# Innovation isn't Optional

## Mercury Racing® use FloEFD™ in the design of their lastest intercooler filter

By Prasad Tota, Application Engineer, Mentor Graphics

**Mercury Racing® is known worldwide for its leadership in powerboat racing and production of high performance consumer and race marine products. Founded in the 1970's as a division of Mercury Marine®, Mercury Racing's philosophy of "innovation isn't optional" has served them well and led their customers to winning multiple championships including the Unlimited Offshore World Championship and Abu Dhabi Grand Prix Class 1 World Championship.**

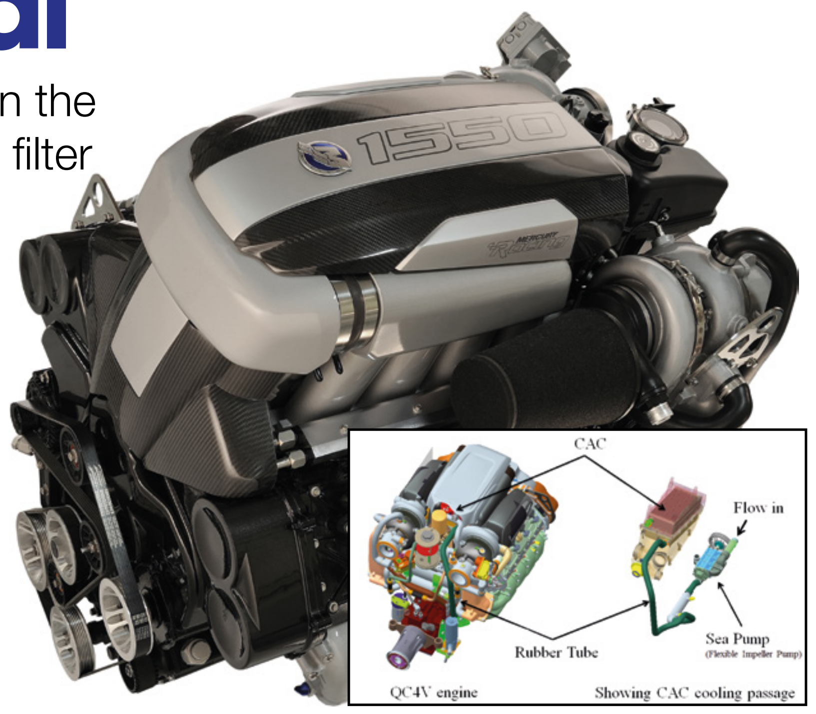


**Figure 1.** QC4V engine with compressed air cooler (CAC)

Their product line includes sterndrive and outboard engines, drive and propellers. We met up with Hiro Yukioka, Technical Specialist, at Mercury Racing and their latest project, a design study of an intercooler filter on a sterndrive engine- QC4V (figure 1) using FloEFD™ 3D CFD simulation software from Mentor Graphics.

The 9L V8 engine with an ouput of up to 1650hp, has two turbochargers. The engine uses a charge air cooler (CAC) to cool the compressed air from the turbo charger. The CAC uses seawater as a coolant and comes with some challenges owing to the debris it picks up, such as sand, sea shell etc. Mercury Marine has found from field experience that not all seawater boat filtration systems are capable of preventing this debris from accumulating in the CAC.

In the existing design, the size of the passage where seawater enters into the CAC is less than 0.033" ( 0.84 mm), figure 2. However, it would be a mistake to assume that all the debris that enters the CAC will exit the CAC with the heated water leaving the unit. Depending on the flow velocity, some of the debris entering the CAC can settle or accumulate in the unit. If the water speed inside CAC is too low then debris could settle inside it. At such low velocities the debris accumulation is also influenced by gravity i.e. weight of the particles. FloEFD simulation software was used to study the performance of the existing filtration system and to come up with an improved design.

FloEFD for Creo is a CAD-embedded general purpose CFD software designed for engineers, this focus makes the software easy to use by designers and engineers in an environment that they are already familiar with. The virtual test setup involves a CAD model with a flow inlet where the debris enters with the seawater, travels through a rubber tube into the CAC where some debris gets filtered and finally leaves from the flow outlet. It is important to note that the flow outlet is at a higher elevation than the inlet and hence the pump needs to deliver enough pressure for it to work against the adverse hydrostatic pressure.

At a flowrate of 60 litres/min the velocity inside the tube is about 3 m/s, but the velocity inside the CAC is less than 0.5 m/s. At such low velocities debris would settle inside the CAC. Hiro Yukioka had an idea to use the particle studies feature in FloEFD to virtually visualize if debris particles of a certain size would be carried by the seawater all the way to the outlet or remain in the unit. The particle study was conducted for debris size of 0.2 to 0. 5mm in diameter in increments of 0.1 mm. The particles were fed in at a mass flow rate of 0.01 kg/s which is less than 1% of the fluid mass flow rate. Activating the gravity field in the model accounted for particles settling under their own weight. The images in figure 3 show the particle trajectory colored by velocity magnitude.

Based on the findings, a sea strainer was created with wire mesh positioned around the inside of a cylindrical perforated part (Figure 4). The mesh element should have openings smaller than 0.3 mm and an off the shelf (OTS) wire cloth was chosen that met the criterion.

"If we wish to run a CFD simulation incorporating this new design the number of computational grid cells needed to refine the fine geometry of wire mesh is extremely high and impractical on a typical designer

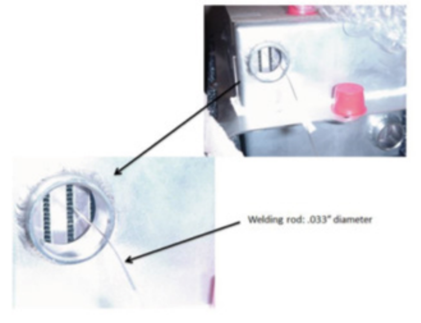


**Figure 2.** Fluid passage size at CAC entry

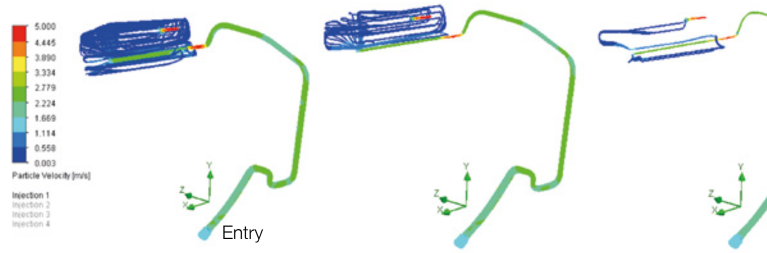


**Figure 3.** Virtual Debris test, Debris size from left to right (a) 0.2 mm (b) 0.3 mm (c) 0.5 mm

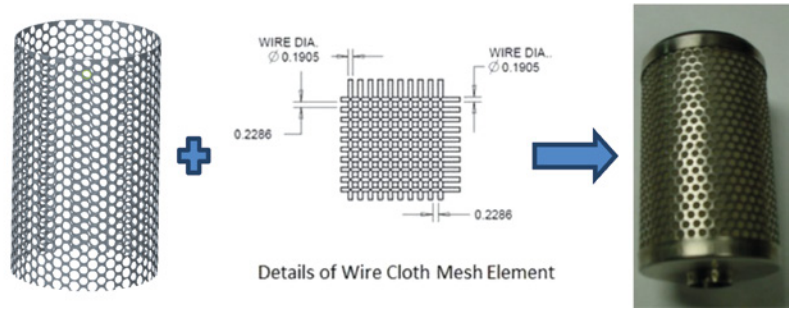


**Figure 4.** Sea strainer formed with a perforated part and wire mesh rolled on it

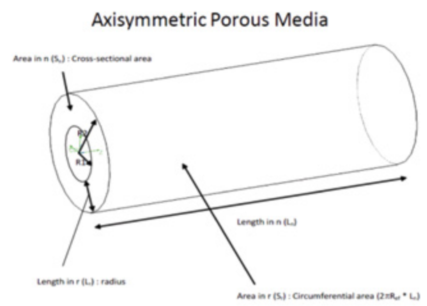


**Figure 5.** Axisymmetric Porous Media in FloEFD software

workstation. Fortunately FloEFD has a modeling technique where an object can be defined as a porous media which allows flow to go through the media with a pressure loss," said Hiro. A resistance curve was attached to the porous object to emulate the flow vs pressure drop characteristics of the actual device. For this particular geometry an axisymmetric porous media is ideal where the flow loss coefficient (K) can be defined normal to flow direction (r, radial) and along the axis (L, length) of cylinder (Fig.5).

The resistance characteristics of the wire mesh can be either obtained in physical testing or virtual tests set up in FloEFD. In this case a section of wire mesh was tested in a virtual wind tunnel set up within FloEFD to come up with a flow vs. resistance curve that was then attached to the cylindrical part in the overall model for CAC.

The final FloEFD model with the wire mesh incorporated is shown in Figure. 7. The fluid flow simulations showed that the sea strainer results in a pressure drop of 20 kPa at a flowrate of 80 l/min.

The next step was to analyze the effect of debris accumulation on the pressure drop when a part of the overall height in cylindrical volume is completely covered with debris. This was easily tested with small modifications to the FloEFD model where a shell was added, blocking 50% of overall volume and using the parametric study feature in FloEFD this height was varied to 75% and 85%. The results show that there is minimal increase in pressure drop with debris accumulation. (Figure 8)

A prototype was built to validate the CFD results using thorough hardware testing. Physical tests showed a pressure drop of 25-30 kPa for the sea strainer that is new (no blockage) to 90% blockage to mimic the effects of debris accumulation. These findings are in good agreement with FloEFD predictions of 25-26 kPa for a flowrate of 80 l/min where blockage was varied from 0% to 85%.

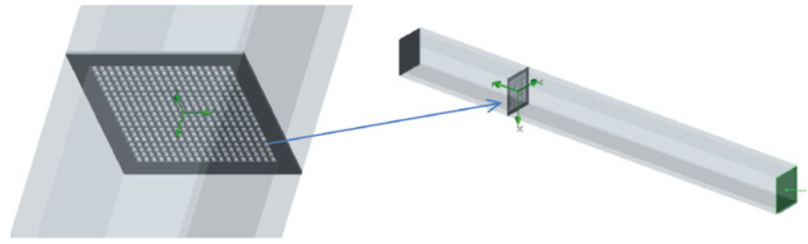

**Figure 6.** Virtual wind tunnel set up to characterize the wire mesh

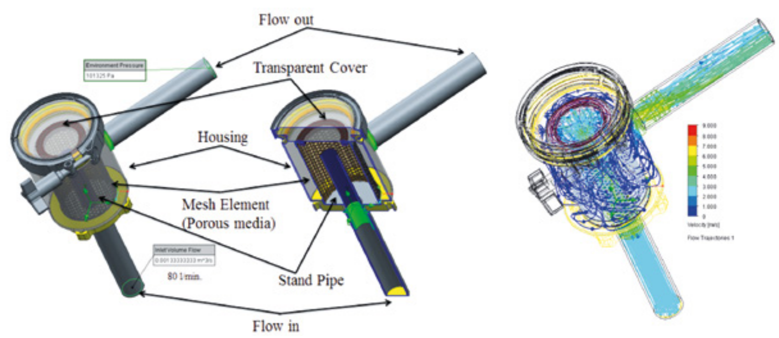


**Figure 7.** Cross section view of sea strainer and flow trajectories colored by speed (left to right).

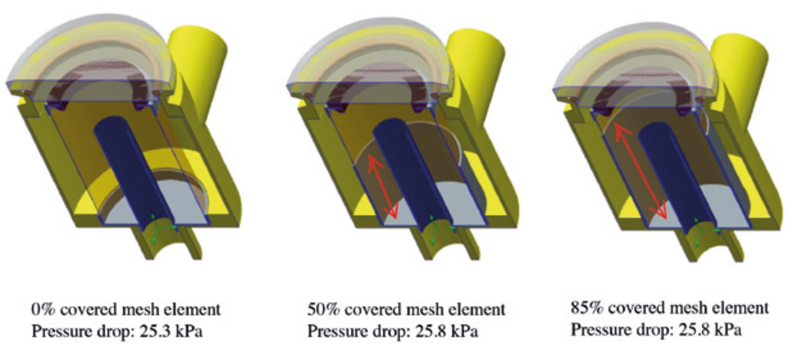


**Figure 8.** Debris accumulation effects on total pressure drop

## Conclusion

After testing the prototype on a test rig for several of Mercury Racing's customers, the redesigned CAC on the field in various conditions, the customer feedback was overwhelmingly positive. Performance was not compromised and the CAC filter was presented at the Miami Boat show in February 2015 and was very well received.

"Without the FloEFD software it would have been very difficult to develop this CAC filter in such a short time. The software is embedded within CAD environment and easy to use, which allowed us to test various ideas and design virtually without the need to create multiple prototypes and several days of physical test." said Hiro Yukioka.

Lastly I would like to express my gratitude to excellent customer support from Mentor Graphics. During this design activity I contacted them several times and every time I was impressed by their professionalism and great technical advice. FloEFD itself is an excellent product and, in my opinion, their support group adds significant value on this product." Hiro Yukioka

## Reference

[1] http://www.mercuryracing.com/sterndrives/engines/1550-2/