

# Relatório sobre uso da solução convergida numa mesma malha como condições iniciais para uma nova simulação.

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Data: 25-27/10/12

## Microcomputador utilizado:

**CFD-6 – Intel Core 2 Duo E6700 - 2,66 GHz – 8 GB de memória RAM – HD de 160 GB**

## Passos:

- 1) Obter a solução até Epi na malha de 224x80 nós, Euler, UDS, MSI e gravar a solução.  
Simulação: mach2d-SEN03\_1001

LISTING FILE OF MACH2D

Date: (25/10/2012)  
Time: 10:54:39

### PARAMETERS

```
SEN03_1001 ....: Simulation identification (up to 100 characters)
226 ....: nx      - Number of real+ficitious volumes in the xsi direction
82 ....: ny      - Number of real+ficitious volumes in the eta direction
1 ....: kg      - Kind of grid (1 = uniform, 2 = Geometric Progression, 3=power law)
1.0000000E-06 ....: al      - Initial step for the geometric progression grid (m)
1 ....: coord   - Coordinate system ( 1=cylindrical, else cartesian)
2.8690000E+02 ....: Rg      - Perfect gas constant (J/(kg.K))
1.4000000E+00 ....: gamma   - Cpo / Cvo in the chamber (Specific heat ratio)
1.7250680E+06 ....: po      - Stagnation pressure in the chamber (Pa)
8.3333000E+02 ....: T0      - Stagnation temperature in the chamber (K)
1.0132500E+05 ....: pr      - atmospheric pressure at the sea level (Pa)
9.8066500E+00 ....: go      - gravitational acceleration at the sea level (m/s2)
0.0000000E+00 ....: beta    - Constant of the UDS/CDS mixing scheme
0.0000000E+00 ....: beta1   - Initial constant of the UDS/CDS mixing scheme
0.0000000E+00 ....: beta2   - Final constant of the UDS/CDS mixing scheme
1000 ....: itb1    - beta = beta1 for it <= itb1
1000 ....: itb2    - beta = beta2 for itb2 <= it
0 ....: modvis  - Viscosity model ( 0 = Euler, 1 = Navier-Stokes)
0 ....: modtur  - turbulence model option (0=laminar, 1=Baldwin-Lomax)
0 ....: cctw    - Temp. bc (0 = adiabatic, 1 = prescribed temperature)
1000 ....: dt = dt1 for it <= it1
1000 ....: dt = dt2 for it2 <= it
1.0000000E-05 ....: Initial time step (s)
1.0000000E-05 ....: Final time step (s)
1000 ....: itmax   - Maximum number of interactions of the time evolution
-1.0000000E-10 ....: tolerance - Parada com base no valor do residuo, se negativo, a parada é feita com base no imax
2 ....: imax    - Maximum number of iterations for the pressure correction
4 ....: nitm_u  - Maximum number of iterations for the TDMA method for u, v and T
4 ....: nitm_p  - Maximum number of iterations for the TDMA method for p
0 ....: reload  - Upload backup data and continue computation (0 = no, 1 = yes)
1000 ....: wbpk   - Frequency of saving backup data
25 ....: wlf    - Frequency of printing in the listing file
1 ....: sem_a   - 1 = do not open result files, 0 = open
1 ....: sem_g   - 0 = visualize the plot, 1 = do not visualize
1 ....: w_g    - Frequency of writing data for graphics
0 ....: w_cam  - 1 = write the fields, 0 = do not
3.0000000E+00 ....: Eu      - E-Factor of u linear system (if Eu.Ev < 0, E-Factor is not applied for u nor v)
-3.0000000E+00 ....: Ev      - E-Factor of v linear system (if Eu.Ev < 0, E-Factor is not applied for u nor v)
-3.0000000E+00 ....: Ep      - E-Factor of p' linear system (if Ep < 0, E-Factor is not applied for p')
-3.0000000E+00 ....: ET      - E-Factor of T linear system (if ET < 0, E-Factor is not applied for T)
```

it	norm / norm1	fmi (kg/s)	fme/fmi	Fd*	dPd*
25	1.454191857808872E-02	3.850971202894873E+00	7.862992197552399E-01	9.440764911901636E-01	9.440764911901636E-01
50	8.783661884502350E-04	3.061328035925094E+00	1.027847466121484E+00	9.758952641068922E-01	3.181877291672863E-02
75	1.232306655055953E-03	3.063787235926305E+00	1.025504136579381E+00	9.717313043957817E-01	4.163959711110499E-03
100	8.634769924273969E-04	3.178604322534626E+00	9.851983458413761E-01	9.669975235011736E-01	4.733780894608075E-03
125	7.085963989031823E-05	3.129978587602765E+00	1.002334390974917E+00	9.697061226682340E-01	2.708599167060344E-03
150	8.275902166074064E-05	3.131824712027705E+00	1.001530959365696E+00	9.693465573061972E-01	3.595653620367401E-04
175	5.862045985805293E-05	3.139238478270611E+00	9.989525868507901E-01	9.690429312055443E-01	3.036261006529317E-04
200	2.102051722913015E-05	3.1357402802006413E+00	1.000193464433756E+00	9.692308247790826E-01	1.878935735383225E-04
225	5.066666084092122E-06	3.135992721804876E+00	1.000094064934251E+00	9.692000826479701E-01	3.074213111253776E-05
250	3.993354622375162E-06	3.136473957945179E+00	9.999271351719061E-01	9.691811605352365E-01	1.892211273357702E-05
275	1.522990352977273E-06	3.136224745930517E+00	1.000015462307764E+00	9.691943621802556E-01	1.320164501905641E-05
300	3.100616920215416E-07	3.136250614276327E+00	1.000005642694208E+00	9.691918596942100E-01	2.502486045607988E-06
325	2.699969735469456E-07	3.136281493844638E+00	9.999949693016382E-01	9.691907088353390E-01	1.151340819682822E-06
350	1.096902426367547E-07	3.136263873074020E+00	1.000001207684467E+00	9.691916255693285E-01	9.172159382009326E-07
375	1.878486208230656E-08	3.136266233746777E+00	1.000000328358120E+00	9.691914263590584E-01	1.992102700576481E-07
400	1.847374619406453E-08	3.136268189830469E+00	9.99996552584273E-01	9.691913580791178E-01	6.827994059044329E-08
425	7.839762385404375E-09	3.136266952180617E+00	1.000000925264723E+00	9.691914211062780E-01	6.302716015760268E-08
450	1.140493790714934E-09	3.136267153976608E+00	1.00000018307534E+00	9.691914056378669E-01	1.546841110755537E-08
475	1.247809575763196E-09	3.136267275915626E+00	9.99999765074560E-01	9.691914016780374E-01	3.959829464328379E-09
500	5.574183794957900E-10	3.136267189553640E+00	1.00000006989137E+00	9.691914060008554E-01	4.322817992452559E-09
525	7.332570980368787E-11	3.136267206081568E+00	1.00000000951692E+00	9.691914048157309E-01	1.185124554048400E-09
550	8.355691235175669E-11	3.136267213539932E+00	9.99999984115084E-01	9.691914046002056E-01	2.155252643021299E-10
575	3.94400811213652E-11	3.136267207552384E+00	1.00000000520637E+00	9.691914048936242E-01	2.934186227321334E-10
600	5.590020840652480E-12	3.136267208866438E+00	1.00000000043773E+00	9.691914048046404E-01	8.898382031219398E-11
625	5.722815348914204E-12	3.136267209311307E+00	9.99999998932670E-01	9.691914047935845E-01	1.105593394612470E-11

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650 2.885712457184496E-12 3.136267208898845E+00 1.000000000038381E+00 9.691914048134397E-01 1.985522857239630E-11
675 5.508362333416680E-13 3.136267209000951E+00 1.000000000001474E+00 9.691914048068080E-01 6.631695192993448E-12
700 5.298249912738878E-13 3.136267209026619E+00 9.9999999992887E-01 9.69191404806321E-01 4.758415883543421E-13
725 3.602057875638798E-13 3.136267208998398E+00 1.000000000002799E+00 9.691914048076625E-01 1.330380250408325E-12
750 1.588650126358424E-13 3.136267209006190E+00 9.99999999999897E-01 9.691914048071713E-01 4.912736883966318E-13
775 1.581709689261366E-13 3.136267209007599E+00 9.99999999995338E-01 9.691914048071631E-01 8.104628079763643E-15
800 1.569340420692788E-13 3.136267209005669E+00 1.00000000000207E+00 9.691914048072501E-01 8.693046282814976E-14
825 1.55981129466207E-13 3.136267209006262E+00 9.9999999999925E-01 9.691914048072147E-01 3.541611448554249E-14
850 1.568336114533981E-13 3.136267209006355E+00 9.99999999999646E-01 9.691914048072140E-01 6.661338147750939E-16
875 1.575342960714806E-13 3.136267209006193E+00 1.00000000000020E+00 9.691914048072205E-01 6.550315845288424E-15
900 1.549237154684813E-13 3.136267209006256E+00 9.9999999999976E-01 9.691914048072177E-01 2.886579864025407E-15
925 1.543549547630849E-13 3.136267209006252E+00 9.9999999999990E-01 9.691914048072179E-01 2.220446049250313E-16
950 1.547688531390312E-13 3.136267209006247E+00 1.00000000000001E+00 9.691914048072184E-01 5.551115123125783E-16
975 1.535720973921564E-13 3.136267209006256E+00 9.9999999999980E-01 9.691914048072183E-01 1.110223024625157E-16
1000 1.520094960858659E-13 3.136267209006254E+00 9.9999999999989E-01 9.691914048072183E-01 0.00000000000000E+00

```

MAIN RESULTS

```

3.1362672090062538E+00 ..... fmi - Mass flow rate in the entrance (kg/s)
3.1362672090062502E+00 ..... fme - Mass flow rate in the exit (kg/s)
3.3010488746324802E+03 ..... Fd - Dynamic thrust (N)
3.067199999787658E+01 ..... tcpu - CPU time (s)
1000 ..... it - Iteration of the end of the cycle

```

\*\*\* Grid parameters \*\*\*

```

7.493000000E-04 = dxmin: min(size of volume controls) in the x direction (m)
9.842500000E-04 = dxmax: max(size of volume controls) in the x direction (m)
1.313559322E+00 = dxmax / dxmin
2.540000000E-04 = dymin: min(size of volume controls) in the y direction (m)
7.937500000E-04 = dymax: max(size of volume controls) in the y direction (m)
3.125000000E+00 = dymax / dymin

```

\*\*\* Nozzle parameters \*\*\*

```

77 = ig: number of the VC in the x direction whose east face coincides with the nozzle throttle
6.487160000E-02 = Xg: x coord. of the nozzle throttle (m)
2.032000000E-02 = rg: radius of the nozzle throttle (m)
1.270000000E-02 = rcg: curvature radius of the nozzle throttle (m)
6.250000000E-01 = Rcag: dimensionless curvature radius of the nozzle throttle
1.297171146E-03 = Sg: area of the nozzle throttle (m2)
9.765625000E+00 = rain: area ratio of the convergent section
6.566597085E+00 = raex: area ratio of the divergent section

```

\*\*\* Analytic solution of the Q1D isentropic flow \*\*\*

```

3.133646450454429E+00 = fmlD: mass flow rate (kg/s)
3.405982511049086E+03 = FdlD: dynamic thrust (N)
-6.603602827141507E+02 = FplD: dynamic thrust at sea level (p = 101325 Pa) (N)
2.027260945258903E+02 = FpvlD: thrust of pressure in the vacuum (N)
2.74562228334935E+03 = FlD: total thrust at sea level (N)
3.608708605574976E+03 = Fvld: total thrust in the vacuum (N)
2.237708435332511E+03 = Fo: standard thrust (N)
1.226979433505577E+00 = CPld: thrust coefficient at sea level (dimensionless)
1.612680431728695E+00 = CPvld: thrust coefficient in the vacuum (dimensionless)
7.140909067798660E+02 = celd: characteristic velocity (m/s)
8.761748562722435E+02 = clD: velocity of effective ejection at the sea level (m/s)
1.151600431839289E+03 = cvld: velocity of effective ejection in the vacuum (m/s)
8.934497063444127E+01 = Isld: specific impulse at sea level (s)
1.174305631218907E+02 = Isvld: specific impulse in the vacuum (s)

```

\*\*\* Analytic solution 2D \*\*\*

```

9.816538761092243E-01 = CdKL: discharge coefficient of Kliegel and Levine (dimensionless)

```

\*\*\* Numeric solution 2D \*\*\*

```

3.136267209006250E+00 = fme: mass flow rate (kg/s)
3.301048974632480E+03 = Fd: dynamic thrust (N)
-6.440341233599643E+02 = Fp: thrust of pressure at sea level (p = 101325 Pa) (N)
2.190522538800768E+02 = Fpv: thrust of pressure in the vacuum (N)
2.657014851272516E+03 = F: total thrust at sea level (N)
3.520101228512557E+03 = Fv: total thrust in the vacuum (N)
2.237708435332511E+03 = Fo: standard thrust (N)
1.187382059842706E+00 = CF: thrust coefficient at sea level (dimensionless)
1.573083058065824E+00 = CPv: thrust coefficient in the vacuum (dimensionless)
7.134941910901609E+02 = ce: characteristic velocity (m/s)
8.471902023024406E+02 = c: velocity of effective ejection at sea level (m/s)
1.122385624032312E+03 = cv: velocity of effective ejection in the vacuum (m/s)
6.638935847638497E+01 = Is: specific impulse at sea level (s)
1.144514818039098E+02 = Isv: specific impulse in the vacuum (s)

```

\*\*\* Efficiency: numerical solution 2D / analytic Q1D (dimensionless) \*\*\*

```

1.000836328728610E+00 = discharge coefficient
9.691914048072183E-01 = dynamic thrust
9.752768908404300E-01 = pressure thrust at sea level (p = 101325 Pa)
1.080533092655724E+00 = pressure thrust in the vacuum
9.677277608885931E-01 = total thrust at sea level
9.754462366605239E-01 = total thrust in the vacuum
9.677277608885931E-01 = thrust coefficient at sea level
9.754462366605238E-01 = thrust coefficient in the vacuum
9.991643701326545E-01 = characterist velocity
9.669190986681353E-01 = velocity of effective ejection at sea level
9.746311246511806E-01 = velocity of effective ejection in the vacuum
9.669190986681353E-01 = specific impulse at sea level
9.746311246511807E-01 = specific impulse at vacuum

```

```

0.000 = tcpuo: accumulated CPU time (s) (before interruption)
30.672 = dtcpu: CPU time (s) (after interruption)
30.672 = tcpu: total CPU time (s)

```

## 2) Fazer o reload e fazer a simulação novamente: Simulação: mach2d-SEN03\_1002

LISTING FILE OF MACH2D

Date: (25/10/2012)  
Time: 11:5:14

### PARAMETERS

```

SEN03_1002 ....: Simulation identification (up to 100 characters)
226 .....: nx - Number of real+fictitious volumes in the xsi direction
82 .....: ny - Number of real+fictitious volumes in the eta direction
1 .....: kg - Kind of grid (1 = uniform, 2 = Geometric Progression, 3=power law)
1.0000000E-06 .....: al - Initial step for the geometric progression grid (m)
1 .....: coord - Coordinate system ( 1=cylindrical, else cartesian)
2.8690000E+02 .....: Rg - Perfect gas constant (J/(kg.K))
1.4000000E+00 .....: gamma - Cpo / Cvo in the chamber (Specific heat ratio)
1.7250680E+06 .....: po - Stagnation pressure in the chamber (Pa)
8.3333000E+02 .....: T0 - Stagnation temperature in the chamber (K)
1.0132500E+05 .....: pr - atmospheric pressure at the sea level (Pa)
9.8065000E+00 .....: go - gravitational acceleration at the sea level (m/s2)
0.0000000E+00 .....: beta - Constant of the UDS/CDS mixing scheme
0.0000000E+00 .....: beta1 - Initial constant of the UDS/CDS mixing scheme
0.0000000E+00 .....: beta2 - Final constant of the UDS/CDS mixing scheme
1000 .....: itb1 - beta = beta1 for it <= itb1
1000 .....: itb2 - beta = beta2 for itb2 <= it
0 .....: modvis - Viscosity model ( 0 = Euler, 1 = Navier-Stokes)
0 .....: modtur - turbulence model option (0=laminar, 1=Baldwin-Lomax)
0 .....: ccTw - Temp. bc (0 = adiabatic, 1 = prescribed temperature)
1000 .....: dt = dt1 for it <= it1
1000 .....: dt = dt2 for it2 <= it
1.0000000E-05 .....: Initial time step (s)
1.0000000E-05 .....: Final time step (s)
1000 .....: itmax - Maximum number of interactions of the time evolution
-1.0000000E-10 .....: tolerance - Parada com base no valor do residuo, se negativo, a parada é feita com base no imax
2 .....: imax - Maximum number of interactions for the pressure correction
4 .....: nitm_u - Maximum number of interactions for the TMA method for u, v and T
4 .....: nitm_p - Maximum number of interactions for the TMA method for p
1 .....: reload - Upload backup data and continue computation (0 = no, 1 = yes)
50000 .....: wbkp - Frequency of saving backup data
25 .....: wlf - Frequency of printing in the listing file
1 .....: sem_a - 1 = do not open result files, 0 = open
1 .....: sem_g - 0 = visualize the plot, 1 = do not visualize
1 .....: w_g - Frequency of writing data for graphics
0 .....: w_cam - 1 = write the fields, 0 = do not
3.0000000E+00 .....: Eu - E-Factor of u linear system (if Eu.Ev < 0, E-Factor is not applied for u nor v)
-3.0000000E+00 .....: Ev - E-Factor of v linear system (if Eu.Ev < 0, E-Factor is not applied for u nor v)
-3.0000000E+00 .....: Ep - E-Factor of p' linear system (if Ep < 0, E-Factor is not applied for p')
-3.0000000E+00 .....: ET - E-Factor of T linear system (if ET < 0, E-Factor is not applied for T)

```

it	norm / norml	fmi (kg/s)	fme/fmi	Fd*	dPd*
1025	1.557005376698120E-13	3.136267209006247E+00	1.0000000000000001E+00	9.691914048072184E-01	9.691914048072184E-01
1050	1.537554213698042E-13	3.136267209006248E+00	1.0000000000000000E+00	9.691914048072179E-01	5.551115123125783E-16
1075	1.531285123795020E-13	3.136267209006253E+00	9.99999999999998E-01	9.691914048072180E-01	1.110223024625157E-16
1100	1.546401601090788E-13	3.136267209006250E+00	1.0000000000000000E+00	9.691914048072183E-01	3.330669073875470E-16
1125	1.544927387832004E-13	3.136267209006257E+00	9.999999999999978E-01	9.691914048072183E-01	0.000000000000000E+00
1150	1.580248126715935E-13	3.136267209006248E+00	1.0000000000000001E+00	9.691914048072177E-01	6.661338147750939E-16
1175	1.543626274533369E-13	3.136267209006252E+00	9.999999999999993E-01	9.691914048072180E-01	3.330669073875470E-16
1200	1.553782549730840E-13	3.136267209006254E+00	9.99999999999998E-01	9.691914048072183E-01	3.330669073875470E-16
1225	1.554737264298759E-13	3.136267209006251E+00	9.99999999999996E-01	9.691914048072179E-01	4.44089209850626E-16
1250	1.541973417694899E-13	3.136267209006251E+00	9.99999999999999E-01	9.691914048072180E-01	1.110223024625157E-16
1275	1.576954098367021E-13	3.136267209006253E+00	9.99999999999990E-01	9.691914048072183E-01	3.330669073875470E-16
1300	1.547745100614110E-13	3.136267209006251E+00	9.99999999999999E-01	9.691914048072183E-01	0.000000000000000E+00
1325	1.506165279813420E-13	3.136267209006247E+00	1.0000000000000001E+00	9.691914048072180E-01	3.330669073875470E-16
1350	1.564862351504029E-13	3.136267209006252E+00	9.99999999999991E-01	9.691914048072180E-01	0.000000000000000E+00
1375	1.543128061661817E-13	3.136267209006250E+00	9.99999999999999E-01	9.691914048072180E-01	0.000000000000000E+00
1400	1.535148939451887E-13	3.136267209006248E+00	1.0000000000000001E+00	9.691914048072180E-01	0.000000000000000E+00
1425	1.535042983359257E-13	3.136267209006252E+00	9.99999999999991E-01	9.691914048072183E-01	3.330669073875470E-16
1450	1.541961206343608E-13	3.136267209006250E+00	9.99999999999996E-01	9.691914048072183E-01	0.000000000000000E+00
1475	1.534561838912973E-13	3.136267209006250E+00	9.99999999999996E-01	9.691914048072180E-01	3.330669073875470E-16
1500	1.559691578761901E-13	3.136267209006247E+00	1.0000000000000001E+00	9.691914048072183E-01	3.330669073875470E-16
1525	1.556014854001804E-13	3.136267209006247E+00	1.0000000000000001E+00	9.691914048072180E-01	3.330669073875470E-16
1550	1.559047446259038E-13	3.136267209006255E+00	9.99999999999998E-01	9.691914048072183E-01	3.330669073875470E-16
1575	1.567126592539303E-13	3.136267209006248E+00	1.0000000000000000E+00	9.691914048072180E-01	3.330669073875470E-16
1600	1.560873096721778E-13	3.136267209006252E+00	9.99999999999994E-01	9.691914048072184E-01	4.44089209850626E-16
1625	1.562511938823029E-13	3.136267209006249E+00	1.0000000000000000E+00	9.691914048072183E-01	1.110223024625157E-16
1650	1.541196784593162E-13	3.136267209006256E+00	9.99999999999998E-01	9.691914048072180E-01	3.330669073875470E-16
1675	1.553989442161799E-13	3.136267209006252E+00	9.99999999999997E-01	9.691914048072183E-01	3.330669073875470E-16
1700	1.530355102646561E-13	3.136267209006252E+00	9.99999999999996E-01	9.691914048072184E-01	1.110223024625157E-16
1725	1.547202034058429E-13	3.136267209006242E+00	1.000000000000002E+00	9.691914048072180E-01	4.44089209850626E-16
1750	1.567630164791398E-13	3.136267209006250E+00	9.99999999999999E-01	9.691914048072179E-01	1.110223024625157E-16
1775	1.511620445028985E-13	3.136267209006251E+00	9.99999999999993E-01	9.691914048072179E-01	0.000000000000000E+00
1800	1.524266150119229E-13	3.136267209006252E+00	9.99999999999990E-01	9.691914048072179E-01	0.000000000000000E+00
1825	1.549340756035817E-13	3.136267209006251E+00	9.99999999999994E-01	9.691914048072179E-01	0.000000000000000E+00
1850	1.536333263191315E-13	3.136267209006248E+00	1.0000000000000001E+00	9.691914048072184E-01	5.551115123125783E-16
1875	1.54580322569289E-13	3.136267209006252E+00	9.99999999999996E-01	9.691914048072184E-01	0.000000000000000E+00
1900	1.536628003619536E-13	3.136267209006247E+00	1.0000000000000001E+00	9.691914048072179E-01	5.551115123125783E-16
1925	1.581756903860381E-13	3.136267209006252E+00	9.99999999999991E-01	9.691914048072180E-01	1.110223024625157E-16
1950	1.573115104921981E-13	3.136267209006252E+00	9.99999999999993E-01	9.691914048072180E-01	0.000000000000000E+00
1975	1.538366075785903E-13	3.136267209006252E+00	9.99999999999993E-01	9.691914048072180E-01	0.000000000000000E+00
2000	1.55891129613855E-13	3.136267209006247E+00	1.0000000000000001E+00	9.691914048072184E-01	4.44089209850626E-16

### MAIN RESULTS

```

3.1362672090062467E+00 .....: fmi - Mass flow rate in the entrance (kg/s)
3.1362672090062498E+00 .....: fme - Mass flow rate in the exit (kg/s)

```

```

3.3010489746324806E+03 .....: Fd   - Dynamic thrust (N)
6.4250000000000000E+01 .....: tcpu - CPU time (s)
      2000 .....: it   - Interaction of the end of the cycle

*** Grid parameters ***

7.493000000E-04 = dxmin: min(size of volume controls) in the x direction (m)
9.842500000E-04 = dxmax: max(size of volume controls) in the x direction (m)
1.313559322E+00 = dxmax / dxmin
2.540000000E-04 = dymin: min(size of volume controls) in the y direction (m)
7.937500000E-04 = dymax: max(size of volume controls) in the y direction (m)
3.125000000E+00 = dymax / dymin

*** Nozzle parameters ***

77 = ig: number of the VC in the x direction whose east face coincides with the nozzle throttle
6.487160000E-02 = Xg: x coord. of the nozzle throttle (m)
2.032000000E-02 = rg: radius of the nozzle throttle (m)
1.270000000E-02 = rcg: curvature radius of the nozzle throttle (m)
6.250000000E-01 = Roag: dimensionless curvature radius of the nozzle throttle
1.297171146E-03 = Sg: area of the nozzle throttle (m2)
9.765625000E+00 = rain: area ratio of the convergent section
6.566597085E+00 = raex: area ratio of the divergent section

*** Analytic solution of the Q1D isentropic flow ***

3.133646450454429E+00 = fmlD: mass flow rate (kg/s)
3.405982511049086E+03 = Fd1D: dynamic thrust (N)
-6.603602827141507E+02 = Fp1D: dynamic thrust at sea level (p = 101325 Pa) (N)
2.027260945258903E+02 = Fpv1D: thrust of pressure in the vacuum (N)
2.745622228334935E+03 = F1D: total thrust at sea level (N)
3.608708605574976E+03 = Fv1D: total thrust in the vacuum (N)
2.237708435332511E+03 = Fo: standard thrust (N)
1.226979433505577E+00 = CF1D: thrust coefficient at sea level (dimensionless)
1.612680431728695E+00 = CFv1D: thrust coefficient in the vacuum (dimensionless)
7.140909067798660E+02 = celD: characteristic velocity (m/s)
8.761748562722435E+02 = clD: velocity of effective ejection at the sea level (m/s)
1.151600431839289E+03 = cv1D: velocity of effective ejection in the vacuum (m/s)
8.93449706344127E+01 = IslD: specific impulse at sea level (s)
1.174305631218907E+02 = Isv1D: specific impulse in the vacuum (s)

*** Analytic solution 2D ***

9.816538761092243E-01 = CgKL: discharge coefficient of Kliegel and Levine (dimensionless)

*** Numeric solution 2D ***

3.136267209006250E+00 = fme: mass flow rate (kg/s)
3.301048974632481E+03 = Fd: dynamic thrust (N)
-6.440341233599642E+02 = Fp: thrust of pressure at sea level (p = 101325 Pa) (N)
2.190522538800769E+02 = Fpv: thrust of pressure in the vacuum (N)
2.657014851272516E+03 = F: total thrust at sea level (N)
3.520101228512558E+03 = Fv: total thrust in the vacuum (N)
2.237708435332511E+03 = Fo: standard thrust (N)
1.187382059842706E+00 = CF: thrust coefficient at sea level (dimensionless)
1.573083058065824E+00 = CFv: thrust coefficient in the vacuum (dimensionless)
7.134941910901611E+02 = ce: characteristic velocity (m/s)
8.471902023024409E+02 = c: velocity of effective ejection at sea level (m/s)
1.122385624032312E+03 = cv: velocity of effective ejection in the vacuum (m/s)
8.638935847638500E+01 = Is: specific impulse at sea level (s)
1.144514818039098E+02 = Isv: specific impulse in the vacuum (s)

*** Efficiency: numerical solution 2D / analytic Q1D (dimensionless) ***

1.000836328728610E+00 = discharge coefficient
9.691914048072184E-01 = dynamic thrust
9.752768908404299E-01 = pressure thrust at sea level (p = 101325 Pa)
1.080533092655724E+00 = pressure thrust in the vacuum
9.677277608885932E-01 = total thrust at sea level
9.754462366605240E-01 = total thrust in the vacuum
9.677277608885932E-01 = thrust coefficient at sea level
9.754462366605239E-01 = thrust coefficient in the vacuum
9.991643701326547E-01 = characterist velocity
9.669190986681355E-01 = velocity of effective ejection at sea level
9.746311246511808E-01 = velocity of effective ejection in the vacuum
9.669190986681356E-01 = specific impulse at sea level
9.746311246511810E-01 = specific impulse at vacuum

30.438 = tcpuo: acumulated CPU time (s) (before interruption)
33.812 = dtcpu: CPU time (s) (after interruption)
64.250 = tcpu: total CPU time (s)

```

3) Fazer o reload de apenas u, v, p, T e ro (propriedades nos nós) e fazer a simulação novamente:

Simulação: mach2d-SEN03\_1003

LISTING FILE OF MACH2D

Date: (25/10/2012)  
Time: 11:9:35

PARAMETERS

```

SEN03_1003 ....: Simulation identification (up to 100 characters)
226 ....: nx - Number of real+ficitious volumes in the csi direction
82 ....: ny - Number of real+ficitious volumes in the eta direction
1 ....: kg - Kind of grid (1 = uniform, 2 = Geometric Progression, 3=power law)
1.000000E-06 ....: al - Initial step for the geometric progression grid (m)
1 ....: coord - Coordinate system ( 1=cylindrical, else cartesian)
2.869000E+02 ....: Rg - Perfect gas constant (J/(kg.K))
1.400000E+00 ....: gamma - Cpo / Cvo in the chamber (Specific heat ratio)
1.7250680E+06 ....: po - Stagnation pressure in the chamber (Pa)
8.333300E+02 ....: T0 - Stagnation temperature in the chamber (K)
1.013250E+05 ....: pr - atmospheric pressure at the sea level (Pa)
9.806550E+00 ....: go - gravitational acceleration at the sea level (m/s2)
0.000000E+00 ....: beta - Constant of the UDS/CDS mixing scheme
0.000000E+00 ....: beta1 - Initial constant of the UDS/CDS mixing scheme
0.000000E+00 ....: beta2 - Final constant of the UDS/CDS mixing scheme
1000 ....: itb1 - beta = beta1 for it <= itb1
1000 ....: itb2 - beta = beta2 for itb2 <= it
0 ....: modvis - Viscosity model ( 0 = Euler, 1 = Navier-Stokes)
0 ....: modtur - turbulence model option (0=laminar, 1=Baldwin-Lomax)
0 ....: ccTw - Temp. bc (0 = adiabatic, 1 = prescribed temperature)
1000 ....: dt = dt1 for it <= it1
1000 ....: dt = dt2 for it2 <= it
1.000000E-05 ....: Initial time step (s)
1.000000E-05 ....: Final time step (s)
1000 ....: itmax - Maximum number of interactions of the time evolution
-1.000000E-10 ....: tolerance - Parada com base no valor do residuo, se negativo, a parada é feita com base no imax
2 ....: imax - Maximum number of interactions for the pressure correction
4 ....: nitm_u - Maximum number of interactions for the TDMA method for u, v and T
4 ....: nitm_p - Maximum number of interactions for the TDMA method for p
1 ....: reload - Upload backup data and continue computation (0 = no, 1 = yes)
50000 ....: wbkp - Frequency of saving backup data
25 ....: wlf - Frequency of printing in the listing file
1 ....: sem_a - 1 = do not open result files, 0 = open
1 ....: sem_g - 0 = visualize the plot, 1 = do not visualize
1 ....: w_g - Frequency of writing data for graphics
0 ....: w_cam - 1 = write the fields, 0 = do not
3.000000E+00 ....: Eu - E-Factor of u linear system (if Eu.Ev < 0, E-Factor is not applied for u nor v)
-3.000000E+00 ....: Ev - E-Factor of v linear system (if Eu.Ev < 0, E-Factor is not applied for u nor v)
-3.000000E+00 ....: Ep - E-Factor of p' linear system (if Ep < 0, E-Factor is not applied for p')
-3.000000E+00 ....: ET - E-Factor of T linear system (if ET < 0, E-Factor is not applied for T)

it norm / norm1 fmi (kg/s) fme/fmi Fd* dPd*
1025 2.794789361434619E-03 2.961383746364742E+00 1.063680794577024E+00 9.743247396607105E-01 9.743247396607105E-01
1050 1.17101775333003E-03 3.168850618467613E+00 9.878435041259238E-01 9.663499128174106E-01 7.974826843299976E-03
1075 5.322780784224721E-05 3.13642268248840E+00 1.001023806669356E+00 9.694677751567486E-01 3.117862339330804E-03
1100 1.041851912601082E-04 3.131020756904650E+00 1.001833472752573E+00 9.694001013786308E-01 6.767377811789377E-05
1125 6.239328730813374E-05 3.139151863917315E+00 9.989843117695280E-01 9.690408033040058E-01 3.592980746249808E-04
1150 3.797866926435930E-06 3.135959132972519E+00 1.000120189670565E+00 9.692211912490709E-01 1.803879450651413E-04
1175 6.265402474164261E-06 3.135925371221214E+00 1.000119719026761E+00 9.692040821943260E-01 1.710905474494595E-05
1200 4.277084862030464E-06 3.136470535821438E+00 9.999285061680212E-01 9.691807812618649E-01 2.330093246105669E-05
1225 3.204458791271904E-07 3.136239025579123E+00 1.000010528117319E+00 9.691936435653842E-01 1.286230351926765E-05
1250 4.036418766591340E-07 3.136245394668456E+00 1.000007505336821E+00 9.691921353362364E-01 1.508229147795248E-06
1275 2.837176413257513E-07 3.136281382662723E+00 9.999949914841646E-01 9.691906813963164E-01 1.453939920015301E-06
1300 9.844042142635113E-08 3.136264805771400E+00 1.000000881737835E+00 9.691915850747185E-01 9.036784021088096E-07
1325 2.533961154598564E-08 3.136265851640674E+00 1.00000046406204E+00 9.691914479908211E-01 1.370838973446808E-07
1350 1.916169918652966E-08 3.136268196271097E+00 9.99996517766564E-01 9.691913556523709E-01 9.23848021938691E-08
1375 7.192393170326071E-09 3.136267013649034E+00 1.000000071197646E+00 9.691914186020079E-01 6.294963694752909E-08
1400 1.539315394700404E-09 3.136267126444708E+00 1.000000028117958E+00 9.691914071708476E-01 1.143116024060475E-08
1425 1.297956692451984E-09 3.136267277364032E+00 9.99999759168516E-01 9.691914014606052E-01 5.710242390044584E-09
1450 5.189529227718897E-10 3.136267193569821E+00 1.000000005596490E+00 9.691914058419646E-01 4.381359386407269E-09
1475 9.36855077644802E-11 3.136267204114146E+00 1.000000001649911E+00 9.691914049216576E-01 9.203070527874502E-10
1500 8.893456189726813E-11 3.136267213708319E+00 9.99999983463727E-01 9.691914045817848E-01 3.398727965731041E-10
1525 3.731673200349954E-11 3.136267207811770E+00 1.000000000441118E+00 9.691914048838924E-01 3.021076722120597E-10
1550 5.714241550401884E-12 3.136267208726671E+00 1.000000000093375E+00 9.691914048120666E-01 7.182587857812450E-11
1575 6.125234262454042E-12 3.136267209327595E+00 9.99999998871117E-01 9.691914047920936E-01 1.997291221300657E-11
1600 2.779179244041498E-12 3.136267208915407E+00 1.000000000032669E+00 9.691914048128409E-01 2.07472927268261E-11
1625 5.047842858802280E-13 3.136267208991100E+00 1.000000000004955E+00 9.691914048073136E-01 5.5273563098804E-12
1650 5.623956737394518E-13 3.136267209028069E+00 9.99999999923508E-01 9.691914048062152E-01 1.09834638261667E-12
1675 3.522389188556508E-13 3.136267208999441E+00 1.000000000002441E+00 9.691914048076270E-01 1.411759589113349E-12
1700 1.570745143671432E-13 3.136267209005496E+00 1.000000000000234E+00 9.691914048072061E-01 4.208855486353968E-13
1725 1.560248216518705E-13 3.136267209007727E+00 9.99999999994862E-01 9.691914048071528E-01 5.329070518200751E-14
1750 1.568025309392403E-13 3.136267209005747E+00 1.000000000000182E+00 9.691914048072484E-01 9.55902024022598E-14
1775 1.573764988830983E-13 3.136267209006213E+00 1.00000000000010E+00 9.691914048072170E-01 3.141931159689193E-14
1800 1.552959759926589E-13 3.136267209006365E+00 9.99999999999608E-01 9.691914048072134E-01 3.552713678800501E-15
1825 1.567750728904917E-13 3.136267209006203E+00 1.000000000000017E+00 9.691914048072210E-01 7.545916567451064E-15
1850 1.547259042782186E-13 3.136267209006256E+00 9.99999999999979E-01 9.691914048072179E-01 3.108624468950438E-15
1875 1.542730661934905E-13 3.136267209006261E+00 9.99999999999962E-01 9.691914048072173E-01 5.551115123125783E-16
1900 1.540608095231362E-13 3.136267209006245E+00 1.000000000000002E+00 9.691914048072187E-01 1.332267629550188E-15
1925 1.547917041636378E-13 3.136267209006257E+00 9.99999999999974E-01 9.691914048072179E-01 7.771561172376096E-16
1950 1.530585408778687E-13 3.136267209006252E+00 9.99999999999993E-01 9.691914048072184E-01 5.551115123125783E-16
1975 1.555211462264454E-13 3.136267209006248E+00 1.000000000000001E+00 9.691914048072184E-01 0.00000000000000E+00
2000 1.537571174049221E-13 3.136267209006245E+00 1.000000000000001E+00 9.691914048072180E-01 4.44809298500626E-16

```

MAIN RESULTS

```

3.1362672090062453E+00 ....: fmi - Mass flow rate in the entrance (kg/s)
3.1362672090062493E+00 ....: fme - Mass flow rate in the exit (kg/s)
3.3010489746324793E+03 ....: Fd - Dynamic thrust (N)
6.04059999999959022E+01 ....: tcpu - CPU time (s)
2000 ....: it - Interaction of the end of the cycle

```

\*\*\* Grid parameters \*\*\*

```

7.493000000E-04 = dxmin: min(size of volume controls) in the x direction (m)
9.842500000E-04 = dxmax: max(size of volume controls) in the x direction (m)
1.313559322E+00 = dxmax / dxmin
2.540000000E-04 = dymin: min(size of volume controls) in the y direction (m)
7.937500000E-04 = dymax: max(size of volume controls) in the y direction (m)
3.125000000E+00 = dymax / dymin

```

\*\*\* Nozzle parameters \*\*\*

```

77 = ig: number of the VC in the x direction whose east face coincides with the nozzle throttle

```

```

6.487160000E-02 = Xg: x coord. of the nozzle throttle (m)
2.032000000E-02 = rg: radius of the nozzle throttle (m)
1.270000000E-02 = rcg: curvature radius of the nozzle throttle (m)
6.250000000E-01 = Rcag: dimensionless curvature radius of the nozzle throttle
1.297171146E-03 = Sg: area of the nozzle throttle (m2)
9.765625000E+00 = rain: area ratio of the convergent section
6.566597085E+00 = raex: area ratio of the divergent section

*** Analytic solution of the Q1D isentropic flow ***
3.133646450454429E+00 = fmlD: mass flow rate (kg/s)
3.405982511049086E+03 = Fd1D: dynamic thrust (N)
-6.603602827141507E+02 = Fp1D: dynamic thrust at sea level (p = 101325 Pa) (N)
2.027260945258903E+02 = Fpv1D: thrust of pressure in the vacuum (N)
2.745622228334935E+03 = F1D: total thrust at sea level (N)
3.608708605574976E+03 = Fv1D: total thrust in the vacuum (N)
2.237708435332511E+03 = Fo: standard thrust (N)
1.22697943305577E+00 = CF1D: thrust coefficient at sea level (dimensionless)
1.612680431728695E+00 = CFv1D: thrust coefficient in the vacuum (dimensionless)
7.140909067798660E+02 = ce1D: characteristic velocity (m/s)
8.761748562722435E+02 = c1D: velocity of effective ejection at the sea level (m/s)
1.1516000431839289E+03 = cv1D: velocity of effective ejection in the vacuum (m/s)
8.93449706344127E+01 = Is1D: specific impulse at sea level (s)
1.174305631218907E+02 = Isv1D: specific impulse in the vacuum (s)

*** Analytic solution 2D ***
9.816538761092243E-01 = CdKL: discharge coefficient of Kliegel and Levine (dimensionless)

*** Numeric solution 2D ***
3.136267209006249E+00 = fme: mass flow rate (kg/s)
3.301048974632479E+03 = Fd: dynamic thrust (N)
-6.4440341233599643E+02 = Fp: thrust of pressure at sea level (p = 101325 Pa) (N)
2.190522538800768E+02 = Fpv: thrust of pressure in the vacuum (N)
2.657014851272515E+03 = F: total thrust at sea level (N)
3.520101228512556E+03 = Fv: total thrust in the vacuum (N)
2.237708435332511E+03 = Fo: standard thrust (N)
1.187382059842706E+00 = CF: thrust coefficient at sea level (dimensionless)
1.573083058065824E+00 = CFv: thrust coefficient in the vacuum (dimensionless)
7.134941910901612E+02 = ce: characteristic velocity (m/s)
8.471902023024405E+02 = c: velocity of effective ejection at sea level (m/s)
1.122385624032312E+03 = cv: velocity of effective ejection in the vacuum (m/s)
8.638935847638496E+01 = Is: specific impulse at sea level (s)
1.144514818039098E+02 = Isv: specific impulse in the vacuum (s)

*** Efficiency: numerical solution 2D / analytic Q1D (dimensionless) ***
1.000836328728610E+00 = discharge coefficient
9.691914048072180E-01 = dynamic thrust
9.752768908404300E-01 = pressure thrust at sea level (p = 101325 Pa)
1.080533092655724E+00 = pressure thrust in the vacuum
9.67277608885928E-01 = total thrust at sea level
9.754462366605237E-01 = total thrust in the vacuum
9.67277608885928E-01 = thrust coefficient at sea level
9.754462366605237E-01 = thrust coefficient in the vacuum
9.991643701326548E-01 = characterist velocity
9.669190986681352E-01 = velocity of effective ejection at sea level
9.746311246511806E-01 = velocity of effective ejection in the vacuum
9.669190986681352E-01 = specific impulse at sea level
9.746311246511807E-01 = specific impulse at vacuum

30.438 = tcpuo: acumulated CPU time (s) (before interruption)
29.968 = dtcpu: CPU time (s) (after interruption)
60.406 = tcptu: total CPU time (s)

```

4) Fazer o reload de u, v, p, T e ro (propriedades nos nós) e ue, vn, un, ve (velocidades nas faces) e fazer a simulação novamente:  
 Simulação: mach2d-SEN03\_1004

LISTING FILE OF MACH2D

Date: (25/10/2012)  
 Time: 12:23:43

PARAMETERS

```

SEN03_1004 ....: Simulation identification (up to 100 characters)
226 ....: nx - Number of real/fictitious volumes in the xsi direction
82 ....: ny - Number of real/fictitious volumes in the eta direction
1 ....: kg - Kind of grid (1 = uniform, 2 = Geometric Progression, 3=power law)
1.0000000E-06 ....: al - Initial step for the geometric progression grid (m)
1 ....: coord - Coordinate system ( 1=cylindrical, else cartesian)
2.8690000E+02 ....: Rg - Perfect gas constant (J/(kg.K))
1.4000000E+00 ....: gamma - Cpo / Cvo in the chamber (Specific heat ratio)
1.7250680E+06 ....: po - Stagnation pressure in the chamber (Pa)
8.3333000E+02 ....: T0 - Stagnation temperature in the chamber (K)
1.0132500E+05 ....: pr - atmospheric pressure at the sea level (Pa)
9.8066500E+00 ....: go - gravitational acceleration at the sea level (m/s2)
0.0000000E+00 ....: beta - Constant of the UDS/CDS mixing scheme
0.0000000E+00 ....: betal - Initial constant of the UDS/CDS mixing scheme
0.0000000E+00 ....: beta2 - Final constant of the UDS/CDS mixing scheme

```

```

1000 ..... itb1 - beta = beta1 for it <= itb1
1000 ..... itb2 - beta = beta2 for itb2 <= it
0 ..... modvis - Viscosity model ( 0 = Euler, 1 = Navier-Stokes)
0 ..... modtur - turbulence model option (0=laminar, 1=Baldwin-Lomax)
0 ..... ccTw - Temp. bc (0 = adiabatic, 1 = prescribed temperature)
1000 ..... dt = dt1 for it <= it1
1000 ..... dt = dt2 for it2 <= it
1.0000000E-05 ..... Initial time step (s)
1.0000000E-05 ..... Final time step (s)
925 ..... itmax - Maximum number of interactions of the time evolution
-1.0000000E-01 ..... tolerance - Parada com base no valor do residuo, se negativo, a parada é feita com base no imax
2 ..... imax - Maximum number of interactions for the pressure correction
4 ..... nitm_u - Maximum number of interactions for the TDMA method for u, v and T
4 ..... nitm_p - Maximum number of interactions for the TDMA method for p
1 ..... reload - Upload backup data and continue computation (0 = no, 1 = yes)
50000 ..... wbkp - Frequency of saving backup data
25 ..... wif - Frequency of printing in the listing file
1 ..... sem_a - 1 = do not open result files, 0 = open
1 ..... sem_g - 0 = visualize the plot, 1 = do not visualize
1 ..... w_g - Frequency of writing data for graphics
0 ..... w_cam - 1 = write the fields, 0 = do not
3.0000000E+00 ..... Eu - E-Factor of u linear system (if Eu.Ev < 0, E-Factor is not applied for u nor v)
-3.0000000E+00 ..... Ev - E-Factor of v linear system (if Eu.Ev < 0, E-Factor is not applied for u nor v)
-3.0000000E+00 ..... Ep - E-Factor of p' linear system (if Ep < 0, E-Factor is not applied for p')
-3.0000000E+00 ..... ET - E-Factor of T linear system (if ET < 0, E-Factor is not applied for T)

```

it	norm / norml	fmi (kg/s)	fme/fmi	Fd*	dPd*
1025	7.656588810545607E-04	3.103427945924216E+00	1.012368107727784E+00	9.704072893204567E-01	9.704072893204567E-01
1050	2.586006230063630E-05	3.137878358630061E+00	9.993860317867600E-01	9.689550493755483E-01	1.452239944908396E-03
1075	5.446612269350824E-05	3.139632965052281E+00	9.988443385440403E-01	9.690676582582207E-01	1.126088826723937E-04
1100	3.702382360226252E-05	3.134566501699012E+00	1.000604637149795E+00	9.692830682499473E-01	2.154099917265340E-04
1125	2.569195272590400E-06	3.136455078346191E+00	9.999293096329931E-01	9.691741710784271E-01	1.088971715201836E-04
1150	3.844572231489925E-06	3.136476629906529E+00	9.999280059529104E-01	9.691839960222062E-01	9.824943779102036E-05
1175	2.5192090805036551E-06	3.136146425237220E+00	1.000042918757755E+00	9.691978215789275E-01	1.382555672135855E-06
1200	1.916960390893406E-07	3.136284058045137E+00	9.99938035370118E-01	9.691900641217991E-01	7.75745712844335E-07
1225	2.440000277756755E-07	3.136280398700377E+00	9.999954731273315E-01	9.691909562461499E-01	8.921243508375198E-07
1250	1.699122764508580E-07	3.136258715191455E+00	1.000003002386966E+00	9.691918375321966E-01	8.812860466944628E-07
1275	1.444875628204380E-08	3.136268631856310E+00	9.99994765361948E-01	9.691912966862778E-01	5.408459188283032E-07
1300	1.528485949822988E-08	3.136268028407412E+00	9.999997193618266E-01	9.691913786739317E-01	8.198765388822693E-08
1325	1.151456197248026E-08	3.136266616904051E+00	1.000000208791663E+00	9.691914343444027E-01	5.567047101084910E-08
1350	4.291092842209767E-09	3.136267324974972E+00	9.999999576834022E-01	9.691913965937308E-01	3.775067192179904E-08
1375	9.298218007356424E-10	3.136267258945747E+00	9.999999829821860E-01	9.691914033726335E-01	6.77890272452966E-09
1400	7.800263749331796E-10	3.136267168004700E+00	1.000000014468008E+00	9.691914068193409E-01	3.446707363963242E-09
1425	3.102290185610178E-10	3.136267218189110E+00	9.99999966698673E-01	9.691914041904710E-01	2.628869899545805E-09
1450	5.674482547043706E-11	3.136267211972211E+00	9.99999989991701E-01	9.691914047369428E-01	5.46471767349453E-10
1475	5.34522143615932E-11	3.136267206185020E+00	1.00000000992303E+00	9.691914049426807E-01	2.057379822062444E-10
1500	2.237365226622881E-11	3.136267209717743E+00	9.99999997431429E-01	9.691914047614392E-01	1.812415773017051E-10
1525	3.504161746025628E-12	3.136267209176231E+00	9.99999999431807E-01	9.691914048041859E-01	4.274669507253748E-11
1550	3.731871637728394E-12	3.136267208813361E+00	1.00000000067770E+00	9.691914048163095E-01	1.212363542890671E-11
1575	1.725663954096635E-12	3.136267209604141E+00	9.99999999805177E-01	9.691914048038589E-01	1.245059610965882E-11
1600	3.671087001554229E-13	3.136267209015495E+00	9.99999999969716E-01	9.691914048071530E-01	3.294142736365302E-12
1625	4.110117039591935E-13	3.136267208993144E+00	1.00000000004595E+00	9.691914048078213E-01	6.68243285218817E-13
1650	2.817184431366970E-13	3.136267209010312E+00	9.99999999985434E-01	9.691914048069740E-01	8.473222123939195E-13
1675	1.594774741970721E-13	3.136267209006711E+00	9.99999999998584E-01	9.691914048072267E-01	2.526867604046856E-13
1700	1.587643629697571E-13	3.136267209005365E+00	1.00000000000309E+00	9.691914048072594E-01	3.275157922644212E-14
1725	1.549736731823840E-13	3.136267209006562E+00	9.99999999998884E-01	9.691914048072005E-01	5.895284260759581E-14
1750	1.531084212348920E-13	3.136267209006278E+00	9.9999999999928E-01	9.691914048072189E-01	1.842970220877760E-14
1775	1.579935084727594E-13	3.136267209006179E+00	1.00000000000024E+00	9.691914048072212E-01	2.331468351712829E-15
1800	1.562502129069147E-13	3.136267209006284E+00	9.99999999999880E-01	9.691914048072164E-01	4.773959005888173E-15
1825	1.535623150476652E-13	3.136267209006243E+00	1.00000000000002E+00	9.691914048072183E-01	1.88739141862766E-15
1850	1.532509329468498E-13	3.136267209006252E+00	9.9999999999996E-01	9.691914048072184E-01	1.11023024625157E-15
1875	1.519664550662005E-13	3.136267209006250E+00	9.9999999999999E-01	9.691914048072179E-01	5.55111512312578E-16
1900	1.541011383972090E-13	3.136267209006257E+00	9.9999999999976E-01	9.691914048072183E-01	4.4408929850626E-16
1925	1.521340108851886E-13	3.136267209006244E+00	1.00000000000002E+00	9.691914048072183E-01	0.00000000000000E+00

MAIN RESULTS

```

3.1362672090062444E+00 ..... fmi - Mass flow rate in the entrance (kg/s)
3.1362672090062493E+00 ..... fme - Mass flow rate in the exit (kg/s)
3.3010489746324802E+03 ..... Fd - Dynamic thrust (N)
5.925100000163913E+01 ..... tcpu - CPU time (s)
1925 ..... it - Iteration of the end of the cycle

```

\*\*\* Grid parameters \*\*\*

```

7.493000000E-04 = dxmin: min(size of volume controls) in the x direction (m)
9.842500000E-04 = dxmax: max(size of volume controls) in the x direction (m)
1.313559322E+00 = dxmax / dxmin
2.540000000E-04 = dymin: min(size of volume controls) in the y direction (m)
7.937500000E-04 = dymax: max(size of volume controls) in the y direction (m)
3.125000000E+00 = dymax / dymin

```

\*\*\* Nozzle parameters \*\*\*

```

77 = ig: number of the VC in the x direction whose east face coincides with the nozzle throttle
6.487160000E-02 = Xg: x coord. of the nozzle throttle (m)
2.032000000E-02 = rg: radius of the nozzle throttle (m)
1.270000000E-02 = rcg: curvature radius of the nozzle throttle (m)
6.250000000E-01 = Rcg: dimensionless curvature radius of the nozzle throttle
1.297171146E-03 = Sg: area of the nozzle throttle (m2)
9.765625000E+00 = rain: area ratio of the convergent section
6.566597085E+00 = raex: area ratio of the divergent section

```

\*\*\* Analytic solution of the Q1D isentropic flow \*\*\*

```

3.133646450454429E+00 = fmlD: mass flow rate (kg/s)
3.405982511049086E+03 = FdlD: dynamic thrust (N)
-6.603602827141507E+02 = FplD: dynamic thrust at sea level (p = 101325 Pa) (N)
2.027260945258903E+02 = FpvlD: thrust of pressure in the vacuum (N)
2.745622228334935E+03 = FlD: total thrust at sea level (N)
3.608708605574976E+03 = Fvld: total thrust in the vacuum (N)
2.237708435332511E+03 = Fo: standard thrust (N)
1.226979433505577E+00 = CPLD: thrust coefficient at sea level (dimensionless)

```

```

1.612680431728695E+00 = CFvLD: thrust coefficient in the vacuum (dimensionless)
7.140909067798660E+02 = ceLD: characteristic velocity (m/s)
8.761748562722435E+02 = cLD: velocity of effective ejection at the sea level (m/s)
1.151600431839289E+03 = cvLD: velocity of effective ejection in the vacuum (m/s)
8.93449706344127E+01 = IsLD: specific impulse at sea level (s)
1.174305631218907E+02 = IsvLD: specific impulse in the vacuum (s)

*** Analytic solution 2D ***

9.816538761092243E-01 = CdKL: discharge coefficient of Kliegel and Levine (dimensionless)

*** Numeric solution 2D ***

3.136267209006249E+00 = fme: mass flow rate (Kg/s)
3.301048974632480E+03 = FD: dynamic thrust (N)
-6.440341233599643E+02 = Fp: thrust of pressure at sea level (p = 101325 Pa) (N)
2.190522538800768E+02 = Fpv: thrust of pressure in the vacuum (N)
2.657014851272516E+03 = F: total thrust at sea level (N)
3.520101228512557E+03 = Fv: total thrust in the vacuum (N)
2.237708435332511E+03 = Fo: standard thrust (N)
1.187382059842706E+00 = CF: thrust coefficient at sea level (dimensionless)
1.573083058065824E+00 = CFv: thrust coefficient in the vacuum (dimensionless)
7.134941910901612E+02 = ce: characteristic velocity (m/s)
8.471902023024409E+02 = c: velocity of effective ejection at sea level (m/s)
1.122385624032312E+03 = cv: velocity of effective ejection in the vacuum (m/s)
8.638935847638500E+01 = Is: specific impulse at sea level (s)
1.144514818039098E+02 = Isv: specific impulse in the vacuum (s)

*** Efficiency: numerical solution 2D / analytic Q1D (dimensionless) ***

1.000836328728610E+00 = discharge coefficient
9.691914048072183E-01 = dynamic thrust
9.752768908404300E-01 = pressure thrust at sea level (p = 101325 Pa)
1.080533092655724E+00 = pressure thrust in the vacuum
9.677277608885931E-01 = total thrust at sea level
9.754462366605239E-01 = total thrust in the vacuum
9.677277608885931E-01 = thrust coefficient at sea level
9.754462366605238E-01 = thrust coefficient in the vacuum
9.991643701326548E-01 = characterist velocity
9.669190986681355E-01 = velocity of effective ejection at sea level
9.746311246511808E-01 = velocity of effective ejection in the vacuum
9.669190986681356E-01 = specific impulse at sea level
9.746311246511810E-01 = specific impulse at vacuum

30.438 = tcpuo: acumulated CPU time (s) (before interruption)
28.813 = dtcpu: CPU time (s) (after interruption)
59.251 = tcpcu: total CPU time (s)

```

5) Fazer o reload de u, v, p, T e ro (propriedades nos nós), ue, vn, un, ve (velocidades nas faces) e roe e ron (massas específicas nas faces) e fazer a simulação novamente:

(Mesmo calculando novamente roe e ron resulta na mesma convergência)

Simulação: mach2d-SEN03\_1005

LISTING FILE OF MACH2D

Date: (25/10/2012)  
Time: 12:26:25

PARAMETERS

```

SEN03_1005 ....: Simulation identification (up to 100 characters)
226 ....: nx      - Number of real-ficititious volumes in the csi direction
82 ....: ny      - Number of real-ficititious volumes in the eta direction
1 ....: kg      - Kind of grid (1 = uniform, 2 = Geometric Progression, 3=power law)
1.0000000E-06 ....: al      - Initial step for the geometric progression grid (m)
1 ....: coord   - Coordinate system ( 1=cylindrical, else cartesian)
2.8690000E+02 ....: Rg      - Perfect gas constant (J/(kg.K))
1.4000000E+00 ....: gamma   - Cpo / Cvo in the chamber (Specific heat ratio)
1.7250680E+06 ....: po      - Stagnation pressure in the chamber (Pa)
8.3333000E+02 ....: T0      - Stagnation temperature in the chamber (K)
1.0132500E+05 ....: pr      - atmospheric pressure at the sea level (Pa)
9.8066500E+00 ....: go      - gravitational acceleration at the sea level (m/s2)
0.0000000E+00 ....: beta    - Constant of the UDS/CDS mixing scheme
0.0000000E+00 ....: beta1   - Initial constant of the UDS/CDS mixing scheme
0.0000000E+00 ....: beta2   - Final constant of the UDS/CDS mixing scheme
1000 ....: itb1    - beta = beta1 for it <= itb1
1000 ....: itb2    - beta = beta2 for itb2 <= it
0 ....: modvis  - Viscosity model ( 0 = Euler, 1 = Navier-Stokes)
0 ....: modtur  - turbulence model option (0=laminar, 1=Baldwin-Lomax)
0 ....: cctw    - Temp. bc (0 = adiabatic, 1 = prescribed temperature)
1000 ....: dt = dt1 for it <= it1
1000 ....: dt = dt2 for it2 <= it
1.0000000E-05 ....: Initial time step (s)
1.0000000E-05 ....: Final time step (s)
925 ....: itmax   - Maximum number of iterations of the time evolution
-1.0000000E-10 ....: tolerance - Parada com base no valor do residuo, se negativo, a parada é feita com base no imax
2 ....: imax    - Maximum number of iterations for the pressure correction
4 ....: nitm_u  - Maximum number of iterations for the TDMA method for u, v and T
4 ....: nitm_p  - Maximum number of iterations for the TDMA method for p
1 ....: reload  - Upload backup data and continue computation (0 = no, 1 = yes)

```

```

50000 ....: wbpk - Frequency of saving backup data
25 ....: wlf - Frequency of printing in the listing file
1 ....: sem_a - 1 = do not open result files, 0 = open
1 ....: sem_g - 0 = visualize the plot, 1 = do not visualize
1 ....: w_g - Frequency of writing data for graphics
0 ....: w_cam - 1 = write the fields, 0 = do not
3.0000000E+00 ....: Eu - E-Factor of u linear system (if Eu.Ev < 0, E-Factor is not applied for u nor v)
-3.0000000E+00 ....: Ev - E-Factor of v linear system (if Eu.Ev < 0, E-Factor is not applied for u nor v)
-3.0000000E+00 ....: Ep - E-Factor of p' linear system (if Ep < 0, E-Factor is not applied for p')
-3.0000000E+00 ....: ET - E-Factor of T linear system (if ET < 0, E-Factor is not applied for T)

```

it	norm / norm1	fmi (kg/s)	fme/fmi	Fd*	dPd*
1025	7.650585250028006E-04	3.103417380467526E+00	1.012372435218869E+00	9.704075100149123E-01	9.704075100149123E-01
1050	2.585834963996367E-05	3.137875702207680E+00	9.993869014086361E-01	9.689550837518938E-01	1.45242626018558E-03
1075	5.450971206752936E-05	3.139635482586362E+00	9.988434534271172E-01	9.690675367218361E-01	1.124529699423338E-04
1100	3.704318668944186E-05	3.134556856795616E+00	1.000604867267339E+00	9.692831089859568E-01	2.155722641207225E-04
1125	2.569392635089986E-06	3.136454932123917E+00	9.999293584887787E-01	9.691741737127505E-01	1.089352732063231E-04
1150	3.847618715878034E-06	3.13647680196948E+00	9.999279461107249E-01	9.691839879918912E-01	9.814279140707427E-06
1175	2.520560479178893E-06	3.136146376750146E+00	1.000042936206479E+00	9.691978245532442E-01	1.383656135300892E-05
1200	1.917220302541816E-07	3.136284051013444E+00	9.999938061320754E-01	9.691900641850911E-01	7.760368153086994E-07
1225	2.442079833475300E-07	3.136280410261543E+00	9.999954690718813E-01	9.691909557139545E-01	8.915288634003815E-07
1250	1.700044230219645E-07	3.136258711561364E+00	1.000003003688829E+00	9.691918377482639E-01	8.820343093685066E-07
1275	1.445138510134813E-08	3.136286831465040E+00	9.99994766605839E-01	9.691912966826933E-01	5.410655702695433E-07
1300	1.529866199654831E-08	3.136268029186952E+00	9.99997190889944E-01	9.691913786389471E-01	8.195625378348836E-08
1325	1.152093962511494E-08	3.136266616635437E+00	1.000000208887786E+00	9.691914343600043E-01	5.572105721274312E-08
1350	4.292239030258967E-09	3.136267324958864E-01	9.99999576881614E-01	9.691913965929488E-01	3.776705548297343E-08
1375	9.307519365368411E-10	3.136267258997926E+00	9.999999829639579E-01	9.691914033703504E-01	6.777410528879068E-09
1400	7.804607342718366E-10	3.136267167985025E+00	1.000000014453835E+00	9.691914068204592E-01	3.450108865266088E-09
1425	3.103222618774421E-10	3.136267218188756E+00	9.99999966699277E-01	9.691914041903790E-01	2.630080264687251E-09
1450	5.680606887398359E-11	3.136267211975677E+00	9.99999989979630E-01	9.691914047367962E-01	5.464172447844362E-10
1475	5.348039452948744E-11	3.136267206183593E+00	1.000000000992812E+00	9.691914049427612E-01	2.059650228147802E-10
1500	2.237971916440482E-11	3.136267209717766E-01	9.99999997431274E-01	9.691914047614301E-01	1.813311722997923E-10
1525	3.508974237662829E-12	3.136267209176452E+00	9.99999999431036E-01	9.691914048041769E-01	4.274680609483994E-11
1550	3.733812595614135E-12	3.136267208813258E+00	1.000000000067806E+00	9.691914048163154E-01	1.213851241743669E-11
1575	1.725337989901778E-12	3.136267209060418E+00	9.99999999805159E-01	9.691914048038582E-01	1.245714642550411E-11
1600	3.694308577935918E-13	3.13626720901511E+00	9.9999999996661E-01	9.691914048071518E-01	3.293587624852989E-12
1625	4.130773195067930E-13	3.136267208993138E+00	1.000000000004598E+00	9.691914048078217E-01	6.699085730588195E-13
1650	2.830384526861144E-13	3.136267209010313E+00	9.999999999985436E-01	9.691914048069741E-01	8.476552793013070E-13
1675	1.566137795678966E-13	3.136267209006711E+00	9.99999999998582E-01	9.691914048072269E-01	2.527977827071481E-13
1700	1.570445310730843E-13	3.136267209005364E+00	1.000000000000309E+00	9.691914048072595E-01	3.264055692397960E-14
1725	1.542077170434230E-13	3.136267209006565E+00	9.99999999998874E-01	9.691914048072007E-01	5.884182030513330E-14
1750	1.525795030000301E-13	3.136267209006282E+00	9.9999999999915E-01	9.691914048072195E-01	1.887379141862766E-14
1775	1.566591007621852E-13	3.136267209006174E+00	1.000000000000026E+00	9.691914048072213E-01	1.776356839400250E-15
1800	1.558070769819018E-13	3.136267209006289E+00	9.99999999999865E-01	9.691914048072164E-01	4.884981308350689E-15
1825	1.527768229848345E-13	3.136267209006244E+00	1.000000000000002E+00	9.691914048072180E-01	1.554312234475219E-15
1850	1.529809077198800E-13	3.136267209006251E+00	1.000000000000000E+00	9.691914048072184E-01	4.44089209850626E-16
1875	1.540529391091023E-13	3.136267209006255E+00	9.99999999999979E-01	9.691914048072180E-01	4.44089209850626E-16
1900	1.545388936649664E-13	3.136267209006252E+00	9.99999999999994E-01	9.691914048072183E-01	3.330669073875470E-16
1925	1.560446242051767E-13	3.136267209006247E+00	1.000000000000001E+00	9.691914048072183E-01	0.000000000000000E+00

MAIN RESULTS

```

3.1362672090062471E+00 ....: fmi - Mass flow rate in the entrance (kg/s)
3.1362672090062498E+00 ....: fme - Mass flow rate in the exit (kg/s)
3.3010489746324802E+03 ....: Fd - Dynamic thrust (N)
5.940700000122935E+01 ....: tcpu - CPU time (s)
1925 ....: it - Interaction of the end of the cycle

```

\*\*\* Grid parameters \*\*\*

```

7.493000000E-04 = dxmin: min(size of volume controls) in the x direction (m)
9.842500000E-04 = dxmax: max(size of volume controls) in the x direction (m)
1.313559322E+00 = dxmax / dxmin
2.540000000E-04 = dymin: min(size of volume controls) in the y direction (m)
7.937500000E-04 = dymax: max(size of volume controls) in the y direction (m)
3.125000000E+00 = dymax / dymin

```

\*\*\* Nozzle parameters \*\*\*

```

77 = ig: number of the VC in the x direction whose east face coincides with the nozzle throat
6.487160000E-02 = Xg: x coord. of the nozzle throat (m)
2.032000000E-02 = rg: radius of the nozzle throat (m)
1.270000000E-02 = rcg: curvature radius of the nozzle throat (m)
6.250000000E-01 = Rcag: dimensionless curvature radius of the nozzle throat
1.297171146E-03 = Sg: area of the nozzle throat (m2)
9.765625000E+00 = rain: area ratio of the convergent section
6.566597085E+00 = raex: area ratio of the divergent section

```

\*\*\* Analytic solution of the Q1D isentropic flow \*\*\*

```

3.133646450454429E+00 = fmiD: mass flow rate (kg/s)
3.405982511049086E+03 = Fg1D: dynamic thrust (N)
-6.603602827141507E+02 = Fp1D: dynamic thrust at sea level (p = 101325 Pa) (N)
2.027620945258903E+02 = Fpv1D: thrust of pressure in the vacuum (N)
2.745622228334935E+03 = F1D: total thrust at sea level (N)
3.608708605574976E+03 = Fv1D: total thrust in the vacuum (N)
2.23770843532511E+03 = Fo: standard thrust (N)
1.226979433505577E+00 = CF1D: thrust coefficient at sea level (dimensionless)
1.612680431728695E+00 = CFv1D: thrust coefficient in the vacuum (dimensionless)
7.140909067798660E+02 = celd: characteristic velocity (m/s)
8.761748562722435E+02 = c1D: velocity of effective ejection at the sea level (m/s)
1.151600431839289E+03 = cv1D: velocity of effective ejection in the vacuum (m/s)
8.934497063444127E+01 = Is1D: specific impulse at sea level (s)
1.174305631218907E+02 = Isv1D: specific impulse in the vacuum (s)

```

\*\*\* Analytic solution 2D \*\*\*

```

9.816538761092243E-01 = CdKL: discharge coefficient of Kliegel and Levine (dimensionless)

```

\*\*\* Numeric solution 2D \*\*\*

```

3.136267209006250E+00 = fme: mass flow rate (kg/s)
3.301048974632480E+03 = Fd: dynamic thrust (N)

```

```

-6.440341233599642E+02 = Fp: thrust of pressure at sea level (p = 101325 Pa) (N)
2.190522538800769E+02 = Fpv: thrust of pressure in the vacuum (N)
2.657014851272516E+03 = F: total thrust at sea level (N)
3.520101228512557E+03 = Fv: total thrust in the vacuum (N)
2.237708435332511E+03 = Fo: standard thrust (N)
1.187382059842706E+00 = CF: thrust coefficient at sea level (dimensionless)
1.573083058065824E+00 = CFv: thrust coefficient in the vacuum (dimensionless)
7.134941910901611E+02 = ce: characteristic velocity (m/s)
8.471902023024408E+02 = c: velocity of effective ejection at sea level (m/s)
1.122385624032312E+03 = cv: velocity of effective ejection in the vacuum (m/s)
8.638935847638498E+01 = Is: specific impulse at sea level (s)
1.144514818039098E+02 = Isv: specific impulse in the vacuum (s)

*** Efficiency: numerical solution 2D / analytic Q1D (dimensionless) ***

1.000836328728610E+00 = discharge coefficient
9.691914048072183E-01 = dynamic thrust
9.752768908404299E-01 = pressure thrust at sea level (p = 101325 Pa)
1.080533092655724E+00 = pressure thrust in the vacuum
9.677277608885931E-01 = total thrust at sea level
9.754462366605239E-01 = total thrust in the vacuum
9.677277608885931E-01 = thrust coefficient at sea level
9.754462366605238E-01 = thrust coefficient in the vacuum
9.991643701326547E-01 = characterist velocity
9.669190986681354E-01 = velocity of efective ejection at sea level
9.746311246511808E-01 = velocity of efective ejection in the vacuum
9.669190986681355E-01 = specific impulse at sea level
9.746311246511810E-01 = specific impulse at vacuum

30.438 = tcpuo: acumulated CPU time (s) (before interruption)
28.969 = dtcpu: CPU time (s) (after interruption)
59.407 = tcpu: total CPU time (s)

```

6) Fazer o reload de u, v, p, T e ro (propriedades nos nós) e Uce e Vcn (contravariantes das velocidades nas faces) e fazer a simulação novamente: Simulação: mach2d-SEN03\_1006

LISTING FILE OF MACH2D

Date: (25/10/2012)  
Time: 12:30:20

PARAMETERS

```

SEN03_1006 ....: Simulation identification (up to 100 characters)
226 ....: nx - Number of real+fictitious volumes in the xsi direction
82 ....: ny - Number of real+fictitious volumes in the eta direction
1 ....: kg - Kind of grid (1 = uniform, 2 = Geometric Progression, 3=power law)
1.0000000E-06 ....: al - Initial step for the geometric progression grid (m)
1 ....: coord - Coordinate system ( 1=cylindrical, else cartesian)
2.8690000E+02 ....: Rg - Perfect gas constant (J/(kg.K))
1.4000000E+00 ....: gamma - Cpo / Cvo in the chamber (Specific heat ratio)
1.7250680E+06 ....: po - Stagnation pressure in the chamber (Pa)
8.3333000E+02 ....: T0 - Stagnation temperature in the chamber (K)
1.0132500E+05 ....: pr - atmospheric pressure at the sea level (Pa)
9.8066500E+00 ....: go - gravitational acceleration at the sea level (m/s2)
0.0000000E+00 ....: beta - Constant of the UDS/CDS mixing scheme
0.0000000E+00 ....: betal - Initial constant of the UDS/CDS mixing scheme
0.0000000E+00 ....: beta2 - Final constant of the UDS/CDS mixing scheme
1000 ....: itb1 - beta = betal for it <= itb1
1000 ....: itb2 - beta = beta2 for itb2 <= it
0 ....: modvis - Viscosity model ( 0 = Euler, 1 = Navier-Stokes)
0 ....: modtur - turbulence model option (0=laminar, 1=Baldwin-Lomax)
0 ....: cctw - Temp. bc (0 = adiabatic, 1 = prescribed temperature)
1000 ....: dt - dt1 for it <= it1
1000 ....: dt - dt2 for it2 <= it
1.0000000E-05 ....: Initial time step (s)
1.0000000E-05 ....: Final time step (s)
975 ....: itmax - Maximum number of interactions of the time evolution
-1.0000000E-10 ....: tolerance - Parada com base no valor do residuo, se negativo, a parada é feita com base no imax
2 ....: imax - Maximum number of interactions for the pressure correction
4 ....: nitm_u - Maximum number of interactions for the TDMA method for u, v and T
4 ....: nitm_p - Maximum number of interactions for the TDMA method for p
1 ....: reload - Upload backup data and continue computation (0 = no, 1 = yes)
50000 ....: wbpk - Frequency of saving backup data
25 ....: wlf - Frequency of printing in the listing file
1 ....: sem_a - 1 = do not open result files, 0 = open
1 ....: sem_g - 0 = visualize the plot, 1 = do not visualize
1 ....: w_g - Frequency of writing data for graphics
0 ....: w_cam - 1 = write the fields, 0 = do not
3.0000000E+00 ....: Eu - E-Factor of u linear system (if Eu.Ev < 0, E-Factor is not applied for u nor v)
-3.0000000E+00 ....: Ev - E-Factor of v linear system (if Eu.Ev < 0, E-Factor is not applied for u nor v)
-3.0000000E+00 ....: Ep - E-Factor of p' linear system (if Ep < 0, E-Factor is not applied for p')
-3.0000000E+00 ....: ET - E-Factor of T linear system (if ET < 0, E-Factor is not applied for T)

```

it	norm / norml	fmi (kg/s)	fme/fmi	FD*	dPd*
1025	3.865836172459224E-03	2.979679387912379E+00	1.056390190512454E+00	9.739018856209886E-01	9.739018856209886E-01
1050	1.313289741288436E-03	3.171747137666665E+00	9.867602907966907E-01	9.661197272044386E-01	7.782158416549945E-03
1075	3.267049731387680E-04	3.127260014263765E+00	1.003250043323447E+00	9.697248543653216E-01	3.605127160883015E-03
1100	7.623086144247715E-05	3.132723309808146E+00	1.001220660064008E+00	9.692890497979209E-01	4.358045674007771E-04
1125	6.206681145089514E-05	3.139495701996592E+00	9.988711003401035E-01	9.690338779012577E-01	2.551718966631311E-04
1150	2.352205659299815E-05	3.135536058064626E+00	1.000268461532281E+00	9.692396653804292E-01	2.057874791714376E-04
1175	4.453353429394026E-06	3.136051175786583E+00	1.000074495844156E+00	9.691960592215551E-01	4.360615887410990E-05
1200	4.256720374948386E-06	3.136488177503630E+00	9.999226005925265E-01	9.691805507520771E-01	1.550846947795392E-05
1225	1.708669392752420E-06	3.136210332853722E+00	1.000020546792949E+00	9.691949049910529E-01	1.435423897577781E-05

1250	2.635187465646851E-07	3.136254747876912E+00	1.000004139787150E+00	9.691915664658339E-01	3.338525218943289E-06
1275	2.800228717048524E-07	3.136282202707154E+00	9.999947314398655E-01	9.691906966766149E-01	8.697892189823975E-07
1300	1.243945218002714E-07	3.136262877477161E+00	1.000001555665319E+00	9.691916702401171E-01	9.735635021490552E-07
1325	1.639229251534846E-08	3.136266541525508E+00	1.000000217361624E+00	9.691914073049650E-01	2.629351520955225E-07
1350	1.870210332645891E-08	3.136268225151079E+00	9.99996438811960E-01	9.691913583490886E-01	4.895587635278531E-08
1375	8.793017408708382E-09	3.136266885033003E+00	1.000000116034617E+00	9.691914241090335E-01	6.5759448282965E-08
1400	1.215029588222088E-09	3.136267176820229E+00	1.00000010110975E+00	9.691914042790161E-01	1.983001740590851E-08
1425	1.255637825834135E-09	3.136267277417633E+00	9.99999760525017E-01	9.691914017408230E-01	2.538193100143360E-09
1450	6.170526130143376E-10	3.136267185057775E+00	1.000000000858718E+00	9.691914061963288E-01	4.455505853151465E-09
1475	8.893133435214441E-11	3.136267207759726E+00	1.000000000349486E+00	9.691914047167375E-01	1.47959133838082E-09
1500	8.402747662919452E-11	3.136267213577394E+00	9.99999984034527E-01	9.691914046078693E-01	1.088681367278355E-10
1525	4.309602749725047E-11	3.136267207253569E+00	1.000000000624843E+00	9.691914049063289E-01	2.984595903754439E-10
1550	7.562656673809440E-12	3.136267208988404E+00	1.000000000002027E+00	9.691914047977704E-01	1.085584955262675E-10
1575	5.680338553182653E-12	3.136267209309306E+00	9.99999998943030E-01	9.691914047943193E-01	3.451128272047299E-12
1600	3.112199492202908E-12	3.136267208879151E+00	1.000000000045225E+00	9.691914048142446E-01	1.992528364525015E-11
1625	2.841369682983561E-13	3.136267209009746E+00	9.9999999983359E-01	9.691914048063149E-01	7.929656931082718E-12
1650	5.256494675650704E-13	3.136267209026169E+00	9.99999999930727E-01	9.691914048064001E-01	8.515410598874951E-14
1675	3.7350991134146395E-13	3.136267208997106E+00	1.000000000003247E+00	9.691914048077133E-01	1.311317193526635E-12
1700	1.588846409574782E-13	3.136267209006820E+00	9.9999999997666E-01	9.691914048071382E-01	5.75095526758311E-13
1725	1.607307193814542E-13	3.136267209007553E+00	9.9999999995538E-01	9.691914048071705E-01	3.230749001659206E-14
1750	1.578550638903968E-13	3.136267209005585E+00	1.000000000000236E+00	9.691914048072535E-01	8.304468224196171E-14
1775	1.575944162649815E-13	3.136267209006311E+00	9.9999999999755E-01	9.691914048072128E-01	4.074518500374325E-14
1800	1.571126486950666E-13	3.136267209006351E+00	9.99999999999661E-01	9.691914048072147E-01	1.887379141862766E-15
1825	1.557616775555788E-13	3.136267209006187E+00	1.000000000000022E+00	9.691914048072212E-01	6.550315845288424E-15
1850	1.539687949504261E-13	3.136267209006262E+00	9.99999999999954E-01	9.691914048072173E-01	3.885780586188048E-15
1875	1.557255211002831E-13	3.136267209006256E+00	9.99999999999979E-01	9.691914048072179E-01	5.55115123125783E-16
1900	1.543429859944932E-13	3.136267209006245E+00	1.000000000000002E+00	9.691914048072184E-01	5.55115123125783E-16
1925	1.583042132615249E-13	3.136267209006252E+00	9.99999999999990E-01	9.691914048072179E-01	5.55115123125783E-16
1950	1.557946438492732E-13	3.136267209006255E+00	9.99999999999986E-01	9.691914048072180E-01	1.110223024625157E-16
1975	1.544917913044916E-13	3.136267209006253E+00	9.99999999999989E-01	9.691914048072180E-01	0.000000000000000E+00

#### MAIN RESULTS

3.1362672090062529E+00 ..... fml - Mass flow rate in the entrance (kg/s)  
 3.1362672090062493E+00 ..... fme - Mass flow rate in the exit (kg/s)  
 3.3010489746324793E+03 ..... Fd - Dynamic thrust (N)  
 6.064199999992549E+01 ..... tcpu - CPU time (s)  
 1975 ..... it - Interaction of the end of the cycle

#### \*\*\* Grid parameters \*\*\*

7.493000000E-04 = dxmin: min(size of volume controls) in the x direction (m)  
 9.842500000E-04 = dxmax: max(size of volume controls) in the x direction (m)  
 1.313559322E+00 = dxmax / dxmin  
 2.540000000E-04 = dymin: min(size of volume controls) in the y direction (m)  
 7.937500000E-04 = dymax: max(size of volume controls) in the y direction (m)  
 3.125000000E+00 = dymax / dymin

#### \*\*\* Nozzle parameters \*\*\*

77 = ig: number of the VC in the x direction whose east face coincides with the nozzle throat  
 6.487160000E-02 = Xg: x coord. of the nozzle throat (m)  
 2.032000000E-02 = rg: radius of the nozzle throat (m)  
 1.270000000E-02 = rcg: curvature radius of the nozzle throat (m)  
 6.250000000E-01 = Rcag: dimensionless curvature radius of the nozzle throat  
 1.297171146E-03 = Sg: area of the nozzle throat (m<sup>2</sup>)  
 9.765625000E+00 = rain: area ratio of the convergent section  
 6.566597085E+00 = raex: area ratio of the divergent section

#### \*\*\* Analytic solution of the Q1D isentropic flow \*\*\*

3.13646450454429E+00 = fmlD: mass flow rate (kg/s)  
 3.405982511049086E+03 = Fd1D: dynamic thrust (N)  
 -6.603602827141507E+02 = Fp1D: dynamic thrust at sea level (p = 101325 Pa) (N)  
 2.027260945258903E+02 = Fpv1D: thrust of pressure in the vacuum (N)  
 2.74562228334935E+03 = FL: total thrust at sea level (N)  
 3.608708605574976E+03 = Fv1D: total thrust in the vacuum (N)  
 2.237708435332511E+03 = Fo: standard thrust (N)  
 1.226979433050577E+00 = CF1D: thrust coefficient at sea level (dimensionless)  
 1.612680431728695E+00 = CFv1D: thrust coefficient in the vacuum (dimensionless)  
 7.140909067798660E+02 = celD: characteristic velocity (m/s)  
 8.761748562722435E+02 = clD: velocity of effective ejection at the sea level (m/s)  
 1.151600431839289E+03 = cv1D: velocity of effective ejection in the vacuum (m/s)  
 8.934497063444127E+01 = Is1D: specific impulse at sea level (s)  
 1.174305631218907E+02 = Isv1D: specific impulse in the vacuum (s)

#### \*\*\* Analytic solution 2D \*\*\*

9.816538761092243E-01 = CdKL: discharge coefficient of Kliegel and Levine (dimensionless)

#### \*\*\* Numeric solution 2D \*\*\*

3.136267209006249E+00 = fme: mass flow rate (kg/s)  
 3.301048974632479E+03 = Fd: dynamic thrust (N)  
 -6.440341233599642E+02 = Fp: thrust of pressure at sea level (p = 101325 Pa) (N)  
 2.190522538800768E+02 = Fpv: thrust of pressure in the vacuum (N)  
 2.657014851272515E+03 = F: total thrust at sea level (N)  
 3.520101228512556E+03 = Fv: total thrust in the vacuum (N)  
 2.237708435332511E+03 = Fo: standard thrust (N)  
 1.187382059842706E+00 = CF: thrust coefficient at sea level (dimensionless)  
 1.573083058065824E+00 = CFv: thrust coefficient in the vacuum (dimensionless)  
 7.134941910901612E+02 = ce: characteristic velocity (m/s)  
 8.471902023024405E+02 = c: velocity of effective ejection at sea level (m/s)  
 1.122385624032312E+03 = cv: velocity of effective ejection in the vacuum (m/s)  
 8.638935847638496E+01 = Is: specific impulse at sea level (s)  
 1.144514818039098E+02 = Isv: specific impulse in the vacuum (s)

#### \*\*\* Efficiency: numerical solution 2D / analytic Q1D (dimensionless) \*\*\*

1.000836328728610E+00 = discharge coefficient  
 9.691914048072180E-01 = dynamic thrust  
 9.752768908404299E-01 = pressure thrust at sea level (p = 101325 Pa)  
 1.080533092655724E+00 = pressure thrust in the vacuum  
 9.67277608885928E-01 = total thrust at sea level  
 9.754462366605237E-01 = total thrust in the vacuum

```

9.677277608885928E-01 = thrust coefficient at sea level
9.754462366605237E-01 = thrust coefficient in the vacuum
9.991643701326548E-01 = characterist velocity
9.669190986681352E-01 = velocity of efective ejection at sea level
9.746311246511806E-01 = velocity of efective ejection in the vacuum
9.669190986681352E-01 = specific impulse at sea level
9.746311246511807E-01 = specific impulse at vacuum

30.438 = tcpuo: acumulated CPU time (s) (before interuption)
30.204 = dtcpu: CPU time (s) (after interuption)
60.642 = tcpu: total CPU time (s)

```

7) Fazer o reload de u, v, p, T e ro (propriedades nos nós) e Uce e Vcn (contravariantes das velocidades nas faces) e calcular com as contravariantes os valores de roe e ron (massas específicas nas faces) e fazer a simulação novamente:

Simulação: mach2d-SEN03\_1007

LISTING FILE OF MACH2D

Date: (25/10/2012)  
Time: 12:32:7

PARAMETERS

```

SEN03_1007 ....: Simulation identification (up to 100 characters)
226 ....: nx - Number of real+ficittitious volumes in the csi direction
82 ....: ny - Number of real+ficittitious volumes in the eta direction
1 ....: kg - Kind of grid (1 = uniform, 2 = Geometric Progression, 3=power law)
1.0000000E-06 ....: al - Initial step for the geometric progression grid (m)
1 ....: coord - Coordinate system ( 1=cylindrical, else cartesian)
2.8690000E+02 ....: Rg - Perfect gas constant (J/(kg.K))
1.4000000E+00 ....: gamma - Cpo / Cvo in the chamber (Specific heat ratio)
1.7250680E+06 ....: po - Stagnation pressure in the chamber (Pa)
8.3333000E+02 ....: T0 - Stagnation temperature in the chamber (K)
1.0132500E+05 ....: pr - atmospheric pressure at the sea level (Pa)
9.8065000E+00 ....: go - gravitational acceleration at the sea level (m/s2)
0.0000000E+00 ....: beta - Constant of the UDS/CDS mixing scheme
0.0000000E+00 ....: beta1 - Initial constant of the UDS/CDS mixing scheme
0.0000000E+00 ....: beta2 - Final constant of the UDS/CDS mixing scheme
1000 ....: itb1 - beta = beta1 for it <= itb1
1000 ....: itb2 - beta = beta2 for itb2 <= it
0 ....: modvis - Viscosity model ( 0 = Euler, 1 = Navier-Stokes)
0 ....: modtur - turbulence model option (0=laminar, 1=Baldwin-Lomax)
0 ....: ccTw - Temp. bc (0 = adiabatic, 1 = prescribed temperature)
1000 ....: dt = dt1 for it <= it1
1000 ....: dt = dt2 for it2 <= it
1.0000000E-05 ....: Initial time step (s)
1.0000000E-05 ....: Final time step (s)
975 ....: itmax - Maximum number of interactions of the time evolution
-1.0000000E-10 ....: tolerance - Parada com base no valor do residuo, se negativo, a parada é feita com base no imax
2 ....: imax - Maximum number of interactions for the pressure correction
4 ....: nitm_u - Maximum number of interactions for the TDMA method for u, v and T
4 ....: nitm_p - Maximum number of interactions for the TDMA method for p
1 ....: reload - Upload backup data and continue computation (0 = no, 1 = yes)
50000 ....: wbkp - Frequency of saving backup data
25 ....: wlf - Frequency of printing in the listing file
1 ....: sem_a - 1 = do not open result files, 0 = open
1 ....: sem_g - 0 = visualize the plot, 1 = do not visualize
1 ....: w_g - Frequency of writing data for graphics
0 ....: w_cam - 1 = write the fields, 0 = do not
3.0000000E+00 ....: Eu - E-Factor of u linear system (if Eu.Ev < 0, E-Factor is not applied for u nor v)
-3.0000000E+00 ....: Ev - E-Factor of v linear system (if Eu.Ev < 0, E-Factor is not applied for u nor v)
-3.0000000E+00 ....: Ep - E-Factor of p' linear system (if Ep < 0, E-Factor is not applied for p')
-3.0000000E+00 ....: ET - E-Factor of T linear system (if ET < 0, E-Factor is not applied for T)

it          norm / norml          fmi (kg/s)          fme/fmi          Fd*          dPd*
1025  3.865836172459224E-03  2.979679387912379E+00  1.056390190512454E+00  9.739018856209886E-01  9.739018856209886E-01
1050  1.313289741288436E-03  3.171747137666665E+00  9.867602907966907E-01  9.661197272044386E-01  7.782158416549945E-03
1075  3.267049731387680E-04  3.127260014263765E+00  1.003250043323447E+00  9.697248543653216E-01  3.605127160883015E-03
1100  7.623086144247715E-05  3.132723309808146E+00  1.001220660064008E+00  9.692890497979209E-01  4.358045674007771E-04
1125  6.206681145089514E-05  3.139495701996592E+00  9.988711003401035E-01  9.690338779012577E-01  2.551718966631311E-04
1150  2.352205659299815E-05  3.135536058064626E+00  1.000268461532281E+00  9.692396653804292E-01  2.057874791714376E-04
1175  4.45335429394026E-06  3.136051175786583E+00  1.000074495844156E+00  9.691960592215551E-01  4.360615887410990E-05
1200  4.256720374948386E-06  3.136488177503630E+00  9.999226005925265E-01  9.691805507520771E-01  1.55084694795392E-05
1225  1.708669392752420E-06  3.136210332853722E+00  1.000020546792949E+00  9.691949049910529E-01  1.435423897577781E-05
1250  2.635187465646851E-07  3.136254747876912E+00  1.000004139787150E+00  9.691915664658339E-01  3.338525218943289E-06
1275  2.800228717048524E-07  3.136282202707154E+00  9.999947314398655E-01  9.691906966766149E-01  8.697892189823975E-07
1300  1.243945218002714E-07  3.136262877477161E+00  1.000001555665319E+00  9.691916702401171E-01  9.735635021490552E-07
1325  1.639229251534846E-08  3.136266541525508E+00  1.00000217361624E+00  9.691914073049650E-01  2.629351520955225E-07
1350  1.870210332645891E-08  3.136268225151079E+00  9.99996438811960E-01  9.691913583490886E-01  4.89558763278531E-08
1375  8.793017408708382E-09  3.136266885033003E+00  1.000000116034617E+00  9.691914241090335E-01  6.57599448282965E-08
1400  1.215029588222088E-09  3.136267176820229E+00  1.000000010110975E+00  9.691914042790161E-01  1.983001740590851E-08
1425  1.255637825834135E-09  3.136267277417633E+00  9.99999760525017E-01  9.691914017408230E-01  2.538193100143360E-09
1450  6.170526130143376E-10  3.1362671185057775E+00  1.000000008558718E+00  9.691914061963288E-01  4.455505853151465E-09
1475  8.893133435214441E-11  3.136267207759726E+00  1.000000000349486E+00  9.691914047167375E-01  1.479591338338082E-09
1500  8.402747662919452E-11  3.136267213577394E+00  9.99999984034527E-01  9.691914046078693E-01  1.088681367278355E-10
1525  4.309602749725047E-11  3.136267207253569E+00  1.000000000624843E+00  9.691914049063289E-01  2.984595903754439E-10
1550  7.562656673809440E-12  3.136267208988404E+00  1.00000000000272E+00  9.691914047977704E-01  1.085584955262675E-10
1575  5.680338553182653E-12  3.136267209309306E+00  9.99999998943030E-01  9.691914047943193E-01  3.451128272047299E-12
1600  3.112199492202908E-12  3.136267208879151E+00  1.000000000045225E+00  9.691914048142446E-01  1.992528364525015E-11
1625  2.841369682983561E-13  3.136267209009746E+00  9.99999999983359E-01  9.691914048063149E-01  7.929656931082718E-12
1650  5.256494675650704E-13  3.136267209026169E+00  9.99999999930727E-01  9.691914048064001E-01  8.515410598874951E-14
1675  3.735099134146395E-13  3.136267208997106E+00  1.000000000003247E+00  9.691914048077133E-01  1.313171793526635E-12

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1700	1.588846409574782E-13	3.136267209006820E+00	9.99999999997666E-01	9.691914048071382E-01	5.75095526755831E-13
1725	1.607307193814542E-13	3.136267209007553E+00	9.99999999995538E-01	9.691914048071705E-01	3.230749001659206E-14
1750	1.578550638903968E-13	3.136267209005585E+00	1.00000000000236E+00	9.691914048072535E-01	8.304468224196171E-14
1775	1.575944162649815E-13	3.136267209006311E+00	9.99999999999755E-01	9.691914048072128E-01	4.074518500374325E-14
1800	1.571126486950666E-13	3.136267209006351E+00	9.99999999999661E-01	9.691914048072147E-01	1.887379141862766E-15
1825	1.557616775555788E-13	3.136267209006187E+00	1.00000000000022E+00	9.691914048072212E-01	6.550315845288424E-15
1850	1.539687949504261E-13	3.136267209006262E+00	9.9999999999954E-01	9.691914048072173E-01	3.885780586188048E-15
1875	1.557255211002831E-13	3.136267209006256E+00	9.9999999999979E-01	9.691914048072179E-01	5.55115123125783E-16
1900	1.543429859944932E-13	3.136267209006245E+00	1.00000000000002E+00	9.691914048072184E-01	5.55115123125783E-16
1925	1.583042132615249E-13	3.136267209006252E+00	9.9999999999990E-01	9.691914048072179E-01	5.55115123125783E-16
1950	1.557946438492732E-13	3.136267209006255E+00	9.9999999999986E-01	9.691914048072180E-01	1.110223024625157E-16
1975	1.544917913044916E-13	3.136267209006253E+00	9.9999999999989E-01	9.691914048072180E-01	0.00000000000000E+00

MAIN RESULTS

3.1362672090062529E+00 ..... fmi - Mass flow rate in the entrance (kg/s)  
3.1362672090062493E+00 ..... fme - Mass flow rate in the exit (kg/s)  
3.3010489746324793E+03 ..... Fd - Dynamic thrust (N)  
6.0563000000081956E+01 ..... tcpu - CPU time (s)  
1975 ..... !t - Iteration of the end of the cycle

\*\*\* Grid parameters \*\*\*

7.493000000E-04 = dxmin: min(size of volume controls) in the x direction (m)  
9.842500000E-04 = dxmax: max(size of volume controls) in the x direction (m)  
1.313559322E+00 = dxmax / dxmin  
2.540000000E-04 = dymin: min(size of volume controls) in the y direction (m)  
7.937500000E-04 = dymax: max(size of volume controls) in the y direction (m)  
3.125000000E+00 = dymax / dymin

\*\*\* Nozzle parameters \*\*\*

77 = ig: number of the VC in the x direction whose east face coincides with the nozzle throttle  
6.487160000E-02 = Xg: x coord. of the nozzle throttle (m)  
2.032000000E-02 = rg: radius of the nozzle throttle (m)  
1.270000000E-02 = rcg: curvature radius of the nozzle throttle (m)  
6.250000000E-01 = Rcag: dimensionless curvature radius of the nozzle throttle  
1.297171146E-03 = Sg: area of the nozzle throttle (m<sup>2</sup>)  
9.765625000E+00 = rain: area ratio of the convergent section  
6.566597085E+00 = raex: area ratio of the divergent section

\*\*\* Analytic solution of the Q1D isentropic flow \*\*\*

3.133646450454429E+00 = fmlD: mass flow rate (kg/s)  
3.405982511049086E+03 = Fd1D: dynamic thrust (N)  
-6.603602827141507E+02 = FplD: dynamic thrust at sea level (p = 101325 Pa) (N)  
2.027260945258903E+02 = FpvlD: thrust of pressure in the vacuum (N)  
2.745622228334935E+03 = F1D: total thrust at sea level (N)  
3.608708605574976E+03 = Fv1D: total thrust in the vacuum (N)  
2.237708435332511E+03 = Fo: standard thrust (N)  
1.226979433505577E+00 = CF1D: thrust coefficient at sea level (dimensionless)  
1.612680431728695E+00 = CFv1D: thrust coefficient in the vacuum (dimensionless)  
7.140909067798660E+02 = celd: characteristic velocity (m/s)  
8.761748562722435E+02 = clD: velocity of effective ejection at the sea level (m/s)  
1.151600431839289E+03 = cv1D: velocity of effective ejection in the vacuum (m/s)  
8.93449706344127E+01 = IslD: specific impulse at sea level (s)  
1.174305631218907E+02 = Isv1D: specific impulse in the vacuum (s)

\*\*\* Analytic solution 2D \*\*\*

9.816538761092243E-01 = CdKL: discharge coefficient of Kliegel and Levine (dimensionless)

\*\*\* Numeric solution 2D \*\*\*

3.136267209006249E+00 = fme: mass flow rate (kg/s)  
3.301048974632479E+03 = Fd: dynamic thrust (N)  
-6.440341233599642E+02 = Fp: thrust of pressure at sea level (p = 101325 Pa) (N)  
2.190522538800768E+02 = Fpv: thrust of pressure in the vacuum (N)  
2.657014851272515E+03 = F: total thrust at sea level (N)  
3.520101228512556E+03 = Fv: total thrust in the vacuum (N)  
2.237708435332511E+03 = Fo: standard thrust (N)  
1.187382059842706E+00 = CF: thrust coefficient at sea level (dimensionless)  
1.573083058065824E+00 = CFv: thrust coefficient in the vacuum (dimensionless)  
7.134941910901612E+02 = ce: characteristic velocity (m/s)  
8.471902023024405E+02 = c: velocity of effective ejection at sea level (m/s)  
1.122385624032312E+03 = cv: velocity of effective ejection in the vacuum (m/s)  
8.638935847638496E+01 = Is: specific impulse at sea level (s)  
1.144514818039098E+02 = Isv: specific impulse in the vacuum (s)

\*\*\* Efficiency: numerical solution 2D / analytic Q1D (dimensionless) \*\*\*

1.000836328728610E+00 = discharge coefficient  
9.691914048072180E-01 = dynamic thrust  
9.752768908404299E-01 = pressure thrust at sea level (p = 101325 Pa)  
1.080533092655724E+00 = pressure thrust in the vacuum  
9.677277608885928E-01 = total thrust at sea level  
9.754462366605237E-01 = total thrust in the vacuum  
9.677277608885928E-01 = thrust coefficient at sea level  
9.754462366605237E-01 = thrust coefficient in the vacuum  
9.991643701326548E-01 = characteristic velocity  
9.669190986681352E-01 = velocity of effective ejection at sea level  
9.746311246511806E-01 = velocity of effective ejection in the vacuum  
9.669190986681352E-01 = specific impulse at sea level  
9.746311246511807E-01 = specific impulse at vacuum

30.438 = tcpuo: accumulated CPU time (s) (before interruption)  
30.125 = dtcpu: CPU time (s) (after interruption)  
60.563 = tcpu: total CPU time (s)

## Conclusões

- O carregamento do backup funciona perfeitamente nesta versão do Mach2D (otimizada via relatorios anteriores), o fato de que o  $dFd^*$  na primeira iteração resultar no próprio  $Fd^*$  é porque seu valor não é salvo da simulação anterior, apenas a 'norm1'
- O uso das propriedades nos nós (u, v, p, T e ro) da solução convergida melhorou pouco a convergência, ao invés de **1000** iterações, levou **975** iterações.
- O uso das propriedades nos nós e as velocidades nas faces da solução convergida melhorou um pouco a convergência, ao invés de **1000** iterações, levou **925** iterações.
- O uso das propriedades nos nós, as velocidades nas faces e as massas específicas nas faces da solução convergida melhorou um pouco a convergência, ao invés de **1000** iterações, levou **925** iterações. (O mesmo resultado se observou quando houve o cálculo das massas específicas nas faces, ao invés do carregamento)
- O uso das propriedades nos nós e das contravariantes das velocidades nas faces da solução convergida melhorou pouco a convergência, ao invés de **1000** iterações, levou **975** iterações. (O mesmo resultado foi observado quando houve o cálculo das massas específicas nas faces).
- Não houve melhora significativa na convergência ao utilizar-se a solução convergida da malha anterior, no melhor caso simulado, o número de iterações para chegar no Epi diminuiu 7,5% (de 1000 para 925).