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Moving Mesh Examples

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1 Introduction

There exists an increasing number of requests to simulate flow-configurations with moving parts. StarCD offers a lot of possibilities for such calculations:

- General Mesh Movement
- Sliding Meshes
- Cell-layer Removal/Addition
- Cell Attachment and Change of Fluid Type
- Mesh Region Inclusion/Exclusion

The major problems involved with sliding mesh calculations will be illustrated with the help of the transient calculation of a side channel fan. This example includes mesh generation, numerical control and the handling of the transient data.

The second example - a Rotating Valve - requires the use of moving partial boundaries.

The third example - a Rotary-Vane-Pump - additionally requires cell layer removal/addition. Only a simplified model will be presented as there are limitations in this feature.

2 Side-Channel-Fan

2.1 Remarks

Side-channel-fans are turbomachines, which are comparable to torque-converters. They do not have symmetrie planes. Therefore always a complete machine has to be simulated. These calculations are possible either using a steady-state-approach (rotating frames) or a transient calculation (sliding mesh). The transient calculations lead to much better results as they take into account the rotor-stator-interaction between the blades and the stripper.

Unfortunately the transient calculations require much more computing time and produce a large amount of data. Also additional steps are required to get a stable run during all time steps.

2.2 Mesh Structure

Figure 1 shows a typical configuration with curved blades and a curved stripper. For such a geometry it is nearly impossible to create a good continuous mesh. Also even it would be possible to create a continuous mesh, it is not useful for a sliding mesh calculation.

Hence a mesh structure was choosen, which does not prefer one fixed impeller position.

For the calculation of the side-channel-fan one has to take into account the small gap between the blades and the stripper. This gap has a height between $0.15\,mm$ and $0.4\,mm$. The influence of this gap increases with an increasing pressure difference between inlet and outlet. To achieve a good efficiency of the machine, the gap should be as small as possible. In addition one has to ensure a safe performance of the machine, so that the gap should not be too small.

As this gap influences very much the results, it has to be included into the model. The sliding interface can now be placed within the gap (Figure 1).

Now all parts of the mesh are created independently and put together using arbitrary interfaces. This mesh structure also allows to exchange easily either the impeller part or the side-channel-part or to adjust the thickness of the gap.

The current mesh was created using PROSTAR for the impeller and the gap and SAMM for the side-channel with inlet and outlet. To avoid too many cells in the center of the side channel a coarser mesh was created in this area by replacing 8 original cells by 1 new cell using a macro.

Also other mesh structures become possible for steady state and transient calculations by using the Moving-Partial-Boundary feature.

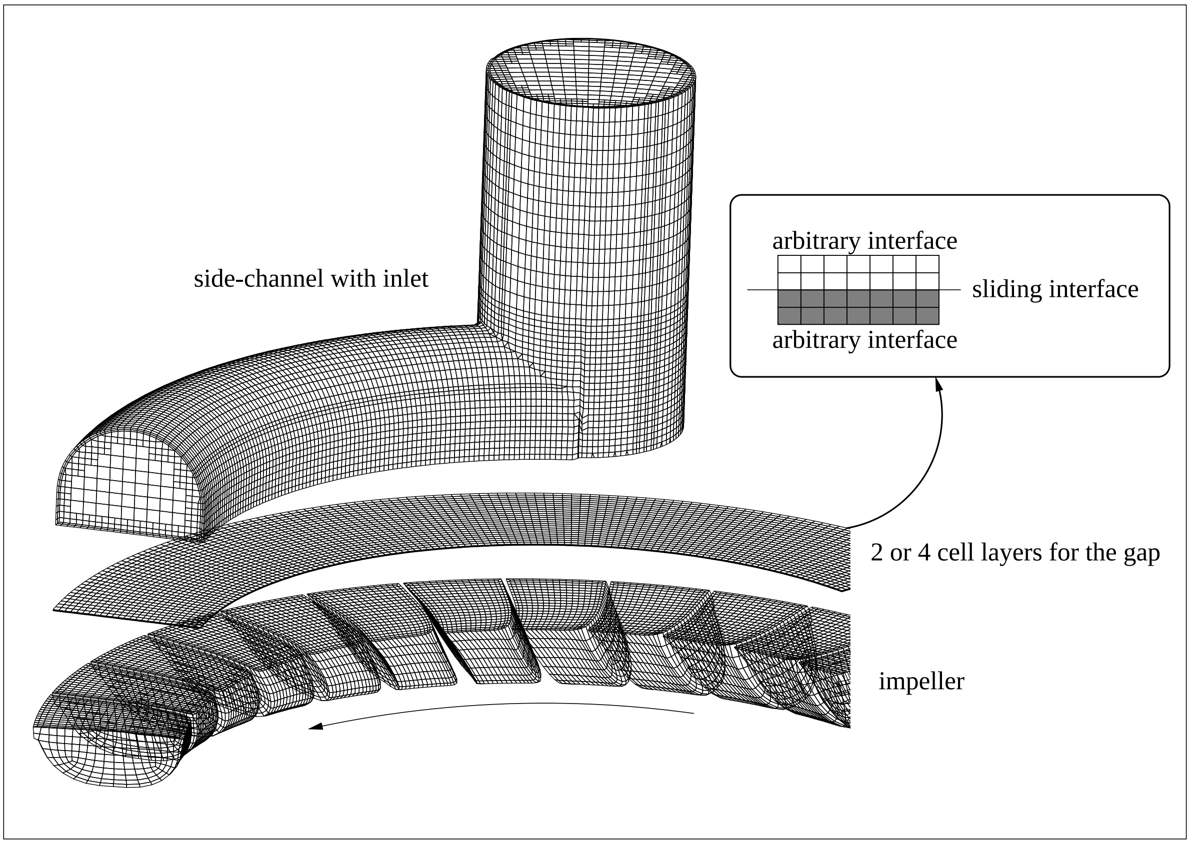

Figure 1: Typical mesh structure

2.3 Data Handling

Beside the local flow distribution, integral values like

- pressure and temperature difference between inlet and outlet
- mass/volume flux at inlet and outlet
- impeller-torque and efficiency

are interesting to judge the numerical solution of a turbomachine.

Because such a calculatoin requires several GB of hard disk space to store the complete flow field for most of the time steps, the user subroutine "posdat.f" was used to extract these data after each time step and write them to a file. From there they can be examined without interrupting the calculation or using PROSTAR.

Figure 2 shows the mass flux at the inlet and the outlet from the start of the calculation up to a periodic stage achieved after about two revolutions. This calculation was started with the results from a rotating frames run.

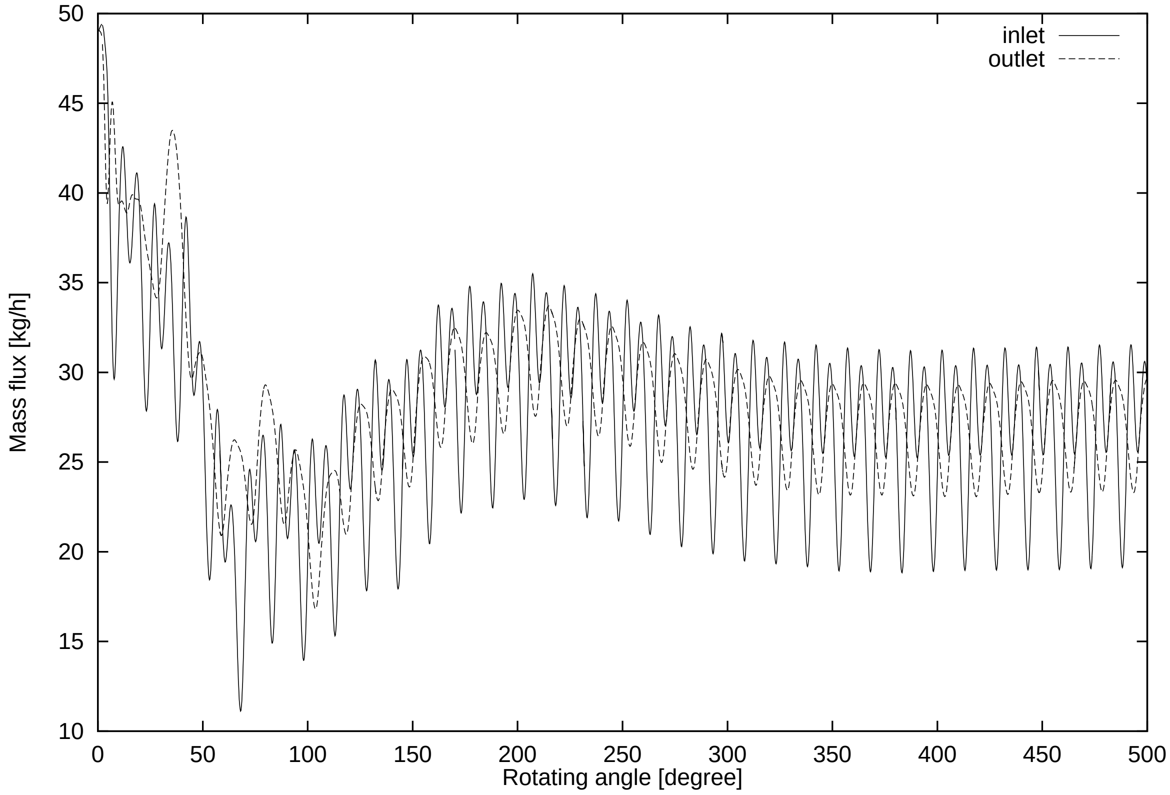

Figure 2: Mass flux during a sliding-mesh calculation at the inlet and outlet

2.4 Numerical Solution Control

To control the process of solution, the following parameters are important:

- time-step-size
- Reduction in Residual for Pressure Correction Stages
- Under-Relaxation Factor for Pressure Correction

Table 1 shows the used values of these parameters as a function of the angular velocity. It turned out, that the COURANT numbers which are printed in file 61 are not very useful to choose the size of suitable time steps.

Angular velocity	Time-Step-Size	Reduction in Residuals for Pres. Cor. Stages	Under-Relaxation Factor for Pressure Correction
3.000 rpm	0.2°/Step	0.15	0.8
14.000 rpm	0.1°/Step	0.1	0.2

Table 1: Numerical Parameters to control the transient calculation

Using these small time steps leads, beside the long computing time, to a stability problem. Because the mesh movement in Prostar is realized by means of single precicion floating point calculations, the mesh updates loose more and more accuracy during the calculation. So the impeller is accelerated in one time step and decelerated in the next time step, which implies strong pressure oscillations.

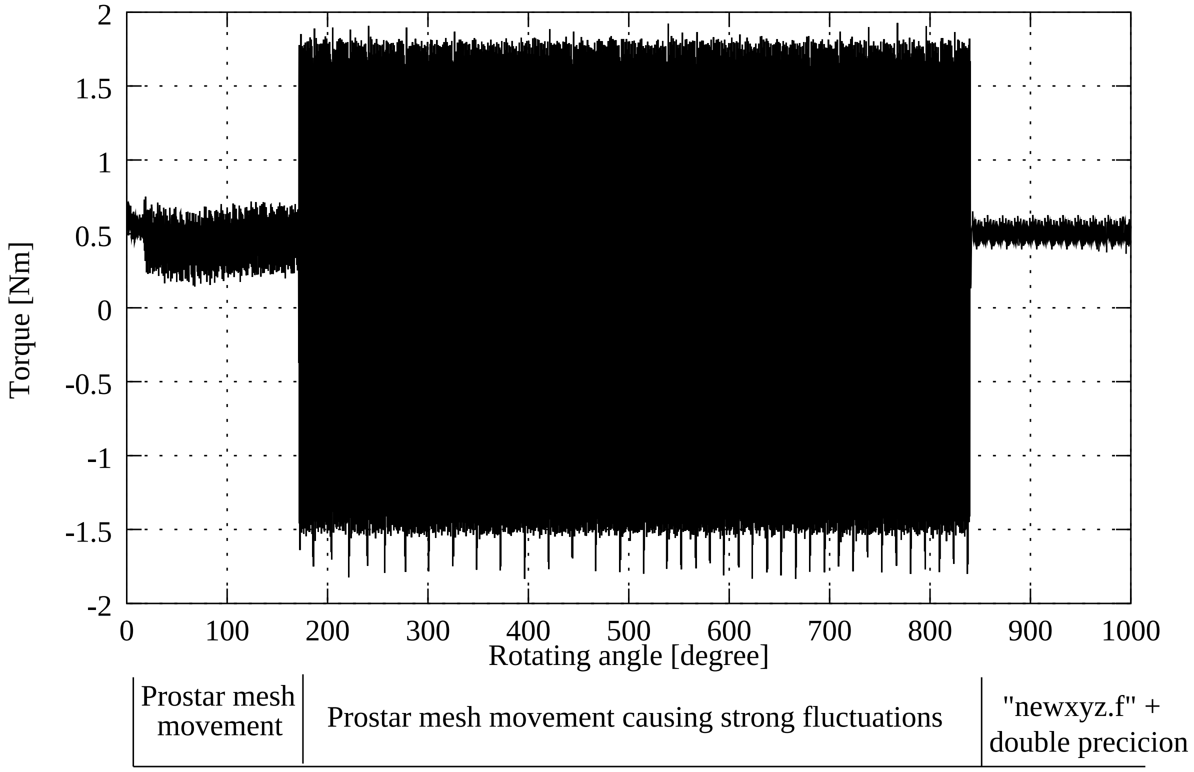

Figure 3: Impeller-Torque computed using "posdat.f"

Figure 3 shows how the impeller-torque changes during the calculation. The strong oscillations start at time step 857 (171.4°rotation) independently of the boundary conditions (different pressure differences).

To avoid these oscillations one has to calculate the mesh-movement using the "newxyz.f" subroutine and run the complete case with double precision. Figure 3 clearly shows, that the solution becomes stable again after switching the mesh movement from Prostar to the subroutine.

Another possibility to avoid the oscillations would be a change in Prostar to run the mesh movement using double precicion floating point calculation. This would be very useful for more difficult mesh movements like in case 3 (Rotary-Vane-Pump).

3 Rotating Valve calculation using Sliding Mesh and Moving Partial Boundaries (MPB)

Rotating Valves are often used in large printing machines to produce a periodic air flow, for instance to separate the paper sheets at the beginning of the printing process.

The main aim of this calculation is the prediction of the time dependent mass flux of air.

The calculation is regarded as a test of the MPB-feature, even though no experimental data are available for a validation of the computed results.

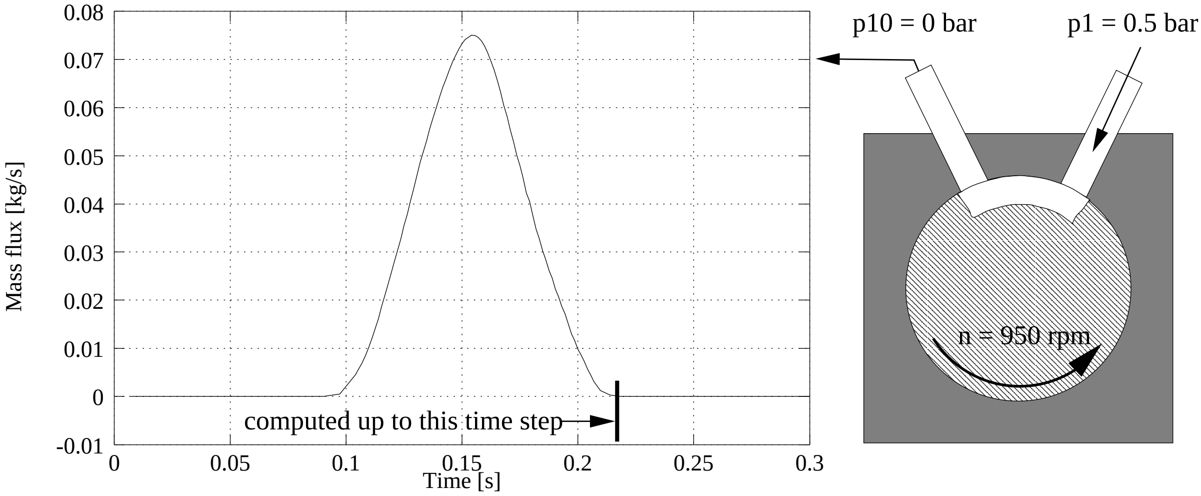

Figure 4: Time dependent Mass-flux at the valve outlet

Figure 4 shows how the mass-flux changes during the "hot" part of a revolution.

The mesh used for this calculation consists of a fixed inlet and outlet part and the moving valve part. The fixed and the moving parts are sometimes connected during a revolution by moving partial boundaries.

During a revolution the boundary types of the mpb change from "connected" to moving or fixed walls. The attach-boundary at the inlet/outlet part has a moving wall as the alternative region. The rotating cylinder has a fixed wall as alternative boundary region.

If more than the "hot" part of a revolution should be simulated, an exclusion of the inlet part is required. It has not been done for the present calculation so that it stopped with a error message (negative density at more than 100 cells) after the moving cylinder passed the inlet part.

Another possibility would be to modell a larger part of the flow configuration either by using GT-Power or just a larger Star modell. By doing this the transient characteristic of the complete system can be analysed.

4 Rotary-Vane-Pump

Rotary-Vane-Pumps are used as vacuum pumps. The setup of the calculation is similar to the Rotating-Valve. The major differences are:

- the mesh movement is not a plain rotation
- there exists a small gap ($0.15\,mm$) where the cells have to be deactivated, while they are passing the gap.

The problem here is, that STAR requires that the cells are activated in an order reverse to the order they have been deactivated (last in - first out). The present case requires that the first deactivated cell is also the first reactivated cell (fifo).

Due to this limitation it was not possible to calculate the original geometry. Using a gap of $2.5\,mm$ the deactivation of cells was no longer required and the calculation run without problems.

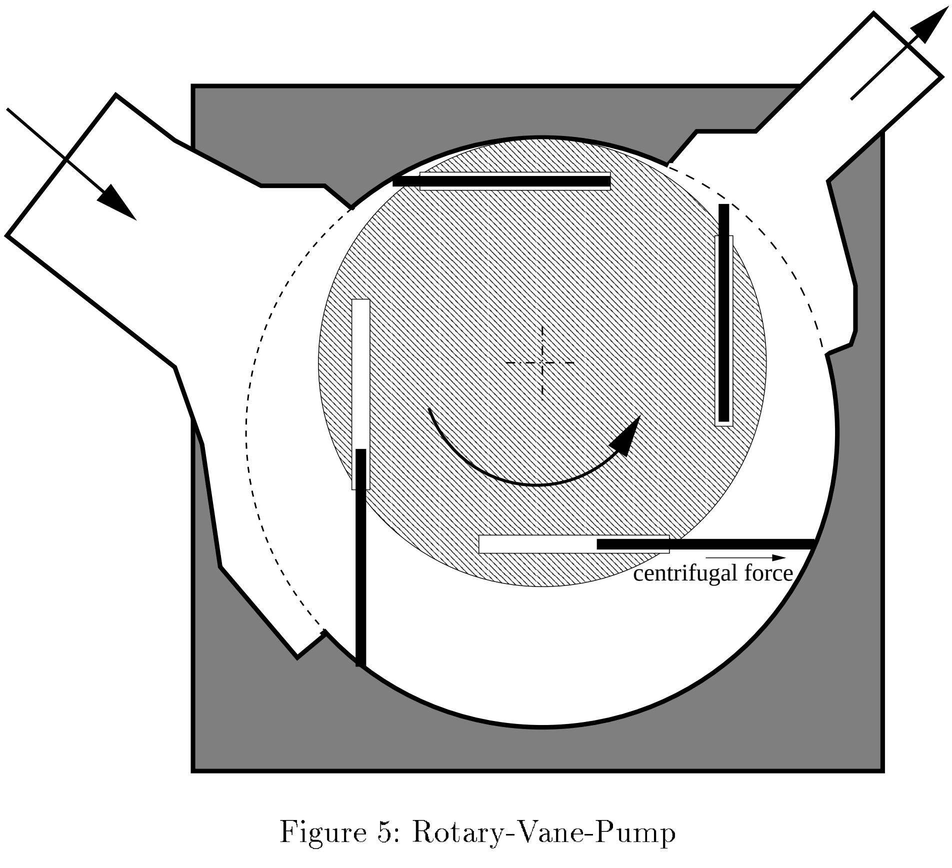

Figure 5: Rotary-Vane-Pump

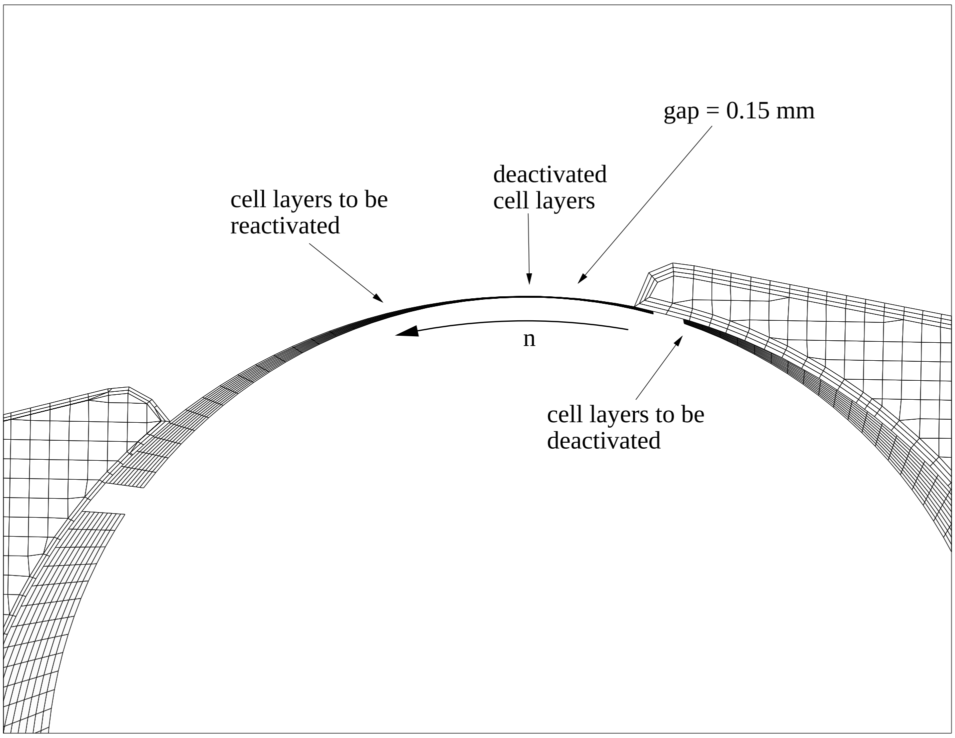

Figure 6: Mesh for the Rotating-Vane-Pump

5 Conclusion

StarCD provides many features, which allow the modelling of a wide range of moving mesh problems.

Because these are transient calculations which require a lot of computing time they have to be prepared very carefully.

The modelling of the Rotating-Vane-Pump is not possible using the original geometry due to a limitation in the cell layer removal/addition feature.

References

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