

APPENDIX 1

FEM1

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1 C *****
2 C
3 C
4 C
5 C
6 C
7 C *****
8 C
9 C
10 C PURPOSE:
11 C PROGRAM FOR SOLVING HEAT CONDUCTION PROBLEMS USING
12 C THREE-NODE LINEAR TRIANGULAR ELEMENTS
13 C
14 C BOUNDARY VALUE PROBLEMS SOLVED:
15 C
16 C      - DIV ( K GRAD U ) = F      IN D
17 C              U = G      ON S1
18 C      K GRAD U.N = H      ON S2
19 C      K GRAD U.N = - A ( U - UO ) ON S3
20 C
21 C      K = HEAT CONDUCTIVITY
22 C      U = TEMPERATURE
23 C      F = HEAT SUPPLY
24 C      N = UNIT VECTOR OUTWARD NORMAL TO THE BOUNDARY
25 C      G = SPECIFIED BOUNDARY TEMPERATURE
26 C      H = SPECIFIED HEAT FLUX THROUGH THE BOUNDARY
27 C      UO = OUTSIDE TEMPERATURE
28 C      A = MATERIAL CONSTANT
29 C
30 C NOTE:
31 C THE PROGRAM ASSUMES THE DOUBLE PRECISION: IMPLICIT REAL*8
32 C (A-H,O-Z).
33 C THE GLOBAL STIFFNESS MATRIX IS STORED IN THE ONE
34 C DIMENSIONAL ARRAY USING THE INDEX TRANSFORMATION.
35 C SK(I,J) --> SK(I,J-I+1) --> SK(MBAND*(I-1)+J-I+1) FOR I<=J
36 C
37 C CONTROL NUMBERS:
38 C LBOUN1 = 1 IF THE 1-ST BOUNDARY CONDITION IS ASSUMED
39 C LBOUN2 = 1 IF THE 2-ND BOUNDARY CONDITION IS ASSUMED
40 C LBOUN3 = 1 IF THE 3-RD BOUNDARY CONDITION IS ASSUMED
41 C LHEATG = 1 IF THE HEAT SUPPLY IS ASSUMED
42 C
43 C STRUCTURE OF THE PROGRAM:
44 C PRE PROCESSING
45 C SUBROUTINE PTITLE ----- READ THE TITLE OF THE
46 C MAIN PROGRAM ----- READ CONTROL NUMBERS
47 C SUBROUTINE HRMESH ----- READ COORDINATES AND
48 C ELEMENT CONNECTIVITIES
49 C SUBROUTINE MATERL ----- READ CONDUCTIVITIES
50 C SUBROUTINE HBANDW ----- COMPUTE HALF-BAND WIDTH
51 C OF STIFFNESS MATRIX
52 C
53 C FINITE ELEMENT PROCESSING
54 C SUBROUTINE ASEMBO ----- ASSEMBLE ELEMENT
55 C STIFFNESS MATRICES
56 C AND LOAD VECTORS
57 C SUBROUTINE ESTIF3 ----- ELEMENT STIFFNESS
58 C MATRIX
59 C SUBROUTINE GRADI3 ----- GRADIENT VECTOR OF
60 C SHAPE FUNCTIONS
61 C SUBROUTINE HEATGE ----- HEAT SOURCES/SINKS
62 C ARE INPUT IN THE LOAD
63 C VECTOR
64 C SUBROUTINE BOUND1 ----- 1-ST BOUNDARY CONDITION
65 C SUBROUTINE BOUND2 ----- 2-ND BOUNDARY CONDITION
66 C SUBROUTINE BOUND3 ----- 3-RD BOUNDARY CONDITION
67 C SUBROUTINE BANDSL ----- SOLVES THE SYSTEM OF
68 C LINEAR EQUATIONS
69 C
70 C POST PROCESSING
71 C SUBROUTINE OUTPUT ----- OUTPUT THE RESULTS
72 C SUBROUTINE QUALIT ----- COMPUTE QUALITY INDICES
73 C TO CHECK THE RESULTS
74 C
75 C INPUT DATA TO BE READ:
76 C 1) SUBROUTINE PTITLE
77 C 1.0 FLAG(I),I=1,10 : 10A8
78 C 1.1 TITLE(I),I=1,10 : 10A8

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76 C      2) MAIN : CONTROL NUMBERS
77 C          2.0 FLAG(I),I=1,10 : 10A8
78 C          2.1 LBOUND1,REM(I),I=1,9 : 15,9A8
79 C          2.2 LBOUND2,REM(I),I=1,9 : 15,9A8
80 C          2.3 LBOUND3,REM(I),I=1,9 : 15,9A8
81 C          2.4 LHEATG,REM(I),I=1,9 : 15,9A8
82 C      3) SUBROUTINE HRMESH
83 C          3.0 FLAG(I),I=1,10 : 10A8
84 C          3.1 NODADD,NELADD : 2I5
85 C          3.2 II,X(II),Y(II),I=1,NODADD : 15,2F10.4
86 C          3.3 NN,MPE(NN),(IJK(J,NN),J=1,3),
87 C              N=1,NELADD : 5I5
88 C      4) SUBROUTINE MATERL
89 C          4.0 FLAG(I),I=1,10 : 10A8
90 C          4.1 MATX : 16I5
91 C          4.2 I,(XYK(J,I),J=1,3),I=1,MATX : 15,3F10.4
92 C      5) SUBROUTINE HEATGE IF LHEATG = 1
93 C          5.0 FLAG(I),I=1,10 : 10A8
94 C          5.1 NHEATG : 16I5
95 C          IF(NHEATG.LT.0) GO TO 5.3
96 C          DO 100 I=1,NHEATG
97 C          5.2 CXY(I,J),J=1,NHEATG : 8F10.4
98 C          100 CONTINUE
99 C          GO TO 7)
100 C          5.3 NODE,VALUE,I=1,-NHEATG : 15,F10.4
101 C      6) SUBROUTINE BOUND1 IF LBOUND1 = 1
102 C          6.0 FLAG(I),I=1,10 : 10A8
103 C          6.1 NBX,PENALTY : 15,F20.5
104 C          6.2 NODE,VALUE,I=1,NBX : 15,F10.4
105 C      7) SUBROUTINE BOUND2 IF LBOUND2 = 1
106 C          7.0 FLAG(I),I=1,10 : 10A8
107 C          7.1 NBX : 16I5
108 C          7.2 NODE1,NODE2,VALUE,I=1,NBX : 2I5,F10.4
109 C      8) SUBROUTINE BOUND3 IF LBOUND3 = 1
110 C          8.0 FLAG(I),I=1,10 : 10A8
111 C          8.1 NBLX,MPBX : 16I5
112 C          8.2 I,(IJB(J,I),J=1,2),MPB(I),
113 C              I=1,NBLX : 4I5
114 C          8.3 I,XKB(I),UO(I),I=1,MPBX : 15,2F10.4
115 C
116 C      *** LOOK AT EACH SUBROUTINE BEFORE MAKING INPUT DATA
117 C
118 C      DIMENSIONING:
119 C      SK(NX*MBAND),F(NX),U(NX),X(NX),Y(NX),CQX(NX),CQY(NX)
120 C      NX = TOTAL NUMBER OF NODAL POINTS IN THE DOMAIN
121 C      MBAND = (HALF-)BAND WIDTH OF THE STIFFNESS MATRIX
122 C      SK = BANDED STIFFNESS MATRIX
123 C      F = GENERALIZED LOAD VECTOR
124 C      U = SOLUTION VECTOR
125 C      X,Y = COORDINATES OF NODAL POINTS
126 C      CQX = QUALITY INDEX AT NODAL POINTS (TEMPERATURE)
127 C      CQY = QUALITY INDEX AT NODAL POINTS (HEAT FLUX)
128 C      IJK(NODE,NELX),MP(NELX)
129 C      NELX = TOTAL NUMBER OF FINITE ELEMENTS
130 C      NODE = TOTAL NUMBER OF NODAL POINTS IN AN ELEMENT
131 C      IJK = ELEMENT CONNECTIVITIES
132 C      MP = MATERIAL GROUP OF THE FINITE ELEMENTS
133 C      XYK(3,MPX)
134 C      MPX = TOTAL NUMBER OF MATERIAL GROUPS
135 C      XYK = MATERIAL PROPERTIES (KXX,KYY,KXY)
136 C      IJB(NODE3,NBX),MPB(NBX),XKB(MBX),UO(MBX)
137 C      NODE3 = TOTAL NUMBER OF NODAL POINTS ON A LINE ELEMENT
138 C      NBX = TOTAL NUMBER OF LINE ELEMENTS
139 C      MBX = TOTAL NUMBER OF DIFFERENT MATERIAL GROUPS ALONG
140 C          THE 3-RD BOUNDARY
141 C      IJB = ELEMENT CONNECTIVITIES ON THE 3-RD BOUNDARY
142 C      MPB = GROUP NUMBER OF MATERIALS
143 C      XKB = COEFFICIENTS OF HEAT TRANSFER
144 C      UO = OUTSIDE TEMPERATURE SPECIFIED
145 C      P(4,NELX)
146 C      P = STORES THE HEAT FLUX VECTORS AND QUALITY INDICES
147 C      FLAG(10),REM(9)
148 C      FLAG = DESCRIPTION OF THE DATA BLOCKS
149 C          ( ANY COMMENTS WITHIN 10A8 CAN BE INPUT IN ORDER TO
150 C            MEMORIZE THE INPUT DATA IN EACH SUBROUTINE. IF YOU
151 C            DO NOT WANT IT, THEN SKIP ONE LINE IN THE DATA FILE )
152 C      REM = REMARK TO THE INPUT DATA
153 C
154 C      DATA STATEMENT: < IMPORTANT >

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155 C      LR      = DISK NUMBER FOR READ STATEMENTS ( STD IS 5 )
156 C      LW      = DISK NUMBER FOR WRITE STATEMENTS ( STD IS 6 )
157 C      LP      = DISK NUMBER FOR WRITE STATEMENTS FOR PLOTTING
158 C              ( STD IS 8 )
159 C      NDIM     > MBAND*NX*NDF
160 C      NODE     = TOTAL NUMBER OF NODAL POINTS IN AN ELEMENT ( = 3 )
161 C      NDF      = NUMBER OF DEGREES OF FREEDOM PER NODAL POINT ( = 1 )
162 C
163 C *****
164 C
165 C      IMPLICIT REAL*8(A-H,O-Z)
166 C      DIMENSION SK(50000),F(300),U(300),X(300),Y(300),
167 C              1 IJK(3,500),MP(500),
168 C              3 XYK(3,10),
169 C              4 IJB(2,100),MPB(100),XKB(30),UO(30),
170 C              5 P(4,500),CQX(300),CQY(300),
171 C              6 FLAG(10),REM(10)
172 C      DATA LR,LW,LP,NDIM,NODE,NDF/5,6,8,50000,3,1/
173 C
174 C ***** PRE-PROCESSING *****
175 C
176 C      ( READ THE TITLE OF THE PROBLEM AND CONTROL NUMBERS )
177 C
178 C      CALL PTITLE(LR,LW)
179 C
180 C      READ(LR,502) (FLAG(I),I=1,10)
181 C      502 FORMAT(10A8)
182 C      WRITE(LW,602)
183 C      602 FORMAT(//////10X,'XXXXXXXXXX CONTROL NUMBERS XXXXXXXXXXXX',//)
184 C      500 FORMAT(I5,9A8)
185 C      600 FORMAT(/10X,I3,3X,9A8)
186 C      READ(LR,500) LBOUN1,(REM(I),I=1,9)
187 C      WRITE(LW,600) LBOUN1,(REM(I),I=1,9)
188 C      READ(LR,500) LBOUN2,(REM(I),I=1,9)
189 C      WRITE(LW,600) LBOUN2,(REM(I),I=1,9)
190 C      READ(LR,500) LBOUN3,(REM(I),I=1,9)
191 C      WRITE(LW,600) LBOUN3,(REM(I),I=1,9)
192 C      READ(LR,500) LHEATG,(REM(I),I=1,9)
193 C      WRITE(LW,600) LHEATG,(REM(I),I=1,9)
194 C
195 C      ( READ THE FINITE ELEMENT MODEL )
196 C
197 C      CALL HRMESH(NX,NELX,X,Y,IJK,NODE,MP,LR,LW)
198 C
199 C      ( READ THE MATERIAL PROPERTIES )
200 C
201 C      CALL MATERL(XYK,LR,LW)
202 C
203 C      ( FIND THE HALF-BAND WIDTH OF THE STIFFNESS MATRIX )
204 C
205 C      CALL HBANDW(MBAND,IJK,NELX,NODE,NDF,LW)
206 C
207 C      IF(NX*MBAND.LE.NDIM) GO TO 100
208 C      WRITE(LW,644)
209 C      644 FORMAT(//////,'ARRAY FOR THE STIFFNESS MATRIX IS TOO SMALL')
210 C      STOP
211 C      100 CONTINUE
212 C
213 C ***** FINITE ELEMENT-PROCESSING *****
214 C
215 C      ( FORM THE STIFFNESS MATRIX AND THE LOAD VECTOR )
216 C
217 C      CALL ASEMBO(SK,F,MBAND,NX,NELX,IJK,NODE,NDF,MP,X,Y,XYK,LW)
218 C
219 C      ( ROUTINE FOR THE HEAT SUPPLY TERM )
220 C
221 C      IF(LHEATG.EQ.1) CALL HEATGE(F,NX,NELX,IJK,X,Y,LR,LW)
222 C
223 C      ( ROUTINES FOR THE BOUNDARY CONDITIONS )
224 C
225 C      IF(LBOUN1.EQ.1) CALL BOUND1(MBAND,SK,F,LR,LW)
226 C      IF(LBOUN2.EQ.1) CALL BOUND2(F,X,Y,LR,LW)
227 C      IF(LBOUN3.EQ.1) CALL BOUND3(MBAND,SK,F,X,Y,IJB,MPB,XKB,UO,LR,LW)
228 C
229 C      ( SOLVE THE SYSTEM OF LINEAR EQUATIONS )
230 C
231 C      CALL BANDSL(SK,F,NX,MBAND,O)
232 C

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233 C ***** POST-PROCESSING *****
234 C
235 C ( PRINT OUT THE RESULTS )
236 C
237 C CALL OUTPUT(F,P,NX,NELX,X,Y,IJK,MP,XYK,LW)
238 C
239 C CALL QUALIT(NELX,NX,MBAND,IJK,X,Y,P,SK,CQX,CQY,NODE,LW)
240 C
241 C ( STORE THE RESULTS FOR THE PLOTTING ROUTINE )
242 C
243 C WRITE(LP,810)
244 810 FORMAT('FINITE ELEMENT MODEL')
245 C WRITE(LP,800) NX,NELX
246 800 FORMAT(2I5)
247 C WRITE(LP,820)
248 820 FORMAT(' < NODAL COORDINATES >')
249 C WRITE(LP,802) (X(I),Y(I),I=1,NX)
250 802 FORMAT(8F10.4)
251 C WRITE(LP,812)
252 812 FORMAT(' < ELEMENT CONNECTIVITIES >')
253 C WRITE(LP,804) ((IJK(J,I),J=1,NODE),I=1,NELX)
254 804 FORMAT(16I5)
255 C WRITE(LP,814)
256 814 FORMAT('TEMPERATURE')
257 C WRITE(LP,806) (F(I),I=1,NX)
258 806 FORMAT(8E10.3)
259 C WRITE(LP,816)
260 816 FORMAT('HEAT FLUX AND QUALITY INDICES')
261 C WRITE(LP,808) ((P(J,I),J=1,4),I=1,NELX)
262 808 FORMAT(8E10.3)
263 C WRITE(LP,818)
264 818 FORMAT('COMFORMING QUALITY INDICES')
265 C WRITE(LP,808) (CQX(I),CQY(I),I=1,NX)
266 C
267 C STOP
268 C END
269 C -----
270 C
271 C SUBROUTINE PTITLE(LR,LW)
272 C
273 C PURPOSE:
274 C PRINT OUT THE TITLE OF THE PROBLEM TO BE SOLVED.
275 C
276 C INPUT DATA TO BE READ:
277 C 0. FLAG(I),I=1,10 : 10A8
278 C 1. TITLE(I) : 10A8
279 C -----
280 C
281 C IMPLICIT REAL*8(A-H,O-Z)
282 C DIMENSION TITLE(10),FLAG(10)
283 C
284 C READ(LR,500) (FLAG(I),I=1,10)
285 C READ(LR,500) (TITLE(I),I=1,10)
286 500 FORMAT(10A8)
287 C
288 C WRITE(LW,600) (TITLE(I),I=1,10)
289 600 FORMAT(1H1,//////////5X,75(' '),/5X,75(' '),////,15X,
290 1 10A8,////5X,75(' '),/5X,75(' '))
291 C
292 C RETURN
293 C END
294 C -----
295 C
296 C SUBROUTINE HRMESH(NX,NELX,X,Y,IJK,NODE,MPE,LR,LW)
297 C
298 C PURPOSE:
299 C READ THE DATA OF THE FINITE ELEMENT MODEL: COORDINATES OF
300 C NODAL POINTS, ELEMENT CONNECTIVITIES.
301 C
302 C ARGUMENTS:
303 C NX = TOTAL NUMBER OF NODAL POINTS
304 C NELX = TOTAL NUMBER OF FINITE ELEMENTS
305 C X,Y = COORDINATES OF NODAL POINTS
306 C IJK = ELEMENT CONNECTIVITIES
307 C NODE = TOTAL NUMBER OF NODAL POINTS IN AN ELEMENT
308 C MPE = GROUP NUMBER OF THE MATERIALS FOR EACH ELEMENT
309 C LR = CONTROL NUMBER OF THE READ STATEMENT
310 C

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311 C      LW      = CONTROL NUMBER OF THE WRITE STATEMENT
312 C
313 C      LOCAL VARIABLES:
314 C      NODES    = FIRST NODE NUMBER ADDED
315 C      NELMS     = FIRST ELEMENT NUMBER ADDED
316 C      NODADD    = TOTAL NUMBER OF ADDITIONAL NODAL POINTS
317 C      NELADD    = TOTAL NUMBER OF ADDITIONAL ELEMENTS
318 C
319 C      EXAMPLE:
320 C
321 C              N3
322 C              / I      IJK(1,NEL)=N1
323 C             / / I      IJK(2,NEL)=N2
324 C            / / I      IJK(3,NEL)=N3
325 C           / / NEL I
326 C          / / I
327 C         / / I
328 C        N1-----N2
329 C
330 C      INPUT DATA TO BE READ:
331 C      0. FLAG(I),I=1,10      :      10A8
332 C      1. NODADD,NELADD      :      16I5
333 C      2. II,X(II),Y(II),I=1,NODADD      :      15,2F10.4
334 C      3. NN,MPE(NN),(IJK(J,NN),J=1,NODE),
335 C         N=1,NELADD      :      5I5
336 C
337 C -----
338 C      IMPLICIT REAL*8(A-H,O-Z)
339 C      DIMENSION X(1),Y(1),IJK(NODE,1),MPE(1),FLAG(10)
340 C
341 C      READ(LR,598) (FLAG(I),I=1,10)
342 C      598 FORMAT(10A8)
343 C      READ(LR,500) NODADD,NELADD
344 C      500 FORMAT(16I5)
345 C      READ(LR,598) (FLAG(I),I=1,10)
346 C      DO 100 I=1,NODADD
347 C      READ(LR,502) II,X(II),Y(II)
348 C      502 FORMAT(15,2F10.4)
349 C      IF(II.GT.NX) NX=II
350 C      100 CONTINUE
351 C      READ(LR,598) (FLAG(I),I=1,10)
352 C      DO 102 N=1,NELADD
353 C      READ(LR,500) NN,MPE(NN),(IJK(J,NN),J=1,NODE)
354 C      IF(NN.GT.NELX) NELX=NN
355 C      102 CONTINUE
356 C
357 C      WRITE(LW,600)
358 C      600 FORMAT(////10X,'XXXXXXXXXX HRMESH : ELEMENTS AND NODES ',
359 C      1 'XXXXXXXXXX',//15X,
360 C      2 '< ELEMENT CONNECTIVITY >',/)
361 C
362 C      DO 104 I=1,NELX
363 C      104 WRITE(LW,602) I,MPE(I),(IJK(J,I),J=1,NODE)
364 C      602 FORMAT(10X,I5,3X,I5,5X,'<IJK>',9I5)
365 C      WRITE(LW,604)
366 C      604 FORMAT(////15X,'< COORDINATES >',/)
367 C      WRITE(LW,606) (I,X(I),Y(I),I=1,NX)
368 C      606 FORMAT(5X,I5,3X,'<',2F10.4,1X,'>',5X,I5,3X,'<',2F10.4,
369 C      1 2X,'>')
370 C
371 C      RETURN
372 C      END
373 C -----
374 C
375 C      SUBROUTINE MATERL(XYK,LR,LW)
376 C
377 C      PURPOSE:
378 C      READ MATERIAL CONSTANTS KXX,KYY, AND KXY.
379 C
380 C      ARGUMENTS:
381 C      XYK = MATERIAL CONSTANTS IN THE MATRIX FORM
382 C      XYK(1,N) = KXX IN THE N-TH GROUP
383 C      XYK(2,N) = KYY IN THE N-TH GROUP
384 C      XYK(3,N) = KXY IN THE N-TH GROUP
385 C
386 C      LOCAL VARIABLES:
387 C      FLAG = ARRAY FOR THE REMARK
388 C      MATX = TOTAL NUMBER OF KINDS OF MATERIALS
389 C

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390 C INPUT DATA TO BE READ:
391 C O. FLAG(I),I=1,10 : 10A8
392 C 1. MATX : 16I5
393 C 2. I,(XYK(J,I),J=1,3),I=1,MATX : I5,3F10.4
394 C
395 C -----
396 C
397 C IMPLICIT REAL*8(A-H,O-Z)
398 C DIMENSION XYK(3,1),FLAG(10)
399 C
400 C READ(LR,500) (FLAG(I),I=1,10)
401 500 FORMAT(10A8)
402 C READ(LR,502) MATX
403 502 FORMAT(16I5)
404 C READ(LR,504) (I,(XYK(J,I),J=1,3),I=1,MATX)
405 504 FORMAT(I5,3F10.4)
406 C
407 C WRITE(LW,600) MATX
408 600 FORMAT(//////10X,'XXXXXXXXXX MATERIAL CONSTANTS XXXXXXXXXXXX',//13X,
409 1 'NUMBER OF DIFFERENT MATERIALS =',I3,////,10X,
410 2 '< MATERIAL CONSTANTS >',/)
411 C WRITE(LW,602) (I,(XYK(J,I),J=1,3),I=1,MATX)
412 602 FORMAT(13X,I3,2X,'KX=',E10.3,2X,'KY=',E10.3,2X,'KXY=',E10.3)
413 C
414 C RETURN
415 C END
416 C -----
417 C
418 C SUBROUTINE HBANDW(MBAND,IJK,NELX,NODE,NDF,LW)
419 C
420 C PURPOSE:
421 C COMPUTE THE HALF-BAND WIDTH OF THE STIFFNESS MATRIX.
422 C
423 C ARGUMENTS:
424 C MBAND = HALF-BAND WIDTH OF THE STIFFNESS MATRIX
425 C IJK = ELEMENT CONNECTIVITIES
426 C NELX = TOTAL NUMBER OF FINITE ELEMENTS
427 C NODE = TOTAL NUMBER OF NODAL POINTS IN AN ELEMENT
428 C NDF = NUMBER OF DEGREES OF FREEDOM PER NODAL POINT
429 C
430 C -----
431 C
432 C DIMENSION IJK(NODE,1)
433 C
434 C MBAND=1
435 C DO 100 NEL=1,NELX
436 C DO 100 IA=1,NODE
437 C IJKIA=IJK(IA,NEL)
438 C DO 100 I=1,NDF
439 C IJKIAI=NDF*(IJKIA-1)+I
440 C DO 100 JB=1,NODE
441 C IJKJB=IJK(JB,NEL)
442 C DO 100 J=1,NDF
443 C IJKJB=IJKJB-NDF*(IJKJB-1)+J
444 C IAIJB=IJKJB-IJKIAI+1
445 C IF(IAIJB.GT.MBAND) MBAND=IAIJB
446 100 CONTINUE
447 C
448 C WRITE(LW,600) MBAND
449 600 FORMAT(//////10X,'XXXXXXXXXX BAND WIDTH XXXXXXXXXXXX',/15X,
450 1 'MBAND = ',I8)
451 C
452 C RETURN
453 C END
454 C -----
455 C
456 C SUBROUTINE ASEMBO(SK,F,MBAND,NX,NELX,IJK,NODE,NDF,MP,X,Y,XYK,LW)
457 C
458 C PURPOSE:
459 C CONSTRUCTS THE GLOBAL STIFFNESS MATRIX AND LOAD VECTOR.
460 C
461 C ARGUMENTS:
462 C SK = GLOBAL STIFFNESS MATRIX
463 C F = GLOBAL LOAD VECTOR
464 C MBAND = HALF-BAND WIDTH OF THE STIFFNESS MATRIX
465 C NX = TOTAL NUMBER OF NODAL POINTS
466 C NELX = TOTAL NUMBER OF FINITE ELEMENTS
467 C IJK = ELEMENT CONNECTIVITIES
468 C NODE = TOTAL NUMBER OF NODAL POINTS IN AN ELEMENT

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469 C      NDF   = NUMBER OF DEGREES OF FREEDOM PER NODAL POINT
470 C      MP    = GROUP NUMBER OF THE MATERIALS
471 C      X,Y   = COORDINATES OF NODAL POINTS
472 C      XYK   = MATERIAL CONSTANTS (KXX,KYY,KXY)
473 C
474 C      LOCAL VARIABLES:
475 C      XE,YE = COORDINATES OF NODAL POINTS IN AN ELEMENT
476 C      SKE   = ELEMENT STIFFNESS MATRIX
477 C
478 C -----
479 C
480 C      IMPLICIT REAL*8(A-H,O-Z)
481 C      DIMENSION SK(1),IJK(NODE,1),MP(1),X(1),Y(1),XYK(3,1),F(1)
482 C      DIMENSION SKE(3,3),FE(3),XE(3),YE(3),XYKE(2,2)
483 C
484 C      ( INITIALIZATION )
485 C
486 C      IMAX=NX*NDF
487 C      DO 100 I=1,IMAX
488 C      100 F(I)=0.DO
489 C      IMAX=MBAND*NX*NDF
490 C      DO 110 I=1,IMAX
491 C      110 SK(I)=0.DO
492 C
493 C      DO 102 NEL=1,NELX
494 C
495 C      ( SET COORDINATES OF NODAL POINTS IN AN ELEMENT )
496 C
497 C      DO 104 IA=1,NODE
498 C      IJKIA=IJK(IA,NEL)
499 C      XE(IA)=X(IJKIA)
500 C      104 YE(IA)=Y(IJKIA)
501 C
502 C      ( SET THE MATERIAL PROPERTIES OF THE ELEMENT )
503 C
504 C      KKK=MP(NEL)
505 C      XYKE(1,1)=XYK(1,KKK)
506 C      XYKE(1,2)=XYK(3,KKK)
507 C      XYKE(2,1)=XYKE(1,2)
508 C      XYKE(2,2)=XYK(2,KKK)
509 C
510 C      ( CONSTRUCT THE ELEMENT STIFFNESS MATRIX )
511 C
512 C      CALL ESTIF3(NEL,SKE,FE,AREA,XE,YE,XYKE,LW)
513 C
514 C      ( ADD THE ELEMENT STIFFNESS MATRIX TO THE GLOBAL ONE )
515 C
516 C      DO 108 IA=1,NODE
517 C      IJKIA=IJK(IA,NEL)
518 C      DO 108 I=1,NDF
519 C      IAI=NDF*(IA-1)+I
520 C      IJKIAI=NDF*(IJKIA-1)+I
521 C      F(IJKIAI)=F(IJKIAI)+FE(IAI)
522 C      DO 108 JB=1,NODE
523 C      IJKJB=IJK(JB,NEL)
524 C      DO 108 J=1,NDF
525 C      JBJ=NDF*(JB-1)+J
526 C      IJKJB=IJKJB-NDF*(IJKJB-1)+J
527 C      IAIJB=IJKJB-IJKIAI+1
528 C      IF(IAIJB.LE.0) GO TO 108
529 C      LOCAT=MBAND*(IJKIAI-1)+IAIJB
530 C      SK(LOCAT)=SK(LOCAT)+SKE(IAI,JBJ)
531 C      108 CONTINUE
532 C
533 C      102 CONTINUE
534 C
535 C      RETURN
536 C      END
537 C -----
538 C
539 C      SUBROUTINE ESTIF3(NEL,SKE,FE,AREA,XE,YE,XYKE,LW)
540 C
541 C      PURPOSE:
542 C      CONSTRUCT THE ELEMENT STIFFNESS MATRIX BY USING THREE-NODE
543 C      TRIANGULAR ELEMENT.
544 C
545 C      ARGUMENTS:
546 C      NEL   = ELEMENT NUMBER

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547 C      SKE  = ELEMENT STIFFNESS MATRIX
548 C      FE   = ELEMENT LOAD VECTOR
549 C      AREA  = AREA OF THE TRIANGLE
550 C      XE,YE = COORDINATES OF THREE NODAL POINTS IN AN ELEMENT
551 C      XYKE  = MATERIAL CONSTANTS (KXX,KXY,KYX,KYY)
552 C
553 C -----
554 C
555 C      IMPLICIT REAL*8(A-H,O-Z)
556 C      DIMENSION SKE(3,3),FE(3),XE(3),YE(3),DN(3,2),XYKE(2,2)
557 C
558 C      ( INITIALIZATION )
559 C
560 C      DO 200 I=1,3
561 C      FE(I)=0.DO
562 C      DO 200 J=1,3
563 C      200 SKE(I,J)=0.DO
564 C
565 C      ( COMPUTE THE FIRST GRADIENT OF THE SHAPE FUNCTIONS )
566 C
567 C      CALL GRAD13(NEL,XE,YE,DN,AREA,LW)
568 C
569 C      ( CONSTRUCT THE STIFFNESS MATRIX )
570 C
571 C      DO 100 I=1,3
572 C      DO 100 J=1,3
573 C      SKEIJ=0.
574 C      DO 102 K=1,2
575 C      DO 102 L=1,2
576 C      102 SKEIJ=SKEIJ+XYKE(K,L)*DN(I,K)*DN(J,L)
577 C      100 SKE(I,J)=SKEIJ*AREA
578 C
579 C      RETURN
580 C      END
581 C -----
582 C
583 C      SUBROUTINE GRAD13(NEL,XE,YE,DN,AREA,LW)
584 C
585 C      PURPOSE:
586 C      CONSTRUCT THE FIRST DERIVATIVES OF THE SHAPE FUNCTIONS.
587 C
588 C      ARGUMENTS:
589 C      NEL  = ELEMENT NUMBER
590 C      XE,YE = COORDINATES OF NODAL POINTS IN AN ELEMENT
591 C      DN   = FIRST DERIVATIVES OF THE SHAPE FUNCTIONS
592 C      AREA  = AREA OF THE TRIANGLE
593 C
594 C -----
595 C
596 C      IMPLICIT REAL*8(A-H,O-Z)
597 C      DIMENSION XE(3),YE(3),DN(3,2)
598 C
599 C      DET=XE(2)*(YE(3)-YE(1))+XE(3)*(YE(1)-YE(2))+XE(1)*(YE(2)-YE(3))
600 C      AREA=0.5DO*DET
601 C      IF(DET.LE.1.E-30) GO TO 100
602 C
603 C      DN(1,1)=(YE(2)-YE(3))/DET
604 C      DN(2,1)=(YE(3)-YE(1))/DET
605 C      DN(3,1)=(YE(1)-YE(2))/DET
606 C      DN(1,2)=(XE(3)-XE(2))/DET
607 C      DN(2,2)=(XE(1)-XE(3))/DET
608 C      DN(3,2)=(XE(2)-XE(1))/DET
609 C
610 C      RETURN
611 C
612 C      100 WRITE(LW,600) NEL, (XE(I),YE(I),I=1,3)
613 C      600 FORMAT(///10X,'***** DETERMINANT IS LESS THAN ZERO *****',
614 C      1 / ,15X,I5,5X,3(' < ',2F8.3,' > '))
615 C      STOP
616 C
617 C      END
618 C -----
619 C
620 C      SUBROUTINE HEATGE(F,NX,NELX,IJK,X,Y,LR,LW)
621 C
622 C      PURPOSE:
623 C      CONSTRUCT THE GENERALIZED LOAD VECTOR DUE TO THE HEAT
624 C      GENERATION.

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625 C
626 C ARGUMENTS:
627 C F = GENERALIZED LOAD VECTOR
628 C NX = TOTAL NUMBER OF NODAL POINTS
629 C NELX = TOTAL NUMBER OF FINITE ELEMENTS
630 C IJK = ELEMENT CONNECTIVITIES
631 C X,Y = COORDINATES OF NODAL POINTS
632 C
633 C LOCAL VARIABLES:
634 C NHEATG = TOTAL NUMBER OF TERMS OF POLYNOMIALS
635 C = 0 IF THERE ARE NO HEAT SOURCES/SINKS
636 C = NEGATIVE IF POINT SOURCES/SINKS EXIST. IN THIS CASE
637 C -NHEATG BECOMES THE NUMBER OF SOURCES/SINKS
638 C CXY = COEFFICIENTS OF THE POLYNOMIAL BASIS
639 C XE,YE = COORDINATES OF NODAL POINTS IN AN ELEMENT
640 C XC,YC = COORDINATES OF THE CENTROID OF AN ELEMENT
641 C AREA = AREA OF AN ELEMENT
642 C
643 C DIMENSIONING:
644 C CXY(M,M) M >= NHEATG
645 C
646 C NOTE:
647 C M = 11 AND 8 >= NHEATG ARE ASSUMED IN THIS ROUTINE.
648 C
649 C INPUT DATA TO BE READ:
650 C O. FLAG(I),I=1,10 : 10A8
651 C 1. NHEATG : 1615
652 C IF(NHEATG.LT.O) GO TO 3
653 C DO 100 I=1,NHEATG
654 C 2. CXY(I,J),J=1,NHEATG : 8F10.4
655 C 100 CONTINUE
656 C RETURN
657 C 3. NODE,VALUE,I=1,-NHEATG : I5,F10.4
658 C
659 C -----
660 C
661 C IMPLICIT REAL*8(A-H,O-Z)
662 C DIMENSION F(1),IJK(3,1),X(1),Y(1),XE(3),YE(3),CXY(11,11),
663 C 1 FLAG(10)
664 C
665 C ( READ INPUT DATA FOR THE BODY FORCE )
666 C
667 C READ(LR,504) (FLAG(I),I=1,10)
668 C 504 FORMAT(10A8)
669 C READ(LR,500) NHEATG
670 C 500 FORMAT(1615)
671 C IF(NHEATG.LE.O) GO TO 300
672 C
673 C ( DISTRIBUTED HEAT SOURCE/SINK )
674 C
675 C DO 100 I=1,NHEATG
676 C 100 READ(LR,502) (CXY(I,J),J=1,NHEATG)
677 C 502 FORMAT(8F10.4)
678 C
679 C DO 102 NEL=1,NELX
680 C
681 C ( SET AREA AND COORDINATES OF THE CENTROID )
682 C
683 C DO 104 I=1,3
684 C IJKI=IJK(I,NEL)
685 C XE(I)=X(IJKI)
686 C 104 YE(I)=Y(IJKI)
687 C DET=XE(2)*(YE(3)-YE(1))+XE(3)*(YE(1)-YE(2))+XE(1)*(YE(2)-YE(3))
688 C AREA=0.5DO*DET
689 C XC=(XE(1)+XE(2)+XE(3))/3.
690 C YC=(YE(1)+YE(2)+YE(3))/3.
691 C
692 C ( COMPUTE THE BODY FORCE )
693 C
694 C FNEL=0.
695 C DO 106 I=1,NHEATG
696 C I1=I-1
697 C DO 106 J=1,NHEATG
698 C J1=J-1
699 C 106 FNEL=FNEL+CXY(I,J)*(XC**I1)*(YC**J1)
700 C
701 C DO 108 I=1,3
702 C IJKI=IJK(I,NEL)

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703      108 F(IJKI)=F(IJKI)+FNEL*AREA/3.
704      C
705      102 CONTINUE
706      WRITE(LW,600)
707      600 FORMAT(////10X,'XXXXXXXXXX BODY FORCES XXXXXXXXXXXX',//15X,
708      1 '< COEFFICIENTS CXY >',/)
709      DO 110 I=1,NHEATG
710      110 WRITE(LW,602) (CXY(I,J),J=1,NHEATG)
711      602 FORMAT(15X,10F8.3)
712      GO TO 304
713      C
714      C      ( POINT HEAT SOURCES/SINKS )
715      C
716      300 IF(NHEATG.EQ.0) RETURN
717      NHEATG=-NHEATG
718      DO 302 I=1,NHEATG
719      READ(LR,530) NODE,VALUE
720      530 FORMAT(I5,F10.4)
721      302 F(NODE)=F(NODE)+VALUE
722      C
723      304 WRITE(LW,604)
724      604 FORMAT(//10X,'< LOAD VECTOR DUE TO HEAT GENERATION >',/)
725      WRITE(LW,606) (I,F(I),I=1,NX)
726      606 FORMAT(5X,I4,1X,E10.3,3X,I4,1X,E10.3,3X,I4,1X,E10.3)
727      C
728      RETURN
729      END
730      -----
731      C
732      SUBROUTINE BOUND1(MBAND,SK,F,LR,LW)
733      C
734      C      PURPOSE:
735      C      READ THE 1-ST BOUNDARY CONDITION AND MODIFY THE STIFFNESS
736      C      MATRIX AND THE LOAD VECTOR USING PENALTY METHODS.
737      C
738      C      ARGUMENTS:
739      C      MBAND = HALF-BAND WIDTH OF THE STIFFNESS MATRIX
740      C      SK    = STIFFNESS MATRIX
741      C      F      = LOAD VECTOR
742      C
743      C      LOCAL VARIABLES:
744      C      NBX   = TOTAL NUMBER OF NODAL POINTS ON WHICH 1-ST BOUNDARY
745      C              CONDITION IS APPLIED
746      C      PENALT= PENALTY PARAMETER (TO BE A SUFFICIENTLY LARGE NUMBER )
747      C              10000.*MAX(XK,YK) IS RECOMMENDED
748      C      XK,YK = HEAT CONDUCTIVITY IN THE X AND Y DIRECTIONS
749      C      NODE  = NODE NUMBER ON WHICH BOUNDARY CONDITION IS GIVEN
750      C      VALUE = BOUNDARY VALUE SPECIFIED
751      C
752      C      INPUT DATA TO BE READ:
753      C      0. FLAG(I),I=1,10          : 10A8
754      C      1. NBX,PENALT              : I5,F20.5
755      C      2. NODE,VALUE,I=1,NBX     : I5,F10.4
756      C
757      C      -----
758      C
759      IMPLICIT REAL*8(A-H,O-Z)
760      DIMENSION SK(1),F(1),FLAG(10)
761      C
762      C      ( READ INPUT DATA )
763      C
764      READ(LR,504) (FLAG(I),I=1,10)
765      504 FORMAT(10A8)
766      READ(LR,500) NBX,PENALT
767      500 FORMAT(I5,F20.5)
768      WRITE(LW,600) PENALT
769      600 FORMAT(////10X,'XXXXXXXXXX 1-ST BOUNDARY CONDITION XXXXXXXXXXXX',/
770      1 15X,'PENALTY PARAMETER =',E10.3,/)
771      C
772      DO 100 I=1,NBX
773      READ(LR,502) NODE,VALUE
774      502 FORMAT(I5,F10.4)
775      WRITE(LW,602) I,NODE,VALUE
776      602 FORMAT(15X,'<',I3,'>',4X,I4,3X,F10.4)
777      C
778      SK(MBAND*(NODE-1)+1)=SK(MBAND*(NODE-1)+1)+PENALT
779      F(NODE)=F(NODE)+PENALT*VALUE
780      C

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781      100 CONTINUE
782      C
783      RETURN
784      END
785      C -----
786      C
787      SUBROUTINE BOUND2(F,X,Y,LR,LW)
788      C
789      C PURPOSE:
790      C READ THE 2-ND BOUNDARY CONDITION AND FORM THE LOAD VECTOR.
791      C < DU/DN = H ON S2 >
792      C
793      C ARGUMENTS:
794      C F = GENRALIZED LOAD VECTOR
795      C X,Y = COORDINATES OF NODAL POINTS
796      C
797      C LOCAL VARIABLES:
798      C FLAG = REMARK FOR THE DATA
799      C NBX = TOTAL NUMBER OF LINE ELEMENTS ON THIS BOUNDARY
800      C NODE1 = NUMBER OF THE LEFT NODAL POINT IN A LINE ELEMENT
801      C NODE2 = NUMBER OF THE RIGHT NODAL POINT IN A LINE ELEMENT
802      C VALUE = VALUE OF THE FLUX FROM THE BOUNDARY
803      C
804      C INPUT DATA TO BE READ:
805      C 0. FLAG(I),I=1,10 : 10A8
806      C 1. NBX : 16I5
807      C 2. NODE1,NODE2,VALUE,I=1,NBX : 2I5,F10.4
808      C
809      C -----
810      C
811      IMPLICIT REAL*8(A-H,O-Z)
812      DIMENSION FLAG(10),F(1),X(1),Y(1)
813      C
814      READ(LR,500) (FLAG(I),I=1,10)
815      500 FORMAT(10A8)
816      READ(LR,502) NBX
817      502 FORMAT(16I5)
818      IF(NBX.LE.0) RETURN
819      WRITE(LW,600)
820      600 FORMAT('/////10X,'XXXXXXXXXX 2-ND BOUNDARY CONDITION XXXXXXXXXXXX',
821      1 //15X,29(' - '),/15X,' NODE I VALUE ',/15X,29(' - '))
822      C
823      DO 100 I=1,NBX
824      READ(LR,504) NODE1,NODE2,VALUE
825      504 FORMAT(2I5,F10.4)
826      WRITE(LW,602) NODE1,NODE2,VALUE
827      602 FORMAT(15X,2I5,' I ',E10.3)
828      DH=DSQRT((X(NODE1)-X(NODE2))**2+(Y(NODE1)-Y(NODE2))**2)
829      F(NODE1)=F(NODE1)+0.5DO*VALUE*DH
830      F(NODE2)=F(NODE2)+0.5DO*VALUE*DH
831      100 CONTINUE
832      C
833      WRITE(LW,604)
834      604 FORMAT(15X,29(' - '))
835      C
836      RETURN
837      END
838      C -----
839      C
840      SUBROUTINE BOUND3(MBAND,SK,F,X,Y,IJB,MPB,XKB,UO,LR,LW)
841      C
842      C PURPOSE:
843      C READ THE 3-RD BOUNDARY CONDITION AND MODIFY THE STIFFNESS
844      C MATRIX AND THE LOAD VECTOR.
845      C < DU/DN = -K( U - UO ) ON S3 >
846      C
847      C ARGUMENTS:
848      C MBAND = HALF-BAND WIDTH OF THE STIFFNESS MATRIX
849      C SK = GLOBAL STIFFNESS MATRIX
850      C F = LOAD VECTOR
851      C X,Y = COORDINATES OF THE NODAL POINTS
852      C IJB = ELEMENT CONNECTIVITY ON THE BOUNDARY
853      C MPB = GROUP NUMBER OF THE MATERIALS ON THE BOUNDARY
854      C XKB = CONSTANTS "K" ON THE BOUNDARY
855      C UO = CONSTANTS "UO" ON THE BOUNDARY
856      C
857      C LOCAL VARIABLES:
858      C FLAG = REMARK TO THE INPUT DATA

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859 C      NBLX   = TOTAL NUMBER OF BOUNDARY ELEMENTS
860 C      MPBX   = TOTAL NUMBER OF MATERIALS ON THE BOUNDARY
861 C
862 C      INPUT DATA TO BE READ:
863 C      0. FLAG(I), I=1, 10      : 10A8
864 C      1. NBLX, MPBX           : 16I5
865 C      2. I, MPB(I), (IJB(J, I), J=1, 2), I=1, NBLX      : 4I5
866 C      3. I, XKB(I), UO(I), I=1, MPBX           : 15, 2F10.4
867 C
868 C -----
869 C
870 C      IMPLICIT REAL*8(A-H, O-Z)
871 C      DIMENSION SK(1), F(1), X(1), Y(1), IJB(2, 1), MPB(1), XKB(1), UO(1)
872 C      DIMENSION SKE(2, 2), FE(2), FLAG(10)
873 C
874 C      ( INPUT DATA )
875 C
876 C      READ(LR, 500) (FLAG(I), I=1, 10)
877 500 FORMAT(10A8)
878 C      READ(LR, 502) NBLX, MPBX
879 502 FORMAT(16I5)
880 C      IF(NBLX.LE.0) RETURN
881 C      READ(LR, 504) (I, MPB(I), (IJB(J, I), J=1, 2), I=1, NBLX)
882 504 FORMAT(4I5)
883 C      READ(LR, 506) (I, XKB(I), UO(I), I=1, MPBX)
884 506 FORMAT(15, 2F10.4)
885 C
886 C      WRITE(LW, 600)
887 600 FORMAT(////10X, 'XXXXXXXXXX 3-RD BOUNDARY CONDITION XXXXXXXXXXXX',
888 1 //10X, '----- BOUNDARY ELEMENT CONNECTIVITY -----', /)
889 C      WRITE(LW, 602) (I, MPB(I), (IJB(J, I), J=1, 2), I=1, NBLX)
890 602 FORMAT(2(5X, I5, 3X, '<MPB>', I3, 5X, '<IJB>', 2I5))
891 C      WRITE(LW, 604)
892 604 FORMAT(////10X, '----- MATERIAL CONSTANTS ON THE BOUNDARY -----',
893 1 /)
894 C      WRITE(LW, 606) (I, XKB(I), UO(I), I=1, MPBX)
895 606 FORMAT(10X, I5, 3X, 'K=', E10.3, 2X, 'UO=', E10.3)
896 C
897 C      ( FOR STIFFNESS MATRIX AND LOAD VECTOR )
898 C
899 C      DO 100 NEL=1, NBLX
900 C
901 C      ( SET VARIABLES )
902 C
903 C      N1=IJB(1, NEL)
904 C      N2=IJB(2, NEL)
905 C      X1=X(N1)
906 C      Y1=Y(N1)
907 C      X2=X(N2)
908 C      Y2=Y(N2)
909 C      HR=DSQRT((X2-X1)**2+(Y2-Y1)**2)
910 C      KKK=MPB(NEL)
911 C      XKBE=XKB(KKK)
912 C      UOE=UO(KKK)
913 C
914 C      ( ELEMENT STIFFNESS MATRIX )
915 C
916 C      SKE(1, 1)=XKBE*HR/3.DO
917 C      SKE(2, 2)=SKE(1, 1)
918 C      SKE(1, 2)=XKBE*HR/6.DO
919 C      SKE(2, 1)=SKE(1, 2)
920 C
921 C      ( ELEMENT LOAD VECTOR )
922 C
923 C      FE(1)=XKBE*UOE*HR/2.DO
924 C      FE(2)=FE(1)
925 C
926 C      ( ASSEMBLING : BAND SOLVER )
927 C
928 C      DO 102 I=1, 2
929 C      NI=IJB(I, NEL)
930 C      F(NI)=F(NI)+FE(I)
931 C      DO 102 J=1, 2
932 C      NJ=IJB(J, NEL)
933 C      KI=NJ-NI+1
934 C      IF(KI.LE.0) GO TO 102
935 C      SK(MBAND*(NI-1)+KI)=SK(MBAND*(NI-1)+KI)+SKE(I, J)
936 102 CONTINUE

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937 C
938 C 100 CONTINUE
939 C
940 C RETURN
941 C END
942 C -----
943 C
944 C SUBROUTINE BANDSL(AK,R,NEQ,MBAND,KKK)
945 C
946 C PURPOSE:
947 C SOLVES A SYSTEM OF LINEAR EQUATIONS.
948 C ( BANDED SYMMETRIC COEFFICIENT MATRIX )
949 C
950 C CONTROL NUMBERS:
951 C KKK = 0 BAND SOLVER
952 C KKK = 1 TRIANGULATION
953 C KKK = 2 REDUCTION AND BACK SUBSTITUTION
954 C
955 C ARGUMENTS:
956 C AK = BANDED SYMMETRIC MATRIX TO BE SOLVED
957 C R = RIGHT HAND SIDE ( LOAD VECTOR )
958 C NEQ = TOTAL NUMBER OF DEGREES OF FREEDOM
959 C MBAND = HALF-WIDTH OF BAND
960 C KKK = CONTROL NUMBER OF THE FLOW OF THE ROUTINE
961 C
962 C NOTE:
963 C HOW TO STORE THE STIFFNESS MATRIX
964 C
965 C ( K11 K12 K13 K15 )
966 C I K22 K23 K24 K25 I
967 C I K33 K34 K35 K36 O I
968 C I SMY K44 K45 K46 K47 I
969 C I K55 K56 K57 I
970 C I K66 K67 I
971 C ( K77 )
972 C
973 C BANDED STIFFNESS MATRIX
974 C
975 C ( K11 K12 K13 O K15 )
976 C I K22 K23 K24 K25 O I
977 C I K33 K34 K35 K36 O I
978 C I K44 K45 K46 K47 O I
979 C I K55 K56 K57 O O I
980 C I K66 K67 O O O I
981 C ( K77 O O O O )
982 C
983 C NEQ = 7 MBAND = 5
984 C
985 C ONE-DIMENSIONAL ARRAY OF THE STIFFNESS MATRIX "AK"
986 C
987 C AK/K11,K12,K13,O,K15,K22,K23,K24,K25,O,K33,K34,K35,K36,O,
988 C K44,K45,K46,K47,O,K55,K56,K57,O,O,K66,K67,O,O,O,K77,O,O,O,O
989 C
990 C -----
991 C
992 C IMPLICIT REAL*8(A-H,O-Z)
993 C DIMENSION AK(1),R(1)
994 C
995 C NRS=NEQ-1
996 C NR=NEQ
997 C IF(KKK.EQ.2) GO TO 200
998 C DO 120 N=1,NRS
999 C M=N-1
1000 C MR=MINO(MBAND,NR-M)
1001 C PIVOT=AK(MBAND*(N-1)+1)
1002 C DO 120 L=2,MR
1003 C CP=AK(MBAND*(N-1)+L)/PIVOT
1004 C IF(CP) 130,120,130
1005 C 130 I=M+L
1006 C J=O
1007 C DO 110 K=L,MR
1008 C J=J+1
1009 C LOCAT=MBAND*(I-1)+J
1010 C 110 AK(LOCAT)=AK(LOCAT)-CP*AK(MBAND*(N-1)+K)
1011 C 120 AK(MBAND*(N-1)+L)=CP
1012 C IF(KKK.EQ.1) RETURN
1013 C 200 DO 230 N=1,NRS
1014 C M=N-1

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1015      MR=MINO(MBAND,NR-M)
1016      CP=R(N)
1017      IF(CP)210,230,210
1018      210 R(N)=CP/AK(MBAND*(N-1)+1)
1019      DO 220 L=2,MR
1020      I=M+L
1021      220 R(I)=R(I)-AK(MBAND*(N-1)+L)*CP
1022      230 CONTINUE
1023      R(NR)=R(NR)/AK(MBAND*(NR-1)+1)
1024      DO 320 I=1,NRS
1025      N=NR-I
1026      M=N-1
1027      MR=MINO(MBAND,NR-M)
1028      DO 320 K=2,MR
1029      L=M+K
1030      320 R(N)=R(N)-AK(MBAND*(N-1)+K)*R(L)
1031      C
1032      RETURN
1033      END
1034      -----
1035      C
1036      SUBROUTINE OUTPUT(F,P,NX,NELX,X,Y,IJK,MP,XYK,LW)
1037      C
1038      C PURPOSE:
1039      C   OUTPUTS THE TEMPERATURE AND THE HEAT FLUX VECTORS.
1040      C
1041      C ARGUMENTS:
1042      C   F      = SOLUTION OBTAINED BY THE F.E. ANALYSIS
1043      C   P      = STORES THE HEAT FLUX VECTORS AND QUALITY INDICES
1044      C   NX     = TOTAL NUMBER OF NODAL POINTS
1045      C   NELX   = TOTAL NUMBER OF FINITE ELEMENTS
1046      C   X,Y    = COORDINATES OF NODAL POINTS
1047      C   IJK    = ELEMENT CONNECTIVITIES
1048      C   MP     = GROUP NUMBER OF THE MATERIALS
1049      C   XYK    = MATERIAL CONSTANT IN THE MATRIX FORM
1050      C
1051      C LOCAL VARIABLES:
1052      C   DFX,DFY = FIRST DERIVATIVES OF THE TEMPERATURE
1053      C   QX,QY   = COMPONENTS OF THE HEAT FLUX VECTOR
1054      C
1055      C -----
1056      C
1057      IMPLICIT REAL*8(A-H,D-Z)
1058      DIMENSION F(1),P(4,1),IJK(3,1),X(1),Y(1),XYK(3,1),MP(1)
1059      DIMENSION XE(3),YE(3),FE(3),DN(3,2)
1060      C
1061      C ( OUTPUT THE SOLUTION VECTOR )
1062      C
1063      WRITE(LW,600)
1064      600 FORMAT(1H1,//////////5X,70(' '),/5X,70(' '),///20X,
1065      1 ' THE SOLUTION VECTORS',///5X,70(' '),/5X,70(' '))
1066      WRITE(LW,602)
1067      602 FORMAT(1H1,//10X,43(' '),/10X,' NODE I      X      Y      ',
1068      1 ' I      F',/10X,43(' '))
1069      WRITE(LW,604) (I,X(I),Y(I),F(I),I=1,NX)
1070      604 FORMAT(10X,I4,2X,'I',1X,F8.3,F9.3,2X,'I',1X,E12.5)
1071      WRITE(LW,606)
1072      606 FORMAT(10X,43(' '))
1073      C
1074      C ( OUTPUT THE GRADIENT )
1075      C
1076      WRITE(LW,608)
1077      608 FORMAT(1H1,//////////5X,70(' '),/5X,70(' '),///20X,
1078      1 ' THE GRADIENTS OF THE SOLUTION',///5X,70(' '),/5X,70(' '))
1079      WRITE(LW,610)
1080      610 FORMAT(1H1,//5X,62(' '),/5X,' NEL I      X      Y      ',
1081      1 ' I      F      I      FX      FY',/5X,62(' '))
1082      C
1083      DO 100 NEL=1,NELX
1084      C
1085      C ( SET THE COORDINATES )
1086      C
1087      DO 102 I=1,3
1088      IJKI=IJK(I,NEL)
1089      XE(I)=X(IJKI)
1090      YE(I)=Y(IJKI)
1091      102 FE(I)=F(IJKI)
1092      C

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1093      XC=(XE(1)+XE(2)+XE(3))/3.DO
1094      YC=(YE(1)+YE(2)+YE(3))/3.DO
1095      FC=(FE(1)+FE(2)+FE(3))/3.DO
1096      C
1097      C      ( CALL THE GRADIENT ROUTINE )
1098      C
1099      CALL GRAD13(NEL,XE,YE,DN,AREA,LW)
1100      C
1101      C      ( GRADIENT OF THE SOLUTION )
1102      C
1103      KK=MP(NEL)
1104      XKNEL=XYK(1,KK)
1105      YKNEL=XYK(2,KK)
1106      XYKNEL=XYK(3,KK)
1107      DFX=0.DO
1108      DFY=0.DO
1109      DO 104 I=1,3
1110      DFX=DFX+FE(I)*DN(I,1)
1111      104 DFY=DFY+FE(I)*DN(I,2)
1112      QX=-(XKNEL*DFX+XYKNEL*DFY)
1113      QY=-(XYKNEL*DFX+YKNEL*DFY)
1114      P(1,NEL)=QX
1115      P(2,NEL)=QY
1116      C
1117      WRITE(LW,620) NEL,XC,YC,FC,QX,QY
1118      620 FORMAT(5X,I4,' I ',F8.3,F9.3,' I ',E10.3,' I ',2E10.3)
1119      C
1120      100 CONTINUE
1121      WRITE(LW,612)
1122      612 FORMAT(5X,62(' '))
1123      C
1124      RETURN
1125      END
1126      C -----
1127      C
1128      SUBROUTINE QUALIT(NELX,NX,MBAND,IJK,X,Y,P,SK,CQX,CQY,NODE,LW)
1129      C
1130      C      PURPOSE :
1131      C      COMPUT QUALTY INDICES OF THE FINITE ELEMENT APPROXIMATION.
1132      C
1133      C      ARGUMENTS :
1134      C      NELX   = TOTAL NUMBER OF ELEMENTS
1135      C      NX     = TOTAL NUMBER OF NODAL POINTS
1136      C      MBAND  = HALF BAND WIDTH OF THE MASS MATRIX
1137      C      IJK    = ELEMENT CONNECTIVITIES
1138      C      X,Y    = COORDINATES OF NODAL POINTS
1139      C      P(1,N) = X COMPONENT OF THE HEAT FLUX IN THE N TH ELEMENT
1140      C      P(2,N) = Y COMPONENT OF THE HEAT FLUX IN THE N TH ELEMENT
1141      C      P(3,N) = QUALITY INDEX IN THE N TH ELEMENT (TEMPERATURE)
1142      C      P(4,N) = QUALITY INDEX IN THE N TH ELEMENT (HEAT FLUX)
1143      C      SK     = MASS MATRIX FOR THE LEAST SQUARES METHOD
1144      C      CQX    = QUALITY INDEX AT NODAL POINTS (TEMPERATURE)
1145      C      CQY    = QUALITY INDEX AT NODAL POINTS (HEAT FLUX)
1146      C      NODE   = TOTAL NUMBER OF NODAL POINTS IN AN ELEMENT
1147      C
1148      C      LOCAL VARIABLES:
1149      C      HX      = SIZE OF FINITE ELEMENT IN THE X DIRECTION
1150      C      HY      = SIZE OF FINITE ELEMENT IN THE Y DIRECTION
1151      C      QIOAV   = AVERAGE QUALITY INDEX FOR TEMPERATURE
1152      C      QI1AV   = AVERAGE QUALITY INDEX FOR HEAT FLUX
1153      C
1154      C      NOTE:
1155      C      ARRAYS "CQX" AND "CQY" ARE USED FOR THE CONFORMING HEAT FLUX
1156      C      VECTORS FIRST, THEN STORE THE QUALITY INDICES AT NODAL POINTS.
1157      C
1158      C -----
1159      C
1160      IMPLICIT REAL*8(A-H,O-Z)
1161      DIMENSION IJK(NODE,1),P(4,1),CQX(1),CQY(1),X(1),Y(1),SK(1)
1162      DIMENSION SME(3,3)
1163      C
1164      DATA SME/2.DO,1.DO,1.DO,1.DO,2.DO,1.DO,1.DO,1.DO,2.DO/
1165      C
1166      C      ( INITIAL SET )
1167      C
1168      IMAX=MBAND*NX
1169      DO 100 I=1,IMAX
1170      100 SK(I)=0.DO
1171      DO 102 I=1,NX

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1172      CQX(I)=0.DO
1173      102 CQY(I)=0.DO
1174      C
1175      C      ( LEAST SQUARES METHODS )
1176      C
1177      DD 200 NEL=1,NELX
1178      C
1179      IJK1=IJK(1,NEL)
1180      IJK2=IJK(2,NEL)
1181      IJK3=IJK(3,NEL)
1182      X1=X(IJK1)
1183      X2=X(IJK2)
1184      X3=X(IJK3)
1185      Y1=Y(IJK1)
1186      Y2=Y(IJK2)
1187      Y3=Y(IJK3)
1188      AREA=0.5DO*(X1*(Y2-Y3)+X2*(Y3-Y1)+X3*(Y1-Y2))
1189      DQX=P(1,NEL)
1190      DQY=P(2,NEL)
1191      C
1192      DO 202 IA=1,NODE
1193      IJKIA=IJK(IA,NEL)
1194      CQX(IJKIA)=CQX(IJKIA)+DQX*AREA/3.DO
1195      CQY(IJKIA)=CQY(IJKIA)+DQY*AREA/3.DO
1196      DO 202 JB=1,NODE
1197      IJKJB=IJK(JB,NEL)
1198      IAJB=IJKJB-IJKIA
1199      IF(IAJB.LT.0) GO TO 202
1200      ND=MBAND*(IJKIA-1)+IAJB+1
1201      SK(ND)=SK(ND)+SME(IA,JB)*AREA/12.DO
1202      202 CONTINUE
1203      C
1204      200 CONTINUE
1205      C
1206      C      ( SOLVE THE SYSTEMS OF LINEAR EQUATIONS )
1207      C
1208      CALL BANDSL(SK,CQX,NX,MBAND,0)
1209      C
1210      CALL BANDSL(SK,CQY,NX,MBAND,2)
1211      C
1212      WRITE(LW,600)
1213      600 FORMAT(////5X,70(' '),//10X,
1214      1 'CONFORMING HEAT FLUX VECTORS AT NODES',//5X,70(' '),/)
1215      WRITE(LW,602)
1216      602 FORMAT(5X,35(' '),/5X,' NODE I      CQX      I      CQY',
1217      1 /5X,35(' '))
1218      WRITE(LW,604) (I,CQX(I),CQY(I),I=1,NX)
1219      604 FORMAT(5X,15,' I ',E11.4,' I ',E11.4)
1220      WRITE(LW,606)
1221      606 FORMAT(5X,35(' '))
1222      C
1223      C      ( COMPUTE THE QUALITY INDEX QIO AND QI1 )
1224      C
1225      QIOTL=0.DO
1226      QI1TL=0.DO
1227      QIOMAX=-1.D20
1228      QI1MAX=-1.D20
1229      C
1230      DO 300 NEL=1,NELX
1231      C
1232      IJK1=IJK(1,NEL)
1233      IJK2=IJK(2,NEL)
1234      IJK3=IJK(3,NEL)
1235      X1=X(IJK1)
1236      X2=X(IJK2)
1237      X3=X(IJK3)
1238      Y1=Y(IJK1)
1239      Y2=Y(IJK2)
1240      Y3=Y(IJK3)
1241      DET=X1*(Y2-Y3)+X2*(Y3-Y1)+X3*(Y1-Y2)
1242      AREA=0.5DO*DET
1243      C
1244      DQX=DABS(P(1,NEL))
1245      DQY=DABS(P(2,NEL))
1246      HX=DMAX1(DABS(X1-X2),DABS(X2-X3),DABS(X3-X1))
1247      HY=DMAX1(DABS(Y1-Y2),DABS(Y2-Y3),DABS(Y3-Y1))
1248      QIOXX=HX*DQX
1249      QIOYY=HY*DQY
1250      QIONEL=DMAX1(QIOXX,QIOYY)*DSQRT(AREA)

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1251      P(3,NEL)=QIONEL
1252      QIOTL=QIOTL+QIONEL
1253      IF(QIOMAX.LT.QIONEL) QIOMAX=QIONEL
1254
1255      C      B1=(Y2-Y3)/DET
1256      B2=(Y3-Y1)/DET
1257      B3=(Y1-Y2)/DET
1258      C1=(X3-X2)/DET
1259      C2=(X1-X3)/DET
1260      C3=(X2-X1)/DET
1261      DQXX=CQX(IJK1)*B1+CQX(IJK2)*B2+CQX(IJK3)*B3
1262      DQXY=CQX(IJK1)*C1+CQX(IJK2)*C2+CQX(IJK3)*C3
1263      DQYX=CQY(IJK1)*B1+CQY(IJK2)*B2+CQY(IJK3)*B3
1264      DQYY=CQY(IJK1)*C1+CQY(IJK2)*C2+CQY(IJK3)*C3
1265      QI1XXX=HX*DABS(DQXX)
1266      QI1YXX=HX*DABS(DQXY)
1267      QI1YXY=HY*DABS(DQYX)
1268      QI1YYY=HY*DABS(DQYY)
1269      QI1NEL=DMAX1(QI1XXX,QI1YXX,QI1YXY,QI1YYY)*DSQRT(AREA)
1270      P(4,NEL)=QI1NEL
1271      QI1TL=QI1TL+QI1NEL
1272      IF(QI1MAX.LT.QI1NEL) QI1MAX=QI1NEL
1273
1274      C      300 CONTINUE
1275
1276      C      QIOAV=QIOTL/NELX
1277      QI1AV=QI1TL/NELX
1278
1279      C      WRITE(LW,620) QIOAV,QI1AV
1280      620 FORMAT(////5X,70(' '),//15X,
1281      1 'QUALITY INDICES FOR TEMPERATURE AND HEAT FLUX',//5X,70(' '),
1282      2 //5X,'AVERAGE QUALITY INDEX (TEMPERATURE) = ',E12.5,/5X,
1283      3 'AVERAGE QUALITY INDEX (HEAT FLUX) = ',E12.5,/,
1284      4 5X,45(' '),/5X,' NEL I LO L1 I QIO I QI1',
1285      5 /5X,45(' '))
1286      DO 310 NEL=1,NELX
1287      QIONEL=P(3,NEL)
1288      QI1NEL=P(4,NEL)
1289      LO=10*(QIONEL+1.D-10)/QIOMAX
1290      L1=10*(QI1NEL+1.D-10)/QI1MAX
1291      WRITE(LW,622) NEL,LO,L1,QIONEL,QI1NEL
1292      622 FORMAT(5X,I5,' I ',2I3,' I ',E11.4,' I ',E11.4)
1293      310 CONTINUE
1294      WRITE(LW,626)
1295      626 FORMAT(5X,45(' '))
1296
1297      C      ( COMPUTE NODAL VALUES OF QUALITY INDICES )
1298
1299      C      DO 400 I=1,NX
1300      CQX(I)=0.DO
1301      CQY(I)=0.DO
1302
1303      C      DO 402 NEL=1,NELX
1304      IJK1=IJK(1,NEL)
1305      IJK2=IJK(2,NEL)
1306      IJK3=IJK(3,NEL)
1307      X1=X(IJK1)
1308      X2=X(IJK2)
1309      X3=X(IJK3)
1310      Y1=Y(IJK1)
1311      Y2=Y(IJK2)
1312      Y3=Y(IJK3)
1313      AREA=0.5DO*(X1*(Y2-Y3)+X2*(Y3-Y1)+X3*(Y1-Y2))
1314      CQX(IJK1)=CQX(IJK1)+P(3,NEL)*AREA/3.DO
1315      CQX(IJK2)=CQX(IJK2)+P(3,NEL)*AREA/3.DO
1316      CQX(IJK3)=CQX(IJK3)+P(3,NEL)*AREA/3.DO
1317      CQY(IJK1)=CQY(IJK1)+P(4,NEL)*AREA/3.DO
1318      CQY(IJK2)=CQY(IJK2)+P(4,NEL)*AREA/3.DO
1319      CQY(IJK3)=CQY(IJK3)+P(4,NEL)*AREA/3.DO
1320      402 CONTINUE
1321
1322      C      CALL BANDSL(SK,CQX,NX,MBAND,2)
1323
1324      C      CALL BANDSL(SK,CQY,NX,MBAND,2)
1325
1326      C      RETURN
1327      END

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