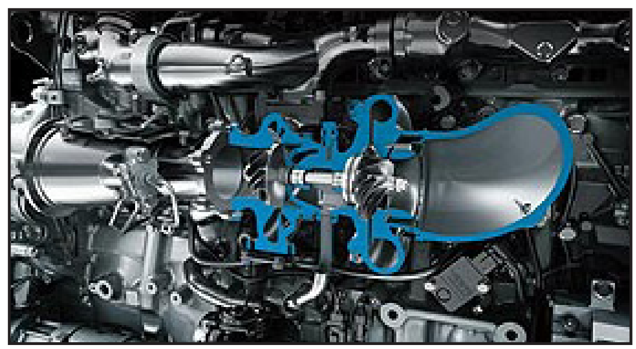
Case Study

Daimler uses Concepts NREC Software to Develop Breakthrough Exhaust Gas Turbocharger

In a bid to further reduce fuel consumption and increase service life in commercial vehicles, Daimler AG brought its turbocharger design function in-house. Using Concepts NREC CAE software programs such as AxCent®, COMPAL®, and RITAL™, the result was an innovative new asymmetric design that is producing impressive results in the new engine used on the Freightliner Cascadia Evolution truck.

It is well documented that the exhaust gas turbocharger is the most efficient device for charging combustion engines. However, taking this one step further, in Daimler AG's heavy duty commercial vehicle engines, the exhaust gas turbocharger is also used as an effective EGR (engine gas recirculation) system. This paradigm shift in turbocharging technology has resulted in a significant fuel consumption advantage – which is very critical for commercial vehicle haulers. Also, EGR rates of up to 35% are being achieved, along with high turbocharging efficiency and an operating service life of over 1 million kilometers.



An Exhaust-Gas Turbocharger for HD Daimler CV Engines. (Image Courtesy of ATZelectronik)

These remarkable results are achieved thanks to the creation of a special asymmetric design, where one turbine scroll is larger than the other. The upshot is there is no longer any need for the alternative variable turbine geometry, which also happens to be less beneficial in terms of fuel consumption.

Asymmetric design has long been a goal at Daimler, but the reality has always meant custom-matching the turbocharger to the engine to achieve optimum performance. This is difficult, both technically and economically, using third party turbocharger suppliers. With this in mind, Daimler decided to start designing its own turbochargers in-house at the company's Stuttgart development plant using Concepts NREC software.

"We undertook some benchmarking work to assess various turbomachinery design software before making our purchase decision," explains Dr. Markus Müller, Manager of Turbocharger Development. Suitably impressed, Dr. Müller and his team opted to acquire one-seat licenses for various elements of Concepts NREC's Agile Engineering Design System®, including RITAL for preliminary turbine design, COMPAL for preliminary compressor design, and AxCent for detailed design of both turbines and compressors.

The selection of Concepts NREC software proved critical in this particular project, where the ability to scale the asymmetric scroll in the radial turbine was facilitated by a new, specially developed feature in

Daimler uses Concepts NREC Software..., continued

RITAL. “It was a sub-project all of its own,” says Dr. Müller. “We worked closely with Dr. Nicholas Baines (Distinguished Corporate Fellow at Concepts NREC) to achieve the levels of functionality required. The support we received was first class.”

With the new software feature in place, RITAL was used to design the asymmetric turbine stage, analyze performance, refine parameters with data reduction, and undertake modelling. The data was easily migrated into AxCent for further blade design and thermodynamic analysis.

Crucially, engine thermodynamics were used to help define the individual scroll sizes of the asymmetric radial turbine. Detailed analysis of 3D numeric flow simulations helped show the turbine areas exhibiting the biggest losses, which were used to optimize efficiency. Similarly, the turbine impeller itself was designed featuring the largest possible exit angle, again to allow for high efficiency, particularly during the part-load operating range of the engine.

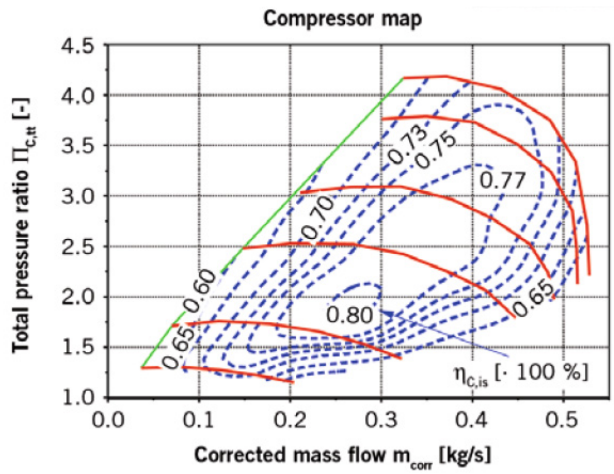
To achieve even further efficiencies at part-load, the target degree of reaction at full load was chosen so that the maximum efficiency could be moved in the direction of the partial load. This optimization depended extensively on the engine application profile of the vehicle and reflected a compromise between high subcomponent efficiencies and low fuel consumption. The repeated use of complex numerical simulation processes was essential to design an asymmetric turbine with maximized mechanical efficiency.

Daimler AG also used COMPAL to help design and develop the compressor wheel. Here, a peak efficiency of 80% is achieved as a compromise between map width and optimum efficiency. This is facilitated by numerically optimized back sweep blades featuring the necessary wrap angle.

After approximately five major compressor wheel iterations and 10 turbine iterations, the design was ready for final endurance test programs to provide functional validation. These entail the continuous inspection of exhaust gas turbocharger characteristic maps. For instance, it must be seen that the turbocharger operates correctly at the oil supply limit of the engine.

Accelerated impeller lifetime tests also took place. The impellers are optimized to achieve over 200,000 cycles on a hot turbocharger rig before fatigue fracture. This is converted into kilometers using a customer relevant cycle. There was also a 2000 hour endurance test on a multi-cylinder engine to check thermo-mechanical strength.

Road tests were staged in Europe, America, Africa, and Asia, at altitude and at high ambient temperatures. In total, over 9 million kilometers of testing took place, along with 150,000 hours of engine operating tests and a further 70,000 hours on the gas test stand – all to satisfy the desired performance, safety, and quality demands of Daimler and its customers.



Compressor Map (Image courtesy of ATZelectronik)

Manufacture of the new turbocharger commenced in Q3 of 2012 at Daimler’s Mannheim production plant. It is being used for the first time as part of Daimler NEG (New Engine Generation) on the Freightliner Cascadia Evolution, which is designed to be the most fuel efficient commercial truck on the road.

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