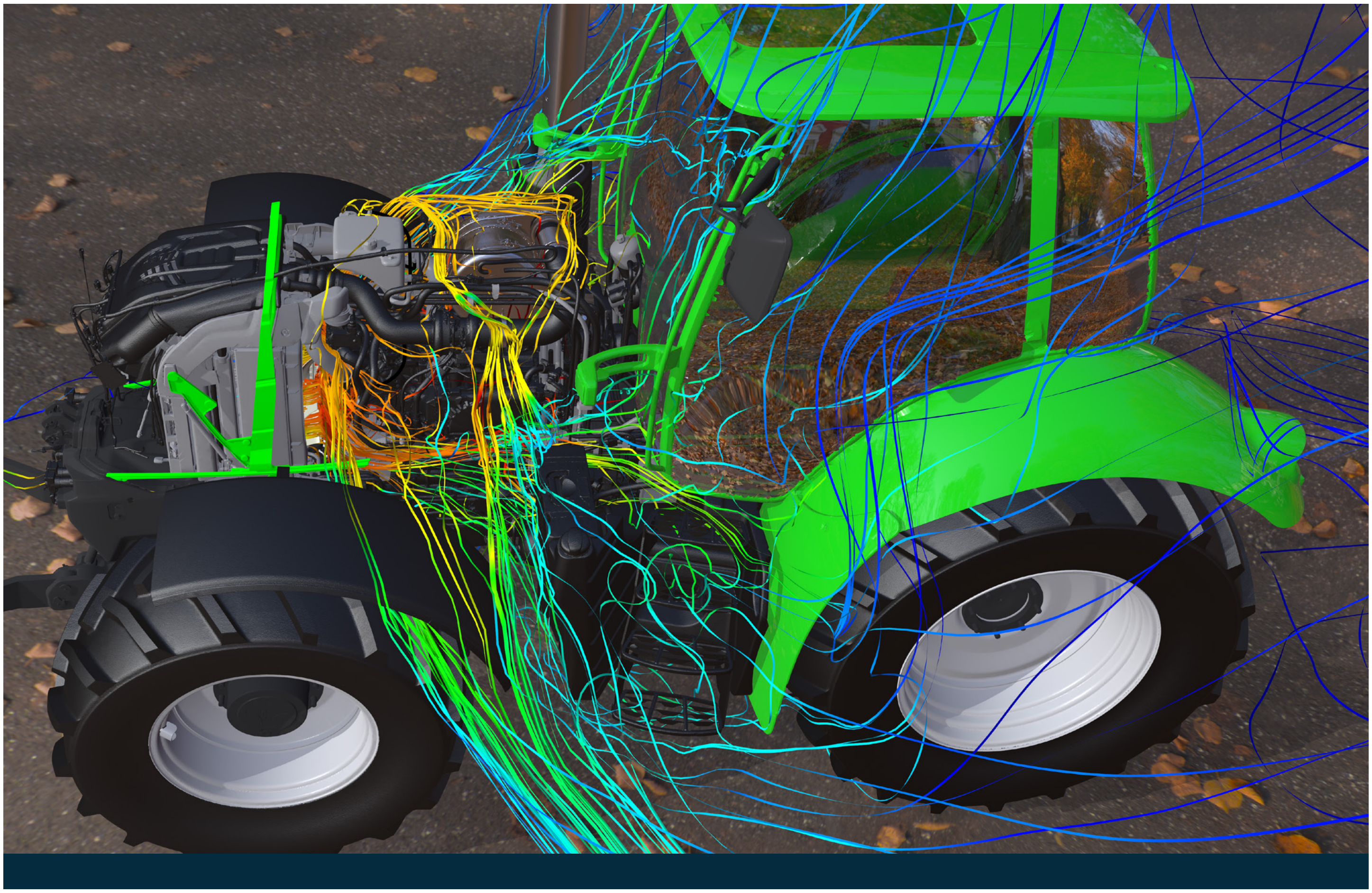

SUCCESS
STORY

SDF

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EXA CORPORATION
exa.com • info@exa.com

"We now are investing more time and effort at the beginning of development"

– Luca Crippa

THE CHALLENGE

For nearly a decade, Exa Corporation has worked in partnership with leading agricultural vehicle manufacturer, SDF, to use Exa PowerFLOW CFD simulation to improve the efficiency of SDF's engine cooling systems and reduce development time and cost.

Agricultural operations place intense demands on engine cooling systems. Tractors and combine harvesters generally move at very low velocities, or are stationary for long periods. At the same time, the torque requested from the engine during productive work like plowing, is very high. The ram air that provides cooling airflow to passenger cars and commercial vehicles is unavailable at agricultural speeds, meaning that the efficiency of the agricultural vehicle's fan-based cooling system is of primary importance. The fan must be placed in the right position in order to provide sufficient cooling airflow to the cooling pack, consisting of radiators and heat exchangers. Design decisions are complicated by the fact that a fan performs differently in the congested underhood area of a tractor compared to how it performs in an empty test laboratory.

At the same time, manufacturers of agricultural vehicles face many of the same challenges as their counterparts in the on-highway sector. Development engineers are under pressure to cut development time and cost, bring greater numbers of models to market without additional resources, and meet the demands of new regulations such as the Tier 4 Final (US) or Stage IV (EU) emissions standards, which themselves demand the adoption of pollution-reduction technologies that generate a lot of heat. There is also the need to balance engineering demands with aesthetic ones, to ensure that the products are attractively styled as well as high performing.

For SDF, Exa PowerFLOW CFD software has proved very successful in meeting these development challenges. In 2008, SDF was using a wind tunnel and other test facilities at the University of Bergamo – about 20km from the company's R&D base at Treviglio, near Milan, Italy – to develop the engine bays and cooling systems for new vehicles. Frustrated with the results it was obtaining from a process based on prototype tests supported by 1D simulations, the SDF engineering team recognized that 3D fluid dynamics simulation was mature enough to be introduced into the development process.

"We began with two or three simulation runs in PowerFLOW to try to find a solution to a lack of cooling system performance on our Explorer 3 tractor," explains Luca Crippa, coordinator of engine systems integration at SDF. "We had not been able to identify the root cause of it through physical tests; instead, it became clear from just a few runs of the CFD simulation that there was too high resistance of the underhood components to the airflow path. The CFD results suggested that an additional opening in the hood would deliver an improvement – and it did. The modified design went into production with performance that fulfilled our specifications. This test case showed it would be good to introduce CFD into our R&D process."

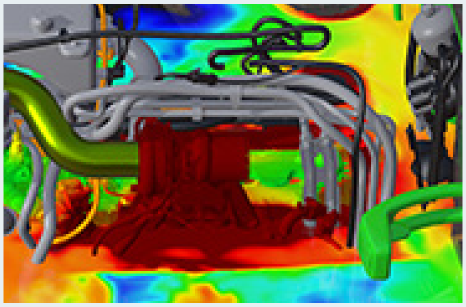
Based on that initial success, SDF started to consider replacing its experimental, wind tunnel and test bench-based process with one based on virtual simulations. In 2012, the PowerFLOW-based process was formally adopted to develop and validate every vehicle cooling system for the SDF Group.

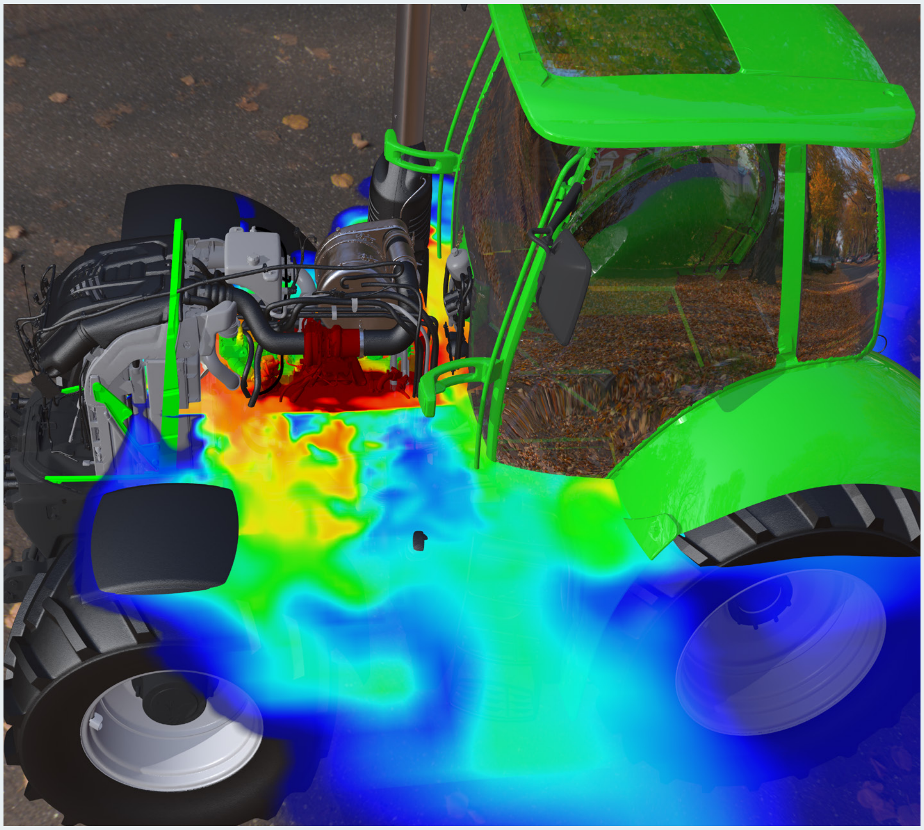
"Validation for us means releasing the procurement of the prototypes," says Crippa. "If, for example, three different suppliers offer three different proposals, thanks to CFD we are now 100% sure of selecting the best cooling system for our application."

POWERFLOW EARLY IN THE DESIGN PROCESS

PowerFLOW helps SDF to improve cooling system design in order to reach the performance target. This might include changing to a different fan, positioning the fan in a different way, changing the cooling pack, or adding flaps or plates around the cooling pack in order to direct the air in a different way.

The number of simulation runs has increased year on year as SDF has renewed all of its product families, from the Series 4 to the Series 11, each of which consists of a range of tractors that might have engine





"THANKS TO CFD, WE ARE NOW 100% SURE"

outputs from 50PS to 530PS. All of these have to fulfill Tier 4 Final/Stage IV legislation, but at the same time all have been given a new hood design, new cab and new powertrain.

The use of an automatic optimization algorithm is central to the way PowerFLOW is used by SDF to manage this model proliferation. Instead of a trial-and-error approach in CFD, a Design of Experiments (DOE) methodology is used. DOE starts with a target and identifies variables that will help achieve the target. PowerFLOW then performs 3D simulations using vehicle models that are accurate to the smallest detail. It provides a shortlist of the best options for the engineers, who then use their experience to select most suitable one.

At SDF, DOE was used for the first time on the TTV tractor model range and now saves time and cost on every development program. It streamlines the process and optimizes the efficiency of the cooling system early on, before a physical prototype is available to test.

“We now are investing more time and effort at the beginning of development,” says Crippa. “Using PowerFLOW, we identify the best combination or configuration for the vehicle from several possible layouts, suppliers or cooler technologies. The Design of Experiments analysis then helps us to identify the correct position for each component. This is very difficult to do in the power take-off (PT) laboratory through physical measurement alone because you need lots of time to set up the configuration, instrument the vehicle, perform the measurements and read the results. CFD saves a lot of time. Moreover, you cannot instrument the vehicle in that environment in a way that would deliver the same information as you can get from CFD.

“Although we invest more time at the beginning of development, the time needed at the end for validation has been reduced dramatically,” he adds. “In the past we might have needed eight weeks to validate a cooling system; now it’s done in just two. We perform a few validation tests to have an understanding of the fan power absorbed, and to have a clear picture of all the operating points of the engine. This process is linear and conducted with a high level of confidence.”

CFD IN NEW AREAS

With the success of the cooling system development programs, SDF has now expanded its use of PowerFLOW into the development of individual components, such as a cooling fan, as well as into other areas of the vehicle. SDF began to use Exa’s software to optimize the conditions in the driver’s cab, where the driver’s ability to be comfortable for many hours at a time is an important market requirement. PowerFLOW is now used to design the ventilation openings and the flow of air inside the cab in order to maximize the level of comfort for the driver, regardless of the external temperature. SDF’s tractors operate in markets from Finland to South America, with wide variations in external temperature. The use of PowerFLOW means that SDF need not test its products in complex, expensive climatic chambers.

In fact, PowerFLOW has also helped SDF to quantify the limitations in some of its physical test facilities. The PT rooms, where the rotating power take-off shaft at the rear of the tractor is braked to load the engine to almost 100%, are a great example.

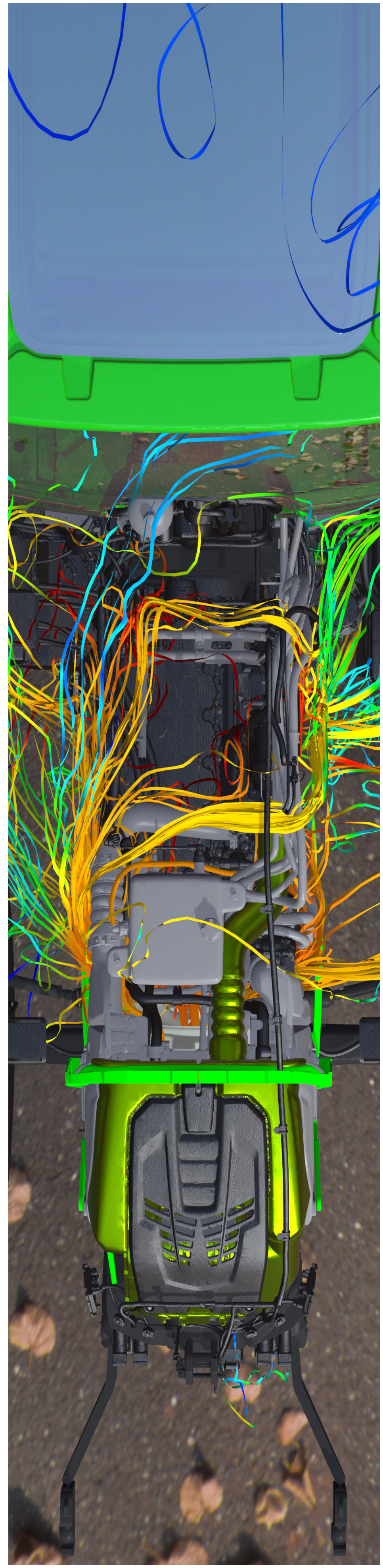
“The finite volume of the PT room influences the behavior of the tractor’s cooling system,” says Crippa. “There is recirculation of warm air into the cooling system; this alters the measurements and affects our performance evaluation. With the support of CFD simulation, we have identified the factor by which cooling system performance differs between CFD and the PT room. We have very good correlation and on occasions when we’ve had the problem of recirculation inside the PT room, we have tested outdoors in free-field conditions and found the same performance that we had simulated with CFD.

“We are now upgrading our PT test beds with the help of CFD simulation,” he continues. “The aim is to stop the room altering the performance of the cooling system. CFD also supported us in a wind tunnel test that we carried out at a supplier facility. In that case the wind tunnel influenced the behavior of the tractor’s cooling system. We used CFD simulation to understand the tunnel’s behavior and to try to modify the features of the blower to avoid recirculation. CFD today is a reference tool for us for finding issues.”

CLOUD-BASED SIMULATION

From the beginning, Exa has supported running PowerFLOW in SDF’s 140-strong R&D department. SDF engineers have become highly skilled in interpreting the results, helped by PowerFLOW’s ability to render simulation results in high-resolution, 3D graphics that enhance understanding of the flow around the engine or cab, Productivity was given a huge boost by the wholesale switch to flexible, Cloud-based simulation via ExaCLOUD.

For the future, CFD methodology will remain an integral part of SDF’s development process as the company pushes ahead with a busy program of new product launches. “We currently have several vehicles in the development phase, for which we have to simulate everything we can in order to avoid wasting time during the validation phase,” Crippa concludes.



Exa PowerFLOW and PowerTHERM thermal simulation images are courtesy of SDF.