1        3x,'xb1 = ',f7.4,3x,'xb2 = ',f7.4,3x,
     2           'xb3 = ',f7.4/3x,'dtc = ',f7.4/
     3       /4x,'i',7x,'x/c',7x,'delta y',4x,
     4           'd(dy)/dx'3x,'d2(dy)/dy2')

      do 10 i = 1,101
      xc      = 0.01*(i-1)
      call bump(xb1,xb2,xb3,dtc,xmax,xc,ymod,ymodp,ymodpp)
   10 write(6,100) i,xc,ymod,ymodp, ymodpp

  100 format(i5,4f12.5)

      stop
      end
```

sample output from the sample main program and subroutine bump.f

```
bump example

xb1 =  0.1000   xb2 =  0.4000   xb3 =  0.6000
dtc =  0.5000

 i       x/c       delta y    d(dy)/dx   d2(dy)/dy2
 1     0.00000     0.00000     0.00000     0.00000
 2     0.01000     0.00000     0.00000     0.00000
 3     0.02000     0.00000     0.00000     0.00000
 4     0.03000     0.00000     0.00000     0.00000
 5     0.04000     0.00000     0.00000     0.00000
 6     0.05000     0.00000     0.00000     0.00000
 7     0.06000     0.00000     0.00000     0.00000
 8     0.07000     0.00000     0.00000     0.00000
 9     0.08000     0.00000     0.00000     0.00000
10     0.09000     0.00000     0.00000     0.00000
11     0.10000     0.00000     0.00000     0.00000
12     0.11000     0.00014     0.04154     8.02448
13     0.12000     0.00107     0.15505    14.41646
14     0.13000     0.00343     0.32490    19.31666
15     0.14000     0.00771     0.53686    22.86090
16     0.15000     0.01426     0.77803    25.18004
17     0.16000     0.02333     1.03680    26.40000
18     0.17000     0.03502     1.30277    26.64177
19     0.18000     0.04938     1.56676    26.02140
20     0.19000     0.06633     1.82070    24.65000
21     0.20000     0.08573     2.05761    22.63374
22     0.21000     0.10740     2.27156    20.07387
23     0.22000     0.13107     2.45760    17.06667
24     0.23000     0.15645     2.61171    13.70350
25     0.24000     0.18319     2.73077    10.07078
26     0.25000     0.21094     2.81250     6.25000
27     0.26000     0.23931     2.85540     2.31770
28     0.27000     0.26791     2.85872    -1.65453
29     0.28000     0.29635     2.82240    -5.60000
30     0.29000     0.32423     2.74702    -9.45699
31     0.30000     0.35117     2.63374   -13.16873
32     0.31000     0.37679     2.48430   -16.68333
33     0.32000     0.40074     2.30089   -19.95391
34     0.33000     0.42270     2.08618   -22.93848
35     0.34000     0.44237     1.84320   -25.60000
36     0.35000     0.45948     1.57536   -27.90638
37     0.36000     0.47380     1.28635   -29.83045
38     0.37000     0.48515     0.98010   -31.35000
39     0.38000     0.49336     0.66075   -32.44773
40     0.39000     0.49834     0.33259   -33.11131
41     0.40000     0.50000     0.00000   -33.33333
42     0.41000     0.49626    -0.74625   -73.87733
43     0.42000     0.48515    -1.47015   -70.53750
44     0.43000     0.46700    -2.14989   -65.06483
45     0.44000     0.44237    -2.76480   -57.60000
46     0.45000     0.41199    -3.29590   -48.33986
47     0.46000     0.37679    -3.72645   -37.53750
48     0.47000     0.33784    -4.04253   -25.50236
49     0.48000     0.29635    -4.23360   -12.60004
50     0.49000     0.25361    -4.29304     0.74764
```

```
51     0.50000     0.21094    -4.21875    14.06247
52     0.51000     0.16967    -4.01368    26.81011
53     0.52000     0.13107    -3.68640    38.39995
54     0.53000     0.09630    -3.25169    48.18510
55     0.54000     0.06633    -2.73105    55.46249
56     0.55000     0.04187    -2.15332    59.47264
57     0.56000     0.02333    -1.55520    59.39999
58     0.57000     0.01068    -0.98183    54.37266
59     0.58000     0.00343    -0.48735    43.46253
60     0.59000     0.00046    -0.13547    25.68523
61     0.60000     0.00000     0.00000     0.00000
62     0.61000     0.00000     0.00000     0.00000
63     0.62000     0.00000     0.00000     0.00000
64     0.63000     0.00000     0.00000     0.00000
65     0.64000     0.00000     0.00000     0.00000
66     0.65000     0.00000     0.00000     0.00000
67     0.66000     0.00000     0.00000     0.00000
68     0.67000     0.00000     0.00000     0.00000
69     0.68000     0.00000     0.00000     0.00000
70     0.69000     0.00000     0.00000     0.00000
71     0.70000     0.00000     0.00000     0.00000
(rest of the output deleted)
```