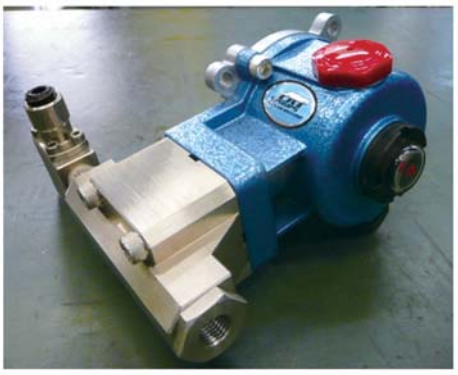
MPS provided a big advantage for free surface simulation including fast large deformation and circulation

Maruyama, a time-honored company in business for 120 years, has achieved continuous and long-term development under its philosophy "Building relationships of trust, by communicating with our customers." and by down-to-earth operation. In addition to keeping the tradition, their design and development site has provided reliable products by introducing innovative technologies. We have had the pleasure to interview Mr. Ichiro Matsuda, a General manager, and Mr. Nobuhiro Yuhashi, Desining Section No.2, in the pump department located at the Chiba factory, to hear the background of introducing Particleworks and simulation examples about the lubrication oil behavior evaluation in an industrial pump.

Please introduce your business.

Matsuda: Maruyama was founded in 1895 with the manufacturing and sales of the first fire extinguisher in Japan. By taking advantage of the fire extinguisher business experience, we have established our pump and engine technologies. Today, based on those technologies, we are handling 3 business fields of agricultural machines, industrial machines, and disaster prevention. The fire extinguisher business, which has continued since our foundation, is categorized in the disaster prevention field. Different from other manufacturers, our fire extinguisher uses stainless-steel to improve corrosion resistance and for better appearance. The agricultural machines field is our main business and we are dealing with a wide range of products such as power sprayers, portable sprayers, small/large scale sprayers mainly for agricultural chemicals and disinfectant, multi-cutters, and chainsaws for farms and orchards.

This factory has roles for agricultural machines and industrial machines, and has the large machine department and the pump department where we are working. The industrial machine pump is a high pressure type as it is to wash out difficult stains or fine stains, which are not able to be cleaned by a general low pressure pump, in the manufacturing sites for automotive and precision components. Our company's strength is that we provide both plunger type, which is strong for high pressure and forced valve type, which has a long-life and easy to maintain. Regarding the forced valve type, we developed it as our own unique technology and received a patent. Maruyama's pump has been highly evaluated because we produce units which suit customers' needs by a consistent process from design to manufacturing and shipping, and realize high pressure and durability with a compact size. Thanks to its quality, we have a lot of orders from overseas and the biggest market share of high pressure pumps for car wash machines in the US. Recently, we are positive towards the application of new viewpoints and joining the project organized by the Ministry of Agriculture, Forestry and Fisheries to make women's knowledge useful for new production. Our business motto is honest and sober management. At the same time, we respect the spirit of willingness for new activities which we haven't tried before.



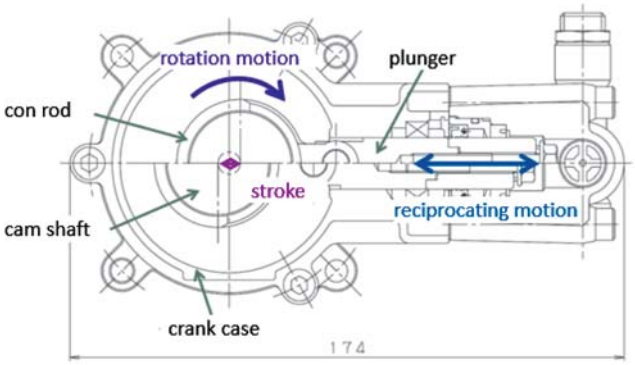


Fig1, The structure of the reciprocating pump

How do you use CAD and CAE in the pump department?

Matsuda: We have been using CAD and CAE for many years, and the full-scale operation had begun after introducing SolidWorks in the late 90's. Since then, we have used SolidWorks for structural analysis. As we also needed to use CFD simulation for our products, we purchased a common CFD software using the grid method during the same period. Then we faced some simulation problems which couldn't be solved by a traditional grid method CFD tool, and this is why we decided to purchase Particleworks. I had organized CFD workshops internally at the beginning, and then Nobuhiro Yuhashi took them over and now he is in charge of our CFD simulation tasks.

Ichiro Matsuda,
General Manager of Pump Division,
Director, Chiba Factory

Yuhashi: Since I began to use simulation 7 years ago, I have been managing all simulation works including structural and fluid dynamics analysis fields because there is no CAE specialist in our company. Though the situation for structural analysis has been almost the same, I personally would like to try non-linear and contact analysis more in the future. At the moment, it is most important to increase the number of people who want to use simulation from the existing 80 designers to as many as possible. As one of the ways to realize this, we have organized workshops to teach a fundamental attitude for simulation work. It is about how to create mesh correctly, the way of validation, and what to pay attention to before/during simulation. In the workshops, we try to develop an ability to evaluate simulation results correctly without doubt. In other words, we focus on ensuring V&V (Verification and Validation). Concretely speaking, we don't simulate the final model from the beginning. Firstly, we evaluate simple models after breaking down the real phenomena. Then, we repeat such simple model evaluations by gradually getting more complex, and finally simulate the completed model. The reason why we are conscious of V&V, is that we often had to redesign from the beginning because of accepting every simulation result on faith, even if the input analysis condition was wrong. So we enforce V&V for both structural and CFD simulations. Now, only I run CFD simulations, and I use Particleworks mainly for the evaluation of oil splashing and mixing resistance in a reciprocating pump.

What was the main reason to start using Particleworks?

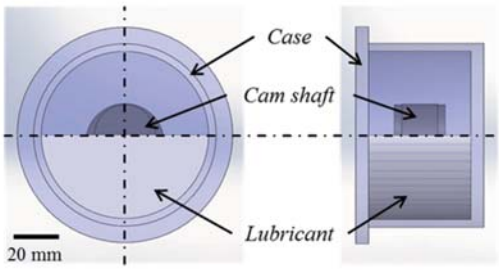
Yuhashi: It was, of course, the capability for free surface simulation. There are many industrial machines using oil for lubrication and cooling. Especially in the structures driven by rotating bodies such as a crank mechanism, the inside fluid has a two-phase flow, including the oil liquid phase and air phase. You can see a very complicated flow field in which the interface between the air and liquid phases deform in a large way and both phases repeat separating and combining in there. Basically, the grid method CFD software can't simulate such a complicated liquid surface with drastic and large deformation enough. Before starting to use Particleworks, I tried to simulate free surface behavior using VOF, one of the grid methods. However, it was necessary to create small enough mesh to resolve liquid droplets for dynamic liquid splashing phenomena, though VOF only simulated smooth liquid deformation. It can be possible in theory, but not in fact, because of the computer resource matter. After all, I had checked the phenomenon only with laboratory tests, as grid method CFD software could not simulate it. In such a situation, luckily I found Particleworks, which was showing very nice eye-catching post-processing animations of gear oil sloshing simulation, at a trade show. To be honest, I was very surprised to see different animations for other fluid dynamics phenomena.

Soon after that, I began to consider purchasing Particleworks, and had benchmark tests with the cooperation of Prometech Software. In fact, it was not easy to simulate thermal problems and splashing conditions, and we continued one and a half years of trial simulation activities. In addition, I was introduced to Prof. Koshizuka of the University of Tokyo, who developed MPS used in Particleworks, to discuss what I wanted to simulate, and started a joint research. After then, we decided to purchase Particleworks. MPS based Particleworks was very attractive because not only of the simulation capabilities for complicated fluid dynamics behavior which we wanted to solve, but also of the unnecessity of mesh creation. Indeed, it is very helpful for our work, as it's strong for mixing and free surface simulations.

Nobuhiro Yuhashi,
Desining Section No.2, Pump Division,
Chiba Factory

Could you please tell us simulation examples using Particleworks?

Yuhashi: I have been researching a reciprocating pump which is placed on an engine to wash out a car that got splashed with mud. The rotational speed rises to 3600 rpm. Such an elevation of the rotational speed increases the temperature of the lubrication oil inside the pump crank case, which is higher than other types of equipment. So I used Particleworks to predict how the oil in the crank case would spatter and the mixing resistance



Calculation conditions	
Density : r [kg/m^3]	935
Kinetic viscosity : n [m^2/s]	10×10^{-6}
Surface tension coefficient : s [N/m]	20.1×10^{-3}
Contact angle : q [deg.]	0
Interparticle distance: d [mm]	1.0
Influence radius : r_e [mm]	3.1d

Fig2, The simulation model and the boundary conditions

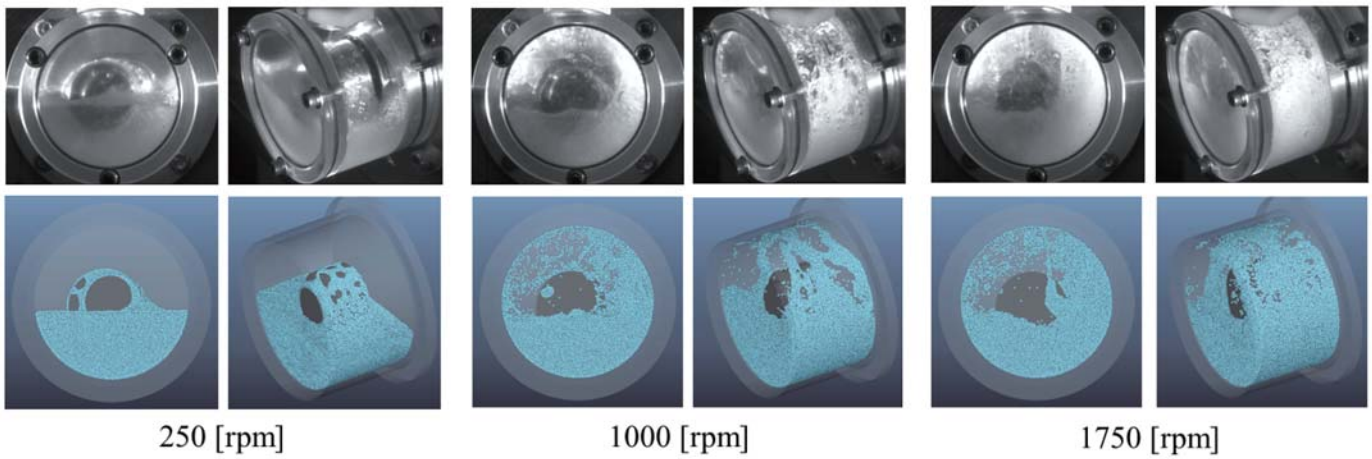


Fig3, The comparison between the experimental results and the simulation results of the oil behavior for each rotation amount

would change as the rotations increase. For the simulation model to verify a calculation, a cam shaft was located in the middle of the cylindrical case and the rotating center was in contact with the liquid phase. **Fig2** shows the simulation model and the boundary conditions. For this simulation, I used particle model for the oil and polygon model for the case and the cam shaft. No-slip condition was defined between the wall and fluid, and the wall weight function was used for the interaction between fluid particles and polygon. Then, potential model which can calculate the wettability with the solid wall was allocated for the surface tension model, and LES, Large Eddy Simulation, was applied to the turbulence model.

In addition to the simulation, I performed experiments by using a simple prototype to validate the simulation results. **Fig3** is the comparison between the experimental results and the simulation results of the oil behavior for each rotation amount. From these results, we can see that the oil was spattered by the cam shaft

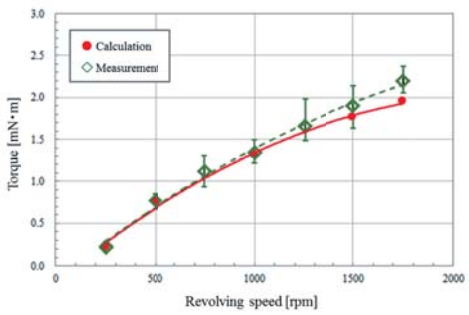


Fig4, The comparison of the torque at each angular velocity

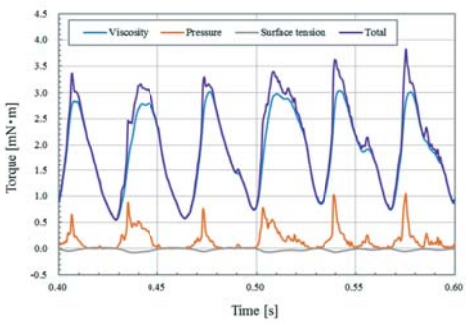


Fig5, Viscosity, pressure, surface tension, and total torque at 1750rpm

rotating motion and flowed on the interior wall inside the case. It was also found that the oil behavior obtained by the simulation was corresponded well to the experimental results in terms of the oil height piled at the bottom and the liquid surface shape for each rotation amount.

Fig4 is the comparison of the torque by increasing the rotation amount. Although there was some slight difference, both roughly correspond. Only in the case of the rotation amount higher than 1000 rpm, the simulation results were lower than the test results. However, the accuracy of the results is enough for using in the design process. It's not a big problem if the calculated value is not as same as the test results. What is important for us is that the tendency is correct. To proceed the manufacturing process, all we need is to indicate information which is necessary for an engineering judgement. The calculated results should be helpful information in the design process.

In this simulation, I validated the simulation results by using the simplest model without using a real complicated model for V&V. As the next step, I'd like to use a little more complicated model, and finally use a model representing a real product for simulation. The simulation time for the case shown in the figure is approximately 8 hours and about 3 days is necessary for the simulation using the smaller particle size. It would be useful in the design process if we can run a simulation for 1 night and totally 2 cases of simulations in 1 day, if the batch process becomes available. It would be also helpful for us, if parameter study could be easier. I have simulated by decreasing the number of phases to 1, and from next year I would like to use the real phase simulation as the product is composed by triplex pump to lead the simulation activities to further the real production.

How do you want to proceed your simulation and research with Particleworks?

Yuhashi: I've attended Prof. Koshizuka's laboratory about twice a month for my study and research of the MPS, Moving Particle Simulation Method. As there are engineers coming from other companies, it's a great opportunity for sharing information between people in different businesses. Truly there is a lot to learn in the MPS and it's a very new simulation method compared to the Finite Volume Method and Finite Element Method, so I

expect that it would develop more in the future. I hope that competent researchers will develop easier to use tools, Prometech will adapt it into the commercial software product, and we in industrial companies will use it in the design process. To realize this, I'd like to gather more case studies and provide them to others. In fact, there are some of our case examples in the MPS basic text book written by Prof. Koshizuka.

Matsuda: Nobuhiro Yuhashi is always using the leading approach for simulation activities. For example, we have adapted Taguchi Method, and invited Dr. Genichi Taguchi who is the founder of the Taguchi Method for our internal studies. Thanks to such an opportunity, engineers here are always considering quality engineering in simulation activities. V&V is also one of the leading ideas, it's encouraging that we have engineers who use such new approaches flexibly by trial & error.

We heard that Mr.Yuhashi got the certificate of 1st grade for the JSME's Computational Mechanics Engineers.

Yuhashi: As studying the JSME's certification drill books, I can learn new things which I haven't noticed. I think we can acquire the habits to evaluate the simulation results correctly from such an experience. So I always recommend young engineers to take examinations for the certification, if they are interested in it. Some engineers took exams this year and there are more engineers who have the 2nd grade of the solid mechanics field now. The study for the certification is enough for getting knowledge to use linear static analysis in the practical design work. So, I want other design engineers to try the examination.

Could you please tell the future expectations of Particleworks and Prometech?

Yuhashi: I'd like to try simulating the coupling between liquid and solid phases. Regarding the DEM/MPS coupling, I want to try to simulate it in the multi-body dynamics and fluid dynamics combination such as, the mechanical dynamics behavior of the pressure control valve and its influence on the fluid, by one-way coupling simulation. It is also appreciated that the simple rendering capability is included in post-processing. It's very convincing and can give a good impression when making presentations inside and outside of the company. I also have a request to Prometech to make a FAQ for users. I guess it would decrease the effort of Prometech technical support staff and gives quick answers to the users who want to have the information as soon as possible.

Thank you very much for your valuable input. About DEM, you can use the existing capabilities included in Particleworks continuously. In addition to them, we will soon release a DEM specialized tool. We have been creating the FAQ and already completed the framework, so it is expected to be available soon. Regarding post-processing, now the charged rendering service is available. However, we'd like to consider a simpler rendering tool which can be used by customers easily in the future. Again thank you for cooperating with the interview despite your busy schedule. Prometech will continue to provide further support for your better product development.

Reference
Journal of the Japan Society for Computational Engineering and Science Vol. 2015 (2015) p. 20150007
"Calculation and evaluation of torque generated by the rotation flow using Moving Particle Semi-implicit method"

MARUYAMA MFG. CO., INC.

Head Office: Chiyoda-ku, Tokyo
Founded: In 1895, as Maruyama Shokai
Activities: Manufacture and sale of agricultural machines (pesticide applicators, forestry equipment etc.), environmental sanitation machines, firefighting equipment, industrial pumps, cleaning equipment, construction machinery, engines, cars and other vehicles used for agriculture Contracted design and construction of plumbing and fire-prevention equipment Real estate and leasing business
URL: http://www.maruyama.co.jp/english/index.html

Interview: November 20, 2015
In front of the Chiba factory of MARUYAMA MFG. CO., INC.

Particleworks™
Particle-based simulation software for CAE

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 free-surface flows at high resolutions, saving the need to generate meshes for the fluid domain.

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The information on this article is of November 2015 at the time of coverage. Please note that product features and configurations may have changed since the time of the interview. Please contact Prometech Software (kaidai@prometech.co.jp) for the latest information.