Case study

Maruyama Mfg. Co., Inc.

Development of fluid control equipment using computer simulation and quality engineering

Cradle CFD
Case study interview

Maruyama Mfg has long been designing and manufacturing agricultural tools and industrial pumps. They use SC/Tetra fluid thermal simulation software for pump analyses to understand how the fluid can be more effectively controlled. Combined with quality engineering, they have improved the efficiency and effectiveness of their development process so they require less prototyping.

Mr. Ichiro Matsuda, Director, Engineering Department, Production Division, Chiba Factory (middle)

Mr. Nobuhiro Yuhashi from Designing Section No.2, Engineering Department, Chiba Factory (right)

Mr. Takashi Ichikawa from Quality and Manufacturing Control Department, Quality and Manufacturing Control Section (left)

Since being founded in 1895 in Niigata, Japan, Maruyama Mfg has been manufacturing agricultural machinery, disaster-proof equipment, industrial tools, and water cleaning devices. The range of Maruyama Mfg agricultural machinery products include power sprayers for spraying chemicals for spraying fields, stereo sprayers for orchards, and high clearance boom sprayers used in paddy and soil fields (Figure 1). Their industrial pumps are not only used in factories but also for desalination. Their misting system is used in amusement parks.

Maruyama Mfg, Chiba Factory

MARUYAMA

Maruyama Mfg. Co., Inc.

www.maruyama.co.jp

Founded	1895
Businesses	Design and manufacturing of agricultural machinery (including pest control and forest machines), industrial and fire equipment, and farm vehicles.
Company President	Masanobu Ogashira

Maruyama Mfg first started out as a fire extinguisher manufacturer. They developed Japan's first mass production fire extinguisher. Their first product produced carbon dioxide by breaking a glass bottle that contains highly concentrated sulfuric acid and sodium bicarbonate, which generated an extinguishing agent (Figure 1).

High-speed power sprayers (with uniflow design technology) were first developed in 1956. This sprayer, called Hope, significantly reduced the weight of the pump and increased processing speed. This was followed by development of industrial pumps, high clearance boom sprayers, mowing machines, and stereo sprayers. In 1991, Maruyama Mfg founded an engine manufacturing firm, and released a 2-cycle engine. In 2004, they launched a new quintuplex piston design pump, and two layers of pistons to successfully dampen the pulse dynamics of the chemical agent. In 2010 they developed their own chainsaw. In 2013 they facilitated the solar energy generation system in the Chiba factory. And in 2015, Maruyama Mfg celebrates their 120th anniversary. They hope to expand their business around the world using a network of overseas offices. Development of disaster-proof equipment, pumps, and engines has become their core strength. In addition Maruyama Mfg has integrated Software Cradle SC/Tetra fluid analysis tool into their pump product design processes.

Evaluation of pump internal component geometry

The pressure control valve regulates the spray pressure in a pump. One of the examples of computational fluid dynamics (CFD) analyses using SC/Tetra is the evaluation

Figure 1: The first fire extinguisher developed in Japan (left). High clearance boom sprayer, the first and one of the most innovative sprayer vehicles in Japanese industry (right)

of how the pump piston geometry affects the pressure control valve. The control valve is designed to adjust the channel gap by the spring load, which changes the spray pressure (Figure 2). Controlling the pressure means controlling the gap opening. “Ideally, the water velocity should be kept uniform when passing through the narrow end,” says Nobuhiro Yuhashi from Designing Section No.2, Engineering Department. Mr. Yuhashi recalls the time he was asked to evaluate the piston geometry, which was when he started considering the use of a fluid analysis tool. He conducted an analysis using Geometry A and B as shown in Figure 3, and found that the flow moved too fast towards the outlet with Geometry A. Based on the results, he decided to employ Geometry B. Experimental tests verified that the flow was too strong and unevenly distributed with Geometry A. No such problem was found with Geometry B.

Maruyama Mfg also evaluated valves in the uniflow pumps designed for high-speed agricultural power sprayers. The valve incorporates Maruyama patented uniflow design structure (Figure 4), which makes the pump behave like a bicycle pump. As a result, the valve is lighter and rotates much faster than conventional valves.

To increase the efficiency of the uniflow design, Maruyama Mfg evaluated the internal geometry using CFD analyses. This enabled them to visualize the phenomena. The geometry of the piston retainer was originally triangular (Geometry A) as shown in Figure 5. The fluid trails towards the discharge end due to leakage through the gap around the triangle (gray area). Although this geometry has been used for many years, Maruyama Mfg decided to conduct a CFD analysis to determine if they could further improve the efficiency.

The results from the CFD analyses showed that the local maximum water flow velocity would be halved for Geometry B compared to Geometry A. The flow distribution is also improved. This is due to using the round shape and four inner holes (Figure 6). “The improved flow means less noise and higher pump efficiency,” says Mr. Ichiro Matsuda, Director of Engineering Department, Production Division, Chiba Factory. The visual outputs of the analyses were effective for demonstrating how changing the geometry of the water suction seal can boost the performance. This would have been almost impossible to determine from only pump experiments.

Combining quality engineering to improve efficiency

In addition to using CFD, quality engineering (the Mahalanobis Taguchi System) was also used to develop the highly efficient stereo sprayer. This machine is designed to spray chemicals across mid to large scale orchards (Figure 7). A blower unit is located at the rear of the machine. The axial fan takes in the air, which is radially dispersed. This helps spray the chemical mist in radial directions and scatter chemicals across the orchard leaves. The chemical must evenly reach all tree leaves, though some tree height can exceed 5m. “To maintain orchards such as apples, not covering the entire

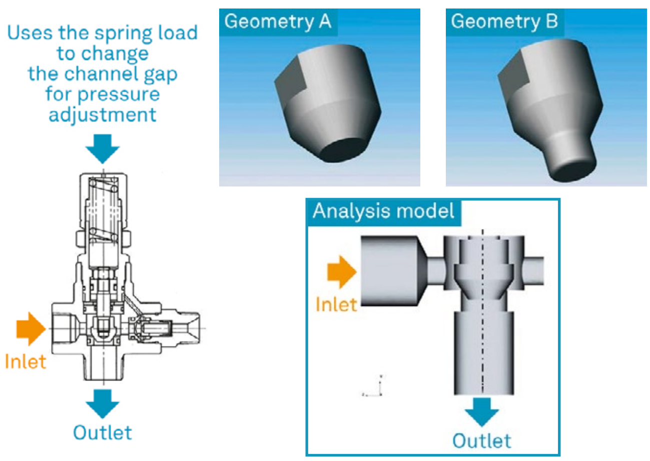


Figure 2: The evaluation on piston geometry on pressure control valve

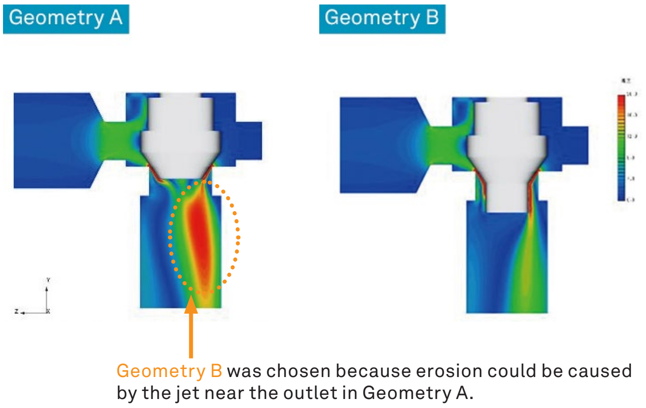


Figure 3: Simulation results of water velocity distribution around the valve

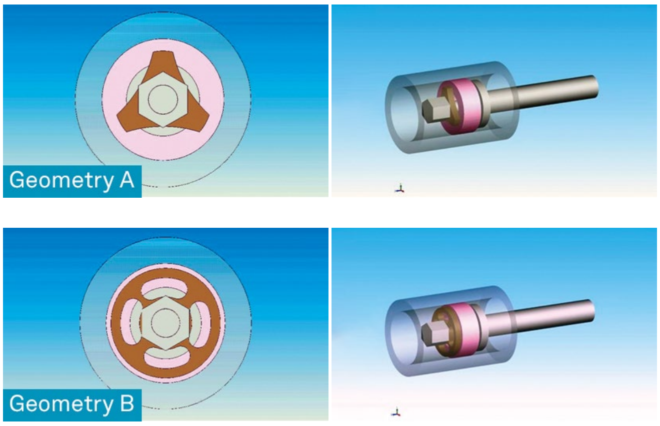


Figure 5: Examining two different geometries for the water suction seal within a pump

tree's leaves with chemical could lead to the outbreak of agricultural pests. Being able to evenly distribute the chemical is a critical requirement for our products," explains Mr. Matsuda. The ideal spray shape, according to Mr. Yuhashi, is "a large, balanced arch that enables equal distribution of chemicals regardless of the direction and distance."

Before introducing CFD, Maruyama Mfg struggled to improve the air velocity distribution from the sprayer's blower as prototyping and testing were time and manpower intensive. To conduct an actual test, engineers needed to produce a prototype, mark coordinates in the space, and allocate a sensor. The air velocity from the blower could reach 40m/s, which was dangerous and noisy. Maruyama Mfg incorporated quality engineering to optimize the combined blower geometry parameters. Identifying optimized conditions and conducting CFD analyses meant they could reduce prototyping and testing.

Maruyama Mfg applied quality engineering to determine the optimized combinations for each design parameter. Then they conducted simulations of the existing and new geometries. This work led them to discover that the overall airflow velocity increased with the new geometry. From this they produced and tested a prototype blower and affirmed the improvement of airflow dispersion.

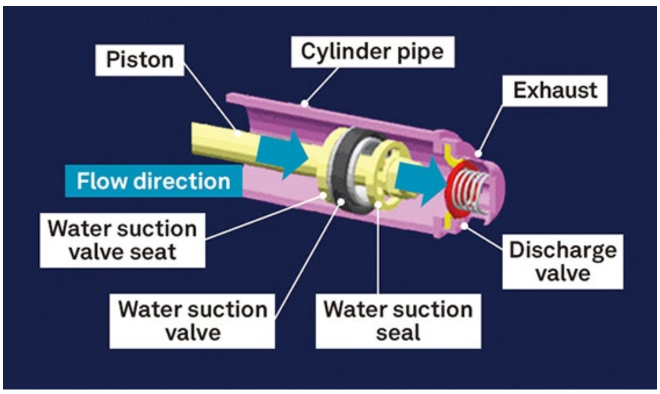
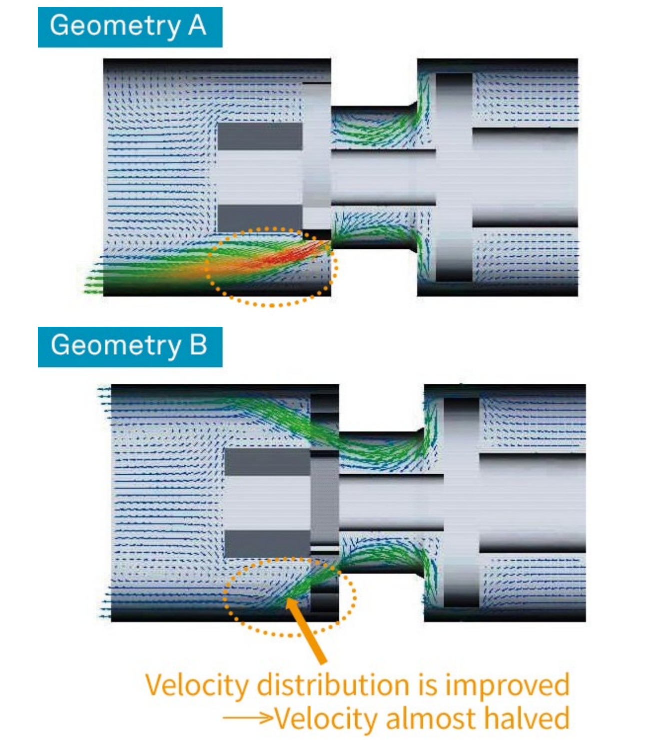


Figure 4: Structure of a pump with uniflow design

Maruyama Mfg successfully reduced prototyping, cost, and development time by applying CFD during the design stage. They claim that the greatest benefit of undertaking CFD analyses in the early design phase is that fewer design iterations are needed in later processes. Visualizing the phenomena also helps when explaining the effects of design changes to team members.

SC/Tetra: well-balanced, useful software

Maruyama Mfg considers Cradle products well-balanced and useful software. They can conduct highly accurate analyses in a relatively short amount of time and for



Velocity is high in certain areas with the conventional triangular water suction seals. Changing to a round shape reduces the local peak velocity to nearly half. It also generates more uniform flow

Figure 6: CFD analysis results (velocity distribution)

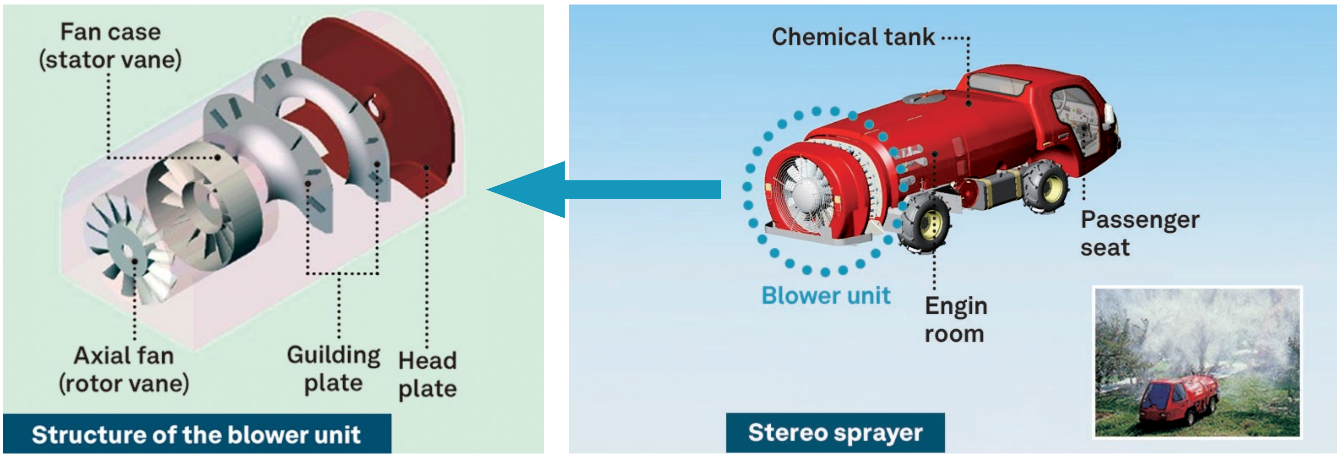


Figure 7: Stereo sprayer used for chemical distribution in orchards

a reasonable price. They are also satisfied with mesh generation in the pre-processor and post-processor. The model modification function reduces the errors caused during mesh generation and helps reduce the labor intensiveness of these CFD tasks.

Cradle SC/Tetra uses an unstructured mesh, which is effective when representing complicated geometries. Boundary layer elements can be accurately included by automatic mesh generation. Mr. Yuhashi thinks that the post-processor display is much better compared to other CFD software. The post-processor plays an important role in visually conveying the results using a wide variety of display formats.

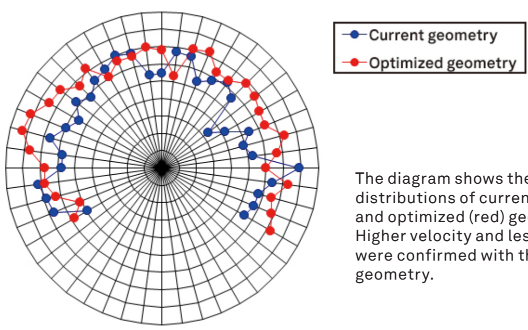
Reliability is the key factor

Extensive 3D CAD at Maruyama Mfg was implemented in 1996. Until that time, 3D CAD was installed on only one computer. The installed software was difficult to operate and costly to develop further. One of Maruyama Mfg's first steps was to purchase two SolidWorks® licenses. Mr. Ichikawa from Manufacturing and Quality Management, Production Head Office, who was responsible for facilitating Computer Aided Engineering (CAE) and CAD at the time, recalls that "this was when we decided to tackle 3D development through CAE as well as CAD."

Maruyama Mfg thought it more appropriate to start fluid flow simulations after their engineers became more experienced conducting structural analysis using the functions in SolidWorks®. They introduced Cradle SC/Tetra in 2000.

"One of the reasons we chose SC/Tetra was that Cradle provided remarkable technical support. This was a key factor back in the time when we were CFD beginners," says Mr. Ichikawa. They compared two other CFD software in addition to SC/Tetra, but both had major drawbacks. Using the other tools, it was difficult to generate precise mesh elements especially around curved faces. The mesh was also difficult to control. In addition, licensing costs were high. Maruyama Mfg chose SC/Tetra because they found it easily operable and capable of generating very high quality meshes. Having introduced 3D SolidWorks® in 2002 the company shifted to full-scale 3D designs. They also started using the 3D capabilities in SC/Tetra. They are happy with the two SC/Tetra floating licenses they purchased. These licenses enable them to undertake parallel calculations.

According to Mr. Matsuda, Maruyama Mfg vision is to achieve further growth by accumulating and expanding CFD technical know-how within the company. This will be possible by improving internal education and training and sharing experiences and the expertise throughout the company. This can reduce the dependencies on certain technical staffs and avoid bottlenecks. Another challenge is to find a solution for cavitation problems. This will be useful for plunger pump development. Maruyama engineers are also excited about extending the CFD application to thermal and noise analyses, and coupling with structural analyses. SC/Tetra is expected to continue to play a significant role in CAD and CFD advancements at Maruyama Mfg.



The diagram shows the velocity distributions of current (blue) and optimized (red) geometries. Higher velocity and less dispersion were confirmed with the optimized geometry.

Figure 8: Testing results

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