Visualization
of Oil Lubrication in the Transfer Case
and the Transmission using Particleworks

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Univance Corporation is a vertically integrated company which specializes in the development, manufacture and assembly of automotive parts and units. They have been pursuing their unique technologies based on business' units including all wheele drive, automotive parts,gearbox. Now they deal with functional components such as one-way clutches, AT/CVT components, transmission and engine gears, EV/HEV gearboxes, manual transmissions, and 4WD transfers cases (Fig1).

In the product development department, they use CAD and CAE to support design process of all products. They generally use CATIA V5 as their standard CAD system and perform simulation by CAE tools including Particleworks by importing CAD models created in CATIA V5. The purposes of the simulation are, for example, prediction during the concept design stage, design validation before prototype testing, and analysis for quality improvement. Especially in the CAEgroup in charge of further analysis, a wide variety of simulation, such as linear-structural analysis, Particleworks for fluid analysis and RecurDyn for MBD (Multi Body Dynamics) coupling with Particleworks, is used as CAE.

Introduction of Particlesworks into Univance Corporation
Oil has various important roles in lubrication, cooling, buffering and air tightness, whereas it causes torque loss for its flow resistance. For that reason, enough considerations and arguments are necessary for deciding conditions of oil physical property and quantity, and shape optimization. Therefore there was a requirement in Univance Corporation to confirm the real phenomena by simulation because it was too difficult to understand it only by
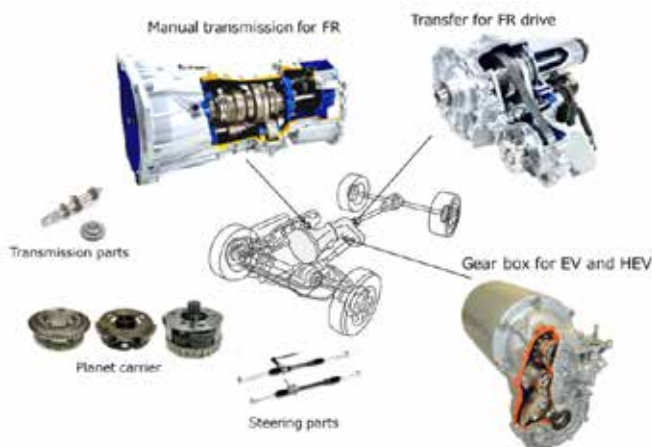

Fig. 1 – Products for automotive

experiment, which couldn't be realized at that time. After a while, the request to visualize oil sloshing and lubrication for sufficient evaluation has increased and they've finally come into introduction of Particleworks through comparison with other CFD competitive solvers and benchmark test. In addition to fluid analysis, they need co-simulation of the chain behavior and the oil lubrication in the transfer case which is their key product. In other words, MBD has been a must and RecurDyn which can be coupled simulation with Particleworks has been introduced as well.

Fig. 2 - Transfer structure

Simulation Example 1 of Particleworks:
Visualization of Oil Lubrication in the Transfer Case

Univance Corporation gives a simulation example of oil lubrication in the transfer case. The transfer case is a device to distribute power from engine-transmission to front wheels and rear wheels of a 4WD vehicle by means of gears, sprockets and a chain (Fig2). They used RecurDyn and Particleworks to simulate the mating of the chain and the sprocket and the oil lubrication. Fig3 shows full model of the chain and sprocket mating, and enlarged images focusing start and end of the chain and sprocket mating are shown fig4 and fig5.
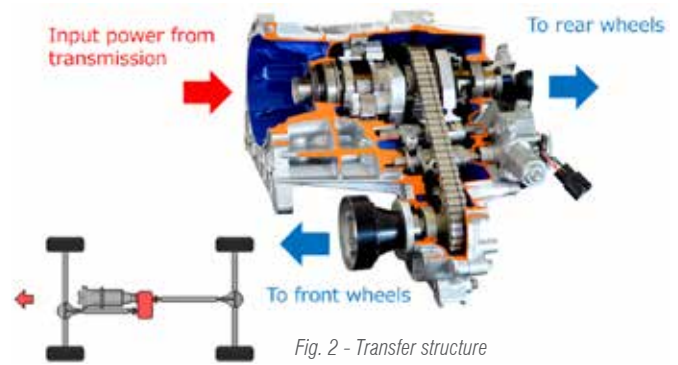
Simulation Example 2 of Particleworks:
Visualization of Oil Lubrication in the Transmission

Nextly, a simulation example of oil lubrication in the transmission is introduced below. The transmission is a machine in a power system, which supplies controlled application of the power. The word "transmission" can be referred as the gearbox consisting of gears and gear trains to provide speed and torque conversions from a rotating power source into other devices. Little oil isn't enough to circulate around the whole gear box and not to work properly its functions of lubrication and cooling, and has a cause of gears' burning. However too much oil gives an extra torque to gears and shafts. Therefore, if we could confirm the oil behavior in the gearbox, we would be able to decide suitable shape and necessary quantity of oil. As mentioned before, visualizing the real phenomena by experiment is difficult, in that case, Particleworks comes into effect to understand the oil behavior. Unlike
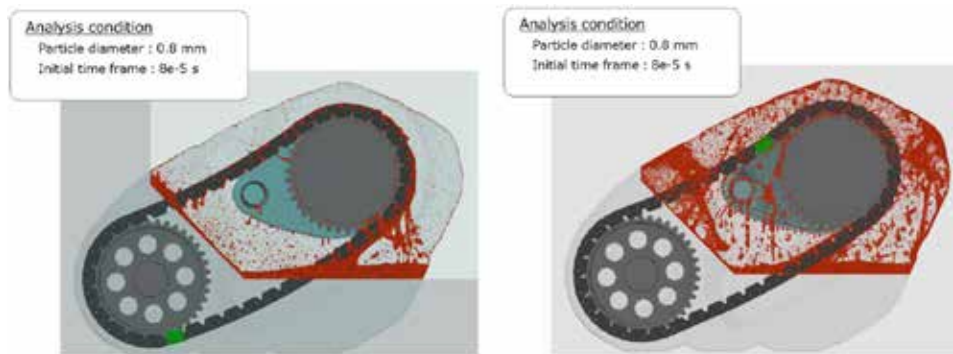

Fig. 3 - Full model of the chain and sprocket mating (left:75rpm, right:400rpm)

Before, they had visually checked the oil lubrication created by the chain using resin clear case and endoscope. Such visual inspections have limitation, and it's difficult to take measures because the inspection is after making real products and significant layout change is impossible even if there are big problems. However, oil lubrication is necessary for antifriction and cooling of the components and has the important role to improve the product quality. It became possible to be visualized by simulation to evaluate how the oil circulates and how the oil flows after circulation.

Regarding to the practical issue of calculation cost, the simulation using Particleworks needs only one day at most for calculation thanks to great improvement of the software and hardware-development such as GPU. The number of particles that Particleworks can handle in simulation largely increased, which let us use a smaller size of particle (diameter) compared to before and perform more accurate simulations.
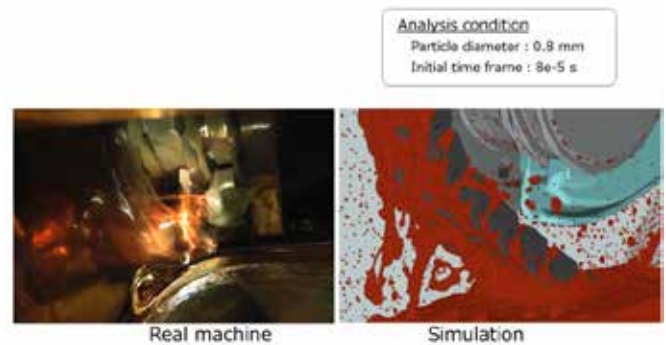

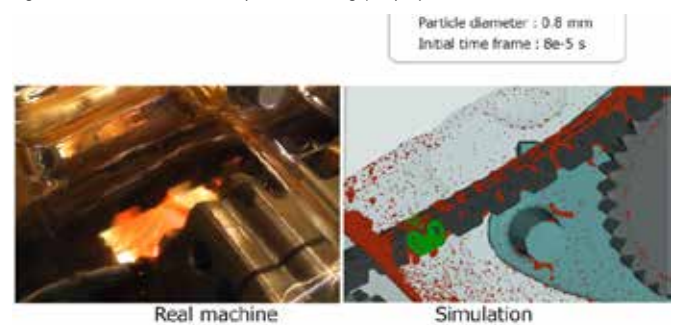Fig. 4 - Start of the chain and sprocket mating (75rpm)

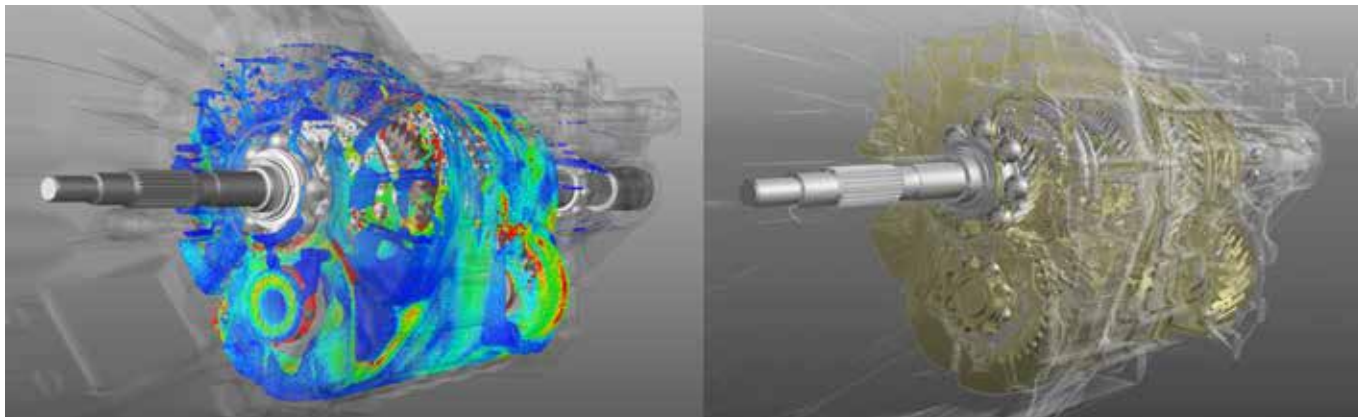Fig. 5 - End of the chain and sprocket mating (75rpm)

Fig. 6 - Full model of the transmission (left: particle image, right: post-rendering)

Example 1:Oil Lubrication in the Transfer Case, this simulation is conducted only through Particleworks. Besides, each gears is given two rotational patterns: low-rotation and high-rotation.

The visual images of the result are given above (Fig6). The left of Fig6 shows the result in particle and the right is rendered image. Using Particleworks, which strength is to easy to analyze free surface flow and large deformation, makes it visualize where and how the oil flows and circulates, and can simulate under the wide variety of conditions by changing not only rotation pattern like this example but also the shape of model and physical property of oil. Moreover, we can evaluate the velocity of oil and the quantity of oil circulating around the model, with post-processing capability. Fig7 shows the graph of torque with changing gears' rotational speed to quantitatively estimate the result of simulation. According to the graph, it is confirmed that the torque increases corresponding to incensement of rotational speed, which the same trend can be seen in the experiment.

However, the values gained through experiment are the total values included of various factors and Particleworks deals with only torque loss due to fluid resistance without considering frictions among gears, bearings, and collusions of each parts. Therefore,
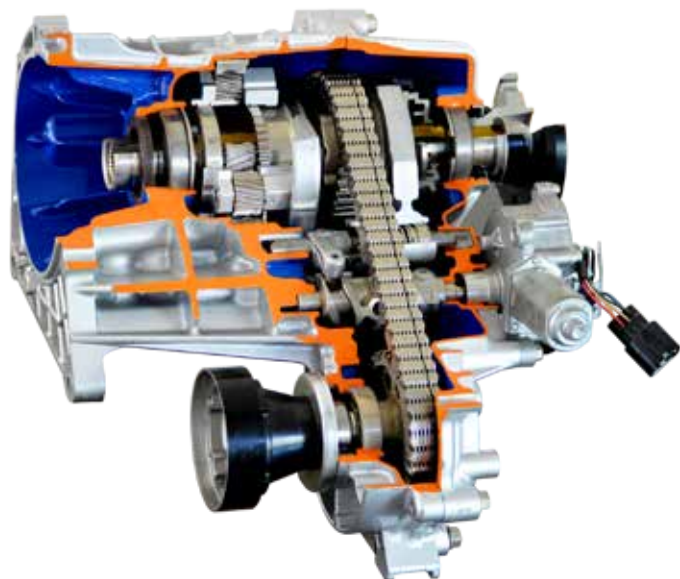
co-simulation with RecurDyn for oil lubrication in the transmission is needed for reproduction of the phenomenon above and better development.
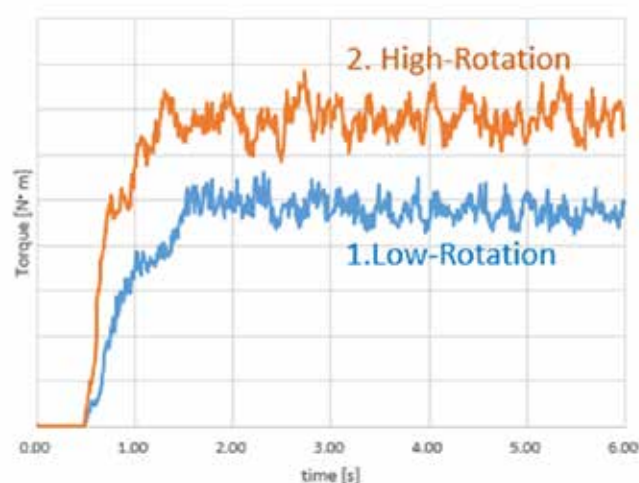

Fig. 7 - Torque graph with changing rotational speed

Conclusions

In this paper, we introduce our Particleworks and RecurDyn user Univance Corporation with their simulation examples. Oil plays an important role in lubrication and cooling of components and can be a cause of torque loss at the same time. Experiment to reproduce the oil behavior is technically and physically difficult problem and fluid simulation such as Particleworks comes into solution. Simulation of oil lubrication in the transfer case and the transmission shows the result that strong-coupling Particleworks and RecurDyn method can simulate not only fluid itself but also interaction between the fluid and components.

Reference

Particleworks users interview UNIVANCE CORPORATION
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Case Histories