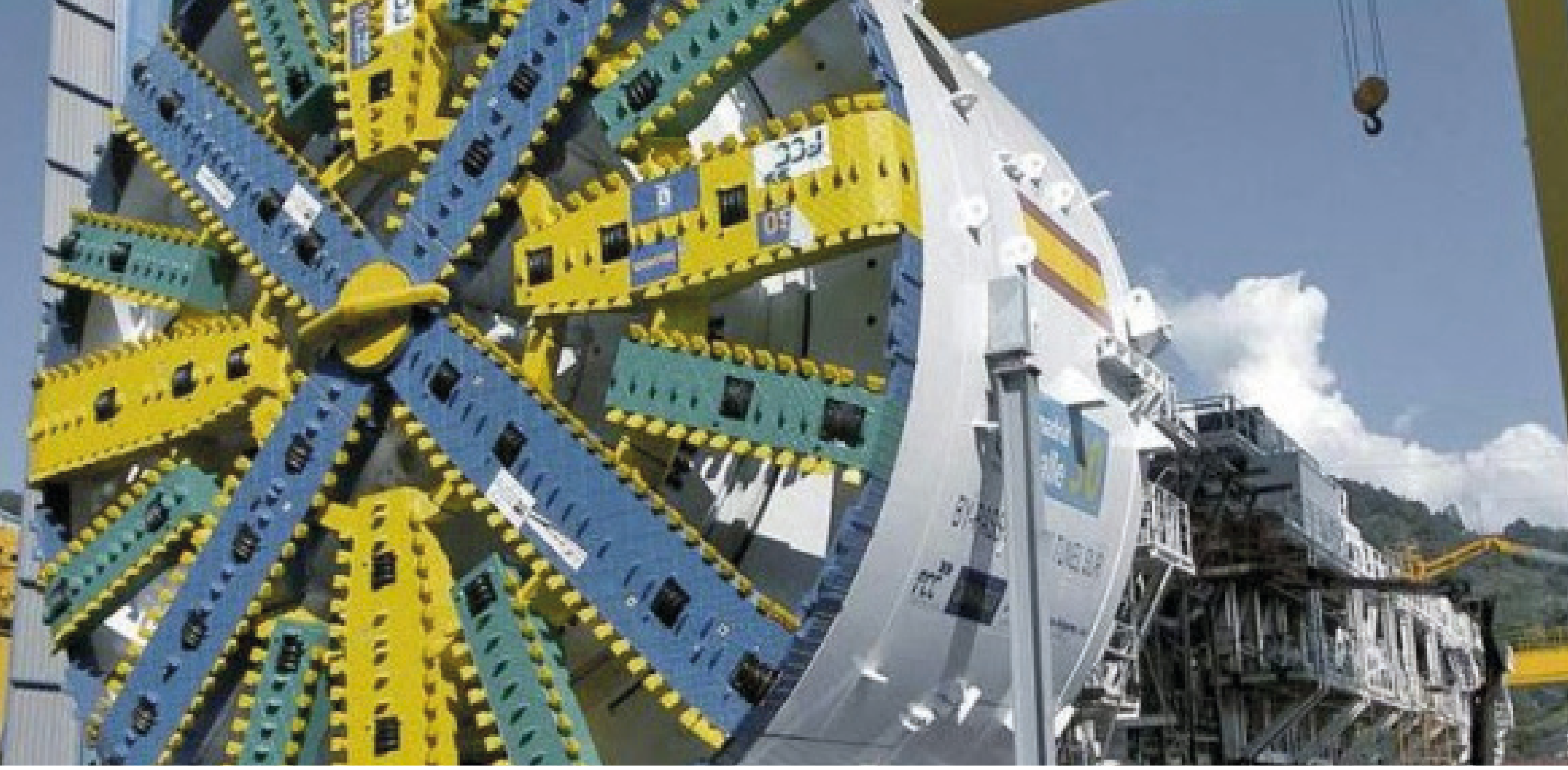

Reliable hydraulic direct drives for improved performance

Torque and losses prediction, calculation of oil residence time and understanding the flow path are key factors during the development phases of a hydraulic motor

This article present the study of a radial piston hydraulic motor using a mesh-less CFD methodology called Moving Particle Simulation and available in the Particleworks software. Torque and losses prediction, calculation of oil residence time and understanding the flow path are key factors during the development phases of the motor. The geometrical complexity and the moving parts of the system are easily handled by the mesh-less CFD methodology.

Rexroth
Bosch Group
The Drive & Control Company

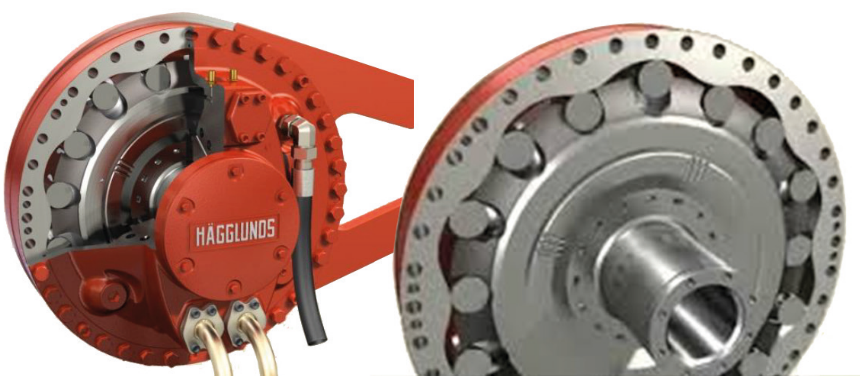

Figure 1 - Cam and piston arrangement of the Radial Piston Engine

Introduction

Bosch Rexroth Mellansel AB delivers complete hydraulic drive systems for the industry, mainly where low rotational speed and high torque are required. Bosch Rexroth drive systems are applied in several industrial sectors for heavy duty applications, from the mining and materials handling to the cement industry, from the Oil&Gas to the pulp and paper industries and many others.

One part of the drive system is the Hägglunds Compact motor. This is a radial piston hydraulic motor with an outside cam arrangement. The housing of the motor is completely filled with hydraulic oil that aids in cooling and lubrication. Extra cooling is added in high power applications by flushing oil through the housing with an external pump.

Reliability and low environmental impact are important customer needs and are characteristic for Bosch Rexroth products. Continuous work on reducing losses is important to fulfill these needs. One source of losses in the motor is the resistance to the rotating motion of the shaft called churning losses. These losses are almost negligible in low speed applications, but at high speed, they will contribute to substantial heating of the motor casing. Churning losses come from drag by pushing oil in front of each roller in a similar way as in a rolling element bearing.

Understanding the oil flow in the piston engine, predicting the cooling efficiency and the churning losses is of paramount importance to improve the performance of the drive system and this has been pursued by Bosch Rexroth in the last years by building mathematical models that try to represent the oil flow inside the engine.

The geometrical complexity of the system and the motion of the shaft and cylinders make the modelling of the complete engine practically unfeasible for traditional fluid-dynamic techniques, based on computational mesh. That is why, so far, only partial models of portions of the system has been created and used to study the local oil behaviour.
Recently Bosch Rexroth decided to try a new methodology to simulate the oil flow inside the entire radial piston engine. This methodology is the Moving Particle Simulation (MPS) available in the Particleworks software. The MPS is a methodology to solve the Navier-Stokes equations, where the fluid volume is discretized by fluid particles instead of grid elements.
The mesh-free nature of the MPS allows easy modelling of complex geometries like the entire radial piston engine, with an easy definition of the motions of the shaft and cylinders and the simulation of the interaction between the moving bodies and the oil flow.

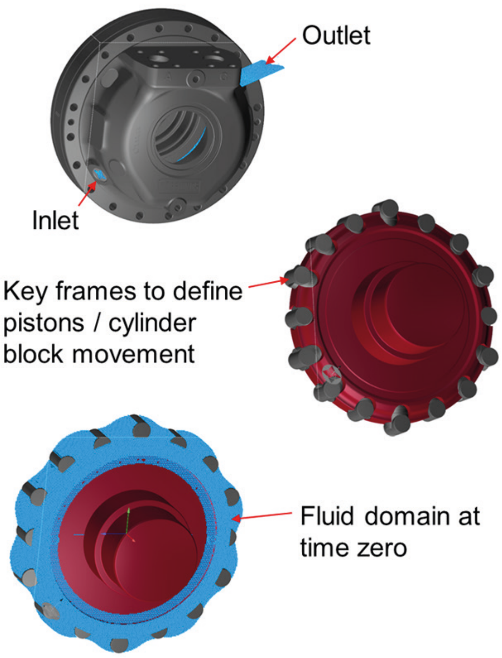

Figure 2- CAD objects of the Radial Piston Engine in Particleworks

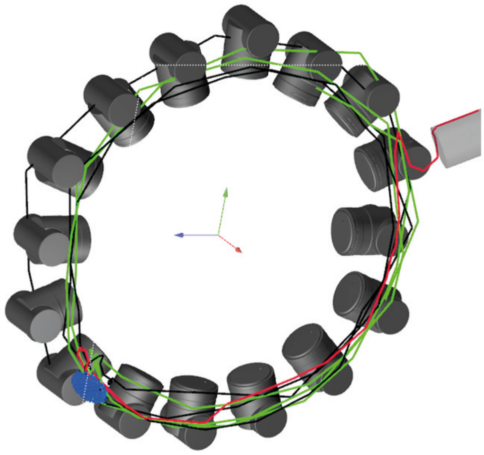

Figure 3- Individual oil particle tracking in Particleworks

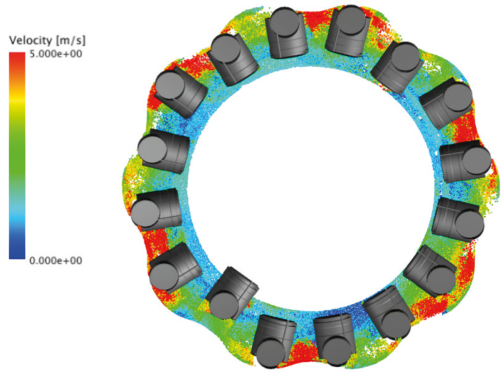

Figure 4- Velocity field between the piston and cam arrangement

In an initial test phase of the MPS methodology Bosch Rexroth built the model of the complete radial piston engine, from the oil inlet to the outlet and performed a number of simulations with promising results.
The 3D model was able to give a deep insight into the system behavior by taking into account every single detail of the engine (no assumptions, reductions or simplifications), and by giving quantitative outputs like churning losses, oil residence time, pressure and velocity in every single point of the engine.
Despite the complexity of the radial piston engine, the time and engineering effort to build the complete MPS model is quite small. The process starts with the direct import of the housing, cylinder

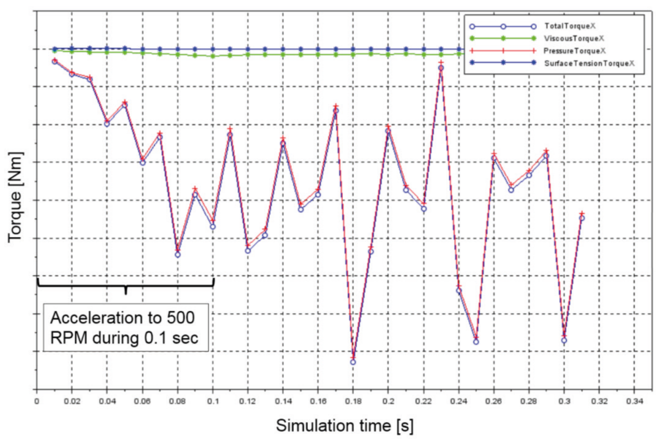

Figure 5 - Torque on the 16 pistons + Cylinder block

Figure 6 - Applications of the Hägglunds compact motor

block and pistons from the CAD into the Particleworks software. Neither geometrical simplifications nor mesh generation are needed.
Key frame scripts define the rotation of the cylinder block and the reciprocating movement of the pistons, while oil properties are defined in the software together with the physical and numerical models, that allow for the solution of the oil motion (Navier-Stokes equations).
The global time needed to create the MPS model starting from the CAD files is less than 1 hour. Running one transient simulation for a total time of 0.5[s] takes between 0.5 and 3.5 days depending on the level of accuracy and on the available hardware.
The level of accuracy in the MPS method is simply defined by the particle size that is applied to discretize the oil volume. Reliable results for the radial piston engine can be obtained with particle size of 1 mm, while very accurate results can be found decreasing the particle size down to 0.5 mm, that allows to solve in a better way the oil fluxes in all the small gaps of the system.
Globally the time to build and run the MPS model of the radial piston engine is between 1 and 4 days. This means that the use of Particleworks and the moving particle simulation really fits in the normal design process and can support the daily design activities of the engine.
Moreover the comparison of different designs of the engine or the investigation of how operating conditions like rpm, flow rate, oil properties affect the performance of the engine can be done virtually, by the use of fluid-dynamic simulation.
The benefit and value of this methodology is not only related to time and money savings in the development of the engine, but it is mainly associated to the knowledge that can be acquired by monitoring what happens inside the system.
In the figure 3 the oil particle location vs. time is plotted in the Radial Piston Engine. By tracking several oil particles the residence time and the circulation time of oil can be calculated, which gives indications of the temperature evolution.
In the figure 4 the velocity field between the pistons and cam arrangement is plotted.
In the figure 5 the total torque (churning losses) from surface tension, viscous force, and pressure force are plotted vs. time. The Radial Piston Engine accelerate during 0.1 sec to nominal speed 500 RPM. It is clear that majority of the torque comes from the pressure forces, in that fluid forces acting normal to the surfaces of the 16 pistons and the cylinder block.

Particleworks is a CFD software based on an advanced numerical method known as the Moving Particle Simulation (MPS) method. The mesh-free nature of MPS allows for robust simulation of confined and free-surface flows at high resolutions, saving the time need to generate meshes for the fluid domain.
Particleworks is distributed in Europe by EnginSoft. Particleworks is a product of Prometech, a Japanese company, founded by experienced professionals and researchers at the University of Tokyo in 2004.

Bosch Rexroth Mellansel AB delivers complete hydraulic drive systems to several industry sectors, like Material handling, Marine and offshore, Recycling, Cement, Rubber, Sugar and different Mobile applications.

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