Turbo
Technologies

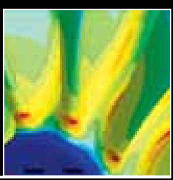
HTi

The Latest Turbocharger News

Testing Waste Heat Expanders for New Generation Diesels

Edition 17:

P5-6
Laser Tip-Timing for Turbocharger Blade Vibration Measurement and Validation



P7-8
Applying Holset Turbocharger Durability in Light Commercial Vehicle Markets

P9-10
Our Engineering Heritage: Its Legacy and Evolution

Executive Comments

There have recently been organisational changes within Cummins Turbo Technologies, a reflection of changes within the larger company itself. On 1 February, Tracy Embree, President of Cummins Turbo Technologies, announced a new organisation which is more customer focused and product and technology oriented.

The changes in leadership are emblematic of how our engineering focus is growing to encompass what lies ahead on the technological front. This, in turn, positions us even better as the number one choice for customers for a wide range of applications.

As we continue to improve our leadership in technology and product management, realignment resulted in the formation of a team in the area of Product Line Management and Marketing. This will bring focus to global product planning and strategic management of each product line, based on market requirements, as well as delivery of platform VPI programs. Heading the team is myself.

A key part of our growth strategy has been focused on small turbos. This product was launched successfully in 2011 and the team did a fantastic job delivering upon that commitment. The organisation within that group has provided many good practices that we are carrying forward into the new structure and we learned that product line focus is very critical to the success of our business. Our focus on the small turbo product line will continue as part of our new business structure.

Another significant part of Tracy's announcement was that of Jonathan Wood, who has now joined the Leadership Team with responsibility for the Research and Engineering function for Cummins Turbo Technologies. Jon has been with Cummins for more than 17 years, all within Cummins Turbo Technologies engineering, based in both the UK and China, most recently providing leadership for engineering activities across all of the Asia business. Jon is Six Sigma Green Belt Certified. We look forward to his valuable and fresh contribution to the team.

Mark Firth

At times, we have the opportunity to communicate our engineering expertise through events, such as the IMechE 10th International Conference on Turbochargers and Turbocharging in London. In this issue of HTi, we take a look at two of the technical papers presented at this year's IMechE event, as well as the paper presented on small turbos at the 16th Supercharging Conference in Dresden last year.

Sharing our world-class knowledge of process and design allows us to remain 'top of mind' to our customers. It is with this and with new and exciting changes within, that we springboard into the rest of 2012.

As such, I leave HTi in Jon's capable hands moving forward. Many thanks for the time taken to read our publication.

Mark Firth
Director; Product Line Management and Marketing

Editorial

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HTi is the Cummins Turbo Technologies' magazine focusing on the world of turbocharging. It aims to bring you news on product and market developments.

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In the News

Waste Heat Recovery Technology Unveiled at MATS

Cummins Turbo Technologies offered a glimpse of its advanced waste heat expander prototype to customers and visitors attending this year's Mid-America Trucking Show (MATS) on 22-24 March.

Cummins Turbo Technologies' expertise in the field of small, high-speed turbines and participation in the US Department of Energy's SuperTruck initiative, means that it is the first to reveal a solution that is currently being developed for specific applications on behalf of a number of customers.

The system, which includes the Holset waste heat expander, can reduce fuel consumption by up to 6 percent, delivering fuel savings of between US$4,000 (typical heavy-duty cycle) and US$40,000 (typical high-horsepower cycle), depending on the application and engine power.

The principles of waste heat recovery, which utilises organic fluids to draw energy from available waste heat, is proven in applications such as electricity generation and very large marine diesel engines, particularly because engine power output determines the scale of fuel, emissions and dollars saved. The Holset waste heat expander is also suitable for smaller applications.

The waste heat turbine expander prototype was displayed alongside Cummins Turbo Technologies' latest range of highly efficient turbocharging solutions, namely electronic variable geometry turbochargers, two-stage turbochargers, small turbochargers and the turbocompound system, highlighting both market relevance and appropriate fit within their wider product portfolio.

The waste heat recovery technology will be next showcased at the IMechE 10th International Conference on Turbochargers and Turbocharging sponsored by Cummins Turbo Technologies in May. (www.ime.com/turbo)

Cummins Sponsors Big Bang 2012

Cummins was a proud sponsor of The Big Bang 2012, held on 15-17 March at the NEC Arena, Birmingham, UK. This event aims to inspire and promote STEM (Science, Technology, Engineering and Math) to young people.

Involvement with The Big Bang demonstrates the desire and determination of Cummins to promote engineering in a positive, dynamic light, highlighting the potential for interesting and worthwhile careers within our industry.

In addition to sponsoring the event. Cummins featured a hands-on, team-working activity that emphasised the technical and environmental nature of our operations, engaging 8 to 18 year olds.

Wuxi Cummins Turbo Technologies Win Customer Awards

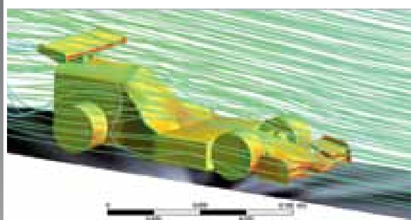
Cummins Turbo Technologies in Wuxi is celebrating success after winning customer recognition and a number of industry awards as a result of excellent quality, advanced technologies, timely delivery and high quality service in the past year.

Wuxi Cummins Turbo Technologies commemorated significant milestones in 2011, including the six millionth turbocharger off the assembly line, the upgrade of production capacity and completion of the technical centre second stage development.

Despite challenging market conditions, the Company achieved 1.17 million units and US$265 million in sales, as well as almost 100 percent delivery in 2011.

Wuxi Cummins Turbo Technologies has been honoured with a host of awards in recognition of its excellent performance and customer-led approach, including Satisfactory Supplier from CNHTC, CCEC and XCEC, Best Technical Support from DCEC and Top Quality from Weifang Diesel Engine.

Young Engineers Work With Cummins to Achieve F1 Success



Team Kinetic, a Huddersfield based F1 in schools team, has been working with Cummins Turbo Technologies' engineers on the design of their racing car. The engineering students used the latest design and simulation software at Cummins, as used by the main Formula 1 teams, to improve the aerodynamic performance of their car.

The team took first place at the regional finals for Yorkshire and the Humber on 23 February. They also took part in the UK national competition at The Big Bang event in March.

As well as developing a competitive car with the support of Cummins' world-class engineering design capabilities, the Kinetic team have also set their sights on future careers in engineering and design.

Testing Waste Heat Expanders

for New Generation Diesels

Written by Ed Halliwell; Senior Mechanic - Facilities Engineering

With increasing pressure to reduce CO_2 emissions and fuel consumption, engine manufacturers and vehicle integrators are looking for more radical ways to increase engine efficiency. One method is to attach a waste heat recovery system to the engine, drawing energy from a number of heat sources. Using organic fluids, this energy can be turned into useful mechanical or electrical work.

A turbine expander is a compact and efficient way of achieving this end and Cummins Turbo Technologies is currently working with a number of customers to develop turbine expander products for specific applications. The technologies used in such devices are allied to those of the turbocharger and require similar design, testing and optimisation of the product.

As organic fluid turbine expander technology is new to Cummins Turbo Technologies, there was a requirement to design a new test cell facility. The organic working fluids have thermophysical properties that are substantially different from those of our normal test fluids (i.e. air and exhaust gas). These differences make it virtually impossible to operate the turbine expander anywhere close to its intended thermodynamic design point if tested on a conventional gas stand. By not operating at its intended design point, it makes design validation very difficult.

To enable comprehensive product test and design validation Cummins designed and built a dedicated test facility. The installation of this facility represents an investment of more than US$1.5 million and provides the capability to evaluate the thermodynamic performance and durability of these high-speed micro-turbine devices. Design of the facility has brought a number of challenges, which include the safe handling and managing the environmental impact of using organic fluids, measurement of power from small high-speed turbines, dynamic control and operational safety.

The main function of the new test facility is to produce a performance map of the turbine expander by controlling the turbine expansion ratio, turbine inlet temperature and shaft speed to pre-determined points while logging data, just like a conventional turbine mapping cell for a turbocharger. The difference between a conventional and an organic fluid expander test cell is that the organic fluid cannot be vented to the atmosphere at the turbine outlet as is the case with turbocharger testing. Therefore the cycle has to be closed loop. Once the expander has extracted all the energy it can, a condensor is required to reject further energy from the fluid to return it to its liquid state.

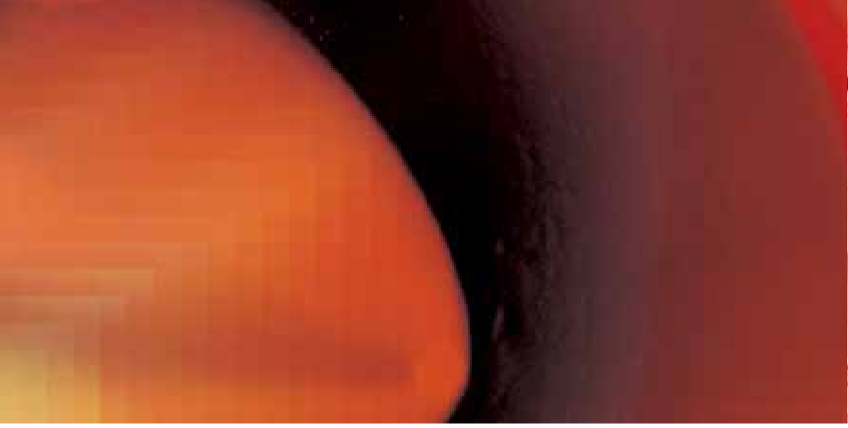
It was always the aim while developing this facility that the on-engine application for the turbine expander would not be simulated, rather that the system would be designed to enable stable, repeatable and safe running. The working fluid used in the test cell can degrade with prolonged exposure to temperatures above 250°C. Therefore, the design of the test cell centred on using electrically heated heat transfer oil that could safely heat the working fluid to the required operating temperature without the risk of overheating.

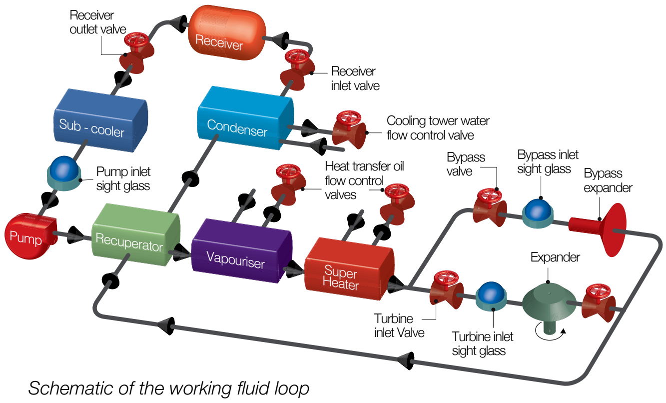
Working fluid loop

The packaging of the high-pressure liquid line from the pump outlet to the super heater outlet is not so critical as regards fluid flow. Care has been taken to allow for expansion of the stainless steel pipework without over stressing components. The main emphasis was on positioning the recuperator, vaporiser and super heater heat exchangers within the cell to allow uninterrupted pipe runs for both the working fluid and the heat transfer fluid (HTF) while not restricting personnel access required for operating and maintaining the cell.

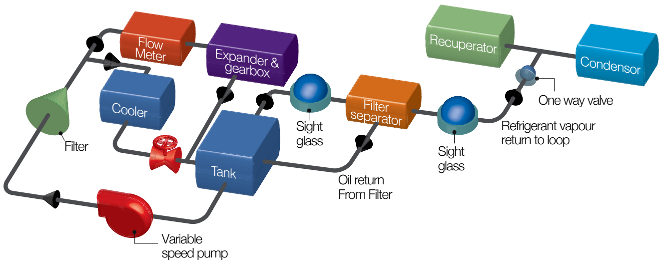
It is important that only super heated dry vapour passes through the turbine expander. At rest, liquid working fluid is present throughout the loop. Before start up, hot HTF is circulated through the vaporiser and super heater. This slowly raises the temperature and pressure of the working fluid in the system. The working fluid is then pumped around the loop against the hot HTF and the fluid states around the loop slowly change to the operating states. Liquid can be present at the outlet from the super heater until the whole loop is at operating conditions.

To stop this liquid entering the expander during warm up, the rig includes an expander bypass loop. The working fluid out of the super heater can be diverted through or around the expander. The inlet to the turbine expander rises up to a shut-off valve; the other path includes another shut-off valve and a fixed orifice expander. This bypass leg feeds back into the turbine outlet pipework before the hot side of the recuperator. There is a third valve on the turbine outlet before the bypass outlet to isolate the turbine expander from the refrigerant loop.





Schematic of the working fluid loop



Schematic of oil system

The most critical section of the working fluid loop is from the condenser outlet to the pump inlet. The pump has a required net positive suction head, which is achieved by a combination of head of liquid in the receiver above the pump, gravity and the vapour pressure of the working fluid. Also, the outlet of the condenser must always remain clear of liquid working fluid so it has to be at the highest point in the system. Therefore, the condenser height determines the maximum receiver height which in turn determines the available net positive suction head.

Testing challenges

Although there are similarities in this rig and a conventional turbocharger gas stand, the added complexities from the necessity to manage the working fluid safely, drive a whole new set of working practices.

When fitting a new expander to the rig for testing, all the pipework between the turbine inlet and outlet shut off valves has to be leak checked at the operating pressure using nitrogen. If leak free, this pipework has to be vacuumed down to 2 torr and the vacuum has been stable. This process can take up to two days. Before removing the expander all the turbine inlet pipework has been emptied of working fluid. This involves using a special fluid reclaim unit. This process can take up to six hours. To swap a turbocharger on a conventional gas stand would usually be done within three hours.

Calibration of the pressure transducers has to be done via special calibration valves so the transducer diaphragm can be isolated from the working fluid without breaking into the system.

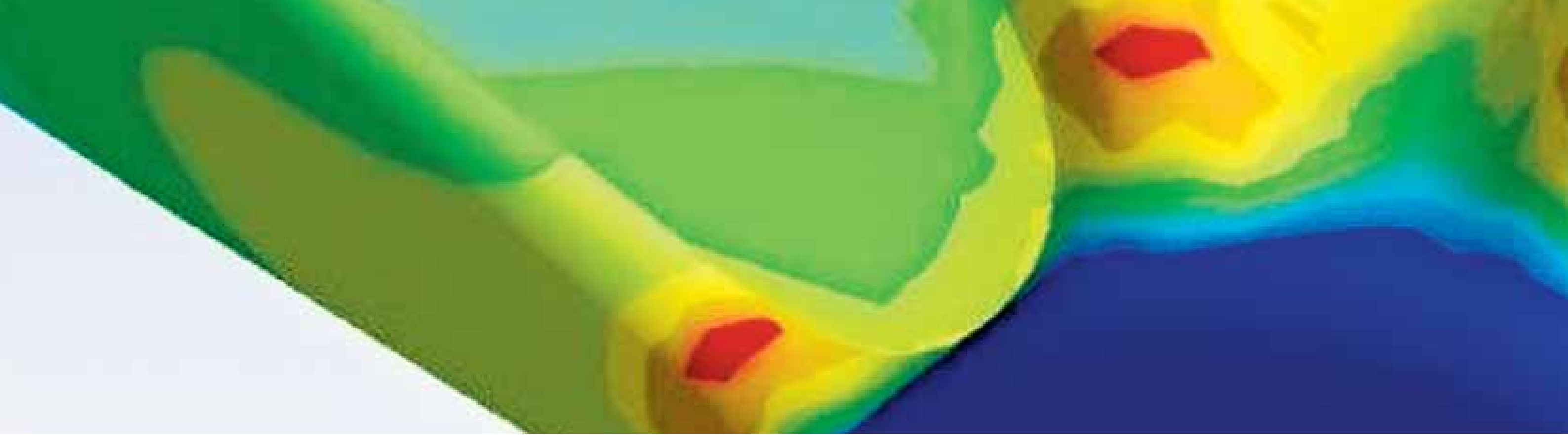
The section of pipework that has the biggest impact on running fluid through the Rankine cycle is the condenser outlet to pump inlet. The relative positions of the condenser, receiver and pump inlet are critical for fluid flow. However the cycle would still not work without the liquid sub-cooler at the outlet from the receiver. Therefore, the liquid sub-cooling heat exchanger is the key component within the whole system.

Using a large electric heater to control HTF temperature has shown that control of the working fluid temperature can be maintained within +/-2°C. This stability affords similar temperature stability at the turbine inlet during steady state running. During transients, turbine inlet pressure, controlled via pump speed is stable and responsive, however mass flow increases disproportionately at the same time before dropping off again at steady state conditions. Also, the heating and condensing responses lag behind mass flow during transients so a stabilising period is required before any steady state data can be recorded.

The added complexities from the necessity to manage the working fluid safely, drive a whole new set of working practices.

Cummins Turbo Technologies' achievement of constructing and utilising a novel waste heat expander test cell adds to the Company's long list of notable achievements. With it, the vision is cast for improving future turbocharging capabilities. Capturing and optimising the use of waste heat via turbine expansion guarantees to increase a turbocharger's range of benefits and solutions for tomorrow's power requirements.

This article is a summary of a technical paper delivered at the IMechE 10th International Conference on Turbochargers and Turbocharging. The full paper can be accessed at www.cummins.com/turbos



Laser Tip-timing for Turbocharger

Blade Vibration Measurement and Validation

Written by John Allport; Talent Development Leader - Asia and Martyn Jupp; Applied Mechanics Development Group Leader

With special thanks to A.Pezouvanis, G.W.Janicki, A.I. Zdunek, A.J.Day, P.Olley, B.Mason and M.K.Ebrahimi, School of Engineering, Design and Technology, University of Bradford

In the turbocharger industry, vibration not only has a direct impact on durability and warranty costs, but also plays an important role in the end user's perception of vehicle quality. That is why an accurate measurement of blade dynamics is necessary when designing a turbine wheel. Although strain gauging has been used for this purpose for many years, it has limitations and so an alternative method has been investigated.

The resulting findings can then be used to optimise the design of turbine wheels, making them more resistant to mechanical loads and their corresponding vibrations. Ultimately, more robust, durable and reliable turbochargers could be produced as a result of this work.

Tip-timing method

The tip-timing method used involves a very accurate measurement of the times at which the blades pass by a series of unequally spaced sensors. In this case, the sensor set consists of a series of laser probes mounted in the turbine housing, which reflect a beam of light off the blade as it passes. If the blade is rotating at a constant rate, a particular blade should pass each sensor at a predictable time.

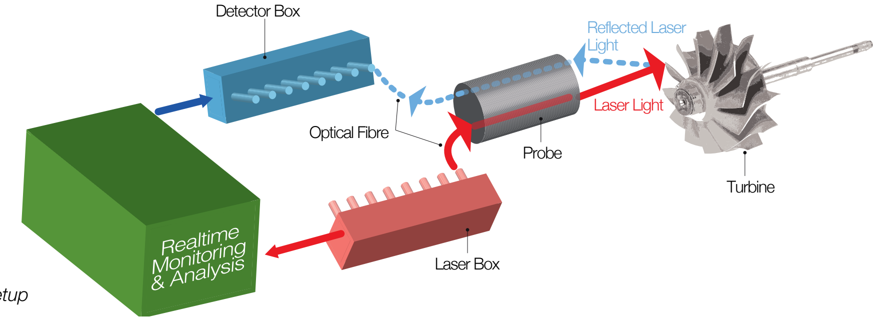


Fig 1 – System setup

Cummins Turbo Technologies and the University of Bradford have collaborated on the Advanced Turbocharger Technology Engineering Project (ATTEP). In this project, a tip-timing method which has been proven in the aero industry but has seen only limited application on small turbines as used in turbochargers, was combined with recently developed finite element simulation techniques to provide a means of assessing the susceptibility of turbine blades to High Cycle Fatigue damage.

The tip-timing method uses a set of optical probes that measure the blades arrival times and uses the time differences between expected and actual arrival times to calculate blade deflections within a time domain. In comparison to the existing strain gauge based testing procedures, the tip-timing represents a non-invasive approach, which is more likely to record real-life turbocharger operation parameters. What is more, tip-timing can provide complete information about the total rotary system, returning a great amount of data for further system analysis, rather than the limited data related to a single blade obtained through the more conventional strain gauging approach.

Deflection due to vibration causes the blade to pass the sensor either earlier or later than predicted, hence the difference of these times can be used to calculate the deflection from the initial position for each individual blade. By using a powerful laser with a small point of focus and a very fast data acquisition card, the system is able to detect vibrations of less than 0.2 µm at the working speed of the turbocharger as shown in figure 1.

For synchronous vibration, the order of interest is defined and the software tries to match the vibration measured to that order and gives the amplitude and level related to the matched order. When there is simultaneous vibration at different frequencies (different modes), the system is still able to recognise and separate modes, provided the appropriate number of sensors are used. By increasing the number of sensors, several modes of vibration can be detected simultaneously, with 2N+2 sensors required to analyse N modes. In this case, eight sensors were used to analyse three modes.

Tip-timing software with output data examples

One of the biggest advantages of the tip-timing system is that it collects data from all the blades simultaneously, so this gives the opportunity to compare their vibration, which was not possible previously. Specific orders and frequencies can be tracked and data can be plotted in a variety of different ways, allowing a more detailed understanding of the underlying physics to be gained.

Synchronous vibration analysis is based on Least Squares Model Fitting (LSMF). The LSMF curve fits sine waves to the data, so the first thing to determine is the order of vibration which is of interest for a given sample. The software checks which order best fits the sample and displays the data in the form of a bar chart (Figure 2). The highest bar is the most probable order of vibration measured in the given data sample.

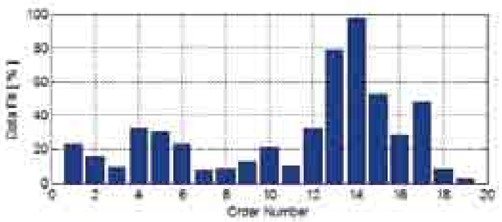


Fig 2 – Chart of model to test data fit

Comparison of laser probes with other sensors

There are a number of advantages of the optical sensors which are used in the tip-timing method relative to the traditional method using strain gauges. There is always some question about measurements where the sensor needs to be attached to the component being measured – is the measurement affected by the act of measuring?

The use of strain gauges requires the rotor speed to be held at the point of resonance so that a reliable measurement can be taken. It is therefore characterised by poor repeatability as it is difficult to maintain all parameters constant simultaneously.

The best type of proximity sensor currently available for this application is a reflective laser sensor. These are characterised by very high working speed, a small focus point that further improves their accuracy and resistance to extremely high temperatures. They are also immune to any kind of electromagnetic interference. Moreover, these sensors require very little space for installation in the housing since they are smaller than most other sensors. Figure 3 shows the relationship between the results from the strain gauge and tip timing methods.

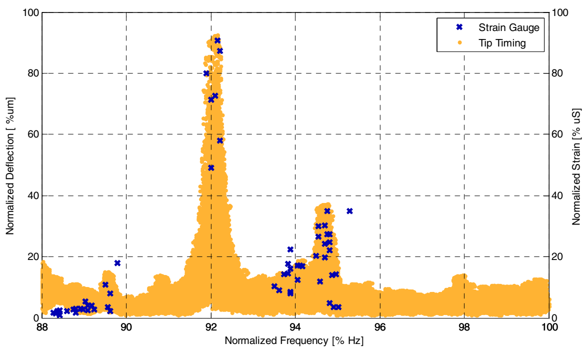


Fig 3 – Typical vibration results

Simulation and test results correlation

In order to minimise possible variation caused by model simplifying assumptions such as cyclic symmetry, the CAD turbine models represented a complete wheel, rather than an individual blade. This approach was believed to produce more complete results, providing information about the inter-coupling effects of the blades and giving a more realistic frequency distribution than is obtained using single blade models.
At the same time, modal analysis returned calculated natural frequencies of the wheel, together with their complex mode shape visualisations. It may be verified that the maximum number of natural frequencies for an object is the number of FE Nodes. Nevertheless, due to the characteristics of the turbine forcing function, the effective vibrations diminish with the increasing frequency, or may even be impossible to achieve. That is why the number of natural frequencies that were investigated has been limited to the fifth mode of vibration.

The analysis of the simulation results involved a classification of the frequencies, based on their value, nodal diameters and mode shapes. Validation of the results proved that the new method is capable of a successful prediction of modes 1, 2 and 3 resonant frequencies. The demonstrated accuracy for the new methodology on the initial limited dataset was found to be within the accepted range.

Summary

After two years of research, some significant improvements have been made. They include the application of tip-timing method and advanced simulation techniques for the prediction of vibration of turbine blades.

Knowledge about turbine vibrations has been extended, enabling the fulfilment of the project's objectives. The effects of various turbocharger operation parameters have been investigated, by both simulation and tests.

With Cummins Turbo Technologies' new, state of the art laser tip timing approach, the potential failure mode of one of the major causes of turbocharger failure, High Cycle Fatigue, is more easily detected. The additional detail provided by this method allows validation of changes to be made with measurement precision far exceeding that of strain gauging. As such, Holset turbocharger customers are assured that their products have been optimised using the most up to date techniques of turbine vibration reduction.

As a result of this collaborative research, a new method for turbine design has been formulated and validated. The analysis of validation results showed a good match between modelled and experimental data. The aims and objectives of this project have therefore been exceeded. This confirms Cummins Turbo Technologies commitment to innovation and ground breaking reliable technologies.

This article is a summary of a technical paper delivered at the IMechE 10th International Conference on Turbochargers and Turbocharging. The full paper can be accessed at www.cummins.com/turbos

Applying Holset Turbocharger Durability

in Light Commercial Vehicle Markets

Written by Dave Green; Director - Engineering, Steve Garrett; Principal Engineer - Advanced Engineering and Martin Lindsay; Component Engineering Manager

The size of the Light Commercial Vehicle (LCV) turbocharger market is estimated at US$1.5 billion a year. It is the second largest sector within the global turbocharger market. With large LCV markets in China expected to grow at 16-20 percent a year, worldwide growth is forecast at 12 percent per annum to 2015 and Cummins Turbo Technologies is geared up for the challenge of producing world class turbochargers for the segment.

Engines in the LCV sector typically have more arduous duty-cycles than passenger cars and they need a greater focus on reliability and durability. However, more sophisticated turbocharging solutions are required to enable engines to comply with increasingly stringent emissions limits. The introduction of carbon dioxide (CO_2) reduction targets for LCV within the European Union, which begin to take effect in 2014, increases the need for sophisticated turbocharging techniques such as variable geometry (VG) and two-stage systems that also enhance fuel economy.

Current passenger car/LCV turbochargers with VG fall short of the full durability and reliability expectations of LCV manufacturers. This prompted Cummins Turbo Technologies' decision to leverage its expertise and experience of supplying turbochargers that satisfy the tougher duty-cycles of heavy-duty diesel engines and apply similar technology into the LCV sector, a market previously not served by our company.

Tackling arduous LCV duty-cycles

In the past Cummins Turbo Technologies had limited experience of this sector but that is changing, not least because of the introduction in 2008 of the Cummins ISF 2.8 litre and 3.8 litre engines, designed specifically for light commercial applications. Demand for VG turbochargers for LCV is poised to grow as manufacturers turn to VG technology in both single and two-stage configurations to help them meet the emissions limits and corporate CO_2 targets.

HE200 during early prototype testing

All VG turbochargers currently used in the LCV market employ swing-vane technology as a means of adjusting their swallowing capacity in order to extend their flow range. Cummins Turbo Technologies' sliding-wall VG technique, proven in the more arduous duty-cycles of heavy-duty diesel engines, would provide superior reliability and durability. It would also facilitate thermal management of exhaust after-treatment systems and can be used for engine exhaust braking.

Re-writing the VG design rule book

While determined to bring the benefits of technology proven in harsher, heavy-duty diesel applications, it was equally important to challenge design rules and limits at every opportunity. While developing what is now the Holset 200 series, we had to examine and test the relevance of heavy-duty rules for LCV applications.

Two VG design options were considered during development. Although selected as the better concept, Option 2 was not without its own design challenges. For example, one objective was for each turbocharger size in the range to have family features, such as a similar style, parts count and assembly method. This would allow each to be assembled on the same line until sales volumes are sufficient for separate assembly lines. This meant forward thinking to take account of future possible bearing systems and wheel sizes.

Although Cummins Turbo Technologies' sliding-wall VG principle is well established in service over 14 years, its application to the new small Holset 200 series broke new ground. Moving the VG mechanism from the bearing housing to the turbine housing is the main design novelty, but the VG mechanism itself is also different in one key respect. Whereas our heavy-duty Holset VGT™ has a sliding nozzle ring and a fixed shroud, that configuration is reversed in the HE200VG; the shroud moves and the nozzle ring and vanes are fixed.

Nozzle and shroud optimisation

In order to fully explore the implications of this we established a Six Sigma project to gain a deeper understanding of the forces from the exhaust gas pulses acting on the nozzle and shroud. The work involved in-depth analysis of the factors affecting loads within the shroud and led to a methodology for predicting nozzle loads. This prediction method cuts development time and cost by reducing the number of iterations of different nozzle vane configurations and seal sizes/positions when seeking the optimum solution.

Modular approach produces different versions from common core

Core

VG turbine assembly

VG product

Wastegate turbine assembly

WG product

The VG configuration adopted for the Holset 200 series reduces the potential for wear by transferring the nozzle torque directly into the turbine housing. This not only relieves the VG mechanism from having to react to this load but also makes it less sensitive to pressure pulsations. Minimising the pulsating aerodynamic loads acting on the shroud produces benefits in terms of the VG mechanism's durability, linkage design and the sourcing of cost-effective actuators with the appropriate torque capability

Developing a modular product range

The use of a modular approach for the Holset 200 series, using a common core for both VG and wastegate versions, would help to control parts proliferation but the risks and compromises of using common parts had to be thoroughly understood. It was essential that modularity generated volume related cost savings rather than giving rise to expensive over-specification that served no purpose and risked alienating the customer.

The new turbocharger range is designed to accommodate VG, wastegate and fixed geometry requirements. VG versions use water-cooled smart electric actuation. Wastegate versions use an air-operated actuator and their design makes it possible to mount the actuator in one of several locations.

Performance testing

Cummins Turbo Technologies underlined its commitment to the small turbocharger market by investing US$5 million in four new state-of-the-art test cells for the project, designed to ensure that every aspect of performance is evaluated as thoroughly as possible. Having selected the better of the two options, a concept verification unit was built in spring 2009, to be used for performance testing.

Applying our inverse design techniques and knowledge of compressor and turbine design for demanding heavy-duty applications, the performance of the new range of turbos is noticeably different from current LCV turbo designs. Competitor benchmarking shows that the new Holset 200 series has more compressor map width than others, evidence that Cummins Turbo Technologies is delivering improved product performance in this market segment.

Cummins Turbo Technologies is the only turbocharger manufacturer serving the LCV market mapping turbines at a wide range of speeds and loads on a dynamometer. Our approach to mapping means we can provide test cell data to populate almost the entire data range required for engine simulation work with minimal extrapolation. Working as a development partner with engine manufacturers, Cummins Turbo Technologies can provide this valuable extra turbine map data to give our customers a competitive edge in their emissions predictions.

This new range of small turbochargers takes the company into a completely new sector of the global turbocharger business and one that is both large and growing quickly. The new turbochargers will suit a plethora of LCV and other light-duty applications meeting Euro 3 to Euro 6, US EPA 2010 and 2013 and Tier 4 exhaust emissions limits. They provide engine manufacturers with a new cost-effective alternative that delivers outstanding levels of reliability and durability.

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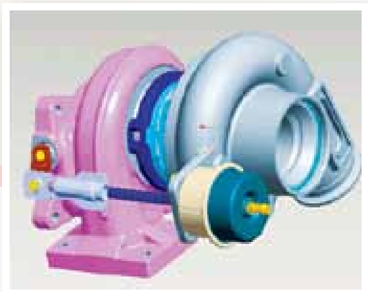
Turbine housing mounted bracket

Flexible compressor cover bracket



Fixed compressor cover bracket

Alternative mounting points for the wastegate actuator

Our Engineering Heritage:

Its Legacy and Evolution

Written by Alison Smith; Senior Marketing Coordinator

At the outset, Holset Engineering was led by forward thinking diesel engineers Paul and Louis Croset. Paul had also engaged Ron Hesselden, a jig and tool designer who later became a strong influence in manufacturing. They were convinced that to stay competitive, the diesel truck engine had to be turbocharged. Sixty years on, we look back at how this insight into diesel engines and the vision of Holset's founding fathers was instrumental to the success of Holset and later to Cummins Turbo Technologies.

Holset Engineering, incorporated as a Limited Company on 29 March 1952, initially focused on dampers and couplings. However, the interest in turbochargers is believed to go back to an early association between Louis Croset and Dr. Alfred Büchi, when they worked together at Sulzer Brothers. Holset's interest in automotive radial-flow turbochargers grew in the early 1950s. Holset recognised the potential of turbochargers as a key future technology and in 1954 began to research the technical and manufacturing processes of turbocharging by collaborating with Dr. Alfred Büchi, the inventor of the turbocharger.

There had been some proven technical advances on small turbochargers in the USA. Initial contact was made with Louis Schwitzer of the Schwitzer Corporation in Indianapolis, Indiana, USA, as early as 1952. After many negotiations, a licence agreement embracing the manufacture and sale of turbochargers and rubber dampers across Europe was signed on 10 May 1957.

This agreement was a key milestone in the history of Holset, taking the company firmly into the turbocharger business and making Holset the only company in the world capable of handling torsional vibration problems across the whole spectrum of internal combustion engines.

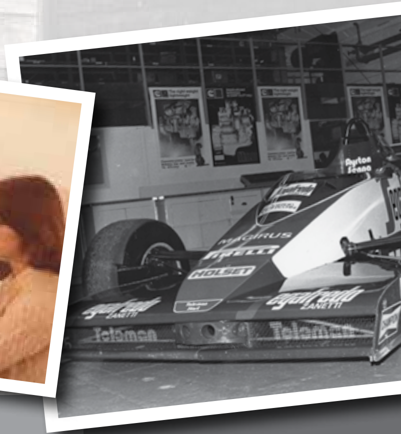
By 1957, the 3, 4 and 6 inch models were developed. Some vibration issues remained but nevertheless Schwitzer achieved a breakthrough in lightweight automotive turbocharger design.

A pivotal hire was an engineer named Ian Goodlet. Goodlet had worked for Power Jets Ltd and was responsible for developing Sir Frank Whittle's W1 turbojet engine. Goodlet worked effectively on the design of turbine wheels for turbochargers. The Holset team was so confident of success that in 1957 Ron Hesselden was given the green light to build a turbocharger manufacturing facility, which was ready to commence manufacture in September 1958.

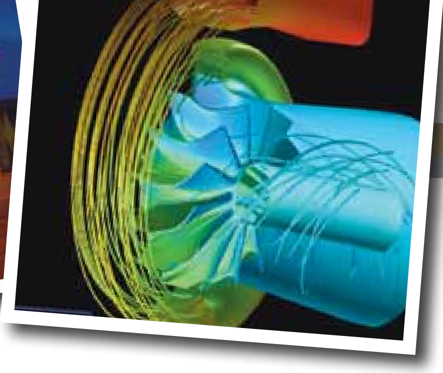
By the late 1950s Holset was uniquely placed to handle all combustion engine torsional vibration developments with the expansion of its manufacturing facility and the first test cell was introduced to check that all turbochargers meet design ratings prior to dispatch.

In 1962, the 1957 licences were superseded by a tripartite arrangement where Schwitzer, Holset and the German group KKK would manufacture and sell the turbocharger range. The model 3LD replaced the 3 inch turbocharger in 1965. This was the first design without a nozzle ring, as the gas flow was being controlled by the turbine housing volute passage. In 1967, a model 4LE with water-cooled turbine housing was released for marine applications.

By the early 1970s there were 15 engineers in the UK and Gerry Donnellan became the first Director of Engineering. The H1, the first of the Holset H range of turbochargers, was released in 1973 when Holset also became part of Cummins. Holset began using computerised stress analysis methods in 1974 and installed a high speed turbine dynamometer to measure torque and speed. Shortly afterwards the first engineering computer was purchased and was used to match turbos, design rotors, bearings and wheels. The first computer-aided design (CAD) system was installed in 1979.







Into the ’80s and beyond

The next decade saw advancements and improvement in component and manufacturing technologies. Vaned diffuser and compressor wheel technology improved further by 1980, achieving 82 percent compressor efficiency at 4:1 pressure ratio. A laser anemometer was installed, enabling gas velocities to be measured inside rotating wheels. Work on “Low Cycle Fatigue,” a process still used today, started in 1983. Friction welding superseded electro-beam welding for joining the shaft to the turbine wheel.

In 1984, the HT3B turbocharger was released in the USA on the 14 litre Cummins N engine. The model H5 was released in 1985 and turbocharger durability was now improved to reach 500,000 miles. In 1986, Map Width Enhancement (MWE) was invented and patented, increasing the map width or range of the compressor by 20 percent. A year later, the development of a smaller and more efficient range of Holset turbochargers began, namely the HX20/30/40. In 1988, a 3D viscous flow analysis programme was introduced and a 2D inviscid flow analysis programme reduced aero dynamic lead time from 13 weeks to 3-4 weeks.

Holset turbochargers reign in motorsport began in the 1980s, with a victory in the 1983 Indy Race Car Championship and a debut in Formula One on the Toleman-Hart 1.5 litre turbocharged 4 cylinder racing car driven the subsequent year by Ayrton Senna. At the 1987 Indianapolis 500, the winner was Al Unser Sr., who drove the Cummins-Holset Turbo Special powered by a Cosworth Engine.

Turbocompounding had been pursued by a number of truck engine makers in search of improved thermal efficiency and fuel consumption. In 1990, the first commercial automotive turbocompound engine was released by Holset and Scania. The crucial on-highway power and torque requirements of a variable-speed engine led to the development of the wastegated and subsequently variable geometry turbocharger (Holset VGT™). The world’s first sliding-wall VGT was launched by Holset in 1998 and became the first heavy-duty volume production application.

In 1997, Holset became a company focused on turbocharging technology for the medium to heavy-duty diesel engines following the sale of the vibration damper business the previous year. In 1998, Holset opened its Worldwide Technical Centre in Huddersfield, UK. There were now 125 engineers globally.

Following the manufacturing expansion around the world in the 1990s, a new world-class US$8 million technical and production facility in Wuxi opened in 2003. The facility included test cells to run performance mapping and mechanical testing. Machined from Solid (MFS) Aluminium Impellers were designed for use on arduous duty-cycles and in 2003 we saw them being produced at a rate of 35,000 wheels per annum across seven customer applications. The year 2007 saw the HP82 released on the Iveco engine and the axial power turbine released on the Daimler engine in the USA.

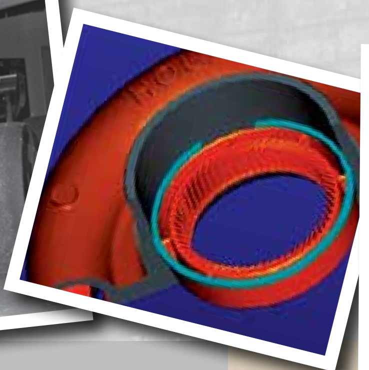
Over the years, the Company has been recognised for its outstanding level of engineering training. One instance came in 2004, when the Institution of Mechanical Engineers (IMechE) presented Holset with the accreditation award for its Monitored Professional Development (MPD) Scheme.

In 2009 the first waste heat turbine expander was produced. It is a compact and efficient means of converting the energy from the vaporised organic fluid into useful mechanical or electrical work.

Cummins Turbo Technologies launched a new family of Holset turbochargers for 2 to 6 litre diesel engines in 2010. This was in response to the increasing focus on fuel economy and engine downsizing of our existing strategic customers and to meet the needs of the global diesel engine market across a range of applications.

In 2011, the waste heat recovery test cell was opened in the UK Technical Centre, a first of its kind, ideally placing Cummins Turbo Technologies to lead on new technologies required for emerging fuel economy and CO_2 legislation.

It is now 60 years since Holset was incorporated as a Limited Company. As we move into another chapter of the ‘Holset’ story we see Jonathan Wood taking his position as Director, Research and Engineering and Mark Firth as Director, Product Line Management and Marketing. Cummins Turbo Technologies now has technical centres in China, India, UK and the USA with 700 engineers around the world, positioning us to deliver the technology of the future.


Turbo Technologies

Our Philosophy

We enable our customers' success through our expertise, dependability and responsiveness.

Our Goals

Cummins Turbo Technologies places the utmost importance on achieving high levels of product and service quality.

Our people are the single most valuable asset we have to ensure we meet your requirements. Through structured training development programmes we encourage our employees to spend approximately 5% of their working time in training and personal development.

Our operations worldwide are certified to TS16949 quality standard and we welcome suggestions as to how we can further improve our performance to meet your needs.

We take our environmental obligations seriously and all our worldwide sites have achieved ISO14001. Our products have an important part to play in helping to improve engine emissions.

Our goal is to provide the lowest total cost solution for your turbocharging needs.

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