Particleworks, an innovative particle method simulation tool, playing an important role in previously-unattainable simulation problems

As one of the particle methods for fluid dynamics simulations, MPS (Moving Particle Simulation) has begun to be used as an innovative and effective computational simulation technique for design and development. In contrast to one of the major particle methods SPH (Smoothed Particle Hydrodynamics), which is mainly used to model compressible flow and adopts explicit scheme for time integration, MPS is formulated to treat incompressible flow and uses semi-implicit scheme for time integration. In general, as most of engineering problems concerning fluid like materials in the manufacturing industries can be treated as incompressible, it is thought that MPS is suitable to treat these problems. In addition, the semi-implicit time integration scheme in MPS has an advantage in computational cost for longer manufacturing process. For these reasons, MPS is used in various fields of industries including automotive, power transmission, chemical and pharmaceutical, food & beverage, medical, and civil & environmental engineering. In this article, we introduce a real application from one of the leading automotive companies in Japan which is using the MPS based simulation software Partickeworks.

Oil flow simulation in a reciprocating engine in Honda R&D

It is important to predict oil flow in a reciprocating engine in design task. In this work the design of the structure of the breather chamber was investigated using Particleworks. The engine and the breather system are shown in Fig.1. The breather chamber is used to separate oil from blow-by gas (or combustion gas). Efficient ability of oil separation of the breather chamber is required. Air-resistance (drag force of the air) in the breather chamber is considered by adding the drag term to Eq.(2). In addition, the drag term was defined considering the size of the particles as in Eq.(3).

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As the size of the real oil mist involved in the blow-by gas is very small (1 μm to 10 μm), the coarse graining model technique was used to reduce computational cost. The MPS particles representing the oil mist were defined as the coarse graining model with the size of approximately 250 μm to 500 μm. The drag force was computed using grid based CFD software prior to the Particleworks simulation and defined as spatial function of external force in the breather chamber in the Particleworks simulation.

*The governing equations for incompressible flow are the continuity and the Navier-Stokes equations:

$$\frac{D\rho}{Dt} = 0 \qquad (1)$$

$$\frac{D\boldsymbol{u}}{Dt} = -\frac{1}{\rho}\nabla P + \nu\nabla^2\boldsymbol{u} + \boldsymbol{g} \qquad (2)$$

where, ρ; density, *u*; velocity, *P*; pressure, ν; diffusion coefficient, and *g*; gravity.

$$\frac{D\boldsymbol{u}}{Dt} = -\frac{1}{\rho}\nabla P + \nu\nabla^2\boldsymbol{u} + \boldsymbol{g} - \frac{R_{cg}^3}{m_l}\boldsymbol{D} \qquad (3)$$

$$\boldsymbol{D} = \frac{C_D}{2}\rho_{air}\left|\boldsymbol{u}_l - \boldsymbol{u}_g\right|\left(\boldsymbol{u}_l - \boldsymbol{u}_g\right)S, \quad R_{cg} = \frac{D_l}{d_l} \qquad (4)$$

where, C_D; coefficient of drag, ρ_{air}; mass density of air, u_l; liquid velocity, u_g; gas velocity, *S*; liquid body surface area, D_l ; particle size of MPS, d_l; particle size of oil mist, and m_l; oil mist mass.

Two types of the breather chambers, type 1 and type 2, shown in Fig.2 were examined. The difference of these two chambers are 1) distance between the inlet hole and the collision plate of 30 mm for type 1 and 15 mm for type 2 and 2) the diameter of inlet of 15 mm for type 1 and 6 mm for type 2.

The results of the simulation and the experiment of breather chamber type 1 and type 2 are shown in Fig.3 and 4 respectively. Type 1 can capture more oil mist on the collision plate and the oil flow toward the oil drainage holes at the bottom of the chamber can be seen clearly in Fig.3. While in the chamber type 2 the oil mist scatters under the collision plate and the oil flow to the oil drainage holes is not formed in Fig.4. According to the result, the breather chamber type 1 showed superior ability of separation of oil mist from the blow-by gas than the breather chamber type 2 and the simulation using MPS could reproduce the tendency of the real oil flow of these chamber types in the experiments.

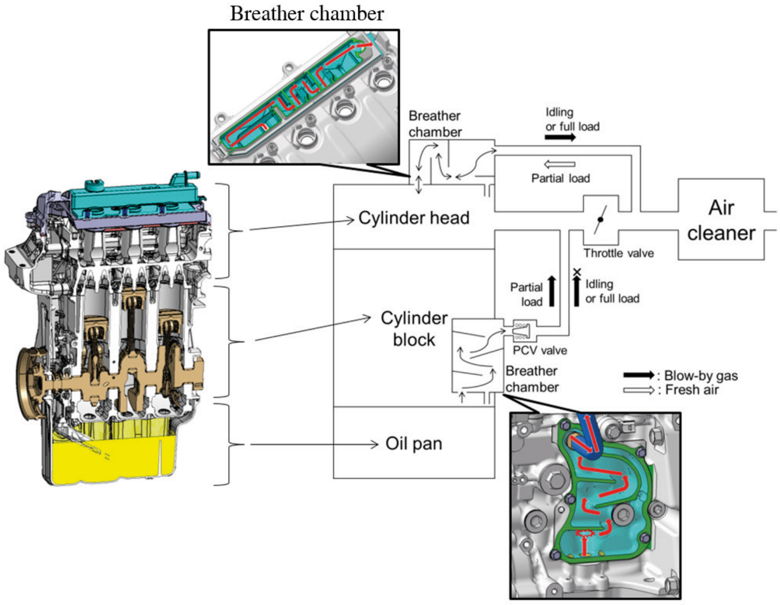

Fig.1 - Engine and breather system

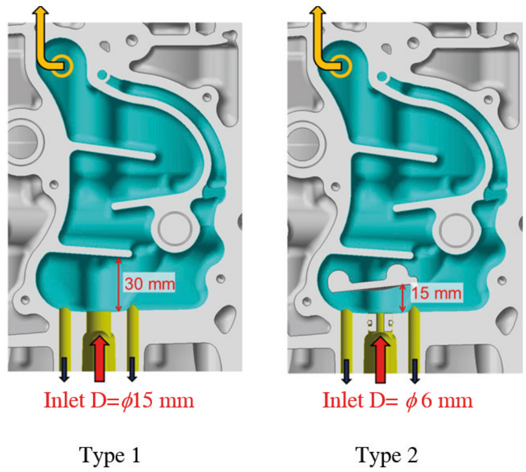

Fig.2 - Breather chamber types compared in the simulation

Conclusions

MPS based numerical computational technology has already been used in the front-line design and development process as introduced in this article. MPS will be more sophisticated technology to supplement the conventional numerical methods, e.g., FEM and Multi Body Dynamics for complex flow problems and fluid structure interaction problems in the near future.

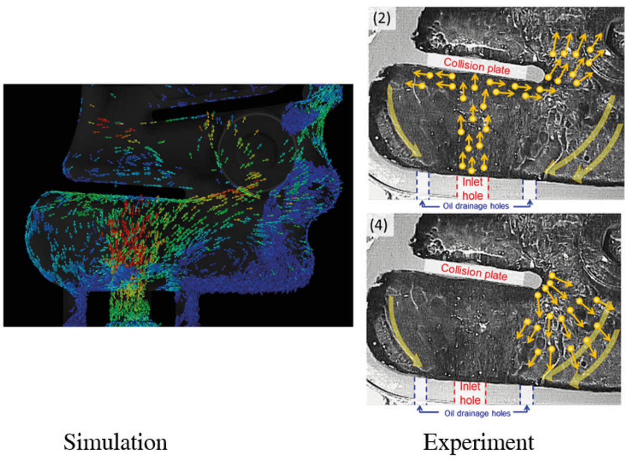

Fig.3 - Oil flow in breather chamber type 1

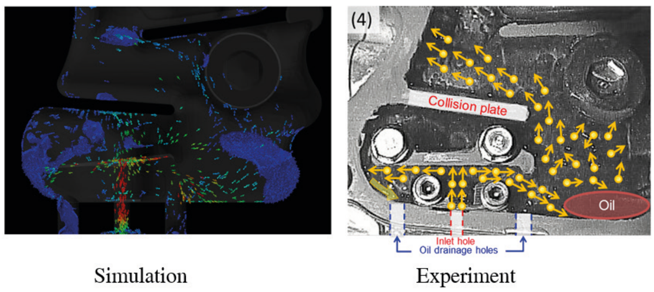

Fig.4 - Oil flow in breather chamber type 2

Acknowledgements
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Source of Image at the top of the article:
http://www.honda.co.uk/cars/new/civic-type-r-2015/overview.html

More detail can be obtained from "Honda R&D Technical Review Vol.26 No.2, 2014" if you have interest in this topic.
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