CFD simulation for multiphase flow of transaxle brake using overset mesh method

Jaeyeol Cho, Department of Mechanical Engineering, Sogang University, Seoul, Korea
Nahmkeon Hur, Department of Mechanical Engineering, Sogang University, Seoul, Korea
Jongrak Choi, Department of R&D, LS Mtron, Gunpo, Korea

Long Abstract

Introduction

Transaxle is a combination of transmission, power shaft and brakes. Inside of the transaxle, there is oil for lubrication and cooling. This oil circulate all of transaxle parts. Cooling and lubrication are key elements of durability and performance of transaxle. Therefore the oil and air multiphase flow physics inside of transaxle are very important. Although significance of these elements, it is hard to approach to inside of transaxle. Especially inside of the transaxle brake, complicated multi physics phenomena are occur such as rotation of compact planetary gear, mixing oil and air, churning of flow and heat generation. In many practical cases ther are flow interrupting problem and overheating problem in brake. So flow information inside of brake has been needed. But it has been limited to measure accurate flow information inside of the brake by experiments and existing other prediction methods. CFD simulation can be good alternatives. But it is hard to simulate compact rotating gear system and circulating multiphase flow by unsteady simulation. Although simulation was completed, solving time is too long and accuracy is not sufficient. For these reason effective CFD simulation technique of multiphase fluid prediction is required.

Tadashi Yamada [1] simulated thermo-fluid characteristics inside of the powertrain. He predicted oil and air multiphase flow characteristics and conjugate heat transfer. He use VOF(Volume Of Fluid) method to simulate multiphase flow. And Mesh regeneration method to simulate rotating gears. All results were compared with experimental results. This numerical method used to improve prior parts. Miad Yazdani et al. [2] investigated effect of cooling oil according to oil speed. And simulated oil flow and temperature distribution inside of the simple gear system. They also used VOF method for multiphase flow and mesh regeneration method for rotating gears. Stosic [3] investigated oil and air multiphase flow and temperature charicteristic inside of compressor using screw gears. He also use VOF and mesh regeneration method. Nirvesh Mehta et al. [4] simulated oil flow and temperature contribution inside of the gearbox which contains three axis and ten gears. They use VOF method and MRF method for rotating gears.

This paper simulated real operation of planetary gear system and brake pad. By this simulation, oil and air multiphase flow circulation physics were predicted. Time dependent flow characteristics of brake was predicted at real operating conditions. Moving computational grid for rotating gear was simulated by overset mesh technique of STARCCM. Most of the prior rotating gear simulation used MRF(Multiple Reference frame) method in steady simulation and mesh regeneration method in unsteady simulation. MRF method is easy to implement but not accurate for this case. Mesh regeneration method takes too much time to solve the simulation. But by using this overset mesh technuque, rotating gear can be simulated more realistic and simulation solving time is much reduced compare with other methods. Standard K-epsilon turbulence modle is used for calculating turbulent flow of oil and air. VOFmethod was used for capturing interface of oil and air multiphase. Simulation is continued until the transaxle system reaches quasi-static state. At this time flow characteristics is predicted. By using this information we can analyze cooling effect of oil and find heating problem and flow stagnation problem. Consequently by using these flow information, the design of the existing brake can be improved. Also CFD technique of this rotating planetary gear simulation can be applied to other complicated gear simulation.

1. Domain and boundary condition

The schematic view of transaxle brake is shown in Fig. 1. Inside of the brake fluid region and solid region, stationary region and rotating region were seperated. Compuational grid number is about 8,000,000. Lubrication oil is filled half height of brake. Rotation rate is about 760 rpm for sungear, 363 rpm for planet gear, and revolution rate is about 136 rpm for planet gear.

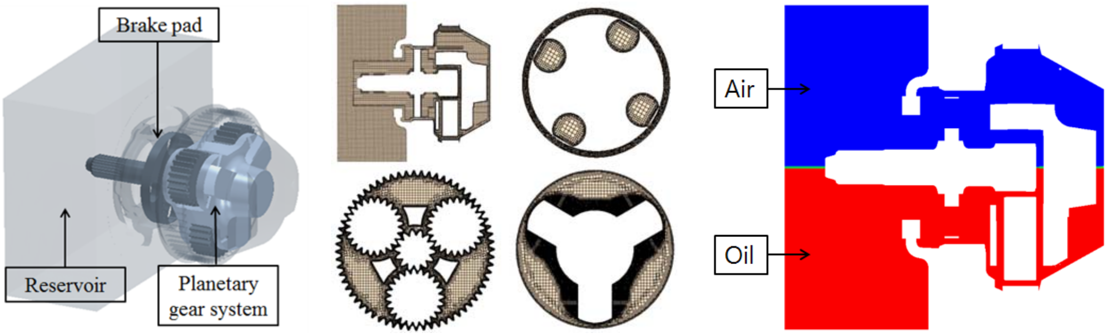

Figure 1. Schematic view of transaxle brake and boundary condition.

2. Result and discussion

Simulation result is shown in Fig. 2. After five seconds oil and air multiphase flow reaches to quasi-static state. Although there are four holes in brake pad, oil flowrate between left and right side of the brake pad is very low. Because rotating brake pad makes air layer and this air layer blocks oil circulation. So lubrication and cooling effect of oil is not sufficient.

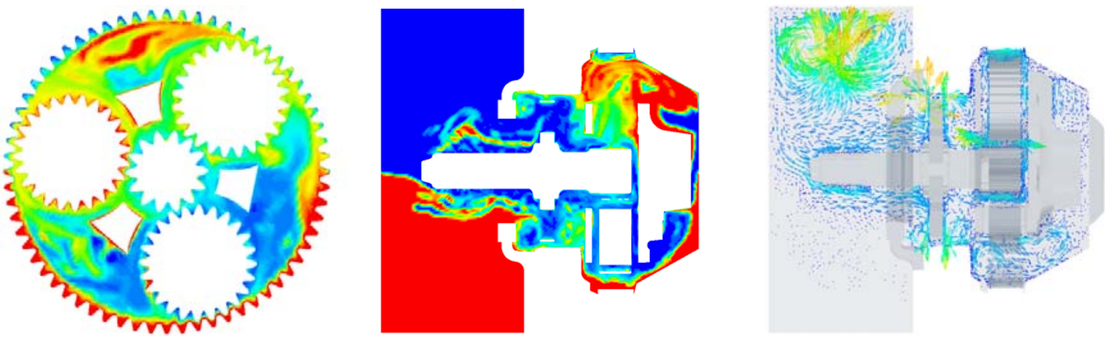

Figure 2. Oil volume fraction and velocity vector plot inside of the brake at quasi-static state.

References

[1] Tadashi Yamada. Measurement and prediction technology of cooling capability for hybrid drivetrain components. *Automotive simulation world congress*, powertrain session, 2014.

[2] Miad Yazdani. A novel approach for modeling the multiscale thermos-fluids of geared systems. *International journal of heat and mass transfer*, 72:517-530, 2014.

[3] N. Stosic. On heat transfer in screw compressors. *International journal of heat and fluid flow*, 51:285-297, 2015.

[4] Nirvesh Mehta, Ravi K. Dayatar, Nilesh J. Parekh. CFD analysis of gearbox. *International journal of engineering research & technology*, Volume 2, Issue 3, 2013.