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Multiple Reference Frame (MRF) in FLUID DYNAMICS ENGINEER ROLE

The multiple reference frame (MRF) is a steady-state approach used in computational fluid dynamics to model the rotating reference in certain simulations which involve fluid interaction with rotary components. The examples can include fluid flow inside centrifugal pumps, turbines, compressors etc. In this writeup, the theory behind MRF is explained and an example with airflow past a rotating propeller is shown with the aid of 3DExperience fluid dynamics engineer.

Background

In fluid dynamics, you can analyze flow either in an inertial (stationary) reference frame or a non-inertial (rotating) reference frame.

- Inertial Frame: Observers in this frame view the rotating object as moving, while the fluid is stationary.
- Rotating (Non-Inertial) Frame: Observers in this frame view the rotating object as stationary, while the surrounding fluid appears to move with an apparent force.

MRF applies a rotating reference frame to specific zones of the computational domain to mimic the effects of rotation in a simplified, steady-state context.

The MRF approach involves dividing the simulation domain into two or more regions: A rotating zone around the rotating component (like a fan, impeller, or blade) and a stationary zone representing the surrounding stationary parts (e.g., casing or external flow).

MRF applies a rotational velocity to the rotating zone, assuming that this region is in a steady-state rotating reference frame. The governing equations in this rotating frame take into account additional forces due to rotation, such as centrifugal and Coriolis forces.

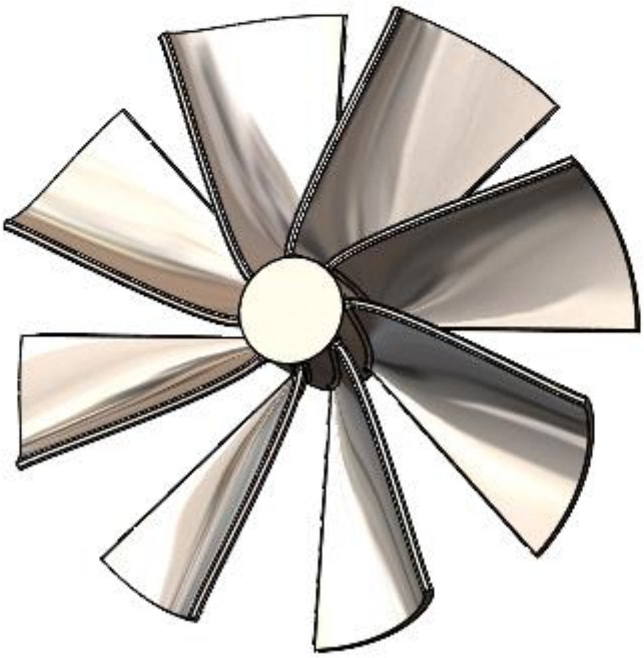
MRF uses a frozen interface between the rotating and stationary zones, meaning the boundary between these two zones remains fixed. The flow velocities at this interface are calculated as though the rotating and stationary parts are adjacent, without actual physical movement. This simplification allows steady-state simulation by avoiding the need for time-dependent mesh motion.

At the interface:

- The relative velocity field from the rotating zone is transferred to the stationary zone.
- There is a smooth transition of velocity and pressure fields across the interface, with the rotation effects accounted for in the rotating zone only.

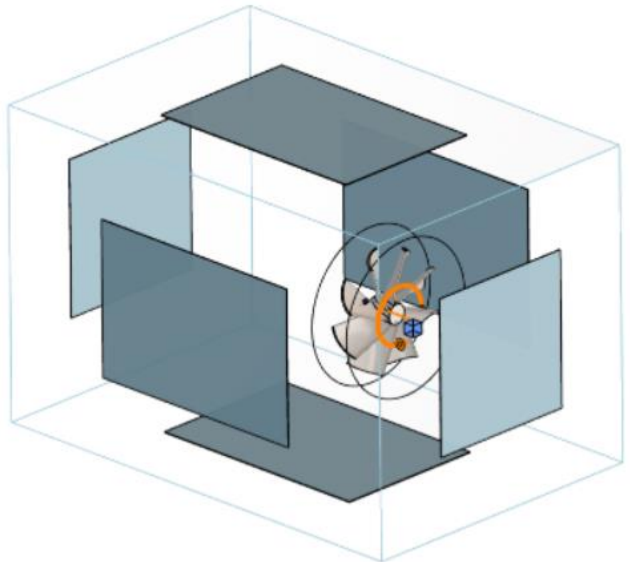
Airflow past a rotating propeller (3DEXEPERIENCE Fluid Dynamics Engineer)

In this example, you simulate steady-state airflow past a rotating propeller to analyze the propeller's performance. The propeller model (shown below) has eight identical blades attached to a central hub. The central hub includes space for a shaft that is connected to a rotor. The diameter of the propeller is 375 mm, and the hub has a length of 88 mm. The propeller rotates at an angular velocity of 20 revolutions per minute (RPM) and is operating in an open environment. Having a relatively low value for the RPM reduces the simulation's run time.



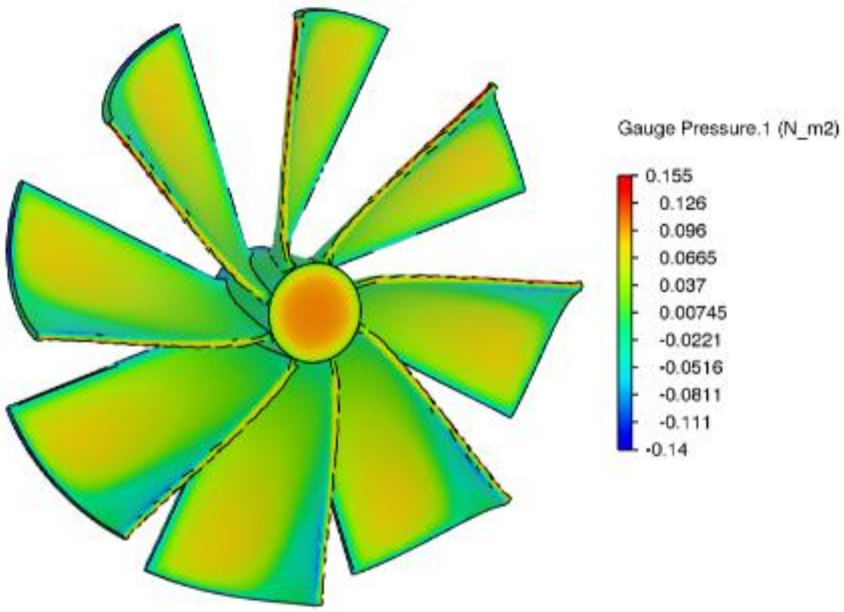
Rotating impeller

A dump solid (cylinder) is drawn over the impeller. A separate fluid region is created inside this body and MRF rotating region is added to this fluid section.

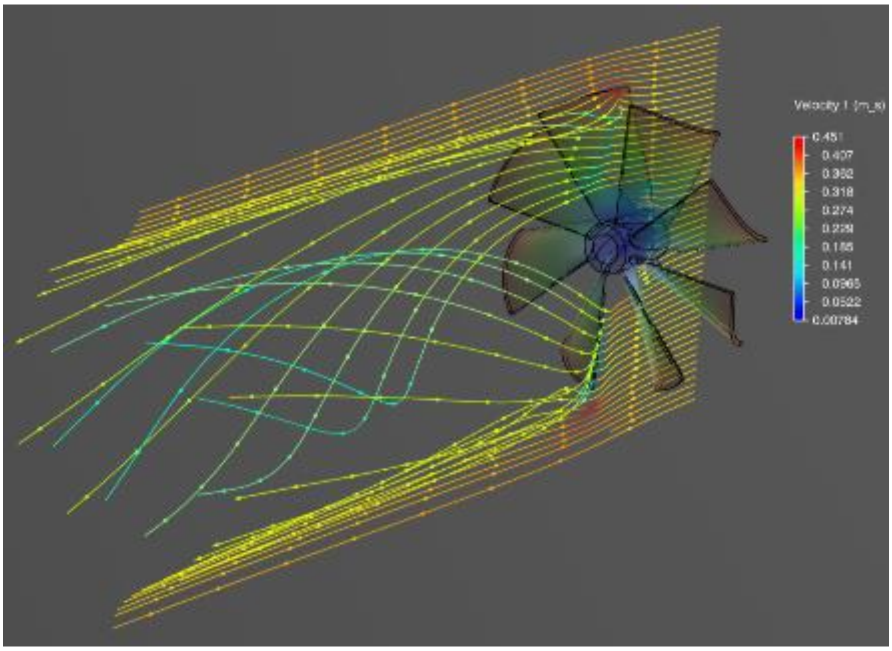


Computational domain with rotating region

The flow results are shown below. The rotating flow after impeller in the flow trajectory shows that the rotating zone is implemented properly.



Gauge pressure



Velocity flow trajectory

Summary

The MRF technique provides a steady-state solution by applying a rotating reference frame to the rotating zones in the domain, capturing the rotational effects without actual motion. By adding centrifugal and Coriolis forces in the governing equations and using a fixed interface, MRF allows CFD simulations to approximate the effects of rotation efficiently. This makes it an effective choice for many preliminary analyses and steady-state applications involving rotating machinery.

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