Comments from the Leadership Team – Steve Caddy

Steve Caddy
Technical Director

Holset continues to increase its share of a growing global market for turbochargers. Unprecedented sales growth and customer demand for new and established products has led to a new facility being built at Charleston, South Carolina in the USA. This builds on our expansion at Dewas, India, earlier this year and the opening of our new facility in Wuxi, China, in 2004.

Key to our success has been Holset's focus on the mid-range and heavy-duty diesel markets and the specific technologies demanded in those applications. Looking towards the end of the decade and beyond, we are committed to ensuring that Holset will be ready with turbocharger technologies matching the ever more advanced, fuel efficient, low emission diesel engines now being developed throughout the world.

Engine refinements addressing each new cycle of emissions legislation are becoming progressively more sophisticated. We have already seen the successful introduction of variable geometry turbocharging (VGT™) to meet Euro 3 and in North America, EPA '02/'04 on-highway emission laws. Holset's R&D teams have moved on to our new product Value Package Introduction (VPI) programmes to introduce further new technologies for Euro 4 and EPA '07 requirements.

We are already working with all our engine manufacturer customers on the development of technologies able to meet the exceptionally demanding emission limits proposed or expected by 2010 and beyond. Prototype Holset turbocharger installations are already under evaluation with customers.

Ever more severe exhaust emission limits, together with different demands from specific markets, will inevitably lead us to greater product diversity in the future; this will require both customer and market dedicated solutions, implying a broader product range. This in turn will bring the challenge of how we support such product diversity whilst ensuring robust product design. Here a vital tool in our strategy is an increasing use of Design for Six Sigma (DFSS) in our product development methodology.

Holset has stepped up its commitment to DFSS over the past 12 months and we will continue with further training of all our engineers until DFSS becomes the preferred way in which we undertake all new product design and development.

In order to provide the customer with technologies to meet their design solutions, Holset increased its engineering staff in its worldwide technical centre in the UK by nearly a third in 2004 and we continue to recruit through the business in 2005.

My colleagues and I are excited by the challenges and opportunities we face in the future. With ever greater globalisation of the engine business, we are committed to increasing our understanding of the key issues facing our customers, most notably their drive to control emissions without compromising fuel economy. Holset is determined to work ever more closely with its customers to achieve our mutual goals.

Steve Caddy
Technical Director

Editorial
Editor: Alison Smith
Editorial Team: Jodie Stephenson, Owen Ryder, Melanie Summers, Kirsty Needham, Rebecca Barron, Sara Hill.
Freelance Copywriter: Alan Bunting
E-mail: turbo.enquiries@holset.com

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New Charleston Plant Strengthens Holset in the USA

Written by Jodie Stephenson, Worldwide Marketing Communications Leader

Holset is further expanding its operations in the USA. Plans have been announced to establish a new $13 million (USD) plant in Charleston, South Carolina. It carries forward the company's corporate business strategy of expanding production capacity in key markets to meet the growing global demand for turbochargers. It builds on Holset's expansion at Dewas, India earlier this year and the opening of the new facility in Wuxi, China in 2004.

After a detailed review of many potential sites across the world, Charleston was chosen for a variety of strategic reasons, not least its geographical proximity to the vital North American diesel engine market. The new facility will be situated in Palmetto Commerce Park, 14 miles (22.5 km) from Holset's existing Charleston plant and whilst it will interact closely with the existing Charleston operation, the new plant will be run as a stand alone facility.

Over 180 new employment opportunities will be created and the plant will expand Holset's capacity by 200,000 units per annum whilst providing space for further growth.

Heading up the venture in Charleston will be Brian Keighley, formerly General Manager of Holset's Wuxi joint venture in China. The new USA plant will focus on manufacturing Holset's latest technology VGT™ product, providing turbochargers for both USA and other global markets. Construction of the new facility commenced in May 2005 and production start up is scheduled for the third quarter of 2006.

Holset's declared policy is to continue to expand its worldwide manufacturing capacity to meet the growing global demand for diesel engine turbochargers. The USA is a key resource base for the company.

On-going investment will help to consolidate Holset's position as one of the world's technology leaders in the increasingly specialised field of turbocharger development.

Evidence of that continued investment and expansion came with the opening earlier this year of Holset's regional office in Shanghai, China, which has created a base for customer account teams to provide closer contact with the company's engine manufacturer customers in the Asia region. In a similar move, Holset has also opened an office in Pune to serve the increasingly important Indian diesel engine industry, whilst also supporting Holset's wider global operations.

Holset regional office in Shanghai, China, which is shared with one of our sister companies.

Artist impression of the new Charleston facility

Compressor Performance Mapping

Written by Andrew Pell, Senior Mechanical Facilities Engineer

The prime aim of a turbocharger is to increase the air density in the engine. This allows the efficient combustion of more fuel, leading to higher power outputs, crucially without increasing the engine's swept volume.

To increase the air density, the waste exhaust gas is used to spin a turbine wheel, which in turn revolves a compressor wheel via a connecting shaft. The turbine/compressor wheel assembly is often referred to as the rotor. The compressor creates the raised charge air density that is fed to the cylinders via the inlet manifold.

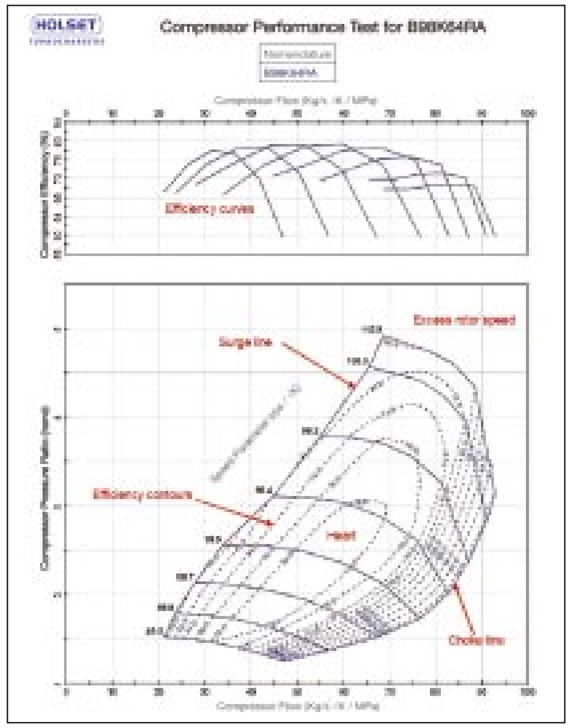


Fig 1 - Compressor Performance Map

When we need to design a compressor wheel for a new customer application, expand the range of applications that an existing component can cover or develop new technology for future applications, the Holset facilities around the world are ideally configured to carry out this test work.

The performance characteristics of a compressor are defined in a performance map, which is measured on a test cell. The following article describes the map and test methods used at Holset.

A Compressor Wheel Performance Map

Figure 1 shows a typical compressor wheel map produced from a test cell.

The centre portion of the map or 'Heart' within the innermost contour line is the area where the turbocharger is working at its peak efficiency. This is the ideal operating region. Moving away from this region reduces compressor efficiency with a likelihood of unstable running in extreme conditions.

'Surge' is an undesirable phenomenon to the left of the map, where the flow of air through the compressor becomes highly unstable. It occurs when the air flow through the compressor is low while the back pressure is high and can lead to the compressor wheel momentarily stalling as it attempts to pump the air against a higher downstream pressure. The point at which surge occurs can be calculated by the test cell computer, enabling surge to be defined in percentage terms as a specified pressure fluctuation worse than that seen during normal flow conditions.

'Choke' is a characteristic occurring to the right of the map, where the air flow is high and moving close to the speed of sound. When conditions move into this region, there is a rapid drop in compressor efficiency. The constant speed lines become nearly vertical to the right of the choke line, indicating that a slight increase in mass flow will result in an undesirable and rapid decrease in pressure ratio. Choked operation of the compressor leads to gross inefficiency and should be avoided.

'Excess rotor speed' is a condition that must be avoided. As the speed of the rotor increases, centrifugal forces and mechanical stresses increase to a point where the wheel may 'burst', suffering a catastrophic mechanical failure. The wheel is not to be run above this design speed and is often operated at a pre-determined percentage of this speed giving a margin of safety.

'Efficiency contours' are lines showing areas of constant efficiency. They are also re-plotted as curves in the upper graph so it is possible to see the efficiency of the compressor at any particular combination of flow rate and speed parameter. There is one curve per speed line.

The results obtained from Holset test cells around the world are directly comparable with each other due to the way they are mapped.

Test Cell Configuration

The test cells created by Holset are designed to be modular ensuring consistency worldwide. Each is designed, installed and commissioned to tried and tested methods. These designs are based on in-house knowledge, experience and also meet national and international standards. These standards include BS EN ISO 5167:2003, formerly BS1042 Measurement of Flow in Closed Conduits, Dangerous Substances and Explosive Atmospheres Regulations 2002 and many more equipment, health, safety, performance and environmental standards. In line with continuous improvement practices, there is also a rolling programme of upgrades to bring older facilities up to the latest specifications and capabilities. Each cell is subjected to a regular measuring instrumentation calibration. As test programmes are carried out on the cells, base turbocharger units are used to provide before, during and after performance comparisons to ensure repeatability. 6 Sigma statistical methods are used to monitor these base turbocharger tests and they provide a complimentary early warning system that can indicate small fluctuations in the cell's performance, which can be corrected before larger issues arise.

The results obtained from Holset test cells around the world are directly comparable with each other due to the way they are mapped. Each set of results is normalised to account for differences in ambient temperature and pressure. Corporate units of measurement are used so that once a performance map has been created and plotted, Holset or customer engineers at any location can read and interpret the results.

Figure 2 shows a typical test cell layout to enable compressor mapping. The turbocharger is held in position by the normal bolted joint at its turbine inlet flange. V-bands are typically used to support the other connections; turbine exhaust, compressor inlet and compressor outlet, also known as boost. The compressor inlet is connected to the plenum chamber via a horn or flow nozzle (shown in red), which allows the inlet air flow rate to be calculated from pressure measurements. On the compressor outlet pipe, temperature and pressure measurements are taken enabling pressure ratios and efficiencies to be calculated. The turbine side of the turbocharger is driven by hot gas from a diesel fuel combustor, typically controlled to 600°C. This then drives the compressor wheel to the required running conditions so that the compressor performance can be evaluated.

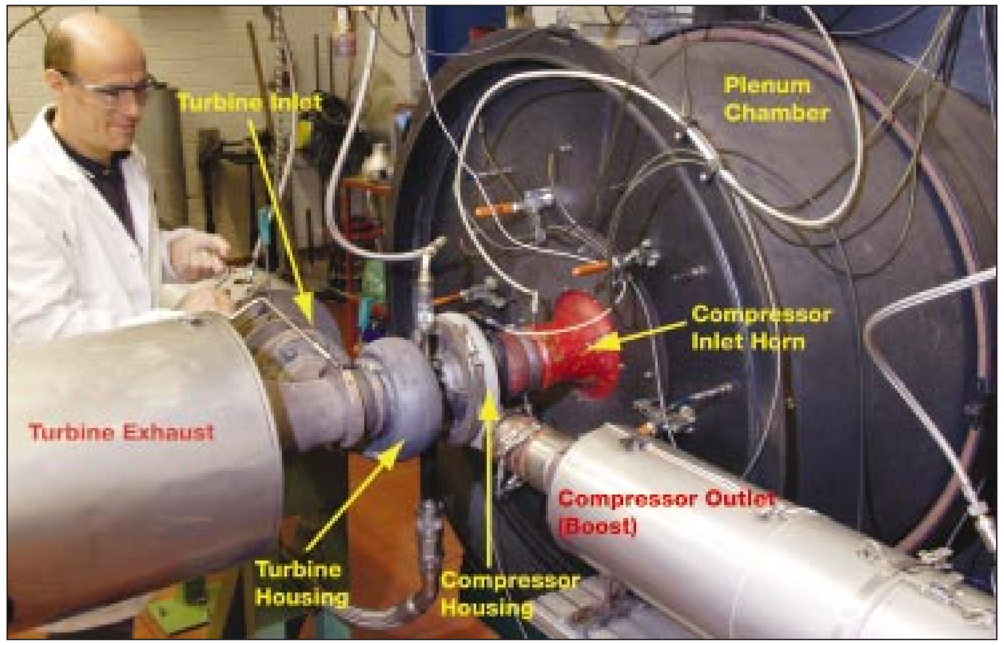


Fig 2 - A compressor mapping cell layout

Mapping Performance Testing

Before the start of each test, the programme engineer specifies the range of turbocharger running speeds to be investigated. In compressor mapping, the maximum design speed is never exceeded for safety reasons. Once the surge point has been found for a given rotational speed and pressure ratio, the flow through the compressor is increased by slowly opening a valve in the compressor outlet piping. Computer controlled test systems calculate the running conditions that give 60% compressor efficiency (defined as the choke point) and then hold the conditions steady to allow snapshot readings to be taken of all the instrumentation channels. Once the pressure ratios and flow rates are known for surge and choke conditions, the computer calculates several intermediate points. The boost valve is then closed to these intermediate flows in order to obtain additional measurement points. Instrumentation readings are electronically taken at each of these points once conditions have become stable, thus a constant speed parameter 'running line' is created. The procedure will then be repeated for each of the remaining test speeds to produce the graph as shown in figure 1.

Different compressors, different applications...

Many factors can influence the performance of a compressor and the map is used to investigate such criteria. Some compressors are designed to provide 'narrow' performance bands, typically for stationary, single-speed engines. Other compressors, notably for applications where there are large fluctuations in engine speed and load are designed to have an appropriately 'wider' map. This gives more flexibility over a range of flow, pressure and speed conditions; it is therefore possible to apply one frame size of turbocharger to many engines from a single manufacturer.

For further information on some of the technologies used to create these wider maps, see edition 4 of HTi where Super Map Width Enhancement (Super MWE™) is discussed.

Changes in the Chinese Market

Written by Kirsty Needham, Marketing Assistant

Since China moved away from a centrally planned and controlled economy and became a full member of the World Trade Organization (WTO), the huge potential of the Chinese market has become apparent. With more than 1.3 billion people looking to buy, sell, manufacture and consume, the opportunities in trade, both import and export, retail and wholesale, as well as investment, support services and of course manufacturing are clearly immense.

Reasons for China's development are however more complex than the abundance of consumers, cheap land and relatively low labour costs. Recent changes in government support aimed at accelerating reform are alleviating the government debt burden allowing more opportunities for growth. New technology and investment from outside the country as well as product imports are transforming the commercial scene in China since the policy of opening up and reform was adopted.

Many observers see automotive manufacture becoming one of the backbone industries around which the Chinese economy will grow. It is already playing a key role in the country's development and helping to raise the standard of living for significant sections of the population. Since the first mid-range truck rolled off the First Auto Works (FAW) production line in Changchin in 1956, the industry has grown, gaining huge momentum in the last decade.

Image courtesy of DFM

In 1999, the total Chinese output of road vehicles was more than 1.8 million units covering more than 150 basic automotive types including trucks, tippers and tractors as well as cars and dual purpose vehicles. By 2004, output had grown nearly threefold, to 5.2 million, itself a 14% increase on the 2003 figure of 4.6 million. Trucks now account for more than half of the total figure; nearly all powered by diesel engines, the majority of these are now turbocharged.

Last year Wuxi Holset, Holset's joint venture operation with Wuxi Diesel increased its production by 50% over the 2003 total. The Chinese plant currently manufactures HX35, HX40, HX50 and HX55 turbocharger models. Wuxi Holset supplies the Chinese domestic market as well as meeting demand from overseas.

Chen Hua, Wuxi Holset's Deputy General Manager, sees the drive towards quality excellence as a major factor in the growth of the company. He commented, "We have put a lot of emphasis on making sure that our quality levels are high, which has ensured healthy sales in China as well as in export markets as well." In a country where the quality of finished goods has sometimes been regarded as inferior to foreign produced items, he points to a series of quality awards that the company has won from various customers including Dalian Diesel, Wuxi Diesel, Yulin Diesel and the Jiangsu Government. In 2004 the plant also won the Holset Worldwide Quality Award.

There are plans to increase export sales from Wuxi Holset considerably in coming years. In 2003 the company exported just 5% of its total production and 10% in 2004. However, it is estimated that this will rise markedly to 30% in 2005.

With a 26% market share for Wuxi Holset of the Chinese heavy-duty turbocharger market last year, there is anticipation of a more intense battle for customers in the future. Chen Hua commented, "There is perhaps just one major competitor in China at the moment but in the future there will be many more international players fighting for turbocharger business and some have major investment plans.

That's why we have such a commitment to quality. There are exciting prospects for us, especially if you look at the number of new engine makers coming into China. Their arrival offers great opportunities for us."

He added that the company is also planning a major promotion of its capabilities in China. "I really want to promote the Holset Turbocharger brand more widely in China. In the past we have just focused on our capacity but we need now to improve brand awareness and to promote our market leadership in the mid-range to heavy-duty segment and the fact that our leading position has been driven by focused technology."

Reinforcing the Holset Turbochargers brand has never been more important than in today's increasingly competitive market. Counterfeit or pirate turbocharger components of inferior quality, which are potentially dangerous, are becoming an increasing problem in China. Holset is taking steps through its marketing strategies to restrict the activities of such copiers. The company is already pursuing legal opposition to a company in China trying to register a trade mark bearing marked similarities to the previous Wuxi Holset company logo. "With the help of Holset UK, Wuxi Holset and Wuxi Diesel we have a very strong case of stopping such action", assures Chen Hua.

Awareness of intellectual property rights is relatively new in China. However, it is of ever increasing importance and not just for Holset. There are many companies now operating in China that are focusing on technology as well as manufacturing. As a result they are protecting their products through the use of trade marks, patents and copyrights. It is estimated that annual global losses from counterfeiting now amount to over $350 billion (USD). It is not just multi-national companies who are adversely affected through the growth of counterfeit products, which can be and often are hazardous to the innocent end user as well as jeopardising product performance, reliability and durability. In the past China has been criticised for the poor enforcement of intellectual property rights, however, this is thankfully changing. Education, technology transfer and licensing are all providing a platform, which may help reduce counterfeiting activities in the long term.

Holset is committed to taking serious legal action against those involved in the violation of trade marks and copyrights of Holset Turbochargers or the distribution of 'pirate' product. The launch of Holset's 'Insist on Genuine' marketing communications campaign is already underway and there are plans to intensify our activities against the copiers in the coming financial year.

China Country Fact File	2004
Population	1,298,847,624
Per Capita GDP (PPP)	$5,000
GDP Growth Rate	9.1%
Total Automotive Sales 2004	5,173,003 (2,328,237)*
Total Automotive Production 2004	5,164,294 (2,318,753)*
Market Growth 2003 vs 2002	39.3% (72.7%)*
Market Growth 2004 vs 2003	16.0% (14.4%)*
Best sold model PC segment 2004	Volkswagen Santana (9.6%)
Best sold model LCV segment 2004	Chang' an Carry (15.0%)

* = passenger cars

Source: Segment Y Automotive Intelligence on emerging market. www.segmenty.com/China

There are plans to increase export sales from Wuxi Holset considerably in coming years.

Image courtesy of FAW

GIVING TURBOCHARGERS AN ELECTRICAL BOOST

Written by Jeff Carter, Consulting Engineer

Integrating an electric motor/generator into the rotor of a turbocharger, as a means of augmenting boost at lower engine speeds, is an attractive solution to what has been perceived as a turbocharger shortcoming.

The electric machine can be incorporated within the bearing housing between the compressor and turbine wheels. Holset's project work on the concept has been undertaken as part of the ELectric Exhaust Gas Turbocharger (ELEGT) project, which has been partly funded by the European Commission. Holset's partners in the project were Durham University in the UK, Iveco in Italy and Switzerland, ATE in Germany for electrical machines and Thien in Austria for electronics.

Electrically assisted turbochargers are worthy of investigation because they can:

- Increase boost pressure at low engine speeds where exhaust flow available to drive the turbine is limited; electrical power from the vehicle's battery can be harnessed to drive the turbocharger to higher speeds.
- Maintain turbocharger speed during gearshifts, when engine revs typically fall away; electrical power can augment the work done by the turbine.
- Reduce turbocharger speed under high engine power conditions, using the electrical machine to apply a restraining torque to that exerted by the turbine.
- Recover exhaust energy that would otherwise be wasted, by using the electrical machine in generator mode, converting excess shaft power to electrical power for battery charging and perhaps eventually eliminating the need for a separate alternator.

Vehicles in the future are expected to have numerous auxiliaries, which today are mechanically driven by gears or belts but will then be electric motor driven on a much more efficient power on demand basis. Excess exhaust energy may be used to generate the additional electrical power required on a vehicle to drive such auxiliaries.

A further role for the electrically boosted turbochargers might also be found in a hybrid powertrain. The turbocharger's electrical machine could supply power to an integrated starter alternator damper (ISAD) mounted on the engine's drive shaft, supplementing the engine's output like a turbocompound installation, but with an electrical rather than a mechanical connection (see figure 1).

An analysis of typical turbocharger shaft torque and speed (see figure 2) provided a logical starting point for the ELEGT investigations. Shaft torque varies between about 1Nm when the turbocharger is accelerating and minus 1.5Nm when it is decelerating. Clearly, if the electrical machine could add an additional 1Nm accelerating torque, then boost pressure would be significantly enhanced at low engine speeds. An electrical generating requirement of 7.6kW was set, based on the typical excess exhaust power available for 'recycling' at high engine speeds (see figure 3).

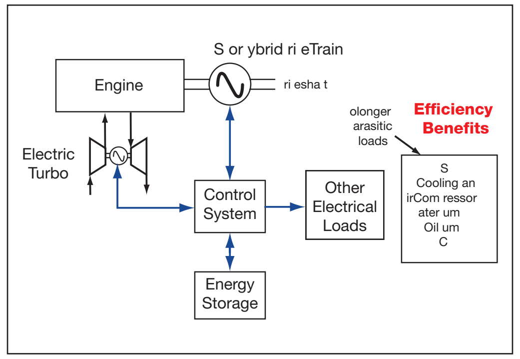


Fig 1 - Integrated Electrical System

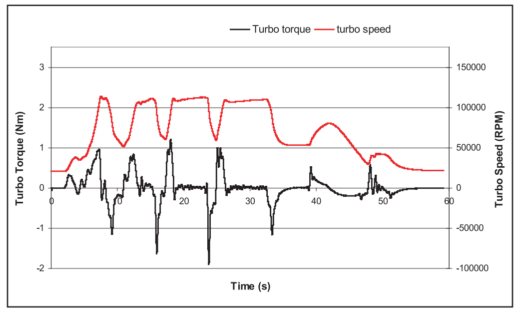


Fig 2 - Typical Turbocharger Operation

For the electrical machine to survive in the extreme temperatures and high vibrations of a turbocharger environment while meeting severe durability requirements, the electrical machine needed to be very robust. A number of different electrical machine types were reviewed: permanent-magnet, switched reluctance and induction (asynchronous).
The induction machine was chosen primarily for its robustness; it can also tolerate the large rotor to stator air gap required by a turbocharger shaft's floating bearing system. It is also a relatively low cost type of electrical machine.

Most induction machines have a rotor formed of a stack of silicon-iron laminations to carry the magnetic flux and bars running through slots in the lamination stack to carry the electrical current. The bars are joined at each end of the lamination stack by end rings. In small electrical machines it is usual to use aluminium for the bars and end rings. However, because of the high rotor temperature, the ELEGT machine was deemed to require cast copper conductors.

Figure 4 shows the Mk 1 ELEGT machine partially dismantled, from left to right: bearing housing, stator, rotor, bearing housing end cap and turbine wheel. Figure 5 shows the cross sectioned three dimensional model.

Testing of the Mk1 machine in Holset's UK technical centre at Huddersfield showed that the shaft motion of the system was acceptable and that the temperature of the bearing housing conformed to finite element analysis predictions. However, it was found that when the coils of the motor/generator were energised, their temperature rose rapidly to the limit of the coil potting material. A Mk2 design (see figure 6) was accordingly developed with deeper stator slots, allowing a bigger winding with lower electrical resistance. Also the winding potting material was changed to increase its temperature tolerance, while the coolant circuit within the turbocharger was re-routed to bring the coolant closer to the surface of the motor/generator.

Complementing the test work at Huddersfield, Durham University is undertaking other ELEGT development work, notably investigating the 'solid rotor' machine, where the rotor of the motor/generator is formed of a simple cylinder of homogeneous material, replacing the lamination stack, bars and end-rings. The material used for the rotor has to be able to carry both magnetic flux and electrical current. Surprisingly, common mild steel was found to be quite suitable, although other materials are also being investigated. It is hoped the solid rotor design will make the machine even more robust, simplify assembly and reduce costs. Holset has submitted a patent application for this design.

Finally, computer modelling of the system has been carried out both at Durham University and at Holset, to determine what level of fuel savings could be brought about by using the generating capability of the ELEGT machine. Depending on a number of factors including vehicle duty cycle and electrical load, fuel savings of approximately 5% are predicted (figure 7).

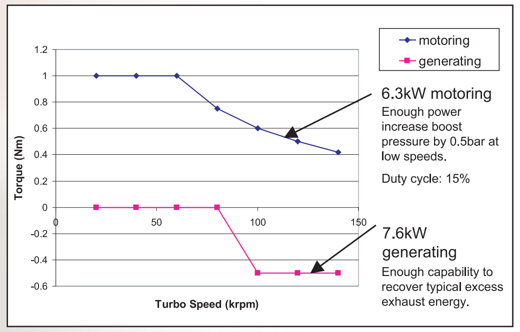


Fig 3 - Electrical Machine Outline Specification

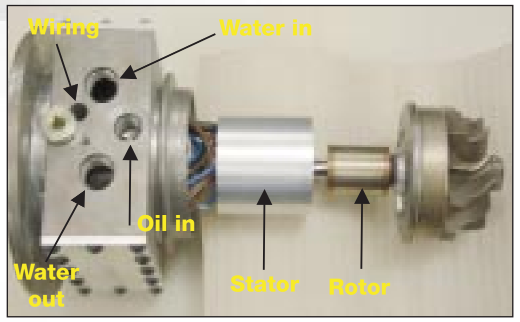


Fig 4 - Turbocharger – Motor Assembly

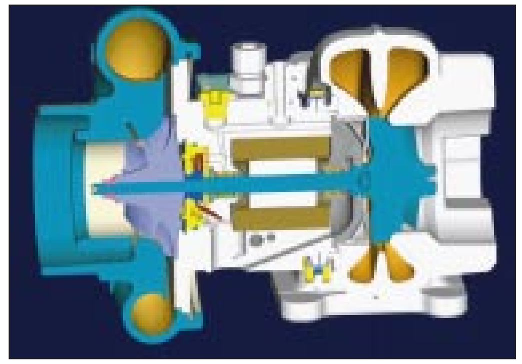


Fig 5 - Turbocharger Integration – Mk1 Squirrel-Cage Machine

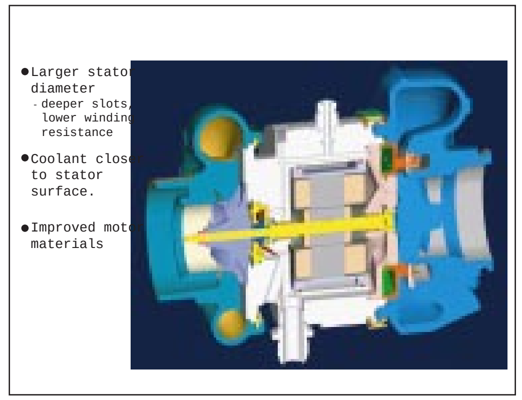


Fig 6 - MK2 ELEGT Machine

Manual transmission, bus unladen (12000 kg)

Alternator efficiency	55%	55%	55%	70%
Electrical load	1000W	2500W	Unrestricted	Unrestricted
Driving cycle	% improvement	% improvement	% improvement	% improvement
CBD	4.7	5.2	6.2	5.0
TRL03	3.7	6.1	6.4	5.2
TRL08	0.2	0.5	0.6	0.6
TRL09	1.7	3.3	3.8	3.0
epa_hwycol	2.2	5.3	10.2	8.0

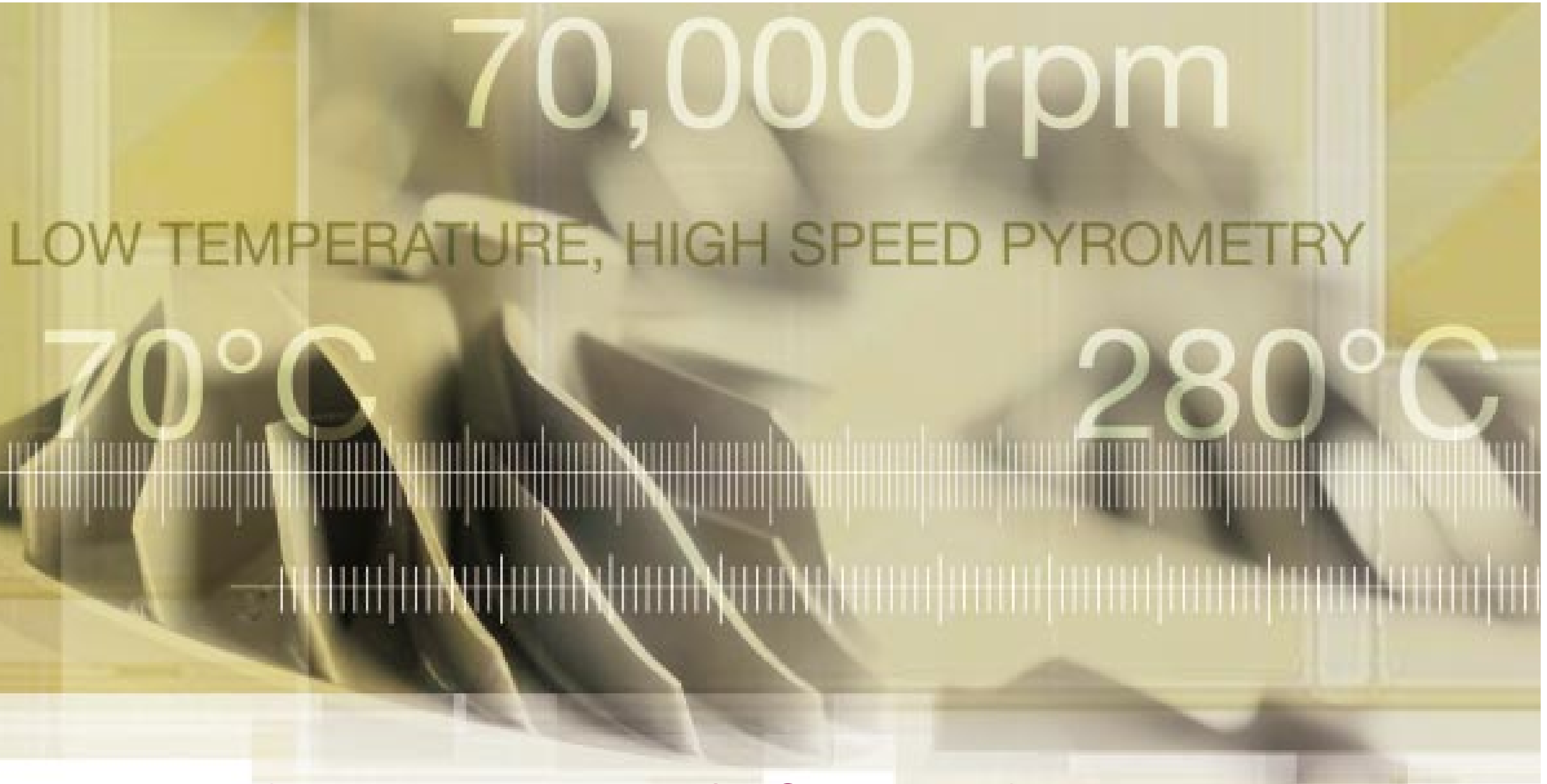
Fig 7 - Example Results of Fuel Savings

This article has been adapted from a paper presented earlier this year by Jeff Carter entitled 'The development of turbocharger accelerator motors and drives and their integration into vehicle electrical systems', at the Institution of Electrical Engineers' first Automotive Conference in London attended by 175 delegates. It was co-authored by Dr. Jim Bumby, Prof. Ed Spooner and Dr. Sue Crossland of Durham University.

Jeff Carter obtained a BEng in Electronic and Control Engineering from the University of Birmingham. He later returned to the university as a research associate and completed a PhD, titled 'A Study of the Single-Phase Three-Level PWM Converter', relating to electrical power conversion for railway locomotives.

He started work at Holset in 1996 as a Senior Development Engineer and is currently a Consulting Engineer, working on various aspects of sensors, control systems, dynamic modelling, electric actuators and the high speed electrical machines required for the ELEGT project.

The ELEGT project is financially supported by the European Commission's GROWTH Programme, as Contract 63083 Project G3RD-CT-2002-00788



LOW TEMPERATURE, HIGH SPEED PYROMETRY MEASUREMENTS ON A TURBOCHARGER IMPELLER

Written by Mike Eastwood, Principal Engineer

A high-speed pyrometry system prototype, designed for operation at temperatures between 70 and 280°C was developed at the Technical University, Berlin and operated in one of Holset's turbocharger test cells at Huddersfield in the UK.

In recent years the demand for ever higher specific outputs, or power densities has led to an inevitable requirement for progressively greater boost pressures in turbocharged diesel engines. As a result, creep and fatigue due to thermal and mechanical stresses on the impeller are posing more severe challenges for impeller designers. More detailed stress analyses are required in strategies aimed at achieving the necessary impeller strength and component durability. For a computer based finite element model to be sufficiently precise, detailed and accurate boundary conditions must be included in the input data. Usually such data is supplied by computational fluid dynamic (CFD) simulation results. Significant uncertainty nevertheless remains about the temperature distribution in the impeller.

Ideally, surface as well as internal temperatures in the impeller material need to be measured accurately. As the component rotates at high speeds, measurement of metal temperatures is not straightforward. Several approaches using embedded thermocouples have been tried at Holset. Whilst useful data was acquired near the impeller hub, it proved difficult to obtain reliable temperature readings towards the outside diameter of the impeller.

It seemed that a promising solution would be remote sensing of the temperatures, using an infrared pyrometry technique. The Technical University in Berlin had previously developed such a system for high speed, high resolution temperature measurements on blades of industrial gas turbines. It was suggested that application of that experience could be used to develop a pyrometry technique suitable for the lower temperatures of impellers. It needed to be capable of providing the accurate temperature readings required for creep calculations as well as for calibrating CFD models with improved accuracy.

Design of the Pyrometry System

For turbocharger machinery pyrometry systems, it is necessary to use a small probe to gain access to the blades. The radiation is then transferred to the detector using a light guide. Such a configuration allows the sensitive detector and the data acquisition electronics to be protected from the harsh environment. Figure 1 shows such a typical setup for a turbine pyrometer.

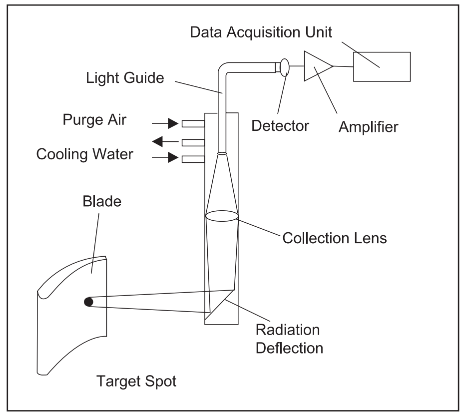


Fig 1 - Setup of a typical turbine pyrometry system

Measurements in a Turbocharger Test Cell

A prototype pyrometer was built, calibrated using a black body radiator. The pyrometer was set up in a Holset test cell on an HX82 turbocharger. The impeller had been anodised with a black coating in order to ensure low reflectivity. The pyrometer was installed at the back of the impeller for access reasons. Two thermocouples were also used to provide comparison readings with the pyrometer data. One thermocouple measured the gas temperature just after the impeller, while the other monitored diffuser plate temperature. Figure 2 shows the experimental installation.

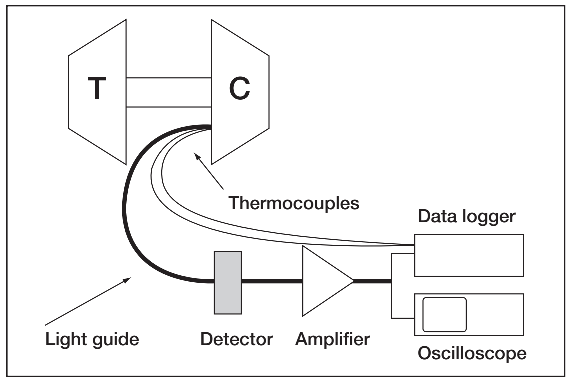


Fig 2 - Experimental pyrometer installation in the compressor and the additional thermocouples

Figure 3 shows the measured gas and detector temperatures over time, which matched quite well except for the first 25 minutes while equilibrium was being reached.

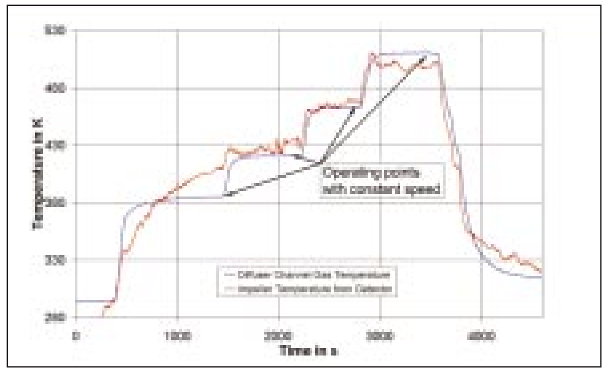


Fig 3 - Gas temperatures measured in the diffuser channel and impeller temperatures measured by the pyrometer

It was originally expected that the pyrometer would show a constant temperature for a constant speed but some slight variations in temperature could be seen in the signal, see figure 4. When synchronising the temperature variations with the revolutions of the turbocharger, it became clear that the variations correlated with the 16 blades and balance groove. A difference of only 7°C between minimum and maximum temperature can be crucial in determining the creep behaviour at high operating temperatures.
Although unexpected, it was valuable and instructive to see how the heat conduction in the impeller influenced the temperature distribution on the back of the impeller.

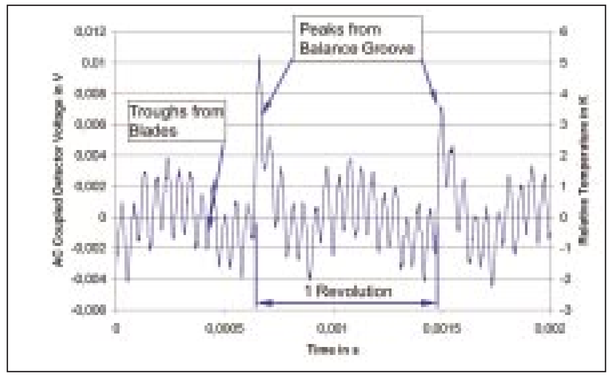


Fig 4 - Detected temperature variations over 2.4 revolutions at an impeller speed of 70,000 rpm

Numerical Calculations

In order to understand the apparent dynamic temperature variations observed by the pyrometry measurements shown in figure 4, a three dimensional finite element analysis of the compressor wheel was undertaken. This gave the expectation of gaining back face temperature predictions that could be used to compare and allow calibration of the dynamic pyrometry voltage output.

A complete impeller finite element model was used to predict temperature distribution and compare those predictions with the pyrometry measurements. Only one full impeller finite element model was available and unfortunately it was not the HX82 impeller as tested. So the existing model was scaled up to HX82 outer diameter size. The main differences between the finite element modelled impeller and that used for test was the existence of two balance grooves on the back face instead of one and 14 blades rather than 16 blades. The two balance grooves were diametrically opposite each other as can be seen in Figure 5.

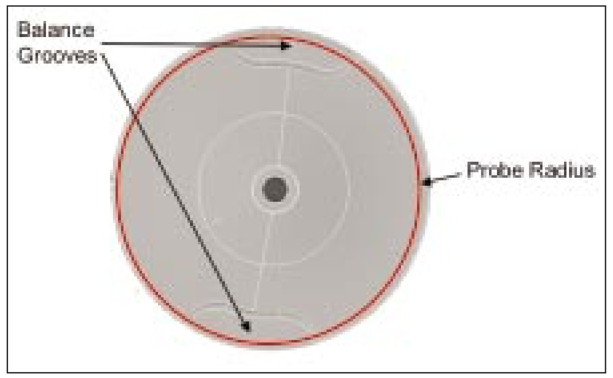


Fig 5 - Finite element model of impeller showing two balance grooves

Figure 6 shows a plot of temperature distribution along a line of constant radius on the impeller back face. The plot's two large peaks coincide with the balance groove positions and 14 troughs line up with the 14 blades on the impeller. The predicted temperature variation seen on the back face of the compressor is caused by the heat transferred between the back face and the blades on the front side of the disc. In the location of the balance groove, the back face disc is significantly thinner, which accounts for the higher temperatures in that area. Each balance groove coincides fully with two blades and the two higher temperature troughs.

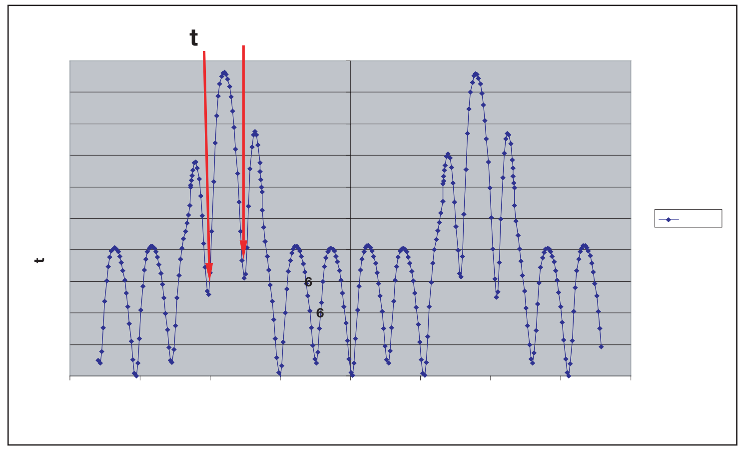


Fig 6 - Temperature variations calculated using finite element analysis and boundary conditions from static measurements. The plot shows temperature distribution along a line of constant radius on the impeller back face

The overall temperature decrease at blade locations was 2°C whilst an increase of 5°C was seen at balance grooves. Comparing the temperature variations with those from measurements in figure 4 it can be seen that they are of similar magnitude, helping to validate the very high speed resolution capability of the pyrometry technique.

Using the new pyrometry system for high speed, low temperature measurements on turbocharger impellers, based on a prototype system tested on a Holset turbocharger compressor in a test cell, it was possible to measure the different heat conduction conditions in the impeller. The results were supported by a finite element analysis of boundary conditions from static temperature measurements. Unexpected variations in the temperature signals from the pyrometry system were found not to be caused by spurious signals in the prototype system.

Using the new pyrometry system, it is possible to measure the different heat conduction conditions in the impeller.

Mike Eastwood, Principal Engineer at Holset, co-presented a paper on this topic at the 6th Turbomachinery Conference in Lille in March 2005. The five day conference was attended by around 300 delegates.
Thank you also to Jonas Nickel of TU Berlin who worked on this project.

A graduate in Mechanical Engineering, Mike worked as a stress engineer for David Brown Tractors, British Aerospace, Williams Fairey Engineering and Rolls Royce Wellman Booth before joining Holset in 1994. He became a Member of the IMechE in 1993.

At Holset, Mike has worked in Applied Mechanics on stress analysis of most components and specialises in thermo-mechanical stress and fatigue analysis of turbine housings and creep analysis. He also chairs the Thermal Applications Limits forum.

STREAMLINING THE SUPPLY CHAIN

Written by Steve Fritchley, 6 Sigma Black Belt

wesupply

Holset is piloting a new supply chain management system using Wesupply software. The decision to use Wesupply and the resulting supply chain process arose from a 6 Sigma project aimed at improving product deliveries to customers.

In pursuit of customer excellence, Holset is committed to continually reducing lead-times to our customers and have set out to streamline communications, with the objective of disseminating information on a daily basis across the whole supply chain.

At the same time we wanted to ensure the availability of material in the supply chain to give Holset suppliers, typically foundries and machining companies, more flexibility and control of their production and available capacity. Results from the 6 Sigma project showed that the greatest impact on our customer delivery performance would come from improving the availability of 'end housings', that is compressor covers and turbine housings. The pilot scheme is accordingly being implemented across our end housing supply chain, linking foundries, machinists and Holset through one generic system.

Wesupply is a web-based hosted supply chain management solution designed to provide a number of key benefits:

- Demand information can be communicated daily, in a common format, across the supply chain.
- Shortfalls can be identified proactively through exception based alerting, under such headings as: 'Shipment overdue', 'Under-receipt', 'Forecast error', 'Stock below minimum'.
- Material availability in the total pipeline, including in-transit consignments, is assessed.
- A means of managing and maintaining consignment stock at all levels in the supply chain is provided, leading to a significant reduction in Holset's own inventory.
- Ready visibility of all stock transactions across the supply chain leads to improved inventory control.
- Safety stock/Kanban levels needed to support Holset customers' lead-times are dynamically recalculated and automatically adjusted.
- Suppliers are given more flexibility and control of their production and available capacity, through defined tolerance bands.
- Advanced Shipment Notification (ASN) information can be sent to and received by suppliers.

A common measurement system is provided to meet agreed service level objectives. All transactions and information can be easily integrated within the suppliers' own systems.

The Wesupply application has been configured to manage inventory levels for castings and machined parts categorised as 'scheduled', 'Kanban' and 'consignment'. The intention is to implement a pull process throughout the supply chain, thereby reducing overall inventory while increasing Holset's ability to react to customer requirements.

Suppliers at every point in the supply chain have real-time access to their requirements from Holset, allowing them to react to changes more efficiently and effectively.

Application of business rules within Wesupply allows tight controls on inventory levels.

By the end of September 2005, the new supply chain control structure is expected to be fully operational for all component parts from six pilot suppliers. A cross-functional senior management team is assessing the benefits of the pilot scheme, with the aim of determining a roll-out strategy for its wider implementation. If successful, further applications of the scheme using the Wesupply software are envisaged, including supplier capacity monitoring and self-billing.

Wesupply's Solutions Consulting Group Director, Andy Wood comments, "This project has been a tremendous example of the benefits that can be achieved with a solution that enables all the trading partners in the supply chain to work collaboratively to meet a common goal." The Wesupply project team is confident that this pilot implementation will derive the expected benefits.

All transactions and information can be easily integrated within the suppliers' own systems.

HOLSET TURBOCHARGER SPECIFIED ON EICHER TRUCKS IN INDIA

Holset turbochargers have been chosen by the Indian truck manufacturer Eicher Motors Ltd for its latest 3.3 litre E483 light commercial vehicle (LCV) diesel engine, which meets the Euro 2 level exhaust emission standards now being demanded in India.

The contract with Eicher Motors marks a further stage in Holset's business strategy of establishing technology partnerships with market leaders, especially in rapid-growth markets in the developing world.

HX25W Turbocharger

Eicher Motors, a part of the Eicher group, was founded in 1982 to manufacture and market 5 to 25 tonne commercial vehicles. Its manufacturing facility is situated at Pithampur, in the province of Madhya Pradesh in central India. In 1986, Eicher Motors entered into a technical and financial collaboration with Mitsubishi Motor Corporation of Japan to manufacture the Canter range of vehicles. The technology transfer agreement with Mitsubishi ended in 1994 and Eicher Motors today is one of the fastest growing players in the LCV segment in India, with a 33% market share in the 7 to 11 tonne segment and an 8% overall commercial vehicle market share in India. Eicher has more recently made advances into the heavy truck segment with locally designed and developed chassis.

In what has been a successful beginning to a promising business relationship, Holset has begun supplying HX25W turbochargers for Eicher's E483 LCV engine. With the light truck model now in series production, the Indian company is now well advanced with plans to introduce Holset turbochargers on its middleweight truck engine range. Eicher expects to build around 33,000 commercial vehicles in 2005-06, of which about 20,000 will be LCVs.

Holset celebrate successful business relationship with Eicher

Eicher E483 LCV

Image courtesy of Eicher Motors

EXHIBITING ACROSS THE WORLD

For the first time, Holset exhibited at the 2005 Goodwood Festival of Speed, held in the UK. The Goodwood event is one of the world's biggest and most diverse celebrations of the history of motorsport. Over three days some of the world's most historical and famous cars and motorbikes are raced on the famous Goodwood circuit, with many more on static display. Holset showed the American Dodge Ram 2500 Quad Cab 4x4 SLT pick-up, powered by a 5.9 litre Cummins 600 diesel engine and equipped with a Holset HE351CW turbocharger.

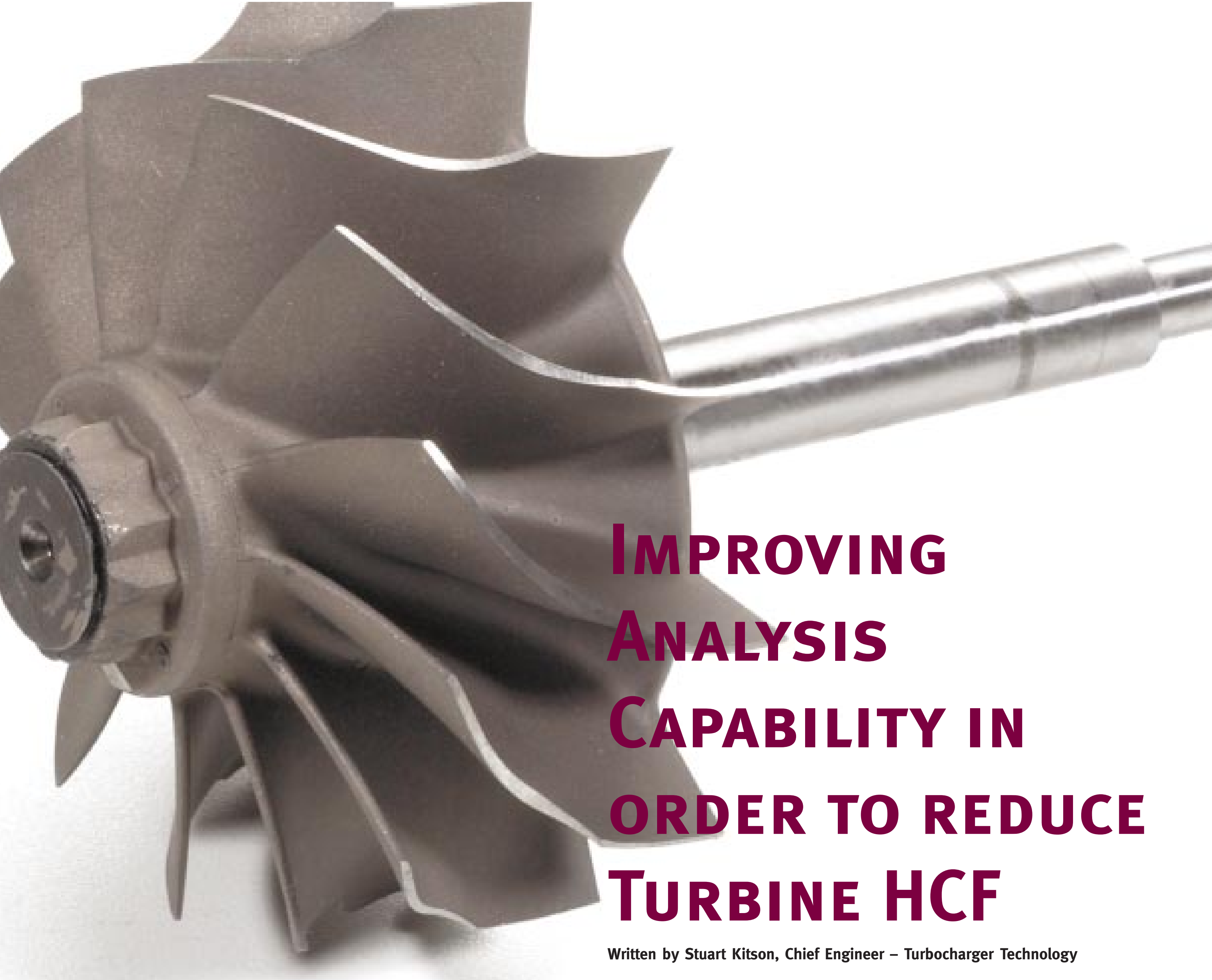
The specially engineered turbocharger boosts the engine to deliver more power and torque than the 2003 variant in a similar high performance Ram pick-up, despite being the same turbocharger frame and rotor size. The new turbocharger is the first production model from Holset to utilise the compressor cover mounted Command Valve™ wastegate technology (see HTi edition 3).

Across the Atlantic, the annual Association of Diesel Specialists (ADS) convention took place from 3 to 6 August in Las Vegas, Nevada. The ADS is the diesel industry's leading trade association, dedicated to the highest level of service on diesel fuel injection and related systems. Holset exhibits each year at the association's four-day August convention.

Meanwhile Holset Brazil attended the annual Automech trade show event, held in July at the convention centre in Anhembi, São Paulo. Over the four days more than 73,000 visitors attended. The exhibition gave Holset the opportunity to showcase its latest product technologies.

Holset exhibits each year at the ADS convention

Holset exhibit at 2005 Goodwood Festival of Speed



Improving Analysis Capability in order to reduce Turbine HCF

Written by Stuart Kitson, Chief Engineer – Turbocharger Technology

Turbine high cycle fatigue (HCF) is a phenomenon that presents a real challenge to turbocharger designers and development engineers. It occurs when aerodynamic forces acting on the turbine blades make the wheel resonate to an undesirable extent.

With each resonant cycle, the blades are deflected from their natural shape, being bent backwards and forwards. Eventually, such repeated bending can lead to material cracking and an ultimate fracture, typically with a piece of blade breaking away, triggering severe out of balance forces likely to cause a failure of the whole turbocharger system. Such an event is referred to as high cycle fatigue because the blades resonate at a very high frequency (around 10,000 Hz cycles per second). It is not to be confused with low cycle fatigue (LCF), arising through the alternating stresses caused by the wheel speed varying due to the operation of the engine, for example in a bus application, where the vehicle is repeatedly accelerating and slowing down.

High cycle fatigue is a difficult problem to avoid and expensive to correct experimentally. Therefore an analysis tool that enabled the engineer to predict HCF blade deflections at the turbine design stage would be extremely helpful.

So how could such an analysis tool be developed?

Firstly, it is necessary to predict the frequency at which the blade will deflect. This is not a straightforward exercise, as there are a number of natural frequencies associated with a piece of rotating machinery. This is because the blades deflect in a number of ways, from a simple, fairly easily understood, bending of the blade through to very complicated bending and twisting modes, often with frequencies increasing as the modes get more complex. Figure 1 shows a picture of the blade with contours of deflection for mode 1 and mode 5. These natural frequencies are calculated by running a modal computer analysis, using the ANSYS finite element package, though with supporting validation using a laser vibrometry measurement technique.

Although such an analysis calculates a turbine blade's natural frequencies, it reveals nothing about the amplitudes, neither does it help distinguish between a good or bad design. Any computer analysis strategy is dependent for its accuracy on having a good experimental technique against which it can be validated. Holset's R&D team has accordingly developed a method to measure blade deflection. It entails applying a strain gauge to two of the blades, running wires down the shaft and picking up the signal via a telemetry system mounted on the compressor end of the turbocharger. Figure 2 shows the strain gauge installation. This associated test is normally run on an engine bed where load and speed are varied until the natural frequencies occur. The maximum amplitude is then recorded as the turbine resonance is maintained.

Before attempting to predict the blade strain it is first necessary to understand the mechanism that produces the force, which in turn 'excites' the blades. As the exhaust gas enters the housing it swirls around the volute before entering the wheel. Some gas particles enter the wheel just downstream from the inlet sections, while others swirl right around the volute before passing through the blades (see figure 3). This aerodynamic flow structure creates a pressure field through which the blades pass. This repeating once per revolution pressure field can be broken down into a series of Fourier components or sine waves, each with an amplitude and phase angle. In figure 4 these are shown superimposed on the pressure field. When the wheel speed reaches a point where its multiple equals one of the wheel's natural frequencies, forced resonance will occur because the force is pushing and pulling the blades at precisely the frequency needed to cause the amplitude to grow. This is called a 'multiplier effect' and determines the order of excitation. For example, if the natural frequency of the first mode of vibration is 10,000 Hz and the wheel is rotating at 120,000 rpm then the strain amplitude will occur at 5th order as 120,000/60 = 2,000 rps x 5 = 10,000 Hz. That is to say the 5th order Fourier component of the pressure field is providing the alternating force at the resonant frequency. The amplitude of the pressure distribution and the Fourier components is a key contributing factor to blade deflection and HCF.

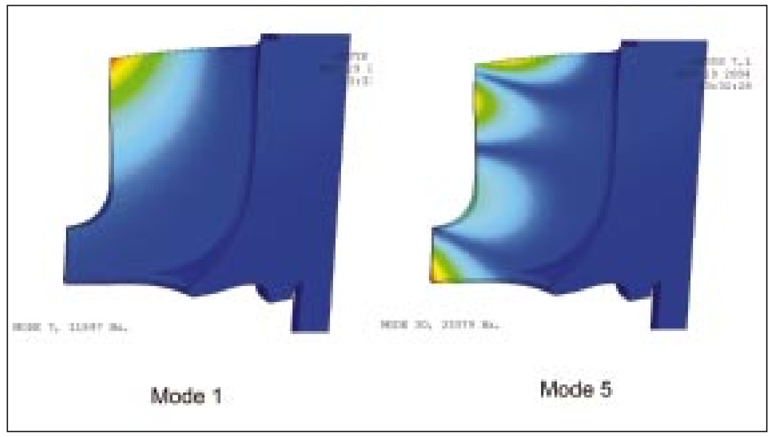


Fig 1 - Contours of deflection for modes 1 and 5

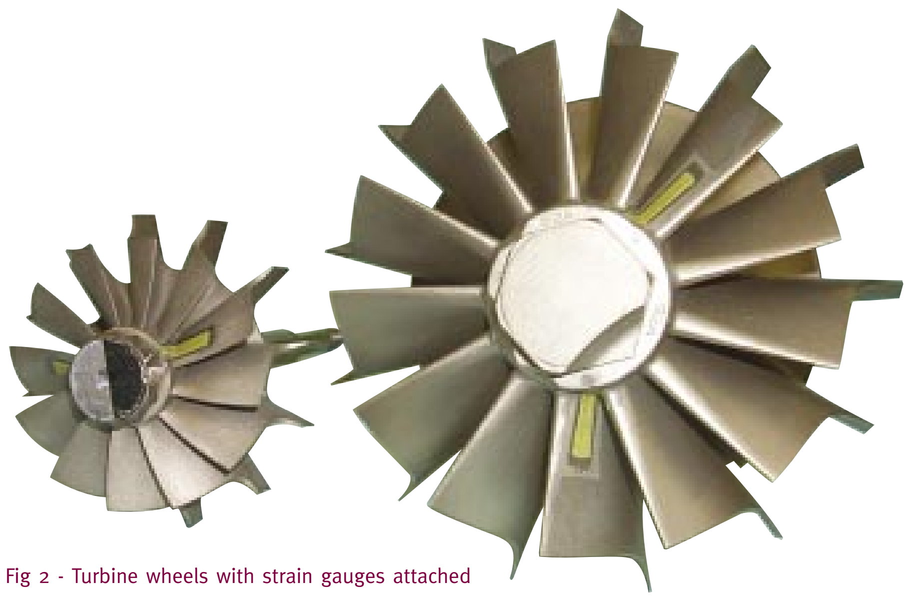


Fig 2 - Turbine wheels with strain gauges attached

It follows that the aerodynamic design of the housing volute is one of the keys to HCF. Figure 5 shows two pressure distributions from an old design and new aerodynamic design. The new design has a much smoother distribution, from which a lower blade vibration could be expected.

Using CFX computational fluid dynamics program it is possible to calculate the full unsteady flow in the housing/wheel combination using our 32 node parallel PC cluster. This calculation can take up to a week to run, even with plenty of computing power. However, from the calculation we can obtain the amplitude and phase angle of the pressure field at every node on the surface of the blade. This can then be used as input into the ANSYS program enabling a full harmonic analysis of the blade deflection.

This calculation was run for the new and old housing using the same wheel. The strains against the telemetry measurement for 5th and 6th order vibration were compared (see figure 6). Clearly the prediction compares well with the measurement and the new housing produces a smaller strain, therefore it should be much less vulnerable to HCF.

Through this work Holset engineers have improved their understanding of how high cycle fatigue occurs and the related contributing factors. Through experimental and computational development a tool is now available that can be used to improve understanding of the interaction between wheel and housing, and of how different wheels behave under vibration. The method works well for simple first mode vibration, although further work is needed to validate the method for more complex modes and work will continue in the quest to gain a better understanding of what are quite complex phenomena.

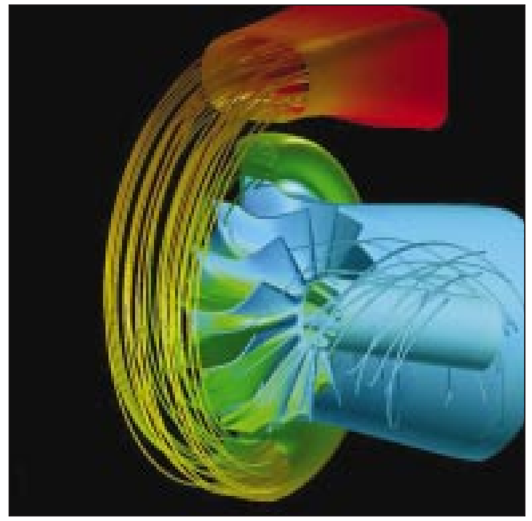


Fig 3 - Computation of exhaust flow around the turbine housing and wheel

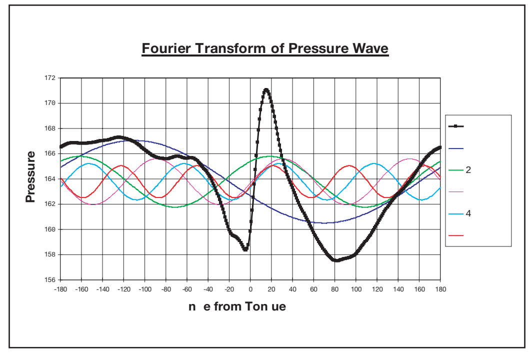


Fig 4 - Turbine housing pressure field with 1st to 5th Fourier components

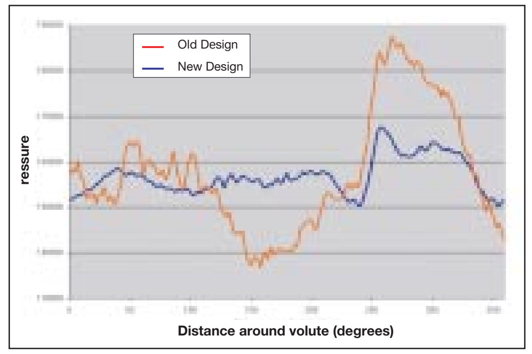


Fig 5 - Pressure field from new and old turbine housing design

Fig 6 - Predicted and measured relative blade strain from old and new housing

HOLSET
TURBOCHARGERS

Our Goals

Holset Turbochargers place 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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THE LATEST NEWS FOR HOLSET TURBOCHARGERS' CUSTOMERS
EDITION 5

Giving Turbochargers an Electrical Boost

Inside this edition: