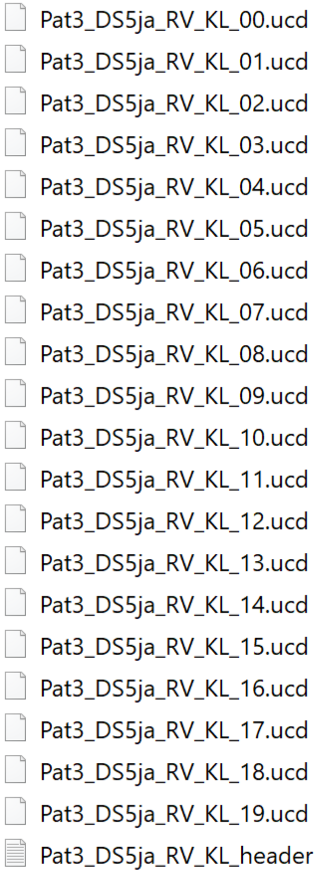
Perform moving mesh simulations based on 3D RTE as explained in Gruenwald et al. 2021

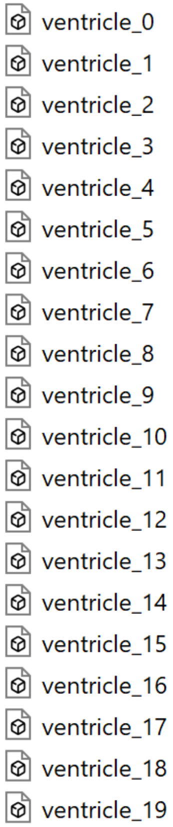
Prerequisites

- Visual Studio (https://visualstudio.microsoft.com/en/downloads/) full version with all packages
- Python and any IDE like Spyder or Sublime Text 3
  - Install: pip, numpy wheel, matplotlib, scipy
- UCD files (export of Tomtec ImageArena) for ventricular cavities at all time steps

Step 0: Use ucd2stl MATLAB code to convert UCD to STL files



```
Pat3_DS5ja_RV_KL_00.ucd
Pat3_DS5ja_RV_KL_01.ucd
Pat3_DS5ja_RV_KL_02.ucd
Pat3_DS5ja_RV_KL_03.ucd
Pat3_DS5ja_RV_KL_04.ucd
Pat3_DS5ja_RV_KL_05.ucd
Pat3_DS5ja_RV_KL_06.ucd
Pat3_DS5ja_RV_KL_07.ucd
Pat3_DS5ja_RV_KL_08.ucd
Pat3_DS5ja_RV_KL_09.ucd
Pat3_DS5ja_RV_KL_10.ucd
Pat3_DS5ja_RV_KL_11.ucd
Pat3_DS5ja_RV_KL_12.ucd
Pat3_DS5ja_RV_KL_13.ucd
Pat3_DS5ja_RV_KL_14.ucd
Pat3_DS5ja_RV_KL_15.ucd
Pat3_DS5ja_RV_KL_16.ucd
Pat3_DS5ja_RV_KL_17.ucd
Pat3_DS5ja_RV_KL_18.ucd
Pat3_DS5ja_RV_KL_19.ucd
Pat3_DS5ja_RV_KL_header
```



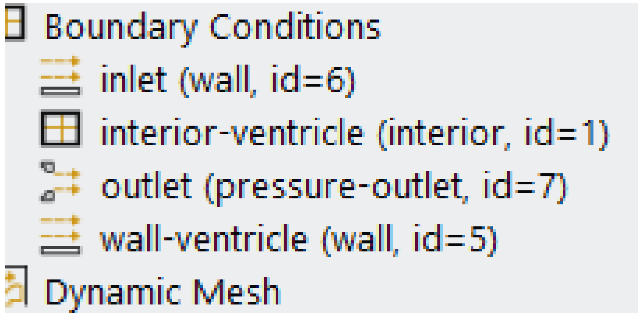
```
ventricle_0
ventricle_1
ventricle_2
ventricle_3
ventricle_4
ventricle_5
ventricle_6
ventricle_7
ventricle_8
ventricle_9
ventricle_10
ventricle_11
ventricle_12
ventricle_13
ventricle_14
ventricle_15
ventricle_16
ventricle_17
ventricle_18
ventricle_19
```

Step 1: Load one timestep and mesh in ANSYS

- Can be done through conversion of STL to stp (with Creo or Solidworks)
- Other approaches (Spaceclaim) also possible
- No specific requirements for meshing

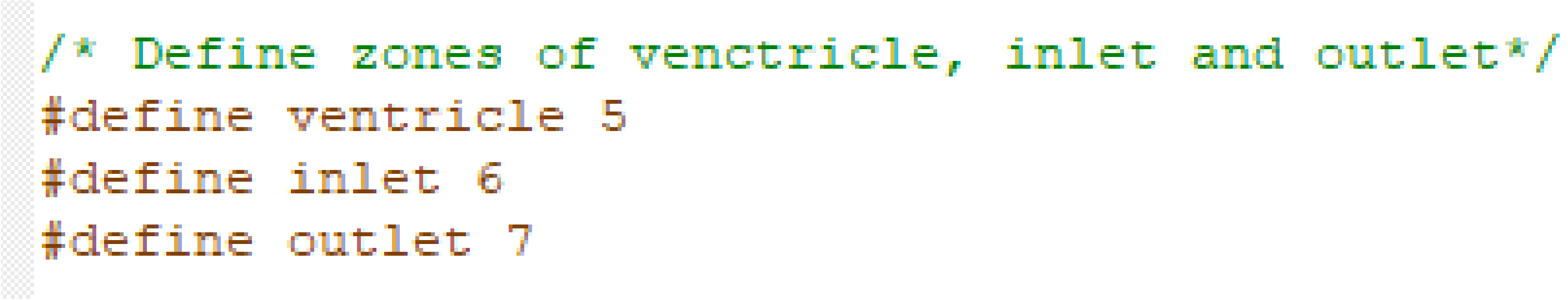
Step 2: Use UDF udf_extPts.c through ANSYS Fluent

- Open FLUENT: Node Memory is used -> user defined -> memory -> turn on node Memory and adjust to number of used cores
- Check and adjust the zone IDs of the outer walls (here: Inlet, outlet and wall-ventricle) in the UDF (if necessary)



Boundary Conditions
- inlet (wall, id=6)
- interior-ventricle (interior, id=1)
- outlet (pressure-outlet, id=7)
- wall-ventricle (wall, id=5)

Dynamic Mesh

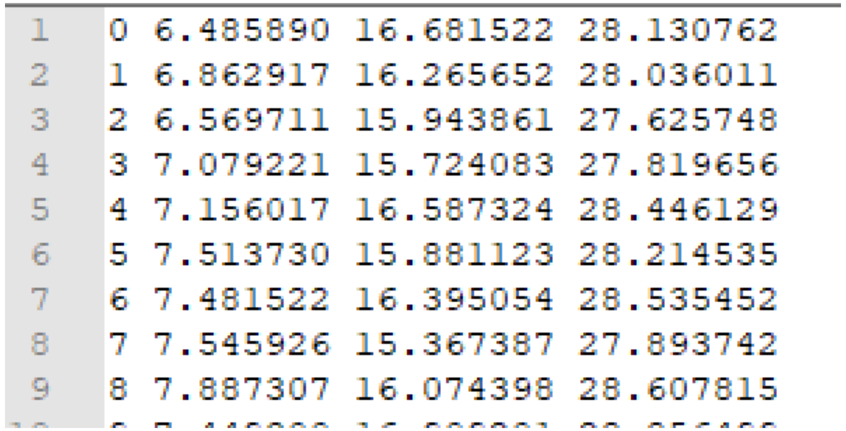


```
/* Define zones of venctricle, inlet and outlet*/
#define ventricle 5
#define inlet 6
#define outlet 7
```

Step 2: Use UDF udf_extPts.c through ANSYS Fluent

- Use of UDF in ANSYS Fluent
  - User defined -> functions -> compiled -> choose udf_extPts
  - User defined -> execute on demand -> First_AssignID
  - File „surface“ is created in the simulation folder
  - Number of nodes for each core are shown in the console (Will be necessary for udf_exeDynMesh)

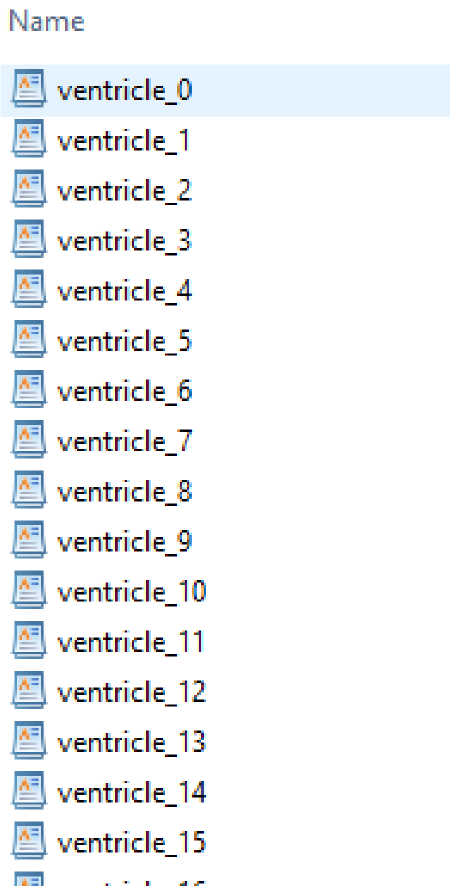
surface file



```
0 6.485890 16.681522 28.130762
1 6.862917 16.265652 28.036011
2 6.569711 15.943861 27.625748
3 7.079221 15.724083 27.819656
4 7.156017 16.587324 28.446129
5 7.513730 15.881123 28.214535
6 7.481522 16.395054 28.535452
7 7.545926 15.367387 27.893742
8 7.887307 16.074398 28.607815
```

Step 3: Create STL folder

- Copy and rename existing STL files (of all time steps) into the folder STL
  - "ventricle_n" with n starting from 0
  - Folder STL is in the same location as code ps_detNPts.py



Name

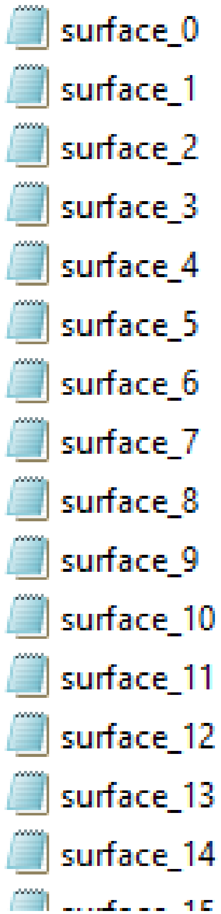
ventricle_0
ventricle_1
ventricle_2
ventricle_3
ventricle_4
ventricle_5
ventricle_6
ventricle_7
ventricle_8
ventricle_9
ventricle_10
ventricle_11
ventricle_12
ventricle_13
ventricle_14
ventricle_15

Step 4: Execute ps_detNPts.py ➔ STL to PTS

- With python e.g. in Sublime Text 3 or Spyder
- If first execution: Answer Do you need to generate correlation file? Yes: 1. No: 0. with “1” beantwortet
- The reference frame ID is the number of the STL-file in the folder STL, that has been loaded and meshed with ANSYS (see step 1).
- Output:
  - Number of Faces
  - allPtsNum

Step 4: Execute ps_detNPts.py ➔ STL to PTS

- First timepoint of cycle as Start FrameID (commonly 0)
- Last used timepoint as End FrameID
- Code creates "surface_" files in a folder PTS



surface_0
surface_1
surface_2
surface_3
surface_4
surface_5
surface_6
surface_7
surface_8
surface_9
surface_10
surface_11
surface_12
surface_13
surface_14
surface_15

Step 5: Execute ps_intNPts.py ➔ PTS to UDFPTS

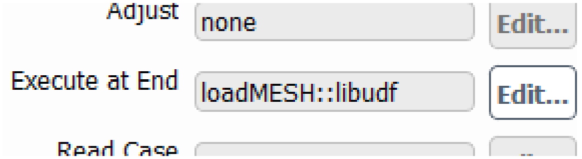
- Execute the ps_intNPts code in (same location as PTS folder)
- Set number of stl files per cycle as „Total number of frames in a cycle”
- Set number of interpolation steps (timesteps form simulation) „Number of intermediate frames“
- Choose a temporal interpolation method between the frames
- Output of Total Number of Frames after interpolation: # of timesteps for one cycle
- Code creates udfsurface.asc files in folder UDFPTS ➔ necessary for mesh movement

Step 6: Adjust udf_exeDynMesh.c

- Before execution several parameters in „dynMesh“ UDF have to be set:
  - nTimeSteps: Number of timesteps= maximum index of udf_surface (output of ps_intNPts.py)
  - allPtsNum: Number of all nodes, output of ps_detNPts.py
  - PtsNum[]: number of points per core (saved as array); Console output after execution of UDF First_Assign_ID (see slide 6)

Step 6: Execute udf_exeDynMesh.c

- User defined -> functions -> compiled -> choose dynMesh
- User defined -> functions -> function hooks -> execute at end -> add loadMesh
- Put folder UDFPTS into folder „Fluent“ of the simulation (same location of the „surface“ file, slide 6)
- User defined -> functions -> execute on demand -> First_load Mesh



Adjust none

Execute at End loadMESH::libudf

Read Case

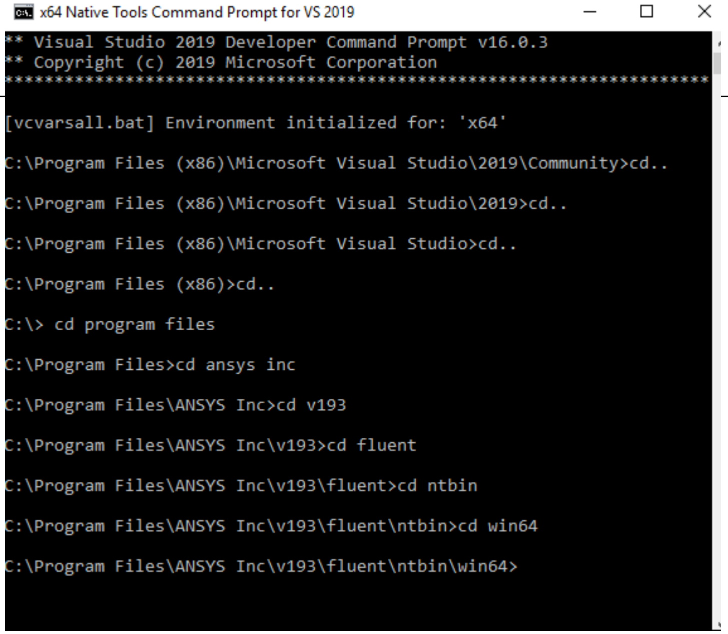
If compiling doesn‘t work

1. Compute locally(Desktop)

2. Compiling of UDFs

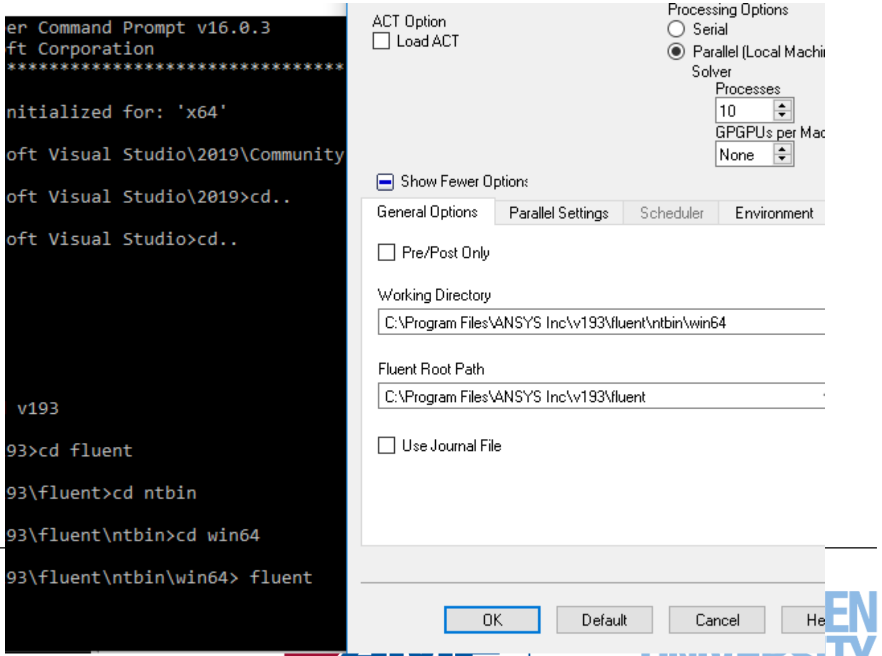
compiling with Native visual command prompt

Go to path and open fluent: enter fluent + ENTER



```
** Visual Studio 2019 Developer Command Prompt v16.0.3
** Copyright (c) 2019 Microsoft Corporation
**********************************************************************

[vcvarsall.bat] Environment initialized for: 'x64'

C:\Program Files (x86)\Microsoft Visual Studio\2019\Community>cd..

C:\Program Files (x86)\Microsoft Visual Studio\2019>cd..

C:\Program Files (x86)\Microsoft Visual Studio>cd..

C:\Program Files (x86)>cd..

C:\> cd program files

C:\Program Files>cd ansys inc

C:\Program Files\ANSYS Inc>cd v193

C:\Program Files\ANSYS Inc\v193>cd fluent

C:\Program Files\ANSYS Inc\v193\fluent>cd ntbin

C:\Program Files\ANSYS Inc\v193\fluent\ntbin>cd win64

C:\Program Files\ANSYS Inc\v193\fluent\ntbin\win64>
```

In launcher: set core numbers
Working directory where simulation has been saved



```
er Command Prompt v16.0.3
ft Corporation
******************************

nitialized for: 'x64'

oft Visual Studio\2019\Community

oft Visual Studio\2019>cd..

oft Visual Studio>cd..




 v193

93>cd fluent

93\fluent>cd ntbin

93\fluent\ntbin>cd win64

93\fluent\ntbin\win64> fluent
```

ACT Option
□ Load ACT

Processing Options
○ Serial
● Parallel (Local Machi

Solver
Processes
10
GPGPUs per Mac
None

⊟ Show Fewer Options

□ Pre/Post Only

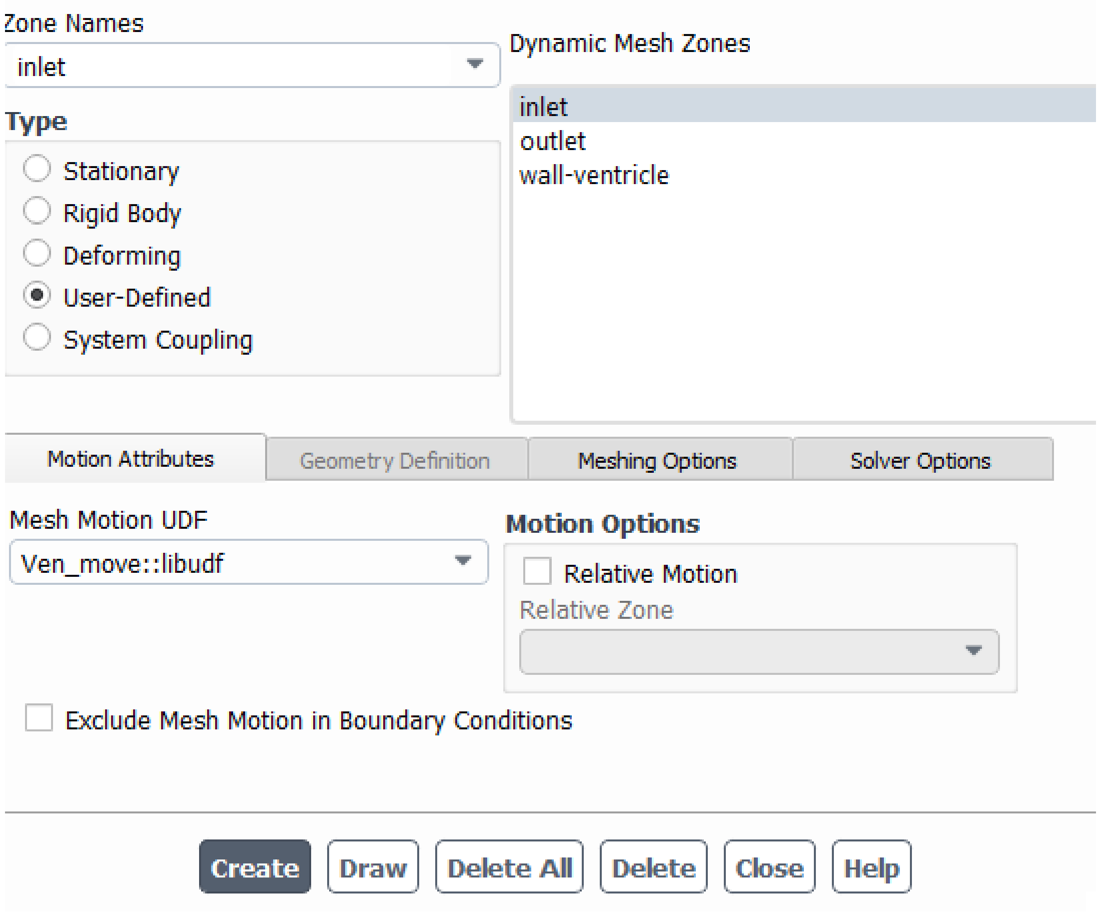
Working Directory
C:\Program Files\ANSYS Inc\v193\fluent\ntbin\win64

Fluent Root Path
C:\Program Files\ANSYS Inc\v193\fluent

□ Use Journal File

Use udf_exeDynMesh.c

- Dynamic Mesh -> Dynamic Mesh zones -> create/edit -> user defined funktion for inlet, outlet, wall-ventricle erstellen



Zone Names: inlet

Type

○ Stationary
○ Rigid Body
○ Deforming
● User-Defined
○ System Coupling

Dynamic Mesh Zones:

inlet
outlet
wall-ventricle

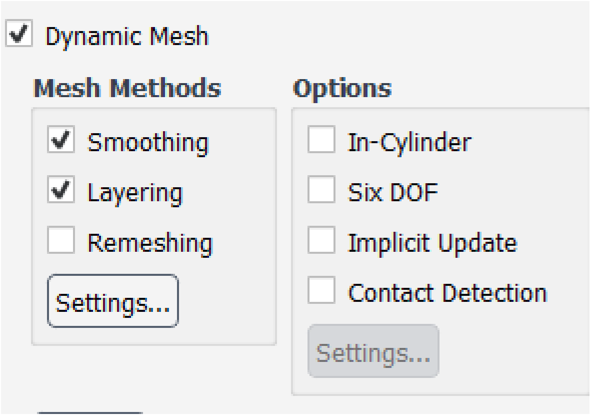
Mesh Motion UDF: Ven_move::libudf

Motion Options

□ Relative Motion
Relative Zone:

□ Exclude Mesh Motion in Boundary Conditions

Dynamic Mesh Settings



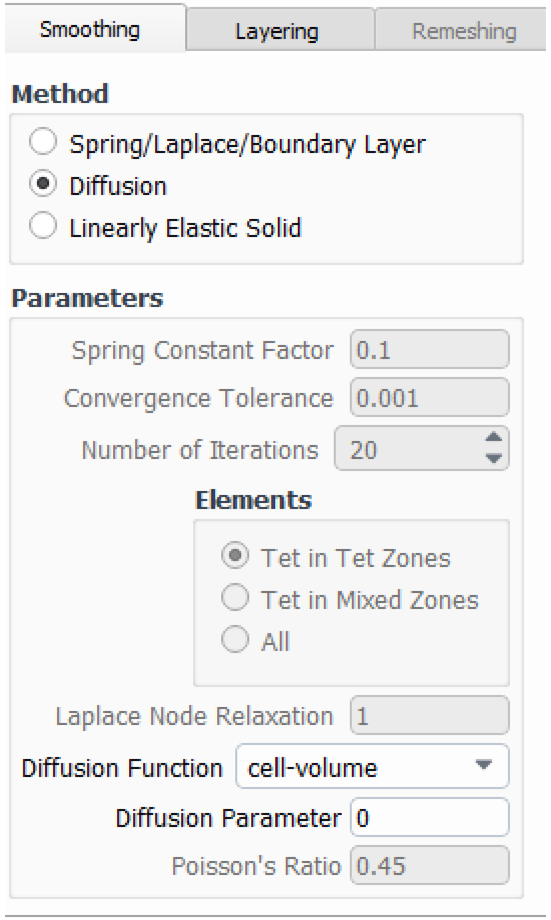
☑ Dynamic Mesh

Mesh Methods

- ☑ Smoothing
- ☑ Layering
- □ Remeshing

Options

- □ In-Cylinder
- □ Six DOF
- □ Implicit Update
- □ Contact Detection



Method

- ○ Spring/Laplace/Boundary Layer
- ● Diffusion
- ○ Linearly Elastic Solid

Parameters

Spring Constant Factor 0.1

Convergence Tolerance 0.001

Number of Iterations 20

Elements

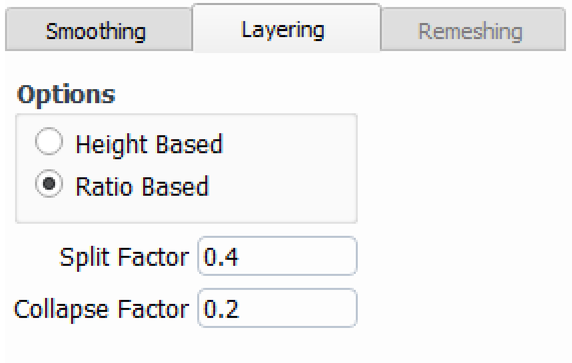
- ● Tet in Tet Zones
- ○ Tet in Mixed Zones
- ○ All

Laplace Node Relaxation 1

Diffusion Function cell-volume

Diffusion Parameter 0

Poisson's Ratio 0.45



Options

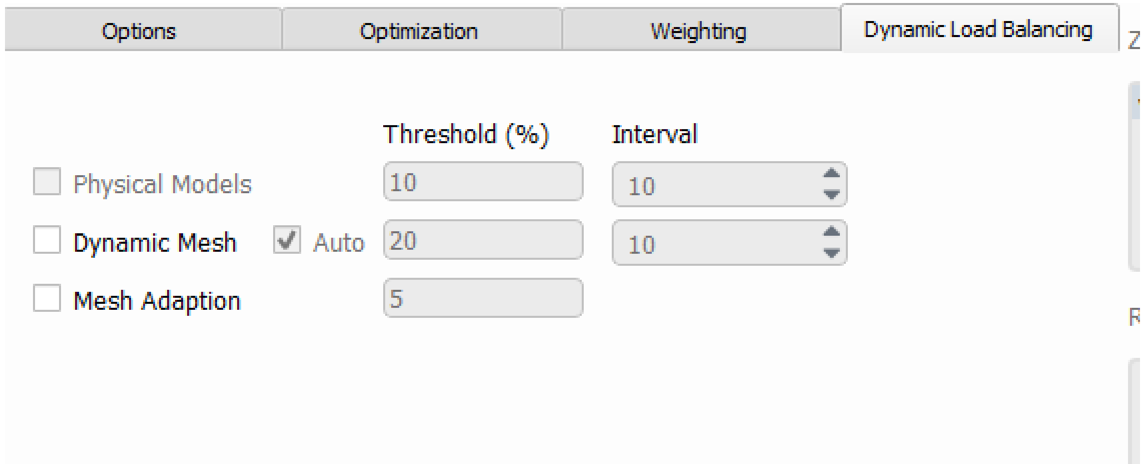
- ○ Height Based
- ● Ratio Based

Split Factor 0.4

Collapse Factor 0.2

Prohibit repartitioning

- Parallel -> Partition/Load Balance ->



		Threshold (%)	Interval
□ Physical Models		10	10
□ Dynamic Mesh	☑ Auto	20	10
□ Mesh Adaption		5	

Mesh motion

- Before simulation start ➔ preview mesh motion
  - Preview Mesh Motion
- If mesh movement doesn‘t work (e.g. negative cell volumes):
  - Fluent in serial model→ Neustart Fluent → Fluent Launcher ***serial***
  - Recompute mesh nodes (steps 2 -5)
  - Settings: Dynamic Mesh → Mesh Methods → Remeshing with default settings

Valve opening/closing

- In „Dynamic Mesh“ → „Events“ set three events
  - Inlet to wall
  - Outlet to pressure-outlet
  - Profile to pressure-outlet

- Initialise simulation, then firstloadmesh, then simulation starten
- At end of cycle NO initialisation, but
  - Inlet to pressure-inlet, Outlet to wall
  - Event – time adjusted to MV closing of next cycle
- start w/o initialisation

Contact

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