DIGITAL INDUSTRIES SOFTWARE

Overcoming submarine design challenges

Simcenter Flomaster helps ThyssenKrupp Marine Systems enhance pipe and pump design

Executive summary
Building a submarine today is far removed from the design processes we associate with automotive engineering because of the large number of integrated systems and parts and the small number of boats ordered by a customer.

The combination of these factors and stringent processes in the defense industry make it difficult for engineers to improve systems during an ordered batch. Therefore, a well-developed 1D computational fluid dynamics (CFD) tool is needed to acquire all the necessary information for the design process and ensure system behavior is defined before the first submarine is commissioned.

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Abstract

Simcenter™ Flomaster™ software enables engineers to find the most effective solution for designing pipes and achieving the required power consumption for pumps. With Simcenter Flomaster you can calculate pressure drops, net positive suction head (NPSH) values, flow rates, fluid velocities, oscillations, etc. Furthermore, it is possible to calculate the heat transfer (interaction) between solids and fluids.

This white paper outlines the challenges engineers face when designing submarines, one of the most complex machines on earth. It also provides insight into to how Simcenter Flomaster is used by ThyssenKrupp Marine Systems at its submarine yard in Kiel, Germany.

Figure 1. HDW Class 212A submarine U34 (photo courtesy of ThyssenKrupp Marine Systems).

The conventional submarine

A modern conventional submarine uses a nonnuclear air independent propulsion (AIP) system based on a diesel fuel cell combination. The tactical advantages of this system are low heat and acoustic signatures combined with the ability to stay submerged for long periods. In 2013 the German Navy submarine U32 set a world record by staying fully submerged during its trip from Germany to the East Coast of the United States. The fluid systems of the modern HDW Class 212A and 214 submarines are integrated with nearly 3,000 valves and many kilometers of pipeline. The following systems are divided into single subsystems: cooling seawater, fuel cell, ballast, freeing and compensating, fuel oil, chilled water, weapon compensating, firefighting, etc.

Of course, all systems must be robust and reliable because the conditions at sea can be rough and sometimes hostile, even without battle scenarios.

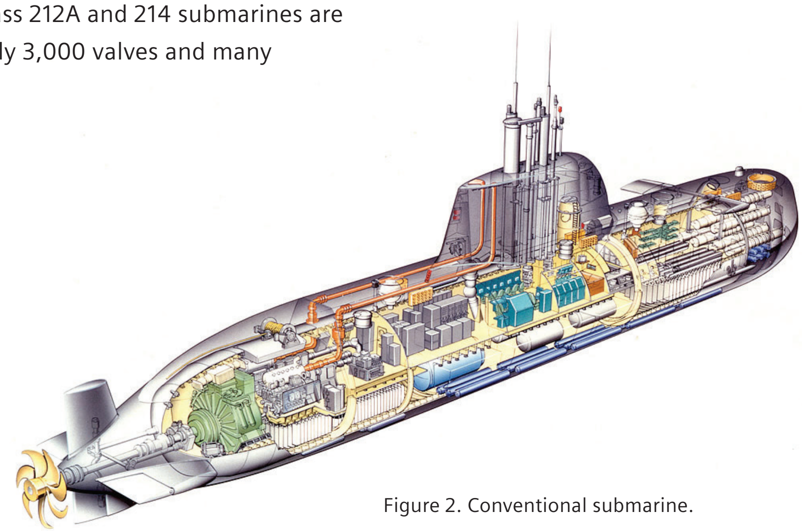

Figure 2. Conventional submarine.

Simulating cooling systems

There are two simulation scenarios in submarine systems: Checking the performance of an existing system or designing a completely new one. The first way is the easiest because in most cases there is existing computer-aided design (CAD) data or isometric drawings of the pipe routing so the network can rapidly be built. The second way is more difficult because the final routing of the pipes is not clarified in detail. The engineer must estimate the routing and calculate possible failures. The timescale of a project makes it necessary to order the pumps long before the piping arrangement is finished, so the second way must be used. Building up numeric networks is always a question of time and money. Usually a simple network will be chosen to shorten the time getting to a first solution.

If the user needs an exact solution or a lot of additional features, they must invest much more time in describing the model, which means the time necessary for transient simulations will increase. In general, it is possible to generate a network according to the specification with a detailed scale of 100 percent.

At ThyssenKrupp Marine Systems the networks are used for:

- Calculating duty points of pumps
- Calculating NPSH values
- Simulating interferences during changes in rotating speeds of pumps (oscillations)
- Checking the thermo management of the system
- Gathering all information of valve positions for the technical manual
- Checking the flow speeds in the pipelines according to mechanical and acoustic boards
- Calculating the fill quantity of the pipe system to support the weight calculation of the submarine

This must all be completed before the submarine can be commissioned, which is necessary to save time and money.

System complexity

Currently, ThyssenKrupp Marine Systems simulates systems that use water, seawater, fuel oil, air, ideal gas, oxygen and hydrogen as working fluids. To do this and use the internal pipe standard for different diameters, materials, pump curves, pressure drops of valves, flaps and filters, ThyssenKrupp Marine Systems saves the data in Simcenter Flomaster.

This makes it easier to define a complex network and set the necessary boundary conditions. In some networks more than 1,100 components are used.

Figure 3 shows a network with many components. With this system it is possible to calculate the required pump dimension and fluid distribution in the different flow paths. It is also possible to calculate the temperature in the pipes because of the thermal heat duty in the heat exchangers. There is a special feature that can be used with the transient solver: It changes the opening position of single valves during the running simulation so one can see the system react live.

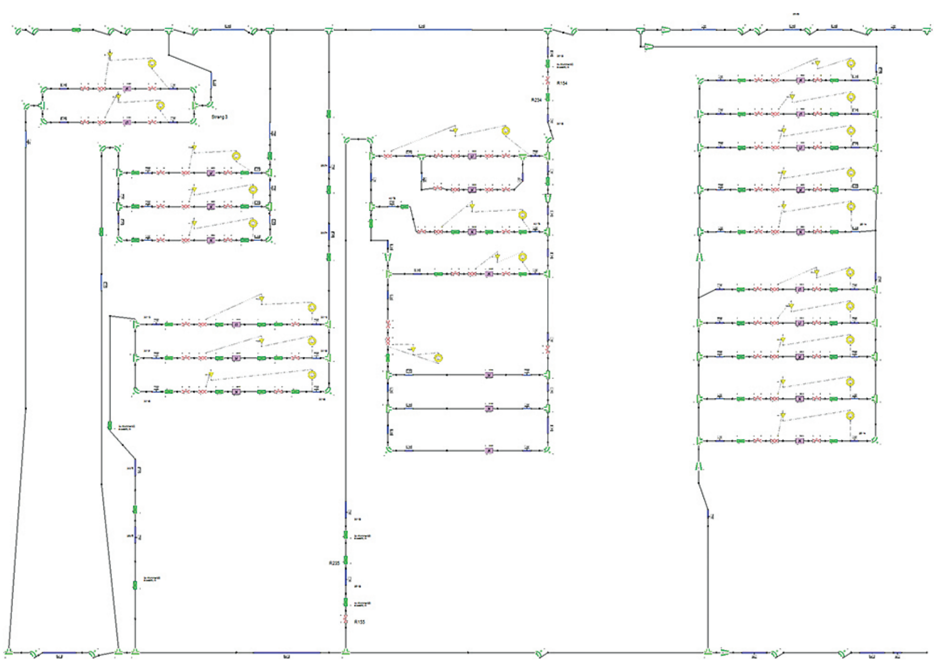

Figure 3. Part of a complex cooling system network.

Transient scenarios

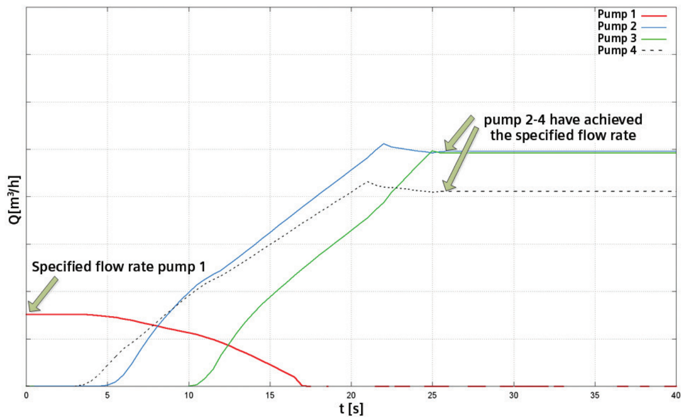

Figure 4. Postprocessing example: Conducting interference analysis for complex pump systems.

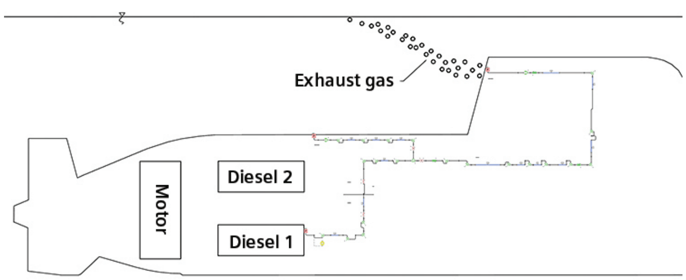

Figure 5. Exhaust gas system network during submerged cruising condition.

In each operating condition of the submarine, the installed cooling pumps have to support a different flow rate. With Simcenter Flomaster, it is possible to define single operating setups for use in parametric studies. Figure 4 shows an example of such a result plot of a transient interference analysis. According to the specification for this cruising condition, pump 1 must provide a constant flow rate although pumps 2, 3 and 4 are starting. It becomes obvious with the current pipe configuration pump 1 will not be able to provide the needed flow rate without increasing its rotational speed. With this information the required speed of pump 1 can be calculated and the best steering and automatic engineering concept for each cruising condition can be found.

Figure 5 shows a network of an exhaust gas system for the diesel generator during submerged cruising condition. Some pipes of the system are flushed with seawater at the exterior wall and some parts are isolated. With this configuration it is possible to calculate heat exchanges between the pipelines and the sea and the temperature of the exhaust gas in the pipes.

Conclusion

Numerical system simulations in the design process of submarines are a good tool for engineers to find the best solution for a fluid or piping system layout in a minimal amount of time. Simcenter Flomaster is the tool of choice for ThyssenKrupp Marine Systems for system analysis. It also makes it possible to support the submarine crew to find the best system setting by calculating valve positions or pump rotating speeds offline. With Simcenter Flomaster and the SQL database, many engineers can work in parallel on a large project, improving efficiency and reducing the design cycle.

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