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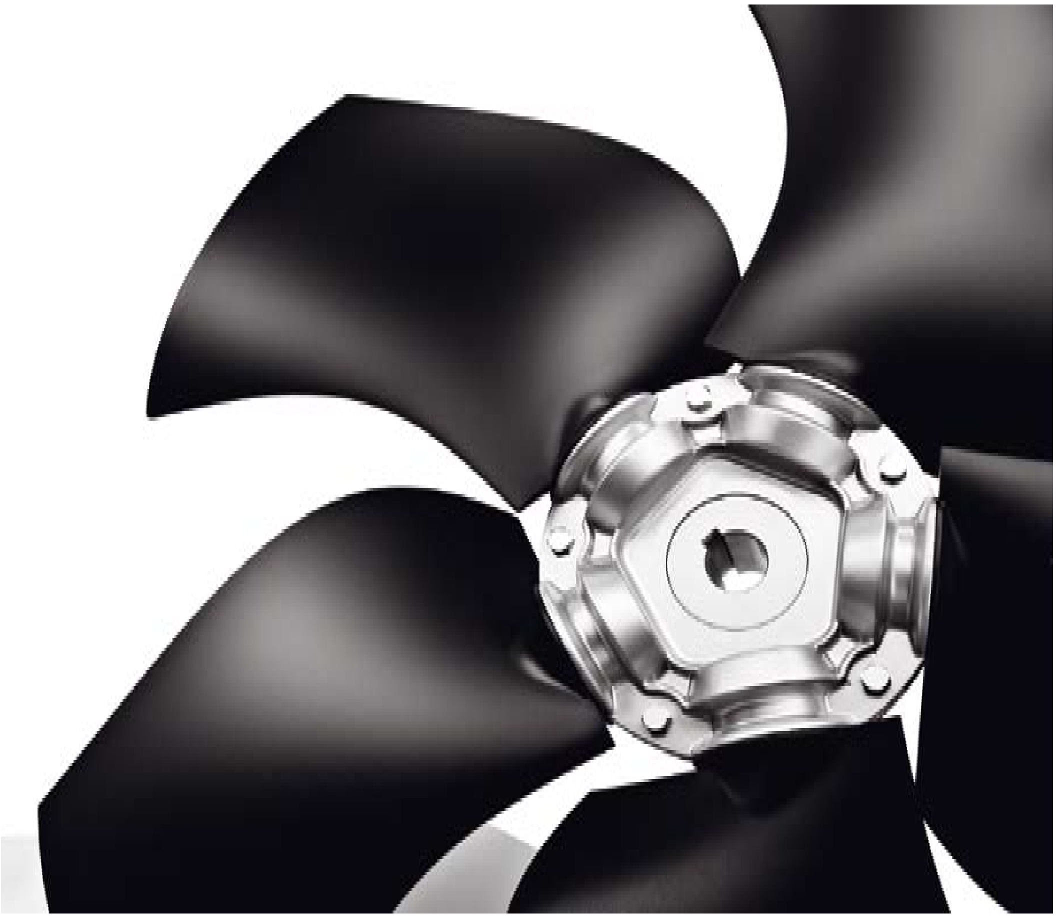
TOOLS OF THE BLADE

While computational fluid dynamics alone is insufficient in establishing impeller characteristics, it has become a useful instrument when looking at a complete cooling system



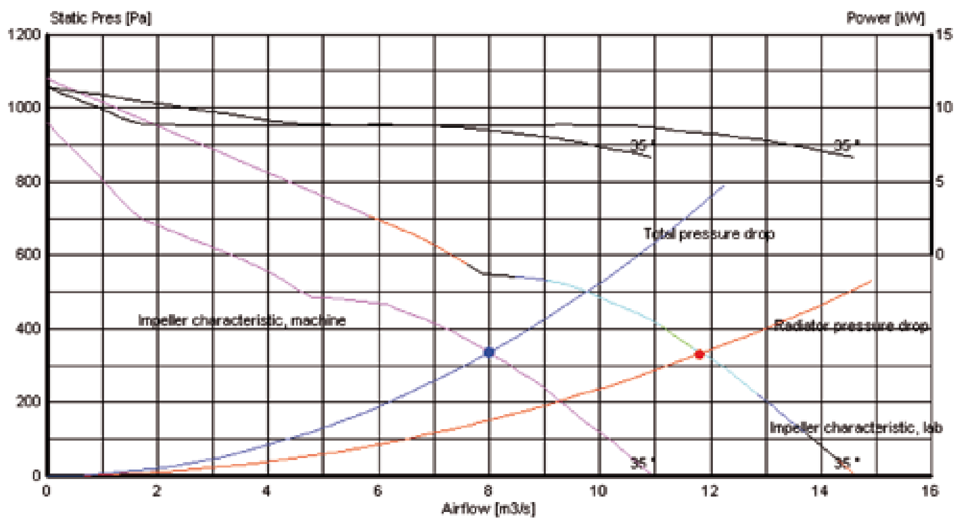


FIGURE 1: **The impeller and radiator characteristic showing the difference between ideal laboratory conditions and actual performance of the machine**

When dimensioning the cooling system for off-highway vehicles, the radiator pressure-drop curve and the impeller characteristic are the most commonly used tools. However, in most cases, this is an insufficient and imprecise approach to reach a realistic working point upon which to base the cooling capacity. Computer Fluid Dynamic (CFD) software could be the answer to avoid many hours in the heat test rig.

The impeller characteristic is traditionally based on wind-tunnel testing used as an engineering tool to dimension the optimum impeller that considers efficiency, power consumption and noise level. Most wind tunnels are designed according to AMCA A (or ISO 5801/ DIN24163), as are the inlet geometries dictated from ventilation and refrigeration applications, such as rounded inlet and small tip clearance.

Simulation

In off-highway equipment there is no place for such luxuries and if the impeller is engine mounted, a big tip clearance is necessary to accommodate the movement due to rubber mounting the engine. This is a commonly known problem and serious impeller engineering software makes it possible to simulate less than ideal inlet conditions.

When it comes to the technical documentation for the radiator, similar consideration should be made. The pressure-drop curve is measured at a uniform velocity profile.

If the inlet only allows uneven access of air, or if the impeller is pusher-type or where there are obstacles close to the radiator, the pressure-drop is not only higher but the velocity will vary over the radiator surface. Such velocity variation is of great importance with advanced cooling systems comprising water, oil and charge-air coolers.

The final critical factor affecting the cooling performance is the additional loss of pressure throughout the vehicle. Many machines are compact and considerations as to dust spill, sound barriers, driver's comfort and design increases the workload of the impeller.

A rule of thumb among engineers is that the radiator pressure drop is multiplied by 2-2.5 to get a realistic dimensioning working point when using ideal condition impeller curves (Figure 1).

At Multi-Wing, the use of CFD was explored from different angles. The idea of a virtual wind tunnel was appealing in order to reduce the invested time for developing the first 3D drawings of new impeller profiles to the actual impeller characteristic. The outcome of this exercise was easy to substantiate because the real wind tunnel results were already known. The conclusion was that with the present software and computing power available, the result was insufficiently precise and the data-processing time unacceptably long.

A more systems-based approach was also conducted. With a given impeller and radiator characteristic, and the geometry of application applied, it is possible to monitor the air velocities at critical sectional views of the application. This was shown to be a useful tool to ensure the lowest possible total pressure drop and the optimum efficiency of the radiator.

In Figure 2, CFD calculations are applied to a rock-drilling rig powered with a 400kW diesel engine. The cooling system consists of two identical impellers and four elements for water, oil, compressor and charge-air cooling. The impellers are driven by hydraulic motors enabling good inlet geometries and have, for this industry, ideal outlet conditions on the pressure side of the impeller. Furthermore, the impellers are mounted in a suction configuration and the application is, in general, close to optimum with no heavy engine room obstacles in the airflow.

Calculations

The CFD calculations are based on one side of the symmetrical cooling system. Due to heavy dust on the ground, the air inlet is on the sides and top only. The sectional view indicates with colours the air velocity through the radiator. While it was expected that the lower-right corner, with poor access on the open side, would present a problem, the CFD calculations showed the velocity in that corner was only marginally

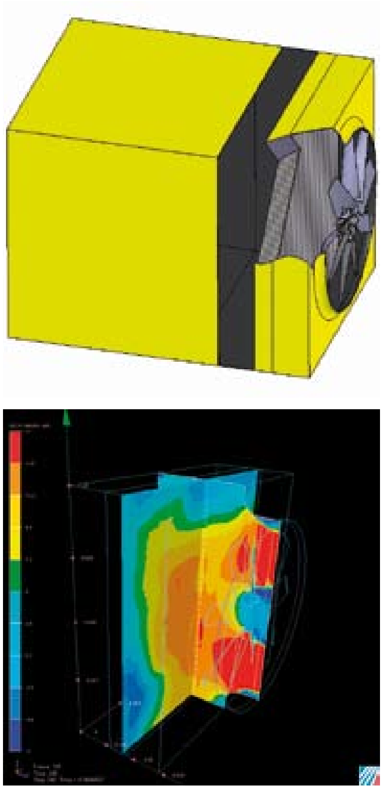


FIGURE 2: **A principle sketch of the radiator package on a rock-drill machine and the velocity profile over the radiator surface**

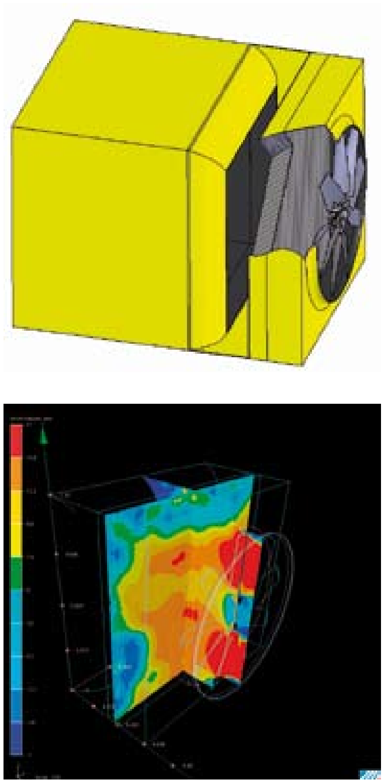


FIGURE 3: **The images show the same scenario with rounded corners at the inlet side of the radiator**

lower than the optimum centre zones. The real problem was the sectors on the radiator closest to the inlet. A relatively narrow inlet results in a high air velocity perpendicular to the radiator surface. Here, it can be seen that because the radiator is fed from two sides, the performance at the corner is better than that of the mid-section of the inlet. This design results in poor performance in an important area of the radiator.

To resolve this problem, the model was changed by increasing the inlet area with a rounded corner towards the motor. Another option would be to increase the distance between the cooling system and the engine but general design considerations do not allow for this.

Figure 3 shows the velocity in the same sectional view. The problem at the edge of the radiator is not as obvious as before and the more homogenous velocity provides for improved radiator efficiency. The total airflow is increased by 6%. This is an example of a relatively small change of the machine design resulting in a clear improvement of the cooling performance.

A useful complement

From an impeller producer's point of view, the use of CFD software is still in the early stages. The wind tunnel remains essential in developing new blade profiles and making valid product documentation. From the experiences at Multi-Wing and working with leading CFD experts in Denmark, the software alone is insufficient in establishing the impeller characteristic. Nevertheless, when looking at the complete integrated cooling system of impeller and radiator in the vehicle, CFD software has proved to be a useful complement to the engineering approach. ***iVT***

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