Churning oil path optimization process development

Application of Moving Particle Simulation Method to Design Process

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Abstract

As demand of transmission efficiency goes higher, churning oil path and loss optimization is getting more important during the design stage.

However, CFD simulation not only takes long computing time but also needed dedicated mesh work for better simulation results. To design on time, bench tests have been preferred then simulation by engineers.

In this paper, Moving Particle Simulation (MPS) method has applied to reduce computing time and remove mesh work. And Correlation with bench test has done on different gear speed and temperature to decide adequate particle size and simulation coefficients.

This made possible to

(1) Development on time with optimized churning oil path and loss
(2) Minimize bench tests
(3) Access easy to design engineers.

As a result, we could make process with transmission of optimized oil flow during the design stage. And bench test shows successful result.

Introduction

During transmission design process, many different kinds of dynamic fluid simulations are required to analize oil flow. For the transsmission design, churning oil path is one of the most important design factors because it is directly related to efficiency of transmission.

However, with conventional process of oil flow simulation, it was impossible to apply simulation result to design because discrepancy of simulation time and time for design.

For the transmission design around 3-4 months are taken but to simulate with conventional method of Grid Method around 3-4 weeks are required.

To solve this problem, comparison of grid method and MPS method has done with simple transmission churning system.

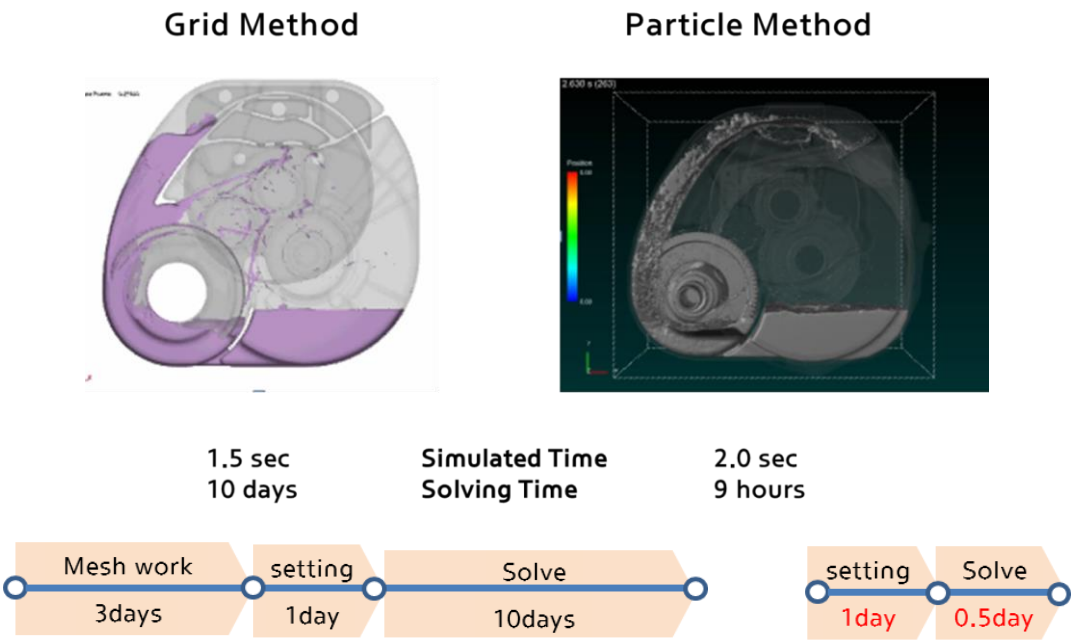


Fig. 1: Comparison of Grid Method and Particle Method

And result shows big progress of not only solving time but pre-process.
In this paper, all simulation has co-simulated with Softwares 'Particleworks' – to solve movement of particles and 'Recurdyn' – to solve dynamics of system.

Churning oil flow Bench test

To utilize MPS method to transmission design, bench test has done with transmission covered window and transparent rear cover.

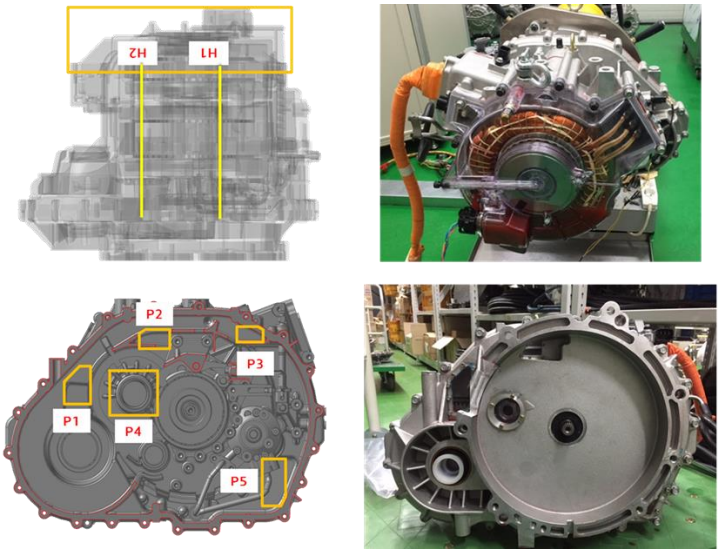


Fig. 2: Transmission with transparent rear cover and window

5 windows (P1-P5) show shape of flow and oil level, and bearing inflow. And rear cover shows H1, H2 flow which cools and lubricates traction motor and bearings.
And correlation has done with 2 points of temperatures and RPMs each. To cover low and mid-range RPMs which can have problems of oil flow.

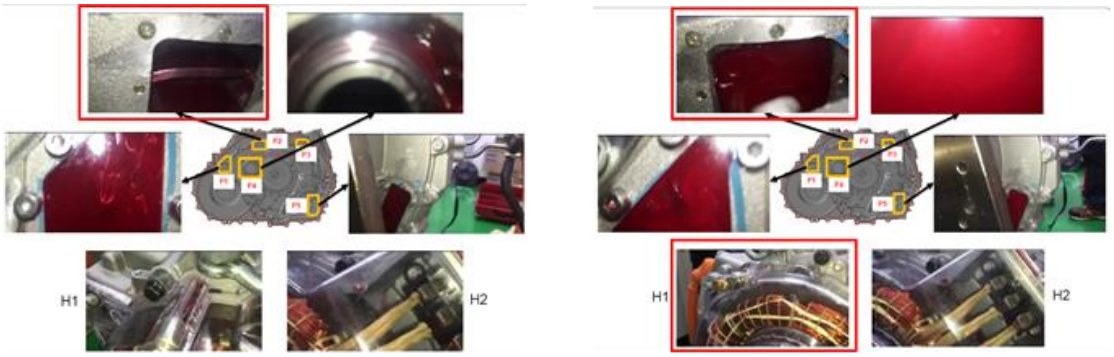


Fig. 3: Flow bench test of low, mid RPM (Room Temperature)

From low-range RPM, oil could not reach to P2, P4, H1, H2. But with mid-range oil reached to all points.

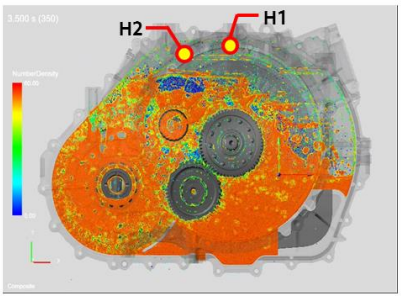
Fig. 4: Flow bench test of low, mid RPM (High Temperature)

Test with high temperature shows better flow shape which caused by low oil viscosity. For low-range RPM, all points got oil without H2. And mid-range RPM shows all points with enough oil supply.

Correlation to these bench tests has done to find out adequate coefficients of simulation. And simulation shows similar results of flow shape and oil reach.

▣ Oil Supply Test (Room Temperature)

Low speed

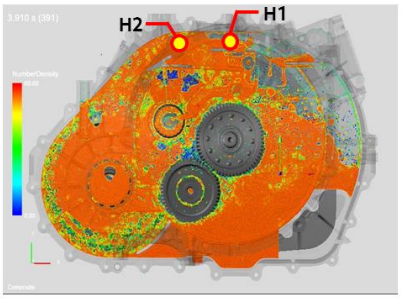


H1

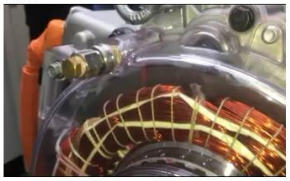
H2

Oil Supply	H1	H2
Simulation	X (no supply)	X (no supply)
Bench Test	X (no supply)	X (no supply)

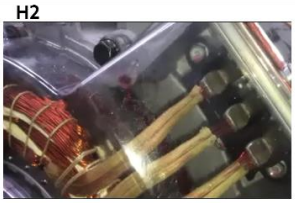
Mid speed



H1



H2

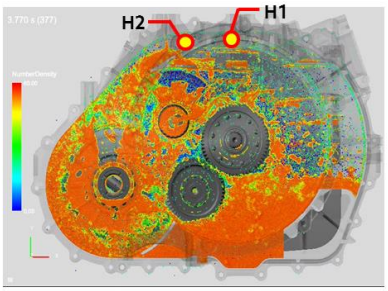


	H1	H2
Simulation	△ (moderate)	O (sufficient)
Bench Test	△ (moderate)	△ (moderate)

Fig. 5: Comparison Simulation with Test (Room Temp.)

▣ Oil Supply Test (High Temperature)

Low speed

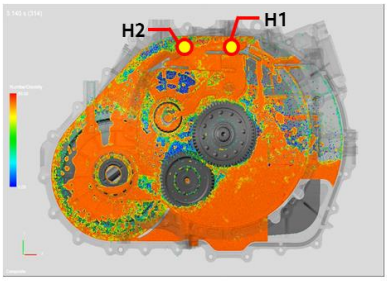


H1

H2

Oil Supply	H1	H2
Simulation	X (no supply)	O (sufficient)
Bench Test	X (no supply)	△ (moderate)

Mid speed



H1

H2

Oil Supply	H1	H2
Simulation	O (sufficient)	O (sufficient)
Bench Test	◎ (very sufficient)	O (sufficient)

Fig. 6: Comparison Simulation with Test (High Temp.)

Design optimization

To solve the problem of oil supply at low speed, several design parameters have found by many trials of simulation. Main factor of oil flow interruption was back flow effect. When churning oil goes up, if there is no holes to remove the oil that has kinetic energy, oil would rebounded by wall. Then rebounded oil falls from the high part of transmission and this causes interruption of new oils coming up.

▣ Flow optimization

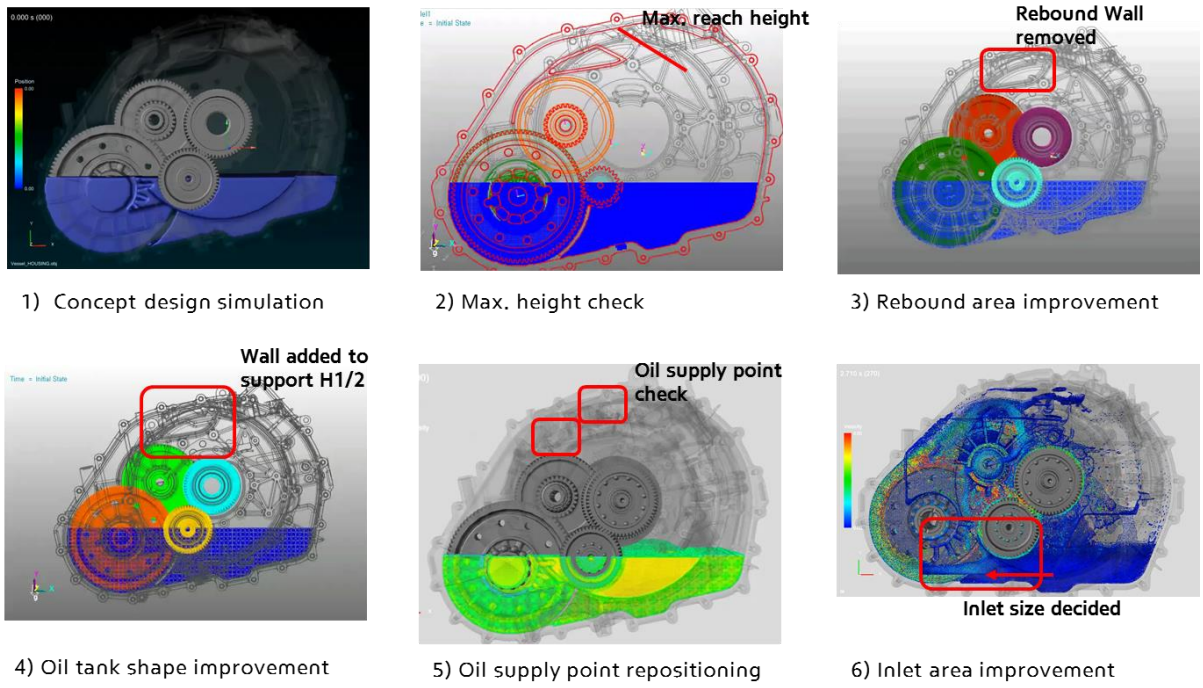
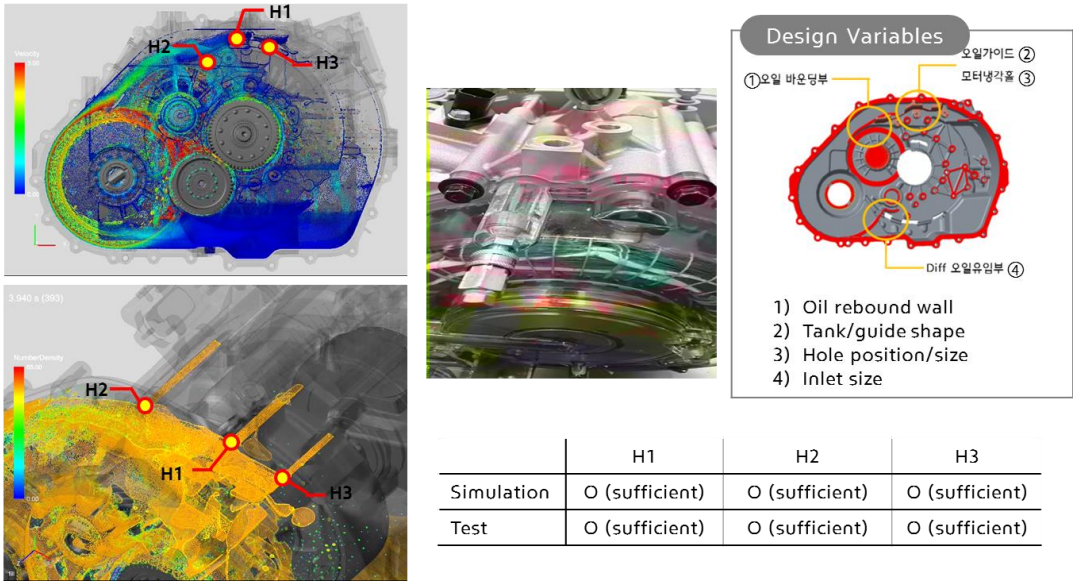


Fig. 7: Flow optimization process

To control the oil flow, Holes, Walls were redesigned and plastic oil guide of special shape is added.

In the end, cooling oil path has added and bench test with revised version shows adequate supply of oil even in the low speed.

▣ Test and Simulation for revised version



	H1	H2	H3
Simulation	O (sufficient)	O (sufficient)	O (sufficient)
Test	O (sufficient)	O (sufficient)	O (sufficient)

Fig. 8: Revised version test and simulation

Conclusion

For application of MPS method to transmission design process, correlation with bench test has done. Based on the correlation, flow optimized transmission design was possible with improved oil flow. And design variables have found which affects oil flow.

For this project, 54 cases have been simulated in 20 days which cannot be done with grid method simulation.

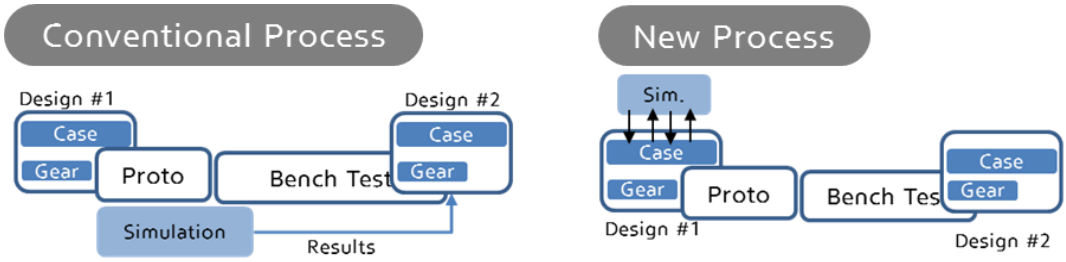


Fig. 9: Design process comparison

Since MPS method simulation is not only fast but also has good accessibility with fewer variables on simulation, it is possible to apply on design stage as fig.9.