

第 4 回演習プログラム

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第 4 回演習資料のプログラムを以下に示します.

第 3 節のプログラム : モジュール mod_elemstiffmat3d, mod_elemexforcevec3d の作成

1. 要素剛性マトリックスモジュール mod_elemstiffmat3d.f90

```
1:      MODULE mod_elemstiffmat3d
2: !#####
3:
4:      USE mod_nodes3d
5:      USE mod_localelement3d
6:      USE mod_elements3d
7:
8: !-----
9:
10:     IMPLICIT NONE
11:
12: !-----
13:
14:     TYPE :: struct_elemstiffmat3d
15:
16:     !-----
17:
18:     PRIVATE
19:
20:     !-----
```

```

21:
22:     TYPE(struct_nodes3d), POINTER      :: ns3d => NULL()
23:     TYPE(struct_localelement3d), POINTER :: le3d => NULL()
24:     TYPE(struct_elements3d), POINTER   :: es3d => NULL()
25:
26:     !-----
27:     !
28:     ! k(:, :, :)
29:     ! Element stiffness matrix
30:     !
31:     !-----
32:     !
33:     ! e(:)
34:     ! Young's modulus
35:     !
36:     ! nu(:)
37:     ! Poisson's ratio
38:     !
39:     !-----
40:     !
41:     ! evec(:, :)
42:     ! Infinitesimal strain
43:     !
44:     ! svec(:, :)
45:     ! Stress
46:     !
47:     ! s_mises(:)
48:     ! Mises stress
49:     !
50:     !-----
51:
52:     REAL(8), ALLOCATABLE :: k(:, :, :)
53:     REAL(8), ALLOCATABLE :: e(:)
54:     REAL(8), ALLOCATABLE :: nu(:)
55:     REAL(8), ALLOCATABLE :: evec(:, :)
56:     REAL(8), ALLOCATABLE :: svec(:, :)

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57:      REAL (8), ALLOCATABLE :: s_mises(:)
58:
59:      !-----
60:
61:      END TYPE
62:
63: !-----
64:
65:      CONTAINS
66:
67:
68:      ! Get element stiffness matrix
69: !#####
70:      SUBROUTINE get_elemstiffmat3d_k(esm3d, k)
71: !#####
72:
73:      TYPE(struct_elemstiffmat3d), INTENT(IN) :: esm3d
74:
75:      REAL (8), INTENT (OUT) :: k(:, :, :)
76:
77: !-----
78:
79:      k = esm3d%k
80:
81: !-----
82:
83:      RETURN
84:
85: !#####
86:      END SUBROUTINE get_elemstiffmat3d_k
87: !#####
88:
89:
90:      ! Set Young's modulus and Poisson's ratio
91: !#####
92:      SUBROUTINE set_elemstiffmat3d_e_nu(esm3d, e, nu)

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```

93: !#####
94:
95:     TYPE(struct_elemstiffmat3d), INTENT(INOUT) :: esm3d
96:
97:     REAL(8), INTENT(IN) :: e(:)
98:     REAL(8), INTENT(IN) :: nu(:)
99:
100: !-----
101:
102:     esm3d%e = e
103:     esm3d%nu = nu
104:
105: !-----
106:
107:     RETURN
108:
109: !#####
110:     END SUBROUTINE set_elemstiffmat3d_e_nu
111: !#####
112:
113:
114:     ! Get Young's modulus and Poisson's ratio
115: !#####
116:     SUBROUTINE get_elemstiffmat3d_e(esm3d, e, nu)
117: !#####
118:
119:     TYPE(struct_elemstiffmat3d), INTENT(IN) :: esm3d
120:
121:     REAL(8), INTENT(OUT) :: e(:)
122:     REAL(8), INTENT(OUT) :: nu(:)
123:
124: !-----
125:
126:     e = esm3d%e
127:     nu = esm3d%nu
128:

```

```

129: !-----
130:
131:     RETURN
132:
133: !#####
134:     END SUBROUTINE get_elemstiffmat3d_e
135: !#####
136:
137:
138:     ! Get infinitesimal strain and stress
139: !#####
140:     SUBROUTINE get_elemstiffmat3d_evec_svec &
141:         (esm3d, evec, svec, s_mises)
142: !#####
143:
144:     TYPE(struct_elemstiffmat3d), INTENT(IN) :: esm3d
145:
146:     REAL (8), INTENT (OUT) :: evec(:, :)
147:     REAL (8), INTENT (OUT) :: svec(:, :)
148:     REAL (8), INTENT (OUT) :: s_mises(:)
149:
150: !-----
151:
152:     evec = esm3d%evec
153:     svec = esm3d%svec
154:
155:     s_mises = esm3d%s_mises
156:
157: !-----
158:
159:     RETURN
160:
161: !#####
162:     END SUBROUTINE get_elemstiffmat3d_evec_svec
163: !#####
164:

```

```

165:
166: !#####
167:     SUBROUTINE init_elemstiffmat3d(esm3d, ns3d, le3d, es3d)
168: !#####
169:
170:     TYPE(struct_elemstiffmat3d), INTENT(INOUT) :: esm3d
171:
172:     TYPE(struct_nodes3d), TARGET, INTENT(IN)      :: ns3d
173:     TYPE(struct_localelement3d), TARGET, INTENT(IN) :: le3d
174:     TYPE(struct_elements3d), TARGET, INTENT(IN)   :: es3d
175:
176: !-----
177:
178:     INTEGER :: le3d_nnodes
179:     INTEGER :: es3d_n
180:
181: !-----
182:
183:     esm3d%ns3d => ns3d
184:     esm3d%le3d => le3d
185:     esm3d%es3d => es3d
186:
187: !-----
188:
189:     CALL get_localelement3d_nnodes(esm3d%le3d, le3d_nnodes)
190:
191:     CALL get_elements3d_n(esm3d%es3d, es3d_n)
192:
193: !-----
194:
195:     ALLOCATE( esm3d%k(3*le3d_nnodes, 3*le3d_nnodes, es3d_n) )
196:
197:     esm3d%k = 0.0D0
198:
199: !-----
200:

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```

201:    ALLOCATE( esm3d%e(es3d_n) )
202:    ALLOCATE( esm3d%nu(es3d_n) )
203:
204:    esm3d%e = 0.0D0
205:    esm3d%nu = 0.0D0
206:
207:    !-----
208:
209:    ALLOCATE( esm3d%evec(6, es3d_n) )
210:
211:    esm3d%evec = 0.0D0
212:
213:    ALLOCATE( esm3d%svec(6, es3d_n) )
214:
215:    esm3d%svec = 0.0D0
216:
217:    ALLOCATE( esm3d%s_mises(es3d_n) )
218:
219:    esm3d%s_mises = 0.0D0
220:
221:    !-----
222:
223:    RETURN
224:
225:    !#####
226:    END SUBROUTINE init_elemstiffmat3d
227:    !#####
228:
229:
230:    !#####
231:    SUBROUTINE cal_elemstiffmat3d(esm3d)
232:    !#####
233:
234:    TYPE(struct_elemstiffmat3d), INTENT(INOUT) :: esm3d
235:
236:    !-----

```

```

237:
238:     INTEGER :: ns3d_n
239:     INTEGER :: le3d_nnodes
240:     INTEGER :: le3d_nqps
241:     INTEGER :: es3d_n
242:     INTEGER, ALLOCATABLE :: es3d_connectivity(:, :)
243:     INTEGER :: nqps_tot
244:     INTEGER :: i, j, k
245:     INTEGER :: id
246:     INTEGER :: na, nb
247:     INTEGER :: ie
248:     INTEGER :: idof
249:     INTEGER :: isize, jsize
250:     INTEGER :: jsize1, jsize2, jsize3
251:     INTEGER :: ijk
252:
253:     REAL (8), ALLOCATABLE :: ns3d_x(:, :)
254:     REAL (8), ALLOCATABLE :: ns3d_u(:)
255:     REAL (8), ALLOCATABLE :: le3d_xi_qp(:, :)
256:     REAL (8), ALLOCATABLE :: le3d_w_qp(:, :)
257:     REAL (8), ALLOCATABLE :: le3d_n_qp(:, :)
258:     REAL (8), ALLOCATABLE :: le3d_dndxi_qp(:, :, :)
259:     REAL (8), ALLOCATABLE :: x_local(:, :)
260:     REAL (8), ALLOCATABLE :: u_local(:)
261:     REAL (8) :: nqps_tot_inv
262:     REAL (8) :: g1(3), g2(3), g3(3)
263:     REAL (8) :: det_j, det_j_inv
264:     REAL (8) :: w_w_det_j
265:     REAL (8) :: cg1(3), cg2(3), cg3(3)
266:     REAL (8), ALLOCATABLE :: dndx(:, :)
267:     REAL (8), ALLOCATABLE :: bmat(:, :)
268:     REAL (8) :: evec(6)
269:     REAL (8) :: lambda, mu
270:     REAL (8) :: dmat(6, 6)
271:     REAL (8), ALLOCATABLE :: cmat(:, :)
272:     REAL (8) :: svec(6)

```



```

273:
274: !-----
275:
276:     CALL get_nodes3d_n(esm3d%ns3d, ns3d_n)
277:     ALLOCATE( ns3d_x(3, ns3d_n) )
278:     CALL get_nodes3d_x(esm3d%ns3d, ns3d_x)
279:     ALLOCATE( ns3d_u(3*ns3d_n) )
280:     CALL get_nodes3d_u(esm3d%ns3d, ns3d_u)
281:
282:     CALL get_localelement3d_nnodes(esm3d%le3d, le3d_nnodes)
283:     CALL get_localelement3d_nqps(esm3d%le3d, le3d_nqps)
284:     nqps_tot = le3d_nqps*le3d_nqps*le3d_nqps
285:     nqps_tot_inv = 1.0D0/DFLOAT( nqps_tot )
286:     ALLOCATE( le3d_xi_qp(3, nqps_tot) )
287:     ALLOCATE( le3d_w_qp(3, nqps_tot) )
288:     CALL get_localelement3d_xi_w_qp      &
289:         (esm3d%le3d, le3d_xi_qp, le3d_w_qp)
290:     ALLOCATE( le3d_n_qp(le3d_nnodes, nqps_tot) )
291:     ALLOCATE( le3d_dndxi_qp(3, le3d_nnodes, nqps_tot) )
292:     CALL get_localelement3d_n_qp      &
293:         (esm3d%le3d, le3d_n_qp, le3d_dndxi_qp)
294:
295:     CALL get_elements3d_n(esm3d%es3d, es3d_n)
296:     ALLOCATE( es3d_connectivity(le3d_nnodes, es3d_n) )
297:     CALL get_elements3d_connectivity(esm3d%es3d, es3d_connectivity)
298:
299:     ALLOCATE( x_local(3, le3d_nnodes) )
300:     ALLOCATE( u_local(3*le3d_nnodes) )
301:     ALLOCATE( dndx(3, le3d_nnodes) )
302:     ALLOCATE( bmat(6, 3*le3d_nnodes) )
303:     ALLOCATE( cmat(6, 3*le3d_nnodes) )
304:
305: !-----
306:
307:     esm3d%k = 0.0D0
308:

```

```

309:      DO ie = 1, es3d_n
310:
311:      !-----
312:
313:      DO na = 1, le3d_nnodes
314:
315:      id = es3d_connectivity(na, ie)
316:
317:      DO i = 1, 3
318:
319:      idof = 3*(id-1)+i
320:      isize = 3*(na-1)+i
321:
322:      x_local(i, na) = ns3d_x(i, id)
323:      u_local(isize) = ns3d_u(idof)
324:
325:      END DO
326:
327:      END DO
328:
329:      !-----
330:
331:      DO ijk = 1, nqps_tot
332:
333:      !-----
334:
335:      ! Covariant basis vector
336:      DO i = 1, 3
337:
338:      g1(i) = 0.0D0
339:      g2(i) = 0.0D0
340:      g3(i) = 0.0D0
341:
342:      DO na = 1, le3d_nnodes
343:
344:      g1(i) = g1(i)+le3d_dndxi_qp(1, na, ijk)*x_local(i, na)

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345:         g2(i) = g2(i)+le3d_dndxi_qp(2, na, ijk)*x_local(i, na)
346:         g3(i) = g3(i)+le3d_dndxi_qp(3, na, ijk)*x_local(i, na)
347:
348:     END DO
349:
350: END DO
351:
352: !-----
353:
354: ! Jacobian
355: det_j = g1(1)*( g2(2)*g3(3)-g2(3)*g3(2) ) &
356:         +g1(2)*( g2(3)*g3(1)-g2(1)*g3(3) ) &
357:         +g1(3)*( g2(1)*g3(2)-g2(2)*g3(1) )
358:
359: det_j_inv = 1.0D0/det_j
360:
361: w_w_w_det_j                                     &
362: = le3d_w_qp(1, ijk)*le3d_w_qp(2, ijk)*le3d_w_qp(3, ijk) &
363:   *det_j
364:
365: !-----
366:
367: ! Contravariant basis vector
368: cg1(1) = det_j_inv                                     &
369:         *( g2(2)*g3(3)-g2(3)*g3(2) )
370: cg1(2) = det_j_inv                                     &
371:         *( g2(3)*g3(1)-g2(1)*g3(3) )
372: cg1(3) = det_j_inv                                     &
373:         *( g2(1)*g3(2)-g2(2)*g3(1) )
374: cg2(1) = det_j_inv                                     &
375:         *( g3(2)*g1(3)-g3(3)*g1(2) )
376: cg2(2) = det_j_inv                                     &
377:         *( g3(3)*g1(1)-g3(1)*g1(3) )
378: cg2(3) = det_j_inv                                     &
379:         *( g3(1)*g1(2)-g3(2)*g1(1) )
380: cg3(1) = det_j_inv                                     &

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```

381:          *( g1 (2)*g2 (3)-g1 (3)*g2 (2) )
382:      cg3 (2) = det_j_inv          &
383:          *( g1 (3)*g2 (1)-g1 (1)*g2 (3) )
384:      cg3 (3) = det_j_inv          &
385:          *( g1 (1)*g2 (2)-g1 (2)*g2 (1) )
386:
387:      !-----
388:
389:      DO na = 1, le3d_nnodes
390:
391:          dndx (1, na)              &
392:          = cg1 (1)*le3d_dndx_i_qp (1, na, ijk) &
393:          +cg2 (1)*le3d_dndx_i_qp (2, na, ijk) &
394:          +cg3 (1)*le3d_dndx_i_qp (3, na, ijk)
395:          dndx (2, na)              &
396:          = cg1 (2)*le3d_dndx_i_qp (1, na, ijk) &
397:          +cg2 (2)*le3d_dndx_i_qp (2, na, ijk) &
398:          +cg3 (2)*le3d_dndx_i_qp (3, na, ijk)
399:          dndx (3, na)              &
400:          = cg1 (3)*le3d_dndx_i_qp (1, na, ijk) &
401:          +cg2 (3)*le3d_dndx_i_qp (2, na, ijk) &
402:          +cg3 (3)*le3d_dndx_i_qp (3, na, ijk)
403:
404:      END DO
405:
406:      !-----
407:
408:      ! B matrix
409:
410:      bmat = 0.0D0
411:
412:      DO nb = 1, le3d_nnodes
413:
414:          jsize1 = 3*(nb-1)+1
415:          jsize2 = 3*(nb-1)+2
416:          jsize3 = 3*(nb-1)+3

```

```

417:
418:      bmat(1, jsize1) = dndx(1, nb)
419:      bmat(4, jsize1) = dndx(2, nb)
420:      bmat(6, jsize1) = dndx(3, nb)
421:      bmat(2, jsize2) = dndx(2, nb)
422:      bmat(4, jsize2) = dndx(1, nb)
423:      bmat(5, jsize2) = dndx(3, nb)
424:      bmat(3, jsize3) = dndx(3, nb)
425:      bmat(5, jsize3) = dndx(2, nb)
426:      bmat(6, jsize3) = dndx(1, nb)
427:
428:      END DO
429:
430:      !-----
431:
432:      evec = 0.0D0
433:
434:      DO i = 1, 6
435:
436:         DO jsize = 1, 3*le3d_nnodes
437:
438:            evec(i) = evec(i)+bmat(i, jsize)*u_local(jsize)
439:
440:         END DO
441:
442:      END DO
443:
444:      !-----
445:
446:      lambda                                     &
447:      = ( esm3d%e(ie)*esm3d%nu(ie) )           &
448:      / ( ( 1.0D0+esm3d%nu(ie) )*( 1.0D0-2.0D0*esm3d%nu(ie) ) )
449:      mu = esm3d%e(ie)/( 2.0D0*( 1.0D0+esm3d%nu(ie) ) )
450:
451:      !-----
452:

```

```

453:      ! D matrix
454:
455:      dmat = 0.0D0
456:
457:      dmat(1, 1) = lambda+2.0D0*mu
458:      dmat(2, 2) = lambda+2.0D0*mu
459:      dmat(3, 3) = lambda+2.0D0*mu
460:      dmat(1, 2) = lambda
461:      dmat(1, 3) = lambda
462:      dmat(2, 1) = lambda
463:      dmat(2, 3) = lambda
464:      dmat(3, 1) = lambda
465:      dmat(3, 2) = lambda
466:      dmat(4, 4) = mu
467:      dmat(5, 5) = mu
468:      dmat(6, 6) = mu
469:
470:      !-----
471:
472:      DO i = 1, 6
473:
474:         DO jsize = 1, 3*le3d_nnodes
475:
476:            cmat(i, jsize) = 0.0D0
477:
478:            DO k = 1, 6
479:
480:               cmat(i, jsize) = cmat(i, jsize)+dmat(i, k)*bmat(k, jsize)
481:
482:            END DO
483:
484:         END DO
485:
486:      END DO
487:
488:      DO isize = 1, 3*le3d_nnodes

```

```

489:
490:     DO jsize = 1, 3*le3d_nnodes
491:
492:         DO k = 1, 6
493:
494:             esm3d%k(isize, jsize, ie)          &
495:             = esm3d%k(isize, jsize, ie)          &
496:             +w_w_w_det_j*bmat(k, isize)*cmat(k, jsize)
497:
498:         END DO
499:
500:     END DO
501:
502: END DO
503:
504: !-----
505:
506: svec = 0.0D0
507:
508: DO i = 1, 6
509:
510:     DO j = 1, 6
511:
512:         svec(i) = svec(i)+dmat(i, j)*evec(j)
513:
514:     END DO
515:
516: END DO
517:
518: !-----
519:
520: DO i = 1, 6
521:
522:     esm3d%evec(i, ie) = esm3d%evec(i, ie)+evec(i)
523:     esm3d%svec(i, ie) = esm3d%svec(i, ie)+svec(i)
524:

```

```

525:      END DO
526:
527:      !-----
528:
529:      END DO
530:
531:      !-----
532:
533:      DO I = 1, 6
534:
535:          esm3d%evec(i, ie) = nqps_tot_inv*esm3d%evec(i, ie)
536:          esm3d%svec(i, ie) = nqps_tot_inv*esm3d%svec(i, ie)
537:
538:      END DO
539:
540:      esm3d%s_mises(ie)                                     &
541:      = DSQRT( 0.5D0*( ( esm3d%svec(1, ie)-esm3d%svec(2, ie) )**2 &
542:                    +( esm3d%svec(2, ie)-esm3d%svec(3, ie) )**2 &
543:                    +( esm3d%svec(3, ie)-esm3d%svec(1, ie) )**2 &
544:                    +6.0D0                                     &
545:                    *( esm3d%svec(4, ie)**2                 &
546:                      +esm3d%svec(5, ie)**2                 &
547:                      +esm3d%svec(6, ie)**2 ) ) )
548:
549:      !-----
550:
551:      END DO
552:
553:      !-----
554:
555:      DEALLOCATE( ns3d_x )
556:      DEALLOCATE( ns3d_u )
557:
558:      DEALLOCATE( le3d_xi_qp )
559:      DEALLOCATE( le3d_w_qp )
560:      DEALLOCATE( le3d_n_qp )

```



```

561:      DEALLOCATE( le3d_dndx_i_qp )
562:
563:      DEALLOCATE( es3d_connectivity )
564:
565:      DEALLOCATE( x_local )
566:      DEALLOCATE( u_local )
567:      DEALLOCATE( dndx )
568:      DEALLOCATE( bmat )
569:      DEALLOCATE( cmat )
570:
571: !-----
572:
573:      RETURN
574:
575: !#####
576:      END SUBROUTINE cal_elemstiffmat3d
577: !#####
578:
579:
580: !#####
581:      SUBROUTINE del_elemstiffmat3d( esm3d)
582: !#####
583:
584:      TYPE(struct_elemstiffmat3d), INTENT(INOUT) :: esm3d
585:
586: !-----
587:
588:      NULLIFY( esm3d%ns3d )
589:      NULLIFY( esm3d%le3d )
590:      NULLIFY( esm3d%es3d )
591:
592: !-----
593:
594:      DEALLOCATE( esm3d%k )
595:
596:      !-----

```

```

597:
598:     DEALLOCATE( esm3d%e )
599:     DEALLOCATE( esm3d%nu )
600:
601:     !-----
602:
603:     DEALLOCATE( esm3d%evec )
604:     DEALLOCATE( esm3d%svec )
605:     DEALLOCATE( esm3d%s_mises )
606:
607: !-----
608:
609:     RETURN
610:
611: !#####
612:     END SUBROUTINE del_elemstiffmat3d
613: !#####
614:
615:
616: !#####
617:     END MODULE mod_elemstiffmat3d

```

2. 要素外力ベクトルモジュール mod_elemexforcevec3d.f90

```

1:     MODULE mod_elemexforcevec3d
2: !#####
3:
4:     USE mod_nodes3d
5:     USE mod_localelement3d
6:     USE mod_elements3d
7:
8: !-----
9:
10:    IMPLICIT NONE
11:
12: !-----

```

```

13:
14:     TYPE :: struct_elemexforcevec3d
15:
16:     !-----
17:
18:     PRIVATE
19:
20:     !-----
21:
22:     TYPE(struct_nodes3d), POINTER      :: ns3d => NULL()
23:     TYPE(struct_localelement3d), POINTER :: le3d => NULL()
24:     TYPE(struct_elements3d), POINTER   :: es3d => NULL()
25:
26:     !-----
27:     !
28:     ! f(:, :)
29:     ! Element external force vector
30:     !
31:     !-----
32:
33:     ! rho(:)
34:     ! Density
35:     !
36:     ! g
37:     ! Gravitational acceleration
38:     !
39:     !-----
40:
41:     REAL(8), ALLOCATABLE :: f(:, :)
42:     REAL(8), ALLOCATABLE :: rho(:)
43:     REAL(8) :: g
44:
45:     !-----
46:
47:     END TYPE struct_elemexforcevec3d
48:

```

```

49: !-----
50:
51:     CONTAINS
52:
53:
54:     ! Get element external force vector
55: !#####
56:     SUBROUTINE get_elemexforcevec3d_f(efv3d, f)
57: !#####
58:
59:     TYPE(struct_elemexforcevec3d), INTENT(IN) :: efv3d
60:
61:     REAL(8), INTENT(OUT) :: f(:, :)
62:
63: !-----
64:
65:     f = efv3d%f
66:
67: !-----
68:
69:     RETURN
70:
71: !#####
72:     END SUBROUTINE get_elemexforcevec3d_f
73: !#####
74:
75:
76:     ! Set density
77: !#####
78:     SUBROUTINE set_elemexforcevec3d_rho(efv3d, rho)
79: !#####
80:
81:     TYPE(struct_elemexforcevec3d), INTENT(INOUT) :: efv3d
82:
83:     REAL(8), INTENT(IN) :: rho(:)
84:

```

```

85: !-----
86:
87:     efv3d%rho = rho
88:
89: !-----
90:
91:     RETURN
92:
93: !#####
94:     END SUBROUTINE set_elemexforcevec3d_rho
95: !#####
96:
97:
98:     ! Get density
99: !#####
100:     SUBROUTINE get_elemexforcevec3d_rho(efv3d, rho)
101: !#####
102:
103:     TYPE(struct_elemexforcevec3d), INTENT(IN) :: efv3d
104:
105:     REAL(8), INTENT(OUT) :: rho(:)
106:
107: !-----
108:
109:     rho = efv3d%rho
110:
111: !-----
112:
113:     RETURN
114:
115: !#####
116:     END SUBROUTINE get_elemexforcevec3d_rho
117: !#####
118:
119:
120:     ! Set gravitational acceleration

```

```

121: !#####
122:      SUBROUTINE set_elemexforcevec3d_g(efv3d, g)
123: !#####
124:
125:      TYPE(struct_elemexforcevec3d), INTENT(INOUT) :: efv3d
126:
127:      REAL(8), INTENT(IN) :: g
128:
129: !-----
130:
131:      efv3d%g = g
132:
133: !-----
134:
135:      RETURN
136:
137: !#####
138:      END SUBROUTINE set_elemexforcevec3d_g
139: !#####
140:
141:
142:      ! Get gravitational acceleration
143: !#####
144:      SUBROUTINE get_elemexforcevec3d_g(efv3d, g)
145: !#####
146:
147:      TYPE(struct_elemexforcevec3d), INTENT(IN) :: efv3d
148:
149:      REAL(8), INTENT(OUT) :: g
150:
151: !-----
152:
153:      g = efv3d%g
154:
155: !-----
156:

```

```

157:      RETURN
158:
159: !#####
160:      END SUBROUTINE get_elemexforcevec3d_g
161: !#####
162:
163:
164: !#####
165:      SUBROUTINE init_elemexforcevec3d(efv3d, ns3d, le3d, es3d)
166: !#####
167:
168:      TYPE(struct_elemexforcevec3d), INTENT(INOUT) :: efv3d
169:
170:      TYPE(struct_nodes3d), TARGET, INTENT(IN)      :: ns3d
171:      TYPE(struct_localelement3d), TARGET, INTENT(IN) :: le3d
172:      TYPE(struct_elements3d), TARGET, INTENT(IN)    :: es3d
173:
174: !-----
175:
176:      INTEGER :: le3d_nnodes
177:      INTEGER :: es3d_n
178:
179: !-----
180:
181:      efv3d%ns3d => ns3d
182:      efv3d%le3d => le3d
183:      efv3d%es3d => es3d
184:
185: !-----
186:
187:      CALL get_localelement3d_nnodes(efv3d%le3d, le3d_nnodes)
188:
189:      CALL get_elements3d_n(efv3d%es3d, es3d_n)
190:
191: !-----
192:

```

```

193:    ALLOCATE( efv3d%f(3*le3d_nnodes, es3d_n) )
194:
195:    efv3d%f = 0.0D0
196:
197:    !-----
198:
199:    ALLOCATE( efv3d%rho(es3d_n) )
200:
201:    efv3d%rho = 0.0D0
202:
203:    efv3d%g = 0.0D0
204:
205: !-----
206:
207:    RETURN
208:
209: !#####
210:    END SUBROUTINE init_elemexforcevec3d
211: !#####
212:
213:
214: !#####
215:    SUBROUTINE cal_elemexforcevec3d(efv3d)
216: !#####
217:
218:    TYPE(struct_elemexforcevec3d), INTENT(INOUT) :: efv3d
219:
220: !-----
221:
222: !-----
223:
224:    RETURN
225:
226: !#####
227:    END SUBROUTINE cal_elemexforcevec3d
228: !#####

```



```

229:
230:
231: !#####
232:     SUBROUTINE del_elemexforcevec3d(efv3d)
233: !#####
234:
235:     TYPE(struct_elemexforcevec3d), INTENT(INOUT) :: efv3d
236:
237: !-----
238:
239:     NULLIFY( efv3d%ns3d )
240:     NULLIFY( efv3d%le3d )
241:     NULLIFY( efv3d%es3d )
242:
243: !-----
244:
245:     DEALLOCATE( efv3d%f )
246:
247:     !-----
248:
249:     DEALLOCATE( efv3d%rho )
250:
251:     efv3d%g = 0.0D0
252:
253: !-----
254:
255:     RETURN
256:
257: !#####
258:     END SUBROUTINE del_elemexforcevec3d
259: !#####
260:
261:
262: !#####
263:     END MODULE mod_elemexforcevec3d

```

第 4 節のプログラム：モジュール mod_fem3d の作成

3. 有限要素法モジュール mod_fem3d.f90

```

1:      MODULE mod_fem3d
2: !#####
3:
4:      USE mod_nodes3d
5:      USE mod_localelement3d
6:      USE mod_elements3d
7:      USE mod_elemstiffmat3d
8:      USE mod_elemexforcevec3d
9:
10: !-----
11:
12:      IMPLICIT NONE
13:
14: !-----
15:
16:      TYPE :: struct_fem3d
17:
18:      !-----
19:
20:      PRIVATE
21:
22:      !-----
23:
24:      TYPE(struct_nodes3d), POINTER      :: ns3d => NULL()
25:      TYPE(struct_localelement3d), POINTER  :: le3d => NULL()
26:      TYPE(struct_elements3d), POINTER      :: es3d => NULL()
27:      TYPE(struct_elemstiffmat3d), POINTER  :: esm3d => NULL()
28:      TYPE(struct_elemexforcevec3d), POINTER :: efv3d => NULL()
29:
30:      !-----
31:      !

```

```

32:      ! ndofs
33:      ! The total number of DOFs
34:      !
35:      ! k(:, :)
36:      ! Stiffness matrix
37:      !
38:      ! f(:)
39:      ! External force vector
40:      !
41:      !-----
42:      !
43:      ! nnodes_loaded
44:      ! The total number of nodes with an equivalent nodal force
45:      !
46:      ! id_loaded(:)
47:      ! Node no. with an equivalent nodal force
48:      !
49:      ! f_loaded(:, :)
50:      ! Equivalent nodal force
51:      !
52:      !-----
53:
54:      INTEGER :: ndofs
55:      INTEGER :: nnodes_loaded
56:      INTEGER, ALLOCATABLE :: id_loaded(:)
57:
58:      REAL(8), ALLOCATABLE :: k(:, :)
59:      REAL(8), ALLOCATABLE :: f(:)
60:      REAL(8), ALLOCATABLE :: f_loaded(:, :)
61:
62:      !-----
63:
64:      END TYPE struct_fem3d
65:
66: !-----
67:

```

```

68:    PRIVATE :: cal_fem3d_stiffmat
69:    PRIVATE :: cal_fem3d_rhs
70:    PRIVATE :: cal_fem3d_dirichletbc
71:    PRIVATE :: cal_fem3d_linearsolver
72:
73: !-----
74:
75:    CONTAINS
76:
77:
78:    ! Get the total number of DOFs
79: !#####
80:    SUBROUTINE get_fem3d_ndofs(fem3d, ndofs)
81: !#####
82:
83:    TYPE(struct_fem3d), INTENT(IN) :: fem3d
84:
85:    INTEGER, INTENT(OUT) :: ndofs
86:
87: !-----
88:
89:    ndofs = fem3d%ndofs
90:
91: !-----
92:
93:    RETURN
94:
95: !#####
96:    END SUBROUTINE get_fem3d_ndofs
97: !#####
98:
99:
100:    ! Get stiffness matrix
101: !#####
102:    SUBROUTINE get_fem3d_k(fem3d, k)
103: !#####

```

```

104:
105:     TYPE(struct_fem3d), INTENT(IN) :: fem3d
106:
107:     INTEGER, INTENT(OUT) :: k(:, :)
108:
109: !-----
110:
111:     k = fem3d%k
112:
113: !-----
114:
115:     RETURN
116:
117: !#####
118:     END SUBROUTINE get_fem3d_k
119: !#####
120:
121:
122:     ! Get external force vector
123: !#####
124:     SUBROUTINE get_fem3d_f(fem3d, f)
125: !#####
126:
127:     TYPE(struct_fem3d), INTENT(IN) :: fem3d
128:
129:     INTEGER, INTENT(OUT) :: f(:)
130:
131: !-----
132:
133:     f = fem3d%f
134:
135: !-----
136:
137:     RETURN
138:
139: !#####

```

```

140:      END SUBROUTINE get_fem3d_f
141: !#####
142:
143:
144:      ! Set equivalent nodal force
145: !#####
146:      SUBROUTINE set_fem3d_f_loaded(fem3d, id_loaded, f_loaded)
147: !#####
148:
149:      TYPE(struct_fem3d), INTENT(INOUT) :: fem3d
150:
151:      INTEGER, INTENT(IN) :: id_loaded(:)
152:      REAL(8), INTENT(IN) :: f_loaded(:, :)
153:
154: !-----
155:
156:      fem3d%id_loaded = id_loaded
157:      fem3d%f_loaded = f_loaded
158:
159: !-----
160:
161:      RETURN
162:
163: !#####
164:      END SUBROUTINE set_fem3d_f_loaded
165: !#####
166:
167:
168:      ! Get equivalent nodal force
169: !#####
170:      SUBROUTINE get_fem3d_f_loaded(fem3d, id_loaded, f_loaded)
171: !#####
172:
173:      TYPE(struct_fem3d), INTENT(IN) :: fem3d
174:
175:      INTEGER, INTENT(OUT) :: id_loaded(:)

```

```

176:      REAL (8), INTENT (OUT) :: f_loaded(:, :)
177:
178: !-----
179:
180:      id_loaded = fem3d%id_loaded
181:      f_loaded  = fem3d%f_loaded
182:
183: !-----
184:
185:      RETURN
186:
187: !#####
188:      END SUBROUTINE get_fem3d_f_loaded
189: !#####
190:
191:
192:      ! Initialize fem3d
193: !#####
194:      SUBROUTINE init_fem3d                                &
195:          (fem3d, ns3d, le3d, es3d, esm3d, efv3d, &
196:           nnodes_loaded)
197: !#####
198:
199:      TYPE(struct_fem3d), INTENT (INOUT) :: fem3d
200:
201:      TYPE(struct_nodes3d), TARGET, INTENT (IN)          :: ns3d
202:      TYPE(struct_localelement3d), TARGET, INTENT (IN)  :: le3d
203:      TYPE(struct_elements3d), TARGET, INTENT (IN)       :: es3d
204:      TYPE(struct_elemstiffmat3d), TARGET, INTENT (IN)   :: esm3d
205:      TYPE(struct_elemexforcevec3d), TARGET, INTENT (IN) :: efv3d
206:
207:      INTEGER, INTENT (IN) :: nnodes_loaded
208:
209: !-----
210:
211:      INTEGER :: ns3d_n

```

```

212:
213: !-----
214:
215:     fem3d%ns3d => ns3d
216:     fem3d%le3d => le3d
217:     fem3d%es3d => es3d
218:     fem3d%esm3d => esm3d
219:     fem3d%efv3d => efv3d
220:
221: !-----
222:
223:     CALL get_nodes3d_n(fem3d%ns3d, ns3d_n)
224:
225: !-----
226:
227:     fem3d%ndofs = 3*ns3d_n
228:
229:     !-----
230:
231:     ALLOCATE( fem3d%k(fem3d%ndofs, fem3d%ndofs) )
232:
233:     fem3d%k = 0.0D0
234:
235:     ALLOCATE( fem3d%f(fem3d%ndofs) )
236:
237:     fem3d%f = 0.0D0
238:
239:     !-----
240:
241:     fem3d%nnodes_loaded = nnodes_loaded
242:
243:     ALLOCATE( fem3d%id_loaded(nnodes_loaded) )
244:
245:     fem3d%id_loaded = 0
246:
247:     ALLOCATE( fem3d%f_loaded(3, nnodes_loaded) )

```



```

248:
249:     fem3d%f_loaded = 0.0D0
250:
251: !-----
252:
253:     RETURN
254:
255: !#####
256:     END SUBROUTINE init_fem3d
257: !#####
258:
259:
260:     ! Calculate fem3d
261: !#####
262:     SUBROUTINE cal_fem3d(fem3d)
263: !#####
264:
265:     TYPE(struct_fem3d), INTENT(INOUT) :: fem3d
266:
267: !-----
268:
269:     ! Stiffness matrix
270:     CALL cal_fem3d_stiffmat(fem3d)
271:
272: !-----
273:
274:     ! RHS vector
275:     CALL cal_fem3d_rhs(fem3d)
276:
277: !-----
278:
279:     ! Dirichlet boundary condition
280:     CALL cal_fem3d_dirichletbc(fem3d)
281:
282: !-----
283:

```

```

284:      ! Linear solver
285:      CALL cal_fem3d_linearsolver(fem3d)
286:
287: !-----
288:
289:      ! Strain and stress
290:      CALL cal_elemstiffmat3d(fem3d%esm3d)
291:
292: !-----
293:
294:      RETURN
295:
296: !#####
297:      END SUBROUTINE cal_fem3d
298: !#####
299:
300:
301:      ! Calculate fem3d (stiffness matrix)
302: !#####
303:      SUBROUTINE cal_fem3d_stiffmat(fem3d)
304: !#####
305:
306:      TYPE(struct_fem3d), INTENT(INOUT) :: fem3d
307:
308: !-----
309:
310:      INTEGER :: le3d_nnodes
311:      INTEGER :: es3d_n
312:      INTEGER, ALLOCATABLE :: es3d_connectivity(:, :)
313:      INTEGER :: i, j
314:      INTEGER :: id, jd
315:      INTEGER :: na, nb
316:      INTEGER :: ie
317:      INTEGER :: idof, jdof
318:      INTEGER :: isize, jsize
319:

```

```

320:      REAL(8), ALLOCATABLE :: esm3d_k(:, :, :)
321:      REAL(8), ALLOCATABLE :: efv3d_f(:, :)
322:
323: !-----
324:
325:      ! Element stiffness matrix
326:      CALL cal_elemstiffmat3d(fem3d%esm3d)
327:
328: !-----
329:
330:      CALL get_localelement3d_nnodes(fem3d%le3d, le3d_nnodes)
331:
332:      CALL get_elements3d_n(fem3d%es3d, es3d_n)
333:      ALLOCATE( es3d_connectivity(le3d_nnodes, es3d_n) )
334:      CALL get_elements3d_connectivity(fem3d%es3d, es3d_connectivity)
335:
336:      ALLOCATE( esm3d_k(3*le3d_nnodes, 3*le3d_nnodes, es3d_n) )
337:      CALL get_elemstiffmat3d_k(fem3d%esm3d, esm3d_k)
338:
339:      ! Stiffness matrix
340:
341:      fem3d%k = 0.0D0
342:
343:      DO ie = 1, es3d_n
344:
345:          DO na = 1, le3d_nnodes
346:
347:              id = es3d_connectivity(na, ie)
348:
349:              DO i = 1, 3
350:
351:                  idof = 3*(id-1)+i
352:                  isize = 3*(na-1)+i
353:
354:                  DO nb = 1, le3d_nnodes
355:

```

```

356:      jd = es3d_connectivity(nb, ie)
357:
358:      DO j = 1, 3
359:
360:         jdof = 3*(jd-1)+j
361:         jsize = 3*(nb-1)+j
362:
363:         fem3d%k(idof, jdof) &
364:         = fem3d%k(idof, jdof)+esm3d_k(isize, jsize, ie)
365:
366:      END DO
367:
368:   END DO
369:
370: END DO
371:
372: END DO
373:
374: END DO
375:
376: !-----
377:
378:   DEALLOCATE( es3d_connectivity )
379:
380:   DEALLOCATE( esm3d_k )
381:
382: !-----
383:
384:   RETURN
385:
386: !#####
387:   END SUBROUTINE cal_fem3d_stiffmat
388: !#####
389:
390:
391:   ! Calculate fem3d (RHS vector)

```

```

392: !#####
393:      SUBROUTINE cal_fem3d_rhs(fem3d)
394: !#####
395:
396:      TYPE(struct_fem3d), INTENT(INOUT) :: fem3d
397:
398: !-----
399:
400:      INTEGER :: le3d_nnodes
401:      INTEGER :: es3d_n
402:      INTEGER, ALLOCATABLE :: es3d_connectivity(:, :)
403:      INTEGER :: i
404:      INTEGER :: id
405:      INTEGER :: id_l
406:      INTEGER :: na
407:      INTEGER :: ie
408:      INTEGER :: idof
409:      INTEGER :: isize
410:
411:      REAL(8), ALLOCATABLE :: efv3d_f(:, :)
412:
413: !-----
414:
415:      ! Element external force vector
416:      CALL cal_elemexforcevec3d(fem3d%efv3d)
417:
418: !-----
419:
420:      CALL get_localelement3d_nnodes(fem3d%le3d, le3d_nnodes)
421:
422:      CALL get_elements3d_n(fem3d%es3d, es3d_n)
423:      ALLOCATE( es3d_connectivity(le3d_nnodes, es3d_n) )
424:      CALL get_elements3d_connectivity(fem3d%es3d, es3d_connectivity)
425:
426:      ALLOCATE( efv3d_f(3*le3d_nnodes, es3d_n) )
427:      CALL get_elemexforcevec3d_f(fem3d%efv3d, efv3d_f)

```

```

428:
429:      !-----
430:
431:      ! External force vector
432:
433:      fem3d%f = 0.0D0
434:
435:      DO id_l = 1, fem3d%nnodes_loaded
436:
437:          id = fem3d%id_loaded(id_l)
438:
439:          DO i = 1, 3
440:
441:              idof = 3*(id-1)+i
442:
443:              fem3d%f(idof) = fem3d%f_loaded(i, id_l)
444:
445:          END DO
446:
447:      END DO
448:
449:      DO ie = 1, es3d_n
450:
451:          DO na = 1, le3d_nnodes
452:
453:              id = es3d_connectivity(na, ie)
454:
455:              DO i = 1, 3
456:
457:                  idof = 3*(id-1)+i
458:                  isize = 3*(na-1)+i
459:
460:                  fem3d%f(idof) = fem3d%f(idof)+efv3d_f(isize, ie)
461:
462:              END DO
463:

```

```

464:      END DO
465:
466:      END DO
467:
468: !-----
469:
470:      DEALLOCATE( es3d_connectivity )
471:
472:      DEALLOCATE( efv3d_f )
473:
474: !-----
475:
476:      RETURN
477:
478: !#####
479:      END SUBROUTINE cal_fem3d_rhs
480: !#####
481:
482:
483:      ! Calculate fem3d (Dirichlet boundary condition)
484: !#####
485:      SUBROUTINE cal_fem3d_dirichletbc(fem3d)
486: !#####
487:
488:      TYPE(struct_fem3d), INTENT(INOUT) :: fem3d
489:
490: !-----
491:
492:      INTEGER :: ns3d_n
493:      INTEGER, ALLOCATABLE :: ns3d_bc(:)
494:      INTEGER :: idof, jdof
495:      INTEGER :: idof_g
496:      INTEGER :: ndofs_given
497:      INTEGER, ALLOCATABLE :: idof_given(:)
498:
499:      REAL(8), ALLOCATABLE :: ns3d_u(:)

```

```

500:      REAL (8) :: u_given
501:
502: !-----
503:
504:      CALL get_nodes3d_n(fem3d%ns3d, ns3d_n)
505:      ALLOCATE( ns3d_u(fem3d%ndofs) )
506:      CALL get_nodes3d_u(fem3d%ns3d, ns3d_u)
507:      ALLOCATE( ns3d_bc(fem3d%ndofs) )
508:      CALL get_nodes3d_bc(fem3d%ns3d, ns3d_bc)
509:
510: !-----
511:
512:      idof_g = 0
513:
514:      DO idof = 1, fem3d%ndofs
515:
516:         IF( ns3d_bc(idof) .EQ. 1 ) THEN
517:
518:            idof_g = idof_g+1
519:
520:         END IF
521:
522:      END DO
523:
524:      ndofs_given = idof_g
525:
526: !-----
527:
528:      ALLOCATE( idof_given(ndofs_given) )
529:
530: !-----
531:
532:      idof_g = 0
533:
534:      DO idof = 1, fem3d%ndofs
535:

```



```

536:      IF( ns3d_bc(idof) .EQ. 1 ) THEN
537:
538:          idof_g = idof_g+1
539:
540:          idof_given(idof_g) = idof
541:
542:      END IF
543:
544:  END DO
545:
546: !-----
547:
548:      ! Dirichlet boundary conditions
549:
550:      DO idof_g = 1, ndofs_given
551:
552:          jdof = idof_given(idof_g)
553:
554:          DO idof = 1, fem3d%ndofs
555:
556:              fem3d%f(idof) = fem3d%f(idof)-fem3d%k(idof, jdof)*ns3d_u(jdof)
557:
558:          END DO
559:
560:      END DO
561:
562:      DO idof_g = 1, ndofs_given
563:
564:          idof = idof_given(idof_g)
565:
566:          fem3d%f(idof) = ns3d_u(idof)
567:
568:      END DO
569:
570:      DO idof_g = 1, ndofs_given
571:

```

```

572:      jdof = idof_given(idof_g)
573:
574:      DO idof = 1, fem3d%ndofs
575:
576:          fem3d%k(idof, jdof) = 0.0D0
577:          fem3d%k(jdof, idof) = 0.0D0
578:
579:      END DO
580:
581:      fem3d%k(jdof, jdof) = 1.0D0
582:
583:  END DO
584:
585: !-----
586:
587:      DEALLOCATE( ns3d_u )
588:      DEALLOCATE( ns3d_bc )
589:
590:      DEALLOCATE( idof_given )
591:
592: !-----
593:
594:      RETURN
595:
596: !#####
597:      END SUBROUTINE cal_fem3d_dirichletbc
598: !#####
599:
600:
601:      ! Calculate fem3d (linear solver)
602: !#####
603:      SUBROUTINE cal_fem3d_linear_solver(fem3d)
604: !#####
605:
606:      TYPE(struct_fem3d), INTENT(INOUT) :: fem3d
607:

```

```

608: !-----
609:
610:     INTEGER :: ipiv(fem3d%ndofs)
611:     INTEGER :: info
612:
613: !-----
614:
615:     ! Linear solver
616:
617:     ipiv = 0
618:
619:     CALL DGESV                                &
620:         (fem3d%ndofs, 1, fem3d%k, fem3d%ndofs, ipiv, &
621:         fem3d%f, fem3d%ndofs, info)
622:
623:     CALL set_nodes3d_u(fem3d%ns3d, fem3d%f)
624:
625: !-----
626:
627:     RETURN
628:
629: !#####
630:     END SUBROUTINE cal_fem3d_linear_solver
631: !#####
632:
633:
634:     ! Delete fem3d
635: !#####
636:     SUBROUTINE del_fem3d(fem3d)
637: !#####
638:
639:     TYPE(struct_fem3d), INTENT(INOUT) :: fem3d
640:
641: !-----
642:
643:     IF( fem3d%ndofs .EQ. 0 ) THEN

```

```

644:
645:     RETURN
646:
647:     END IF
648:
649: !-----
650:
651:     NULLIFY( fem3d%ns3d )
652:     NULLIFY( fem3d%le3d )
653:     NULLIFY( fem3d%es3d )
654:     NULLIFY( fem3d%esm3d )
655:     NULLIFY( fem3d%efv3d )
656:
657: !-----
658:
659:     fem3d%ndofs = 0
660:
661:     !-----
662:
663:     DEALLOCATE( fem3d%k )
664:     DEALLOCATE( fem3d%f )
665:
666: !-----
667:
668:     IF( fem3d%nnodes_loaded .EQ. 0 ) THEN
669:
670:         RETURN
671:
672:     END IF
673:
674: !-----
675:
676:     fem3d%nnodes_loaded = 0
677:
678:     !-----
679:

```

```

680:      DEALLOCATE( fem3d%id_loaded )
681:      DEALLOCATE( fem3d%f_loaded )
682:
683: !-----
684:
685:      RETURN
686:
687: !#####
688:      END SUBROUTINE del_fem3d
689: !#####
690:
691:
692: !#####
693:      END MODULE mod_fem3d

```

第 5 節のプログラム：メッシング用のアプリケーションモジュール mod_appli の修正

4. アプリケーションモジュール mod_appli.f90

```

1:      MODULE mod_appli
2: !#####
3:
4:      USE mod_nodes3d
5:      USE mod_localelement3d
6:      USE mod_elements3d
7:      USE mod_elemstiffmat3d
8:      USE mod_elemexforcevec3d
9:      USE mod_fem3d
10:     USE mod_rectmesher3d
11:
12: !-----
13:
14:     IMPLICIT NONE
15:

```

```

16: !-----
17:
18:     TYPE(struct_nodes3d), POINTER      :: ns3d
19:     TYPE(struct_localelement3d), POINTER :: le3d
20:     TYPE(struct_elements3d), POINTER    :: es3d
21:     TYPE(struct_elemstiffmat3d), POINTER :: esm3d
22:     TYPE(struct_elemexforcevec3d), POINTER :: efv3d
23:     TYPE(struct_fem3d), POINTER         :: fem3d
24:     TYPE(struct_rectmesher3d), POINTER  :: rm3d
25:
26:     !-----
27:     !
28:     ! Problem number
29:     ! prob
30:     !
31:     !-----
32:
33:     INTEGER :: prob
34:
35: !-----
36:
37:     CONTAINS
38:
39:
40:     ! Start appli
41: !#####
42:     SUBROUTINE start_appli()
43: !#####
44:
45:     INTEGER :: ns3d_n
46:     INTEGER :: le3d_nboundaries
47:     INTEGER :: le3d_nnodes
48:     INTEGER :: le3d_nqps
49:     INTEGER :: es3d_n
50:     INTEGER :: rm3d_n_x(3)
51:

```

```

52:    REAL (8) :: rm3d_x_start(3)
53:    REAL (8) :: rm3d_x_end(3)
54:    REAL (8) :: e
55:    REAL (8) :: nu
56:    REAL (8) :: rho
57:    REAL (8) :: g
58:
59:    CHARACTER(1) :: dataname
60:
61: !-----
62:
63:    ALLOCATE ( ns3d )
64:    ALLOCATE ( le3d )
65:    ALLOCATE ( es3d )
66:    ALLOCATE ( esm3d )
67:    ALLOCATE ( efv3d )
68:    ALLOCATE ( fem3d )
69:    ALLOCATE ( rm3d )
70:
71: !-----
72:
73:    OPEN(13, FILE = 'param_meshing.dat')
74:
75:    READ(13, *) dataname
76:    READ(13, *) rm3d_n_x(1), rm3d_n_x(2), rm3d_n_x(3)
77:    READ(13, *) dataname
78:    READ(13, *) rm3d_x_start(1), rm3d_x_start(2), rm3d_x_start(3)
79:    READ(13, *) dataname
80:    READ(13, *) rm3d_x_end(1), rm3d_x_end(2), rm3d_x_end(3)
81:    READ(13, *) dataname
82:    READ(13, *) prob
83:    READ(13, *) dataname
84:    READ(13, *) e
85:    READ(13, *) dataname
86:    READ(13, *) nu
87:    READ(13, *) dataname

```

```

88:      READ(13, *) rho
89:      READ(13, *) dataname
90:      READ(13, *) g
91:      READ(13, *) dataname
92:
93:      CLOSE(13)
94:
95: !-----
96:
97:      OPEN(13, FILE = 'param_fea.dat')
98:
99:      WRITE(13, '(A)') '!ANALYSIS_TYPE'
100:     WRITE(13, '(A)') 'STATIC_ANALYSIS'
101:     WRITE(13, '(A)') '!YOUNG'S_MODULUS'
102:     WRITE(13, '(E17.8)') e
103:     WRITE(13, '(A)') '!POISSON'S_RATIO'
104:     WRITE(13, '(E17.8)') nu
105:     WRITE(13, '(A)') '!DENSITY'
106:     WRITE(13, '(E17.8)') rho
107:     WRITE(13, '(A)') '!GRAVITATIONAL_ACCELERATION'
108:     WRITE(13, '(E17.8)') g
109:
110: !-----
111:
112:     CALL init_rectmesher3d                &
113:         (rm3d, ns3d, le3d, es3d,          &
114:         rm3d_n_x, rm3d_x_start, rm3d_x_end)
115:
116: !-----
117:
118:     CALL get_nodes3d_n(ns3d, ns3d_n)
119:
120:     CALL get_localelement3d_nboundaries(le3d, le3d_nboundaries)
121:     CALL get_localelement3d_nnodes(le3d, le3d_nnodes)
122:     CALL get_localelement3d_nqps(le3d, le3d_nqps)
123:

```



```

124:      CALL get_elements3d_n(es3d, es3d_n)
125:
126:      !-----
127:
128:      CALL init_nodes3d(ns3d, ns3d_n)
129:
130:      CALL init_localelement3d                                &
131:          (le3d, le3d_nboundaries, le3d_nnodes, le3d_nqps)
132:
133:      CALL init_elements3d(es3d, ns3d, le3d, es3d_n)
134:
135:      !-----
136:
137:      RETURN
138:
139:      !#####
140:      END SUBROUTINE start_appli
141:      !#####
142:
143:
144:      ! Run appli
145:      !#####
146:      SUBROUTINE run_appli()
147:      !#####
148:
149:      INTEGER :: ns3d_n
150:      INTEGER, ALLOCATABLE :: ns3d_bc(:)
151:      INTEGER :: le3d_nboundaries
152:      INTEGER :: le3d_nnodes
153:      INTEGER :: le3d_nnodes_boundary
154:      INTEGER, ALLOCATABLE :: le3d_table_na(:, :)
155:      INTEGER :: es3d_n
156:      INTEGER, ALLOCATABLE :: es3d_connectivity(:, :)
157:      INTEGER :: es3d_ie_max_volume
158:      INTEGER :: es3d_ie_min_volume
159:      INTEGER :: fem3d_ndofs

```

```

160:      INTEGER :: fem3d_nnodes_loaded
161:      INTEGER, ALLOCATABLE :: fem3d_id_loaded(:)
162:      INTEGER :: i
163:      INTEGER :: id
164:      INTEGER :: id_l
165:      INTEGER :: na
166:      INTEGER :: ie
167:      INTEGER :: idof
168:
169:      REAL (8), ALLOCATABLE :: ns3d_x(:, :)
170:      REAL (8), ALLOCATABLE :: ns3d_u(:)
171:      REAL (8), ALLOCATABLE :: es3d_volume(:)
172:      REAL (8) :: es3d_max_volume
173:      REAL (8) :: es3d_min_volume
174:      REAL (8) :: es3d_sum_volume
175:      REAL (8), ALLOCATABLE :: fem3d_f_loaded(:, :)
176:      REAL (8) :: rm3d_x_start(3)
177:      REAL (8) :: rm3d_x_end(3)
178:      REAL (8) :: rm3d_x_center(3)
179:      REAL (8) :: rm3d_length_x(3)
180:      REAL (8), ALLOCATABLE :: x_local(:, :)
181:
182: !-----
183:
184:      CALL cal_rectmesher3d(rm3d)
185:
186:      CALL cal_elements3d(es3d)
187:
188: !-----
189:
190:      CALL get_nodes3d_n(ns3d, ns3d_n)
191:
192:      ALLOCATE( ns3d_x(3, ns3d_n) )
193:      CALL get_nodes3d_x(ns3d, ns3d_x)
194:      ALLOCATE( ns3d_u(3*ns3d_n) )
195:      ns3d_u = 0.0D0

```

```

196:    ALLOCATE( ns3d_bc(3*ns3d_n) )
197:    ns3d_bc = 0
198:
199:    CALL get_localelement3d_nboundaries(le3d, le3d_nboundaries)
200:    CALL get_localelement3d_nnodes(le3d, le3d_nnodes)
201:    CALL get_localelement3d_nnodes_boundary(le3d, le3d_nnodes_boundary)
202:    ALLOCATE( le3d_table_na(le3d_nnodes_boundary, le3d_nboundaries) )
203:    CALL get_localelement3d_table_na(le3d, le3d_table_na)
204:
205:    CALL get_elements3d_n(es3d, es3d_n)
206:    ALLOCATE( es3d_volume(es3d_n) )
207:    CALL get_elements3d_volume          &
208:        (es3d, es3d_volume,             &
209:        es3d_max_volume, es3d_ie_max_volume, &
210:        es3d_min_volume, es3d_ie_min_volume, &
211:        es3d_sum_volume)
212:    ALLOCATE( es3d_connectivity(le3d_nnodes, es3d_n) )
213:    CALL get_elements3d_connectivity(es3d, es3d_connectivity)
214:    CALL get_rectmesher3d_x_start_x_end &
215:        (rm3d, rm3d_x_start, rm3d_x_end, &
216:        rm3d_x_center, rm3d_length_x)
217:
218:    ALLOCATE( x_local(3, le3d_nnodes_boundary) )
219:
220: !-----
221:
222:    ! Tensile deformation
223:    IF( prob .EQ. 1 ) THEN
224:
225:    !-----
226:
227:        id_l = 0
228:
229:        DO id = 1, ns3d_n
230:
231:            IF( DABS( ns3d_x(1, id)-rm3d_x_end(1) ) .LT. EPSILON(1.0D0) ) THEN

```

```

232:
233:     id_l = id_l+1
234:
235:     END IF
236:
237:     END DO
238:
239:     fem3d_nnodes_loaded = id_l
240:
241:     !-----
242:
243:     END IF
244:
245:     !-----
246:
247:     CALL init_elemstiffmat3d(esm3d, ns3d, le3d, es3d)
248:     CALL init_elemexforcevec3d(efv3d, ns3d, le3d, es3d)
249:     CALL init_fem3d          &
250:         (fem3d, ns3d, le3d, es3d, esm3d, efv3d, &
251:         fem3d_nnodes_loaded)
252:
253:     CALL get_fem3d_ndofs(fem3d, fem3d_ndofs)
254:     ALLOCATE( fem3d_id_loaded(fem3d_nnodes_loaded) )
255:     fem3d_id_loaded = 0
256:     ALLOCATE( fem3d_f_loaded(3, fem3d_nnodes_loaded) )
257:     fem3d_f_loaded = 0.0D0
258:
259:     !-----
260:
261:     ! Tensile deformation
262:     IF( prob .EQ. 1 ) THEN
263:
264:         !-----
265:
266:         DO id = 1, ns3d_n
267:

```

```

268:      IF( DABS( ns3d_x(1, id)-rm3d_x_start(1) ) .LT. EPSILON(1.0D0) ) THEN
269:
270:          idof = 3*(id-1)+1
271:
272:          ns3d_u(idof) = 0.0D0
273:          ns3d_bc(idof) = 1
274:
275:      IF( DABS( ns3d_x(2, id)-rm3d_x_center(2) ) .LT. EPSILON(1.0D0) ) THEN
276:
277:          idof = 3*(id-1)+2
278:
279:          ns3d_u(idof) = 0.0D0
280:          ns3d_bc(idof) = 1
281:
282:      END IF
283:
284:      IF( DABS( ns3d_x(3, id)-rm3d_x_center(3) ) .LT. EPSILON(1.0D0) ) THEN
285:
286:          idof = 3*(id-1)+3
287:
288:          ns3d_u(idof) = 0.0D0
289:          ns3d_bc(idof) = 1
290:
291:      END IF
292:
293:      END IF
294:
295:      END DO
296:
297:      !-----
298:
299:      END IF
300:
301:      !-----
302:
303:      id_l = 0

```

```

304:
305:     ! Tensile deformation
306:     IF( prob .EQ. 1 ) THEN
307:
308:         !-----
309:
310:         DO id = 1, ns3d_n
311:
312:             IF( DABS( ns3d_x(1, id)-rm3d_x_end(1) ) .LT. EPSILON(1.0D0) ) THEN
313:
314:                 id_l = id_l+1
315:
316:                 fem3d_id_loaded(id_l) = id
317:                 fem3d_f_loaded(1, id_l) = 2.5D6
318:
319:                 IF( DABS( ns3d_x(2, id)-rm3d_x_center(2) ) .LT. EPSILON(1.0D0) ) THEN
320:
321:                     fem3d_f_loaded(1, id_l) = 5.0D6
322:
323:                 END IF
324:
325:                 IF( DABS( ns3d_x(3, id)-rm3d_x_center(3) ) .LT. EPSILON(1.0D0) ) THEN
326:
327:                     fem3d_f_loaded(1, id_l) = 5.0D6
328:
329:                 END IF
330:
331:                 IF( DABS( ns3d_x(2, id)-rm3d_x_center(2) ) .LT. EPSILON(1.0D0) ) THEN
332:
333:                     IF( DABS( ns3d_x(3, id)-rm3d_x_center(3) ) .LT. EPSILON(1.0D0) ) THEN
334:
335:                         fem3d_f_loaded(1, id_l) = 1.0D7
336:
337:                     END IF
338:
339:                 END IF

```

```

340:
341:     END IF
342:
343:     END DO
344:
345:     !-----
346:
347:     END IF
348:
349:     CALL set_fem3d_f_loaded      &
350:         (fem3d, fem3d_id_loaded, fem3d_f_loaded)
351:
352: !-----
353:
354:     OPEN(10, FILE = 'mesh.dat')
355:
356:     WRITE(10, '(A)') '!NODE'
357:
358:     DO id = 1, ns3d_n
359:
360:         WRITE( 10, '( I8, 3(A, E17.8) )' )      &
361:             id, ( ', ', ns3d_x(i, id), i = 1, 3 )
362:
363:     END DO
364:
365:     WRITE( 10, '(A, 3(A, I3) )' )      &
366:         '!ELEMENT', ', ', ', ', le3d_nboundaries, &
367:         ', ', ', ', le3d_nnodes, ', ', ', 2
368:
369:
370:     DO ie = 1, es3d_n
371:
372:         WRITE( 10, '( I8, 27(A, I8) )' )      &
373:             ie, ( ', ', es3d_connectivity(na, ie), &
374:                 na = 1, le3d_nnodes )
375:

```

```

376:      END DO
377:
378:      WRITE(10, '(A)') '!END'
379:
380:      CLOSE(10)
381:
382: !-----
383:
384:      OPEN(11, FILE = 'ic.dat')
385:
386:      WRITE(11, '(A)') '!DISPLACEMENT'
387:
388:      DO id = 1, ns3d_n
389:
390:          WRITE( 11, '(I8, 3(A, E17.8) )' )           &
391:              id, ( ' ', ' ', ns3d_u( 3*(id-1)+i ), i = 1, 3 )
392:
393:      END DO
394:
395:      WRITE(11, '(A)') '!END'
396:
397:      CLOSE(11)
398:
399: !-----
400:
401:      OPEN(12, FILE = 'bc.dat')
402:
403:      WRITE(12, '(A)') '!DISPLACEMENT'
404:
405:      DO id = 1, ns3d_n
406:
407:          WRITE( 12, '(I8, 3(A, I8) )' )           &
408:              id, ( ' ', ' ', ns3d_bc( 3*(id-1)+i ), i = 1, 3 )
409:
410:      END DO
411:

```



```

412:    WRITE(12, '(A)') '!END'
413:
414:    CLOSE(12)
415:
416: !-----
417:
418:    WRITE(13, '(A)') '!F_LOADED'
419:
420:    DO id_l = 1, fem3d_nnodes_loaded
421:
422:        WRITE( 13, '(I8, 3(A, E17.8) )' )           &
423:            fem3d_id_loaded(id_l),                  &
424:            ( ', ', fem3d_f_loaded(i, id_l), i = 1, 3 )
425:
426:    END DO
427:
428:    WRITE(13, '(A)') '!END'
429:
430:    CLOSE(13)
431:
432: !-----
433:
434:    OPEN(14, FILE = 'mesh.inp')
435:
436:    WRITE(14, '( 5(I8, 1X) )') ns3d_n, es3d_n, 3, 13, 0
437:
438:    DO id = 1, ns3d_n
439:
440:        WRITE( 14, '( (I8, 1X), 3(E17.8, 1X) )' ) &
441:            id, ( ns3d_x(i, id), i = 1, 3 )
442:
443:    END DO
444:
445:    DO ie = 1, es3d_n
446:
447:        WRITE( 14, '( 2(I8, 1X), (A5, 1X), 27(I8, 1X) )' )           &

```

```

448:          ie, 1, ' hex',                                &
449:          ( es3d_connectivity(na, ie), na = 1, le3d_nnodes )
450:
451:      END DO
452:
453:      WRITE(14, '( 4(I8, 1X) )') 1, 3
454:      WRITE(14, '(A)') 'DISPLACEMENT, m'
455:
456:      DO id = 1, ns3d_n
457:
458:          WRITE( 14, '( (I8, 1X), 3(E17.8, 1X) )' )      &
459:              id, ( ns3d_u( 3*(id-1)+i ), i = 1, 3 )
460:
461:      END DO
462:
463:      WRITE(14, '( 14I8 )') 1, 1
464:      WRITE(14, '( (A, 1X) )') 'VOLUME, m3'
465:
466:      DO ie = 1, es3d_n
467:
468:          WRITE( 14, '( (I8, 1X), (E17.8, 1X) )' ) &
469:              ie, es3d_volume(ie)
470:
471:      END DO
472:
473:      CLOSE(14)
474:
475: !-----
476:
477:      DEALLOCATE( ns3d_x )
478:      DEALLOCATE( ns3d_u )
479:
480:      DEALLOCATE( le3d_table_na )
481:
482:      DEALLOCATE( es3d_volume )
483:      DEALLOCATE( es3d_connectivity )

```

```

484:
485:     DEALLOCATE( fem3d_id_loaded )
486:     DEALLOCATE( fem3d_f_loaded )
487:
488:     DEALLOCATE( x_local )
489:
490: !-----
491:
492:     RETURN
493:
494: !#####
495:     END SUBROUTINE run_appli
496: !#####
497:
498:
499: !#####
500:     SUBROUTINE finish_appli()
501: !#####
502:
503:     CALL del_nodes3d(ns3d)
504:     CALL del_localelement3d(le3d)
505:     CALL del_elements3d(es3d)
506:     CALL del_elemstiffmat3d(esm3d)
507:     CALL del_elemexforcevec3d(efv3d)
508:     CALL del_fem3d(fem3d)
509:     CALL del_rectmesher3d(rm3d)
510:
511: !-----
512:
513:     DEALLOCATE( ns3d )
514:     DEALLOCATE( le3d )
515:     DEALLOCATE( es3d )
516:     DEALLOCATE( esm3d )
517:     DEALLOCATE( efv3d )
518:     DEALLOCATE( fem3d )
519:     DEALLOCATE( rm3d )

```

```

520:
521: !-----
522:
523:     RETURN
524:
525: !#####
526:     END SUBROUTINE finish_appli
527: !#####
528:
529:
530: !#####
531:     END MODULE mod_appli

```

第 6 節のプログラム:有限要素解析用のアプリケーションモジュール mod_appli の作成

5. アプリケーションモジュール mod_appli.f90

```

1:     MODULE mod_appli
2: !#####
3:
4:     USE mod_nodes3d
5:     USE mod_localelement3d
6:     USE mod_elements3d
7:     USE mod_elemstiffmat3d
8:     USE mod_elemexforcevec3d
9:     USE mod_fem3d
10:
11: !-----
12:
13:     IMPLICIT NONE
14:
15: !-----
16:
17:     TYPE(struct_nodes3d), POINTER      :: ns3d

```

```

18:      TYPE(struct_localelement3d), POINTER    :: le3d
19:      TYPE(struct_elements3d), POINTER        :: es3d
20:      TYPE(struct_elemstiffmat3d), POINTER    :: esm3d
21:      TYPE(struct_elemexforcevec3d), POINTER :: efv3d
22:      TYPE(struct_fem3d), POINTER             :: fem3d
23:
24: !-----
25:
26:      CONTAINS
27:
28:
29:      ! Start appli
30: !#####
31:      SUBROUTINE start_appli()
32: !#####
33:
34:      INTEGER :: ns3d_n
35:      INTEGER, ALLOCATABLE :: ns3d_bc(:)
36:      INTEGER :: le3d_nboundaries
37:      INTEGER :: le3d_nnodes
38:      INTEGER :: le3d_nqps
39:      INTEGER :: es3d_n
40:      INTEGER, ALLOCATABLE :: es3d_connectivity(:, :)
41:      INTEGER :: fem3d_nnodes_loaded
42:      INTEGER, ALLOCATABLE :: fem3d_id_loaded(:)
43:      INTEGER :: fem3d_ndofs
44:      INTEGER :: i
45:      INTEGER :: id
46:      INTEGER :: na
47:      INTEGER :: ie
48:      INTEGER :: ib
49:      INTEGER :: idof_g
50:      INTEGER :: idof_l
51:      INTEGER :: number
52:
53:      REAL(8), ALLOCATABLE :: ns3d_x(:, :)

```

```

54:     REAL (8), ALLOCATABLE :: ns3d_u(:)
55:     REAL (8), ALLOCATABLE :: esm3d_e(:)
56:     REAL (8), ALLOCATABLE :: esm3d_nu(:)
57:     REAL (8), ALLOCATABLE :: efv3d_rho(:)
58:     REAL (8), ALLOCATABLE :: fem3d_f_loaded(:, :)
59:     REAL (8) :: e
60:     REAL (8) :: nu
61:     REAL (8) :: rho
62:     REAL (8) :: g
63:
64:     CHARACTER(1) :: dataname
65:
66: !-----
67:
68:     ALLOCATE( ns3d )
69:     ALLOCATE( le3d )
70:     ALLOCATE( es3d )
71:     ALLOCATE( esm3d )
72:     ALLOCATE( efv3d )
73:     ALLOCATE( fem3d )
74:
75: !-----
76:
77:     OPEN(10, FILE = 'mesh.dat')
78:
79:     READ(10, *) dataname
80:
81:     ns3d_n = 0
82:
83:     DO
84:
85:         READ(10, *) dataname
86:
87:         ns3d_n = ns3d_n+1
88:
89:         IF( dataname .EQ. '!' ) THEN

```

```

90:
91:     EXIT
92:
93:     END IF
94:
95:     END DO
96:
97:     ns3d_n = ns3d_n-1
98:
99:     es3d_n = 0
100:
101:     DO
102:
103:         READ(10, *) dataname
104:
105:         es3d_n = es3d_n+1
106:
107:         IF( dataname .EQ. '!' ) THEN
108:
109:             EXIT
110:
111:         END IF
112:
113:     END DO
114:
115:     es3d_n = es3d_n-1
116:
117:     CLOSE(10)
118:
119:     !-----
120:
121:     OPEN(13, FILE = 'param_fea.dat')
122:
123:     READ(13, *) dataname
124:     READ(13, *) dataname
125:     READ(13, *) dataname

```

```
126:      READ(13, *) dataname
127:      READ(13, *) dataname
128:      READ(13, *) dataname
129:      READ(13, *) dataname
130:      READ(13, *) dataname
131:      READ(13, *) dataname
132:      READ(13, *) dataname
133:
134:      READ(13, *) dataname
135:
136:      fem3d_nnodes_loaded = 0
137:
138:      DO
139:
140:          READ(13, *) dataname
141:
142:          fem3d_nnodes_loaded = fem3d_nnodes_loaded+1
143:
144:          IF( dataname .EQ. '!' ) THEN
145:
146:              EXIT
147:
148:          END IF
149:
150:      END DO
151:
152:      fem3d_nnodes_loaded = fem3d_nnodes_loaded-1
153:
154:      CLOSE(13)
155:
156: !-----
157:
158:      OPEN(10, FILE = 'mesh.dat')
159:
160:      READ(10, *) dataname
161:
```



```

162:      CALL init_nodes3d(ns3d, ns3d_n)
163:
164:      ALLOCATE( ns3d_x(3, ns3d_n) )
165:
166:      DO id = 1, ns3d_n
167:
168:        READ(10, *) number, ( ns3d_x(i, id), i = 1, 3 )
169:
170:      END DO
171:
172:      CALL set_nodes3d_x(ns3d, ns3d_x)
173:
174:      READ(10, *) dataname, le3d_nboundaries, le3d_nnodes, le3d_nqps
175:
176:      CALL init_localelement3d                                &
177:        (le3d, le3d_nboundaries, le3d_nnodes, le3d_nqps)
178:      CALL init_elements3d(es3d, ns3d, le3d, es3d_n)
179:
180:      ALLOCATE( es3d_connectivity(le3d_nnodes, es3d_n) )
181:
182:      DO ie = 1, es3d_n
183:
184:        READ(10, *) number, ( es3d_connectivity(na, ie), &
185:                               na = 1, le3d_nnodes )
186:
187:      END DO
188:
189:      CALL set_elements3d_connectivity(es3d, es3d_connectivity)
190:
191:      CLOSE(10)
192:
193:      !-----
194:
195:      CALL init_elemstiffmat3d(esm3d, ns3d, le3d, es3d)
196:      CALL init_elemexforcevec3d(efv3d, ns3d, le3d, es3d)
197:      CALL init_fem3d                                &

```

```

198:      (fem3d, ns3d, le3d, es3d, esm3d, efv3d, 9)
199:
200:      CALL get_fem3d_ndofs(fem3d, fem3d_ndofs)
201:
202:      !-----
203:
204:      OPEN(11, FILE = 'ic.dat')
205:
206:      READ(11, *) dataname
207:
208:      ALLOCATE( ns3d_u(3*ns3d_n) )
209:
210:      DO id = 1, ns3d_n
211:
212:         READ(11, *) number, ( ns3d_u( 3*(id-1)+i ), i = 1, 3 )
213:
214:      END DO
215:
216:      CALL set_nodes3d_u(ns3d, ns3d_u)
217:
218:      READ(11, *) dataname
219:
220:      CLOSE(11)
221:
222:      !-----
223:
224:      OPEN(12, FILE = 'bc.dat')
225:
226:      READ(12, *) dataname
227:
228:      ALLOCATE( ns3d_bc(3*ns3d_n) )
229:
230:      DO id = 1, ns3d_n
231:
232:         READ(12, *) number, ( ns3d_bc( 3*(id-1)+i ), i = 1, 3 )
233:

```

```

234:      END DO
235:
236:      CALL set_nodes3d_bc(ns3d, ns3d_bc)
237:
238:      READ(12, *) dataname
239:
240:      CLOSE(12)
241:
242: !-----
243:
244:      OPEN(13, FILE = 'param_fea.dat')
245:
246:      READ(13, *) dataname
247:      READ(13, *) dataname
248:      READ(13, *) dataname
249:      READ(13, *) e
250:      READ(13, *) dataname
251:      READ(13, *) nu
252:      READ(13, *) dataname
253:      READ(13, *) rho
254:      READ(13, *) dataname
255:      READ(13, *) g
256:
257: !-----
258:
259:      ALLOCATE( esm3d_e(es3d_n) )
260:      ALLOCATE( esm3d_nu(es3d_n) )
261:
262:      ALLOCATE( efv3d_rho(es3d_n) )
263:
264:      DO ie = 1, es3d_n
265:
266:          esm3d_e(ie) = e
267:          esm3d_nu(ie) = nu
268:
269:          efv3d_rho(ie) = rho

```

```

270:
271:     END DO
272:
273:     CALL set_elemstiffmat3d_e_nu(esm3d, esm3d_e, esm3d_nu)
274:
275:     CALL set_elemexforcevec3d_rho(efv3d, efv3d_rho)
276:     CALL set_elemexforcevec3d_g(efv3d, g)
277:
278:     !-----
279:
280:     READ(13, *) dataname
281:
282:     ALLOCATE( fem3d_id_loaded(fem3d_nnodes_loaded) )
283:     ALLOCATE( fem3d_f_loaded(3, fem3d_nnodes_loaded) )
284:
285:     DO idof_l = 1, fem3d_nnodes_loaded
286:
287:         READ(13, *) fem3d_id_loaded(idof_l),          &
288:             ( fem3d_f_loaded(i, idof_l), i = 1, 3 )
289:
290:     END DO
291:
292:     CALL set_fem3d_f_loaded          &
293:         (fem3d, fem3d_id_loaded, fem3d_f_loaded)
294:
295:     READ(13, *) dataname
296:
297:     CLOSE(13)
298:
299: !-----
300:
301:     DEALLOCATE( ns3d_x )
302:     DEALLOCATE( ns3d_u )
303:     DEALLOCATE( ns3d_bc )
304:
305:     DEALLOCATE( es3d_connectivity )

```

```

306:
307:    DEALLOCATE( esm3d_e )
308:    DEALLOCATE( esm3d_nu )
309:
310:    DEALLOCATE( efv3d_rho )
311:
312:    DEALLOCATE( fem3d_id_loaded )
313:    DEALLOCATE( fem3d_f_loaded )
314:
315: !-----
316:
317:    RETURN
318:
319: !#####
320:    END SUBROUTINE start_appli
321: !#####
322:
323:
324:    ! Run appli
325: !#####
326:    SUBROUTINE run_appli()
327: !#####
328:
329:    INTEGER :: ns3d_n
330:    INTEGER :: le3d_nnodes
331:    INTEGER :: es3d_n
332:    INTEGER, ALLOCATABLE :: es3d_connectivity(:, :)
333:    INTEGER :: i
334:    INTEGER :: id
335:    INTEGER :: na
336:    INTEGER :: ie
337:
338:    REAL(8), ALLOCATABLE :: ns3d_x(:, :)
339:    REAL(8), ALLOCATABLE :: ns3d_u(:)
340:    REAL(8), ALLOCATABLE :: esm3d_evec(:, :)
341:    REAL(8), ALLOCATABLE :: esm3d_svec(:, :), esm3d_s_mises(:)

```

```

342:
343: !-----
344:
345:     CALL cal_elements3d(es3d)
346:
347:     CALL cal_fem3d(fem3d)
348:
349: !-----
350:
351:     CALL get_nodes3d_n(ns3d, ns3d_n)
352:     ALLOCATE( ns3d_x(3, ns3d_n) )
353:     CALL get_nodes3d_x(ns3d, ns3d_x)
354:     ALLOCATE( ns3d_u(3*ns3d_n) )
355:     CALL get_nodes3d_u(ns3d, ns3d_u)
356:
357:     CALL get_localelement3d_nnodes(le3d, le3d_nnodes)
358:
359:     CALL get_elements3d_n(es3d, es3d_n)
360:     ALLOCATE( es3d_connectivity(le3d_nnodes, es3d_n) )
361:     CALL get_elements3d_connectivity(es3d, es3d_connectivity)
362:
363:     ALLOCATE( esm3d_evec(6, es3d_n) )
364:     ALLOCATE( esm3d_svec(6, es3d_n) )
365:     ALLOCATE( esm3d_s_mises(es3d_n) )
366:     CALL get_elemstiffmat3d_evec_svec          &
367:         (esm3d, esm3d_evec, esm3d_svec, esm3d_s_mises)
368:
369: !-----
370:
371:     OPEN(14, FILE = 'result.inp')
372:
373:     WRITE(14, '( 5(I8, 1X) )') ns3d_n, es3d_n, 3, 13, 0
374:
375:     DO id = 1, ns3d_n
376:
377:         WRITE(14, '( (I8, 1X), 3(E17.8, 1X) )') &

```

```

378:          id, ( ns3d_x(i, id), i = 1, 3 )
379:
380:      END DO
381:
382:      DO ie = 1, es3d_n
383:
384:          WRITE(14, '( 2(I8, 1X), (A5, 1X), 27(I8, 1X) )')      &
385:              ie, 1, ' hex',                                     &
386:              ( es3d_connectivity(na, ie), na = 1, le3d_nnodes)
387:
388:      END DO
389:
390:      WRITE(14, '( 4(I8, 1X) )') 1, 3
391:      WRITE(14, '(A)') 'DISPLACEMENT, m'
392:
393:      DO id = 1, ns3d_n
394:
395:          WRITE(14, '( (I8, 1X), 3(E17.8, 1X) )')      &
396:              id, ( ns3d_u( 3*(id-1)+i ), i = 1, 3 )
397:
398:      END DO
399:
400:      WRITE(14, '( 14I8 )') 13, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1
401:      WRITE(14, '( (A, 1X) )') 'STRAIN_11, unit_unknown'
402:      WRITE(14, '( (A, 1X) )') 'STRAIN_22, unit_unknown'
403:      WRITE(14, '( (A, 1X) )') 'STRAIN_33, unit_unknown'
404:      WRITE(14, '( (A, 1X) )') 'STRAIN_12, unit_unknown'
405:      WRITE(14, '( (A, 1X) )') 'STRAIN_23, unit_unknown'
406:      WRITE(14, '( (A, 1X) )') 'STRAIN_31, unit_unknown'
407:      WRITE(14, '( (A, 1X) )') 'STRESS_11, Pa'
408:      WRITE(14, '( (A, 1X) )') 'STRESS_22, Pa'
409:      WRITE(14, '( (A, 1X) )') 'STRESS_33, Pa'
410:      WRITE(14, '( (A, 1X) )') 'STRESS_12, Pa'
411:      WRITE(14, '( (A, 1X) )') 'STRESS_23, Pa'
412:      WRITE(14, '( (A, 1X) )') 'STRESS_31, Pa'
413:      WRITE(14, '( (A, 1X) )') 'STRESS_MISES, Pa'

```

```

414:
415:     DO ie = 1, es3d_n
416:
417:         WRITE(14, '( (I8, 1X), 13(E17.8, 1X) )')           &
418:             ie, ( esm3d_evec(i, ie), i = 1, 6 ),           &
419:             ( esm3d_svec(i, ie), i = 1, 6 ), esm3d_s_mises(ie)
420:
421:     END DO
422:
423:     CLOSE(14)
424:
425: !-----
426:
427:     DEALLOCATE( ns3d_x )
428:     DEALLOCATE( ns3d_u )
429:
430:     DEALLOCATE( es3d_connectivity )
431:
432:     DEALLOCATE( esm3d_evec )
433:     DEALLOCATE( esm3d_svec )
434:     DEALLOCATE( esm3d_s_mises )
435:
436: !-----
437:
438:     RETURN
439:
440: !#####
441:     END SUBROUTINE run_appli
442: !#####
443:
444:
445:     ! Finish appli
446: !#####
447:     SUBROUTINE finish_appli()
448: !#####
449:

```



```

450:      CALL del_nodes3d(ns3d)
451:      CALL del_localelement3d(le3d)
452:      CALL del_elements3d(es3d)
453:      CALL del_elemstiffmat3d(esm3d)
454:      CALL del_elemexforcevec3d(efv3d)
455:      CALL del_fem3d(fem3d)
456:
457: !-----
458:
459:      DEALLOCATE( ns3d )
460:      DEALLOCATE( le3d )
461:      DEALLOCATE( es3d )
462:      DEALLOCATE( esm3d )
463:      DEALLOCATE( efv3d )
464:      DEALLOCATE( fem3d )
465:
466: !-----
467:
468:      RETURN
469:
470: !#####
471:      END SUBROUTINE finish_appli
472: !#####
473:
474:
475: !#####
476:      END MODULE mod_appli

```