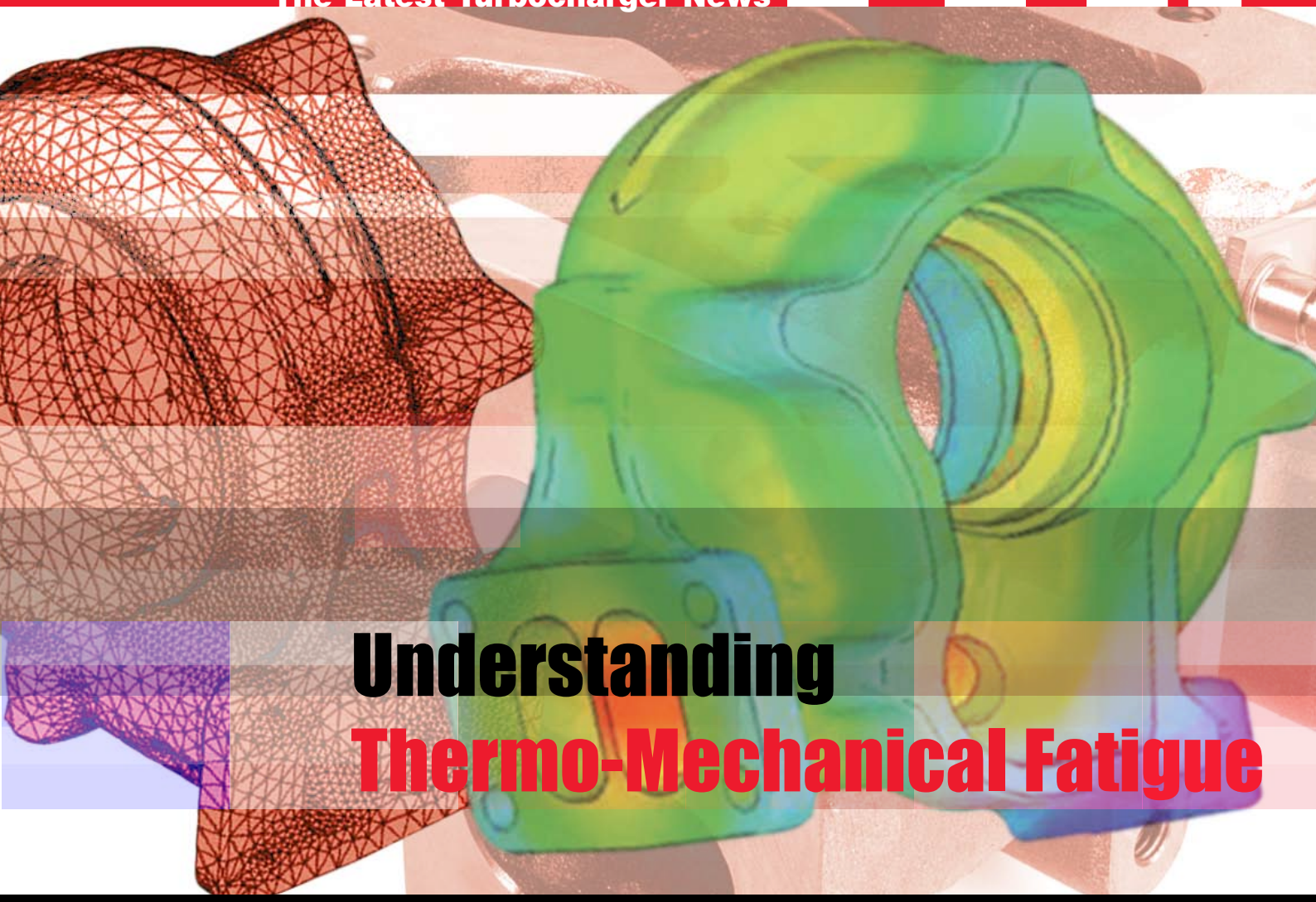
Cummins Turbo Technologies

HTi

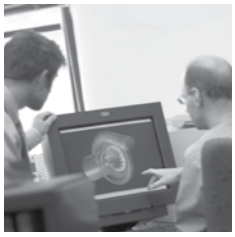
The Latest Turbocharger News

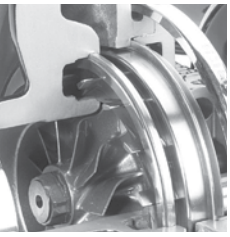


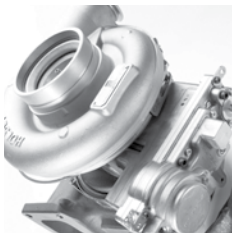
Understanding Thermo-Mechanical Fatigue

EDITION 8:

Turbo Technologies







Comments from the Leadership Team

Welcome to this, the eighth issue of HTi, where the content very much reflects the focus of our business: Technical Excellence. Naturally, there is a strong core of technology and innovation. As such, we outline how we design and engineer key components such as turbine housings, turbine blades and wastegate valves to withstand the challenges of life on the wrong side of 700°C. Thermo-mechanical fatigue, violently pulsing exhaust gases, differential rates of expansion, engine vibration, high cycle fatigue... we explain how all are mastered with the aid of a modern array of tools, such as finite element analysis and three-dimensional computer modelling, something we refer to as Analysis-Led-Design (ALD). We hope this insight into our design work is both interesting and reassuring; our customers know that the Holset brand delivers reliable performance. This issue goes some way into explaining how and why.

However, technology alone is never enough. It needs a solid business platform and particularly in today's world, the leverage of the right global strategy. Our features on our commercial developments and re-branding in China and India give a flavour of how we are growing the business outside the long established markets such as Europe and USA. Particularly impressive is our success in China with Wuxi Cummins Turbo Technologies, as the booming automotive industry adopts stricter emission controls and growth. The result underscores what happens when the right technology and the right business strategy come together at the right time. Our commitment to protecting this business and its customers by tracking down fraudsters who attempt to copy Holset products is, as you will read, whole-hearted. We are determined to protect our intellectual property and our Holset® Brand.

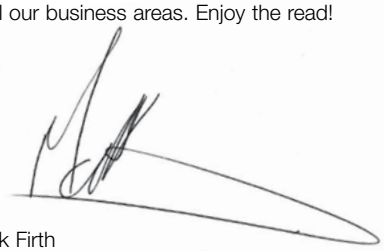
We also describe the benefits of the Oracle 11i planning software that is now being rolled out at our sites right across the world. Working quietly behind the scenes it will give the cohesion needed for a global business like ours to move forward. It is the conduit for spreading best practice and will touch every aspect of our operations.

Mark Firth

While focusing on big internal projects like this we must not overlook the importance of making ourselves accessible to our customers. We hope the new marketing portal is a useful addition to our website, providing a user-friendly route to marketing support.

Cummins Turbo Technologies is dedicated to 'Technical Excellence' and 'Innovation that You Can Depend On', this is the objective of our Technical Functions. As you will read, this not only applies to base engineering, it applies to all aspects of our business. The innovations in all our business areas are an integral part of our strategy.

In the role as Head of our Technical Functions, I am dedicated to the development of technology and products to meet our customers' needs. This edition of HTi demonstrates our commitment to apply this to all our business areas. Enjoy the read!



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

HTi is produced using an environmentally approved printing process and is printed on fully recyclable and biodegradable paper.

Strategic Changes in India and China

Written by Jodie Stephenson, Global Marketing Communications Leader

New signage for Cummins Turbo Technologies, India

It was in May last year that Cummins announced that it would adopt a unified branding strategy that would align all its family of businesses under the Cummins brand. This allows the various subsidiaries to communicate more effectively and present a strong and consistent corporate image right across the world. It started with Holset Engineering becoming Cummins Turbo Technologies.

This year, it is the turn of our joint venture businesses to be brought under the Cummins brand umbrella. Tata Holset in India is now renamed Cummins Turbo Technologies. However, this is not simply a matter of a new name. Cummins Inc. now owns 100% of the company in India, having bought the share of its former joint venture partner, the Tata Group of Companies.

This year, it is the turn of our joint venture businesses to be brought under the Cummins brand umbrella.

Cummins Turbo Technologies and the Tata Group have manufactured turbochargers in India through a 50/50 joint venture agreement since 1994. "We have enjoyed our partnership with the prestigious Tata Group over the last 12 years and will continue to sell our Holset branded products to their subsidiary; Tata Motors, one of our key strategic customers," said Charles Kaye, Director, Asia Joint Ventures for Cummins Turbo Technologies. "This move will enable us to further leverage the Cummins brand in India where we already have many successful business and customer relationships."

Charles continued: "Our track record in India has been excellent. We have experienced strong growth both in domestic and export business over the last few years. As a result, we expanded and upgraded our manufacturing facility two years ago so that we now have a state-of-the-art, world class operation in Dewas. We have also opened an office in Pune to support our domestic and global operations. We expect to further tap into the impressive growth in the domestic market in India."

In addition to Tata Motors, Cummins Turbo Technologies' other key Indian customers include Cummins India Ltd, Eicher Motors, Mahindra & Mahindra and Tata Cummins.

Meanwhile, in China, February's Spring Festival was an opportune time and a fitting celebration to launch the new name and brand identity for our Chinese joint venture, previously called Wuxi Holset. Spring Festival is a celebration of brand new beginnings and a brand new year. Furthermore, 2007 is the year of the Golden Pig, a symbol that is seen in Chinese culture as representing good luck and prosperity.

The changes were planned so that when employees returned to work after Spring Festival, they were welcomed back to a facility with a new look and a new name. Employees assembled at the gates and in true Chinese tradition, firecrackers were released and fireworks shot up into the sky to mark the start of the new year and the new identity. Qian Hanqing, Board Chairman and Mark O'Connor, General Manager together unveiled the new name at the gates to signal a new beginning for the company.

The joint venture's new name is Wuxi Cummins Turbo Technologies. The retention of the name Wuxi in the title reflects not only the involvement of our joint venture partner, Wuxi Power but also represents the Chinese city where the plant is based.

Mark O'Connor and Qian Hanqing unveiling the new signage

Understanding
Thermo-Mechanical Fatigue

Written by Mike Eastwood, Principal Engineer - Applied Mechanics & John Allport, Manager - Applied Mechanics

Turbine housings have a difficult life. The exhaust gases passing through them may be over 700°C, whereas the surrounding air is only around 90°C giving a thermal gradient across the turbine housing walls. However, at low engine powers, the exhaust gas is much cooler giving a temperature range of 600°C during some duty cycles. It is this cycling of exhaust temperature that incurs stresses in the turbine housing, which must be carefully considered at the design stage.

As the turbine housing geometry is complex and includes flanges, bosses and varying section thicknesses, metal temperature is non-uniform. The temperature gradients (figures 1 & 2) cause varying rates of expansion, which along with varying stiffness cause stress. A tensile stress during heating usually becomes a compressive stress during cooling and vice versa, creating a fatigue cycle.

Turbine housing materials have to meet tough specifications as they must withstand temperatures of 800°C without cracking, creeping or scaling.

How Thermo-Mechanical Fatigue Analysis is Performed

Cummins Turbo Technologies first performed Finite Element Analysis to assess thermal stress and fatigue of turbine housings in 1994. This was originally carried out on 2D axis-symmetric sections due to constraints imposed by the capabilities of the analysis software and computer hardware at the time. Advances over the last 13 years in the analysis software and computer hardware now allow a full 3D model of a turbine housing to be analysed (figure 3). This involves meshing, applying thermal and structural boundary conditions, running the model with a heating and cooling thermal transient and producing temperature, stress and fatigue results.

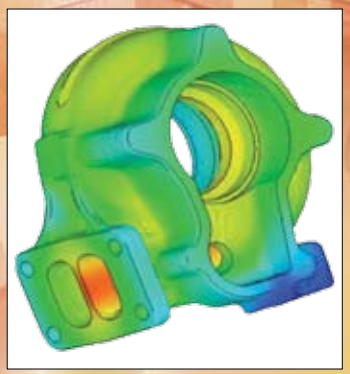


Fig 1 - Turbine housing temperature distribution (red is hottest)

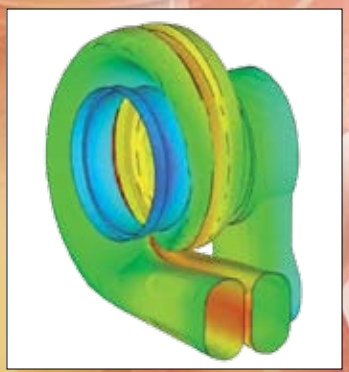


Fig 2 - Temperature distribution in volute

Fig 3 - Meshed turbine housing

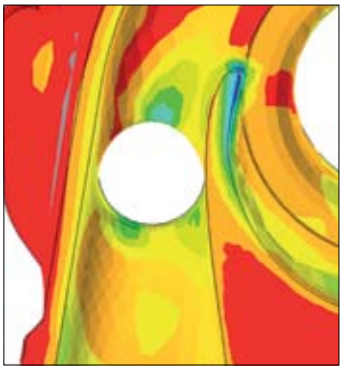


Fig 4 - Compressive stress plot (blue is most compressive)

The analysis is run in a number of stages. Thermal, structural and fatigue analyses are run automatically by macro on each proposed geometry. This process takes a few hours on current hardware using a mesh with around 500,000 nodes. Results can be compared between different iterations of geometry and also standard test results.

The results of the analyses can be examined to see if there are any potential failure points in the design (figures 4 & 5).
An initial design proposal will be modified to improve the fatigue life, based on knowledge of failure modes built up from experience of previous analyses and test work.

Fig 5 - Fatigue life plot (blue is lowest life)

At elevated metal temperatures, the strength and fatigue resistance of the turbine housing material is greatly reduced compared to room temperature. A new material option with higher temperature capability would give great benefits in designing a turbine housing to withstand the trend of increasing turbine inlet temperatures. Candidate materials have a tough specification as they must:

1. Withstand high temperatures up to around 800°C without cracking or creeping and with low scaling.
2. Withstand impact during a containment test at temperature.
3. Be castable and machinable.
4. Be relatively inexpensive.

Finding new materials to meet all these requirements is not easy however, research is ongoing.

Turbine housings therefore have to be designed to resist thermal cracking such as shown below, (figures 6 & 7) by keeping section thicknesses constant where possible and avoiding stress raisers such as sharp edges and tight internal radii.

Fig 6 - Thermal cracking at wastegate bore

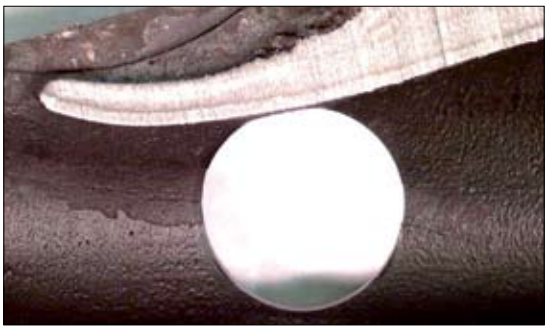


Fig 7 - Thermal crack looking from volute

Turbine Housing Design Optimisation

The ideal turbine housing geometry to resist cracking would be a single entry fixed geometry turbine with a uniform wall thickness and no external features such as bosses. In real applications however, many other things have to be taken into consideration. Some of these are considered below:

1. **Space claim on engine.**
   The turbocharger needs to be mounted close to the exhaust ports to maximise the amount of energy recovery from the exhaust gases. It is usually required to fit into a confined space between the engine block and other components and this can limit the external envelope available for the turbine.

2. **Customer flange and mounting feature requirements.**
   The outlet flange of the exhaust manifold is determined by the customer and has to be matched by the turbine inlet flange. This gives an initial geometric constraint to the design. Bosses for mounting heat shields and actuators also add complexity and change the wall thickness.

3. **Volute shape to suit performance requirements.**
   This is often twin entry to minimise the effects of pressure pulsations from the exhaust gas.

4. **Design for containment.**
   The turbine housing has an important secondary function, to contain any broken pieces in the event of a turbine wheel failure (figure 8). The turbine wheel possesses a large amount of kinetic energy under running conditions and the housing has to be able to dissipate that energy safely without allowing any pieces to escape. Although a wheel failure is a very rare occurrence in practice, the consequences are so serious that it warrants critical consideration throughout the design.

Fig 8 - Containment tested turbine housing

5. **Ease of casting the component.**
   It is important to make sure that the housing can be cast in order to ensure good material properties throughout. Bad design can lead to casting faults such as porosity or cold shut lines, which are detrimental to the final product.

6. **Machining the finished part.**
   Machining of connections can often impose requirements for tool clearances or involve undercuts, which can cause high thermal stress concentrations.

7. **Cladding requirements.**
   External thermal cladding is sometimes required on marine housings to reduce surface temperature in engine rooms. This can change the temperature distribution within the housing and hence the stress distribution and fatigue life.

8. **Turbocharger complexity.**
   To meet performance and emissions requirements, wastegates and variable geometry are often needed adding complexity to the turbine housing shape.

9. **The size of the housing.**
   The bigger a housing is, the more likely it is to have large thermal gradients and the more it is prone to thermal cracking.

10. **The effects of pressure.**
    Increased pressure due to two stage charging and turbocompounding increases thermal convection coefficients in the gas passage and can therefore increase thermal gradients.

It can sometimes take a number of iterations to achieve a suitable design to resist thermal cracking and satisfy all other requirements. The final design is therefore usually a compromise between fatigue life and application constraints. However, the use of these analysis techniques allows a reasoned, data based decision to be taken, having considered all the design constraints.

Cummins Turbo Technologies is studying field data, developing analysis tools and researching new materials in order to ensure the best possible durability of our products. Turbine housing design is one of many challenges that we have to conquer in order to provide the quality of product that can survive the harsh operating conditions of the heavy-duty diesel engines of today and tomorrow.

Marketing Support
at the Click of a Mouse

Written by Jodie Stephenson, Global Marketing Communications Leader

An important new on-line marketing resource is now up and running, providing a quick and simple way to obtain the wealth of marketing support offered by Cummins Turbo Technologies.

The new 'Marketing Portal' on our website is designed to function as a one-stop shop for marketing support via a secure site accessible only by you, our customers.

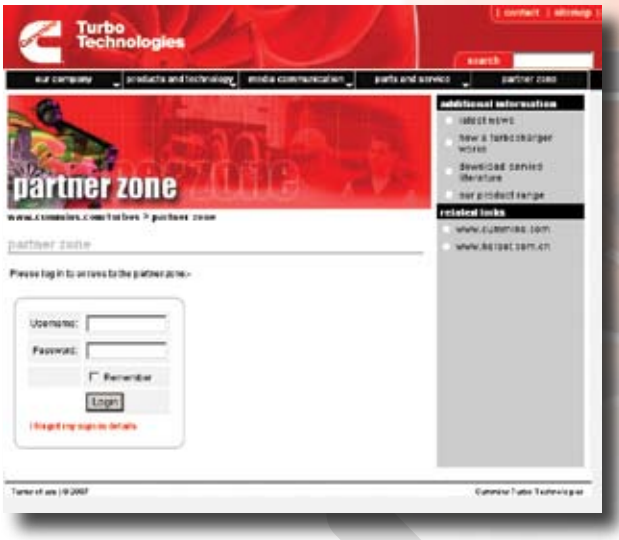
To log on, go to **www.cummins.com/turbos**, click on 'Partner Zone' and enter your passwords that we provide. Once you are logged on, the Partner Zone menu is activated, putting a wide range of marketing support material and services at your fingertips.

There are four major sections; Product Support, Promotional Material, Exhibition Schedule and Magazines.

The **Product Support** section includes a handy cross reference guide with details of engine models and the corresponding Holset turbocharger details. In addition, this section includes compressor maps that can be downloaded. There is also an orientation calculation guide and we have included some technology training aids too. These include animated clips that illustrate the function of a turbocharger wastegate and how the more sophisticated Holset VGT™ works.

In the **Promotional Material** section, you will find a range of leaflets and posters. You may either download these or order hard copies on-line. The material available includes training support publications outlining the technology and describing how our turbochargers work - ideal for new starters in the turbocharger industry. There is also a sub-section devoted to multimedia resources, such as our corporate overview DVD and the new animated Turbocharger Fundamentals DVD that shows in detail how a turbocharger works.

There are four major sections; Product Support, Promotional Material, Exhibition Schedule and Magazines.



Product Support

The **Exhibition Schedule** section gives details of all the events that Cummins Turbo Technologies will be attending in 2007.

Finally, the **Magazines** section allows you to download the current and previous issues of HTi, providing a record of all the technological and business news from Cummins Turbo Technologies.

From the Marketing Portal, you also have access to the rest of the Cummins Turbo Technologies website. This gives you access to a comprehensive list of information including all the service repair manuals and similar literature. You can also go to the media communication section that contains the archive of product pictures and imagery.

For details of your passwords to access the Marketing Portal, please e-mail turbo.enquiries@cummins.com

We have done our best to incorporate all the marketing support that you might need in our website's new Marketing Portal. We welcome your feedback, together with suggestions for improving or adding to the marketing support we provide. Please send your feedback to turbo.enquires@cummins.com

Dynamics of Mistuned Turbine Wheels

Written by Xiaozhen Sheng, Senior Engineer - Applied Mechanics

Turbine wheel blades are required to be as thin as possible in order to allow efficient passage of gas through the turbine. These long thin blades vibrate easily and the wheel must be designed so damaging vibration amplitudes are avoided. Understanding which is the weakest blade on a wheel is essential to predicting the life of the wheel as a whole.

Why blades vibrate

A turbine wheel rotates at high speeds in a housing full of pressurised gas. Each blade is subject to a time-varying pressure from the gas flow, which excites the blade vibration. Pressure time-history on one blade is identical to that on another blade apart from a certain time delay. Blade resonances occur at certain turbocharger speeds, during which the strong blade vibration generates high cycle fatigue (HCF) and may cause blade failure (figure 1).

Fig 1 - Blade failure due to high cycle fatigue

Mistuning and its effects

A turbine wheel is normally designed to be tuned, i.e. all the blades have the same geometry, material properties and spacing. Due to the casting process and machining tolerance, random blade-to-blade variations will always exist, not only in geometry but also in material properties. This phenomenon is called mistuning. Rotating in a turbine housing and subjected to gas pressure excitation, the blades of a tuned wheel will have the same vibrational displacement, stress and strain. This, however, is far from true for a mistuned wheel, even when mistuning is small. A mistuned wheel may exhibit vibration localisation; where a few blades have responses much greater than those of other blades (figure 2) and amplification; where the response of the most responsive blade is much greater than the response if the wheel were tuned. Those mistuning effects not only significantly reduce the HCF life of the wheel but also make it difficult to predict and measure the representative blade response.

The mistuning of turbine wheel blades is important in our understanding of how to predict turbine wheel life with greater accuracy.

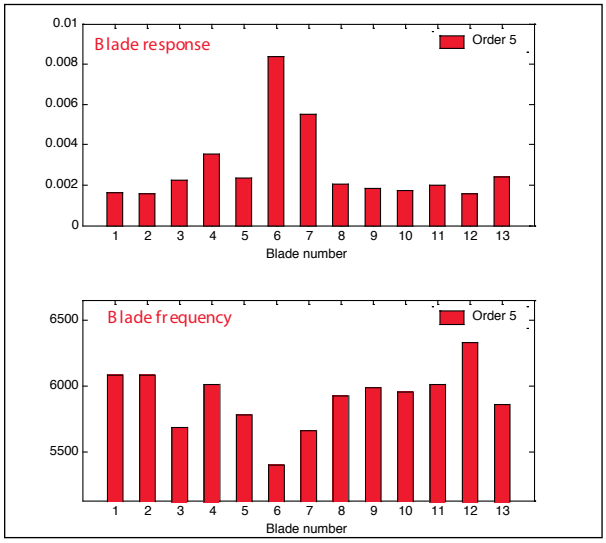


Fig 2 - Blades in a mistuned wheel have different frequencies and vibrational responses

Identification of the most responsive blade

Since blades in a mistuned wheel may have significantly different vibrational responses and current technologies do not allow measuring the responses of all the blades simultaneously, methods must be developed to identify the most responsive blade. Currently Cummins Turbo Technologies is using a method based on a blade frequency survey to select a blade for measurement (blade 6 in figure 2). Strain measurement is performed on that blade as well as on another blade (figure 3) to assess the HCF life of the wheel.

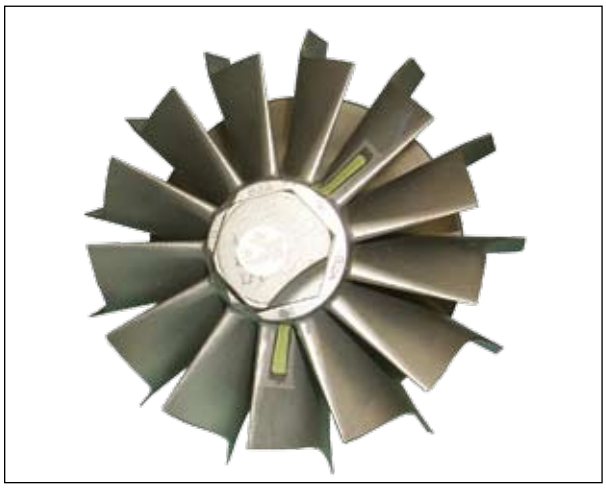


Fig 3 - Strain gauges on the identified most responsive blade and another blade. Tip-to-tip frequency response is the displacement of one tip due to a unit force at the same or another tip

Research conducted at Cummins Turbo Technologies shows that there is room for improving the accuracy of the above method of identifying the most responsive blade. However, an alternative method is proposed using a lumped parameter model of a turbine wheel, shown in figure 4. In this model, the hub is represented by a disk and a blade represented by two masses connected to each other and to the disk through springs. According to the proposed method, tip-to-tip frequency response functions are required to be measured. A tip-to-tip frequency response function is the displacement of one tip due to a unit force at the same or another tip (figure 3).
There are N x N such functions, where N is the number of

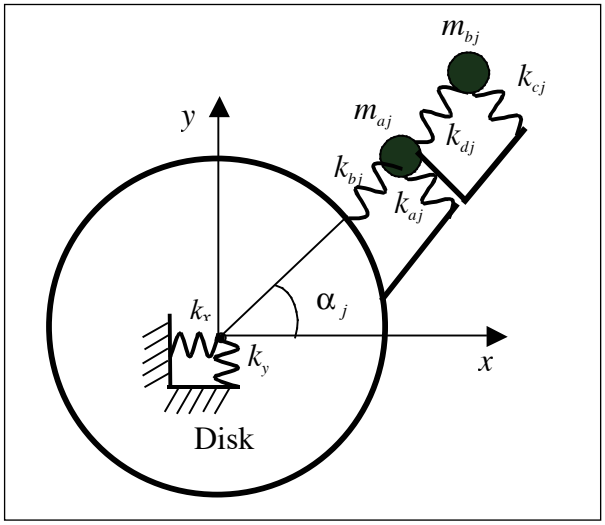
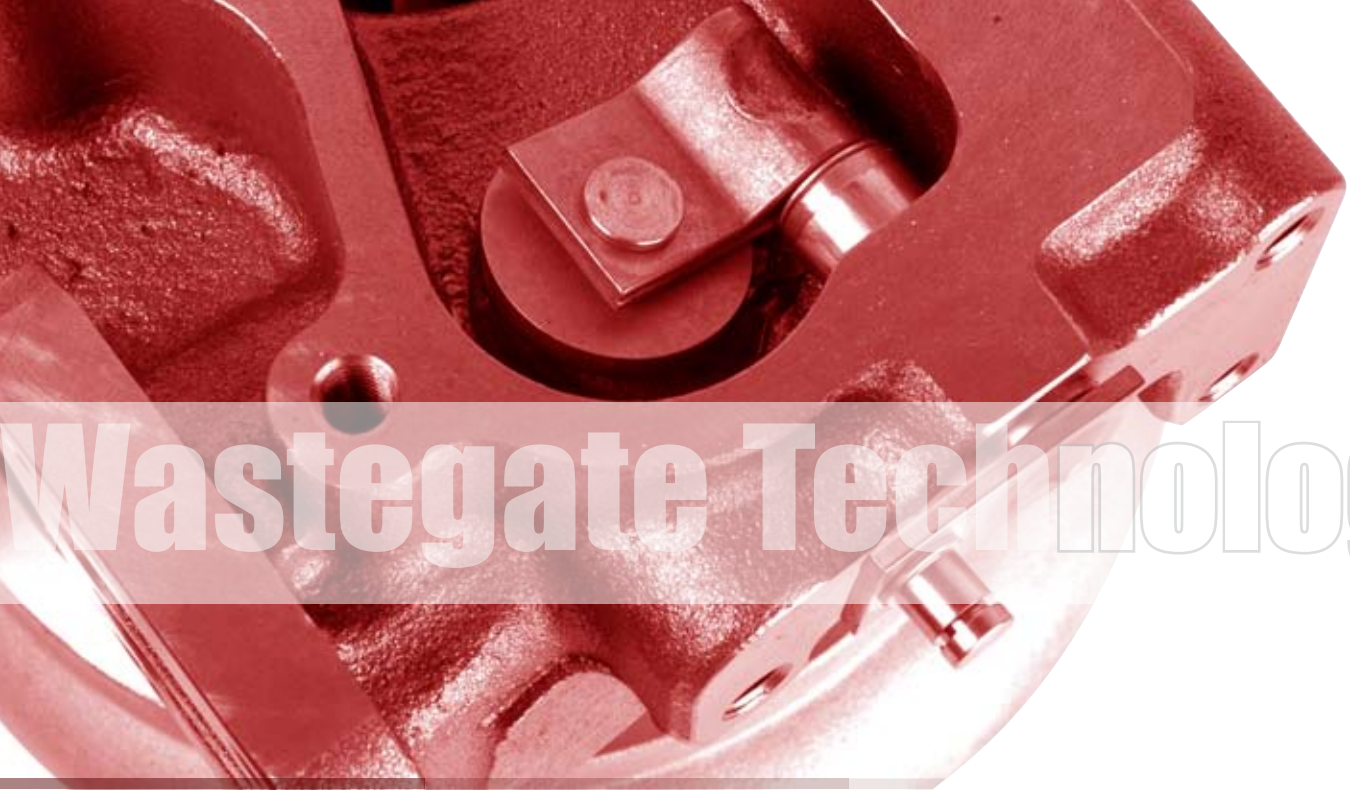


Fig 4 - A lumped parameter model for studying the dynamics of mistuned turbine wheels. Only one blade is shown

blades. The number of measurements can be significantly reduced by making use of reciprocity relations. From these functions, blade tip displacements under any excitation configuration can be calculated and the blade with the maximum tip displacement can be identified. It is shown that this blade is highly likely to be the most strained blade with a likelihood of greater than 90%. The mistuning of turbine wheel blades is important in our understanding of how to predict turbine wheel life with greater accuracy.

(Extract from a paper presented by X Sheng, DC Clay and J Allport , Dynamics of Mistuned Radial Turbine Wheel, Proceedings of the IMechE 8th International Conference on Turbochargers and Turbocharging, 2006 London, pp. 251-260).



We Need a Bypass - Wastegate Technology

Written by Owen Ryder, Senior Engineer - Air Handling

In today's world of efficiency and pollution improvements, the word 'wastegate' seems an unfortunate name to apply to a turbocharger feature. However, wastegates, or turbine bypasses, are an important part of air handling systems that allow engines to meet advancing emissions legislation.

What is Wastegating?

A wastegate is simply a valve that allows some of the exhaust gas to pass directly from the exhaust manifold to the exhaust pipe, however this is still an effective way to control the turbocharger speed and boost pressure.

The History of Wastegating

The concept of wastegating is almost as old as turbocharging itself, being used on World War 2 aircraft to allow absolute boost pressures to remain constant at high altitude. It seems astonishing these days that such wastegates were manually operated by the pilot!

The first production passenger cars fitted with turbochargers had wastegates, these being the Chevrolet Corvair Monza and the Oldsmobile Jetfire, both launched in 1962. Passenger car use of turbochargers did not pick up again until the 1970s and heavy duty vehicles followed suit in the 1980s with the highest power ratings needing a wastegated turbine.

Fig 1 - Early poppet valve design

Most of the early wastegates used a poppet valve and Cummins Turbo Technologies developed such a design, (figure 1), although the final solution was to develop a flap valve that was remotely actuated from the hot turbine (figure 2). The Holset WH1C was our first wastegate turbocharger, which was used on Cummins and Paccar engines in the USA in the 1980s.

Why Wastegate?

In order to understand the reason for using a wastegate, we need to look at the boost pressure and turbocharger speed characteristics when using a fixed geometry turbine. The dark blue line in figure 3 shows how boost pressure increases with engine speed for a fixed geometry turbine and figure 4 shows that the turbocharger speed will also increase. The size of the turbine housing is chosen so that the maximum turbocharger speed does not exceed the recommended limit, in this case 113,000rpm. This means at lower engine speeds the boost pressure is lower than we would like.

Ideally we would like the full boost pressure to be available across all of the engine speed range. By fitting a smaller turbine housing, shown as red lines in figures 3 and 4, a higher boost pressure is achieved from the compressor at each engine running condition. The downside is that the turbocharger will go above its maximum allowable speed as engine speed increases, risking a catastrophic failure of the turbocharger, engine or both. This is where the wastegate is useful. A small turbine is used to give good boost at low engine speeds, however the turbocharger speed is controlled to a safe level by letting some of the engine exhaust gas bypass the turbine.

A common way of operating the wastegate is to use the boost pressure itself. When the desired pressure is reached, the wastegate opens, producing the characteristics shown by the green lines in Figures 3 and 4. Recently, an alternative method has become popular, controlling the wastegate using the engine control unit (ECU). This generates higher boost pressure in the middle of the speed range without exceeding the recommended speed limit, shown as light blue lines in figures 3 and 4. The Holset Command Valve™ is a compact design that allows the ECU to control the wastegate using boost air from the compressor (see HTi edition 3).

For readers who are familiar with compressor maps, figure 5 will help explain the relationships between boost and turbocharger speed for the different options considered.

Besides improving boost at low engine speeds, wastegates are used for other reasons: Gas fuelled engines use them to precisely control air flow into the engine and two stage systems can use wastegates to change the work split between the two turbines.

As emissions aftertreatment systems become more widespread, variation of the turbine characteristics is becoming necessary as exhaust systems exhibit variable back pressures during their life, which would otherwise affect boost pressures.

Wastegate Design

Fitting a bypass valve into a turbine housing presents a number of challenges. The exhaust gas is typically around 700°C on a diesel engine and higher on gas and petrol engines. The gas flow is pulsing violently as the exhaust valves open and close and engine vibrations add to the harsh environment.

The actuator must be kept cool and mounting it on the compressor housing helps to do this. It is popular on high volume applications but for most situations, Cummins Turbo Technologies prefers mounting the actuator on the turbine housing. This poses a big challenge both in terms of structural and thermal loading but it offers advantages in flexibility of end housing orientation. This can reduce part count and the ability to re-orientate the assembly without destroying the wastegate setting is a benefit for customers supplying loose engines.

Finite Element Analysis and ProMechanica software tools are used to predict the vibration mode shapes and natural frequencies of brackets and actuator rods so that they can be designed to survive the engine vibration frequencies. The frequency response and durability of prototype parts are then

Wastegates are an important part of air handling systems for future emissions legislation

established on shaker rigs to ensure the bracket and actuator will be durable in the field. Holset turbochargers have a piston guided actuator, which means the vibration node is near the diaphragm, leading to less movement of the diaphragm and increased durability.

Cummins Turbo Technologies' guidelines for actuator design and spring specification ensure spring loads and diaphragm movement is kept to a minimum. Springs are heat set after winding for stability and they have special coatings in order to stop cracking and corrosion. Attention to detail is also essential in the articulation of the valve head and valve seat design, to ensure a good seal in all operating conditions.

The actuator is subjected to many approval tests: Salt spray tests check for corrosion resistance; dust tests check that particles cannot penetrate to cause internal damage and chemical tests show that the components are not sensitive to the fluids that might be found around a diesel engine during its life. Cyclic tests of diaphragms and springs are done to establish their durability.

The Future

Whilst variable geometry turbines offer further benefits, particularly on EGR engines, wastegates are still valuable for current and future emissions legislation. Cummins Turbo Technologies can offer turbine bypasses for a range of applications that require variable turbine characteristics and we have the skill and experience to ensure it is executed to the highest standard.

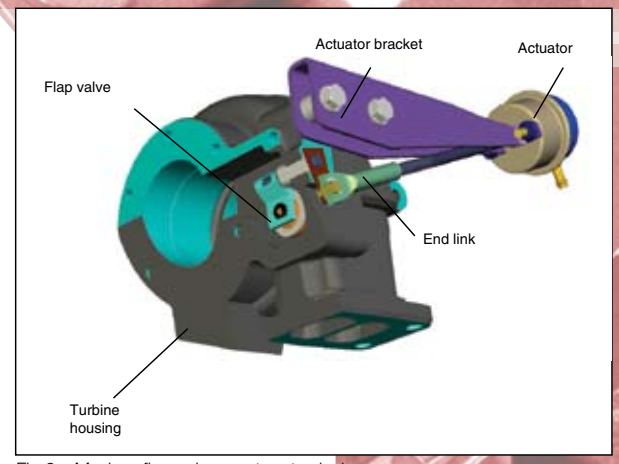


Fig 2 - Modern flap valve wastegate design

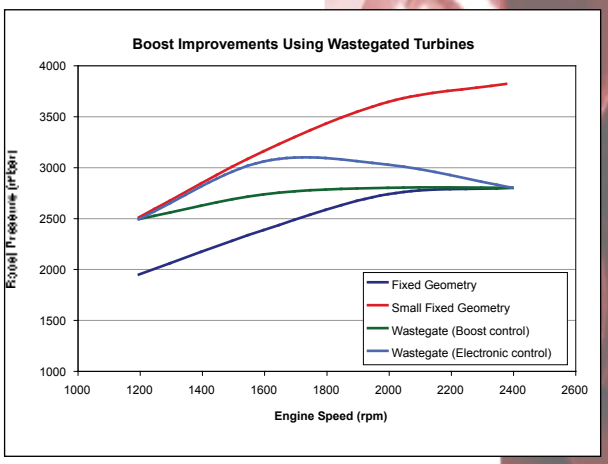


Fig 3 - Effect of turbine size on boost pressure

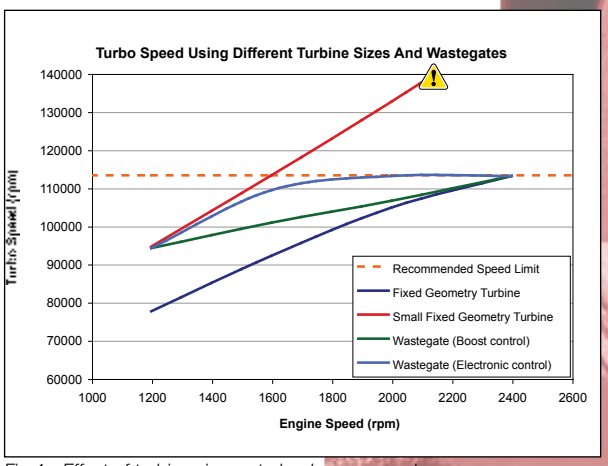


Fig 4 - Effect of turbine size on turbocharger speed

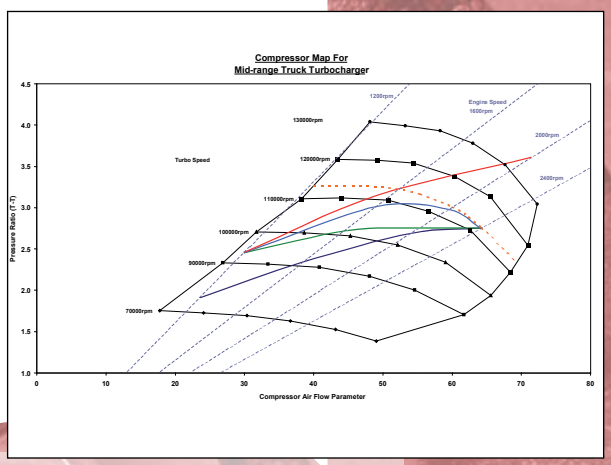


Fig 5 - Compressor map showing engine running lines

ERP Standardisation for Global Best Practice

Written by Chris Starmer, Global Oracle 11i Projects Leader

The computer systems that support all the Cummins Turbo Technologies' manufacturing plants - the Enterprise Resources Planning (ERP) systems - are soon to be unified and upgraded, providing a standardised and cutting-edge system right across the business.

Over the next three to four years the Oracle 11i applications suite will be installed in all plants, replacing a variety of individual locally used systems. This will deliver a common ERP platform that will enable us to standardise processes and adopt best practices in all plants. Reporting will become easier: The new ERP systems will be designed to handle greater volumes and a wide range of new products to satisfy ever more demanding customer requirements.

The implementation of the system is a major project that will be controlled via a new Cummins Turbo Technologies Oracle 11i Program Office. This will be staffed by Global Functional Leaders who will work with individual site teams to develop processes for use worldwide. Each of the Global Functional Leaders covers a specific business function; finance, materials, supply chain, sales and marketing, manufacturing and quality.

The project's sponsor is David Womersley, Director, Manufacturing. He is unequivocal about the benefits of replacing our existing ERP systems and the need for a Program Office to standardise processes. "We need to manage greater complexity in product mix and provide improved speed of response to our customers," says David. "We need better information to target improvements in efficiency, profitability and cost reduction to achieve our business goals for growth and customer service. Ensuring that we standardise processes across our plants to industry best practice is an important step and the Program Office approach is the best way to achieve that."

The technique of using a Program Office has been proven elsewhere in industry, including at our sister company, Cummins Filtration, where it also made a substantial reduction in the time and cost of site implementations.

The first step in introducing Oracle 11i in Cummins Turbo Technologies was taken at our new Palmetto plant in Charleston, USA, where we build the heavy-duty Holset VGT.™ The plant has been using Oracle 11i for financial, commercial and operational functions since it opened in July 2006. The system has also been used at the Huddersfield plant since December 2006 to manage the complete 'order to cash' cycle for a particular pilot customer. This is a precursor to a project transferring all Huddersfield's current customers to Oracle 11i during 2007.

The next location for Oracle 11i implementation is the Wuxi Cummins Turbo Technologies' plant in China, where the local team received training in Oracle applications during the early part of this year, ready for an implementation scheduled for completion by the year-end. Says Mark O'Connor, General Manager of Wuxi Cummins Turbo Technologies, "I am really enthusiastic about the feedback I have had from members of the leadership team about their impression of Oracle software. It has been very positive."

Following this, implementation of Oracle 11i is planned for our remaining worldwide facilities.

Part of the role of the Global Functional Leaders in the Program Office will be to manage a single Oracle 11i 'change control' process. This will ensure that when any plant develops a plan for continuous improvement, all other plants easily can adopt the same techniques and reap the same benefits without delay. Explains Chris Starmer, Global Oracle 11i Projects Leader, "We need to ensure developments on the Oracle system are controlled but we want to encourage innovative ideas and creative solutions from any plant, so we can improve the use of the system at all plants."

"We need to manage greater complexity in product mix and provide improved speed of response to our customers"

The role of the Global Functional Leaders is key to enabling this development and distribution of best practice. The Program Team will use Six Sigma methods to reduce variation in processes and will be working with Black Belts to incorporate Six Sigma tools into the system's solution design and testing processes.

The Oracle 11i projects have already allowed Cummins Turbo Technologies to create a technical team of database and system administrators within IT, supporting the software from offices in India, UK and USA. With the creation of the Cummins Turbo Technologies Oracle 11i Program Office, a single team of developers and applications experts will be able to support system implementations at company locations around the world.

Two Million and Counting:

Our Contribution to Economic Development and Environmental Protection in China.

Written by Li Aihua, Marketing Manager

The soaring growth of the Chinese economy has captured the world's attention. However, the rate of expansion of its gross domestic product (GDP) is matched by the increasing threat to the environment. Air pollution from the growing number of vehicles is an obvious concern, so China is adopting increasingly stringent engine exhaust emission limits. The Euro 3 emission standard for medium and heavy-duty diesel engines comes into force in the near future; Euro 4 is due to be implemented by 2011.

Qian Hanqing, Board Chairman of Wuxi Cummins Turbo Technologies and Charles Kaye, Director, Asia Joint Ventures for Cummins Turbo Technologies unveil the two millionth turbocharger in Wuxi

Turbochargers are key to this progress, because naturally aspirated heavy-duty diesel engines cannot deliver the combination of high power density, good torque characteristics and low fuel consumption, yet still produce the reduction in exhaust gases and particulates needed to comply with the ever tightening emission legislation. It is said that the current USA heavy-duty diesel engine produces double the power of its 1970 equivalent, has fuel economy that is 50 per cent better, durability that is four times longer, emissions that are 90 per cent lower and yet costs 70 per cent less in real terms. The turbocharger is the enabling technology for much of this improvement.

The combination of China's surging economy and its adoption of tougher emission standards is driving exponential growth at Wuxi Cummins Turbo Technologies. In addition, Wuxi Cummins Turbo Technologies is exporting a significant percentage of its production to global customers like Doosan Infracore, Komatsu, Scania and Volvo. Established in China in February 1996, it was not until April 2002 that turbocharger production reached half a million. However, the rate of production has accelerated sharply in the last couple of years. The millionth turbocharger was produced on 16 June 2004 and just three years later, on 21 March 2007, Wuxi Cummins Turbo Technologies was celebrating the production of the two millionth Holset turbocharger.

Cummins Turbo Technologies is the world's biggest manufacturer of medium and heavy-duty diesel engine turbochargers. Its Holset turbochargers are used not only on Cummins engines but are also supplied to major customers such as DaimlerChrysler, Iveco, MAN, Scania, Tata Motors and Volvo Powertrain. The scale of Wuxi Cummins Turbo Technologies' achievements means that this pattern is now also repeated in China. The company is the market leader for medium and heavy-duty diesel engine turbochargers in China, supplying the big names in the Chinese automotive industry such as CNHTC, DFM, FAW, Weifang Diesel and Yulin Diesel. Working with business partners such as these, Wuxi Cummins Turbo Technologies can justifiably claim to be playing an important role in addressing the issue of air quality in China.

Winning this business is not only a recognition of the technical attributes of the Holset turbochargers. It would not have been possible without making huge financial investments and commitment in China. In 2004, the company moved to a world-class manufacturing plant in Wuxi's New Technology Development Zone, which also includes a technical centre. The work in the Wuxi technical centre includes testing turbocharger installations on customers' engines and contributing to the continuous process of improving and developing products. This primarily is focused on meeting the needs of Chinese customers, ensuring that Wuxi Cummins Turbo Technologies will continue to play its part as China works hard to grow its economy but also protect its environment.

On the Trail of the Counterfeiters

Written by Li Aihua, Marketing Manager

Cummins Turbo Technologies has always been prepared to take on the challenge of rivals in our industry. Competition brings out the best in companies and drives technological development and business excellence. However, in recent years we have also had to counter a less wholesome challenge coming from those who are producing copies of our products and attempting to pass them off as the genuine article. Perhaps this is a symptom of our success. After all, it is said that imitation is the most sincere form of flattery. However, counterfeits undermine the genuine product and for the safety of our customers and our own business, this is a problem that we cannot ignore.

Counterfeit products being seized

Counterfeit component parts

Imitation Holset packaging

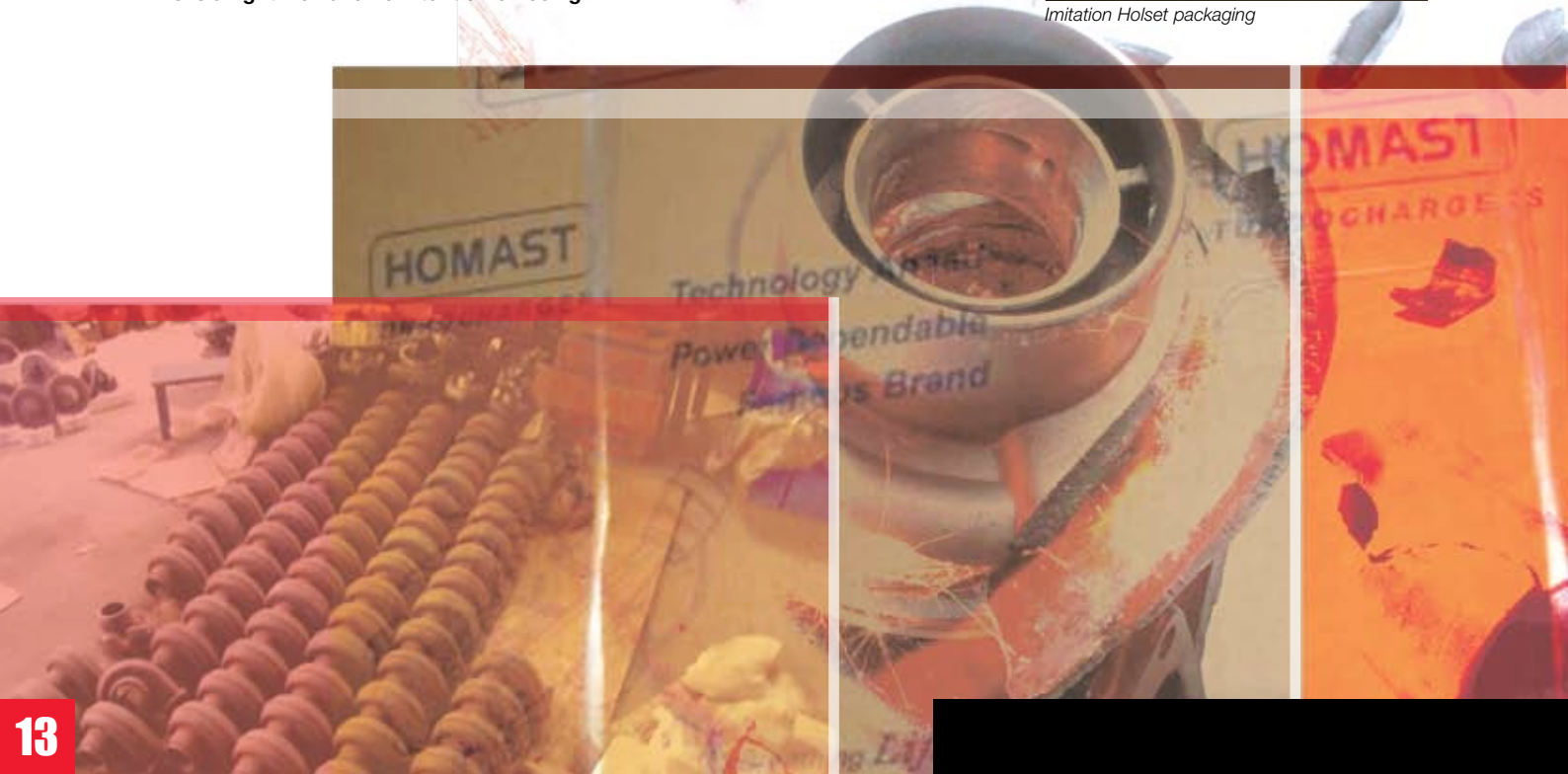
Our Chinese joint venture business, Wuxi Cummins Turbo Technologies, has been particularly active in tackling this issue. Counterfeit Holset products are a problem not just in China but in many other markets throughout the world. Ever since 2003, Wuxi Cummins Turbo Technologies has been combating these illegal manufacturers, both through its own initiatives and by working alongside the authorities in the city of Wuxi. It has been a long-running battle and as we have stepped up our efforts these manufacturers too have become slicker, taking more care to cover their tracks. It soon became clear that more radical action was needed.

Therefore, Wuxi Cummins Turbo Technologies decided to work with lawyers in China to undertake a series of investigations. This enabled us to uncover several manufacturers engaged in producing counterfeit versions of Holset turbochargers and components. We also tracked down those who were prepared to distribute and sell the counterfeit products.

Officials from Wuxi Administration for Industry and Commerce investigated five of these companies and went on to carry out a series of raids. The raids resulted in the discovery and seizure of many counterfeit turbocharger parts and numerous examples of packaging with imitation Holset branding. This success sends a strong message to the counterfeiters that Cummins Turbo Technologies is not prepared to tolerate any infringement of its Holset trademark.

Cummins Turbo Technologies is so determined to stop all counterfeiting of its Holset products that it has decided to address the issue by means of the powerful and effective Six Sigma business improvement technique. A Six Sigma project was established late last year with the objective to close two of the largest counterfeit operations in China.

This is a fight we have no intention of losing.



Exhibitions 2007

Dates for Your Diary

Cummins Turbo Technologies are scheduled to participate in the following shows during 2007. Please contact Central Marketing Services for more details about each event.

May

Engine Expo, Stuttgart, Germany, 8-10 May, 2007

June

Yorkshire Trucking Spectacular, Driffield, UK, 16-17 June, 2007

Goodwood Festival of Speed, West Sussex, UK, 22-24 June, 2007

July

Association of Diesel Specialists (ADS), San Diego, California, USA, 11-15 July, 2007

ADS, August 2006

IAA Hanover, September 2006

Goodwood Festival of Speed, July 2006

HTi Feedback Survey

We welcome your feedback on our HTi magazine. To help us to ensure the magazine meets your needs, we would like to request that you please fill in the short survey below, providing information on how you rate our current articles and what you would like to see more of, in the future. The first 100 respondents will receive a 256Meg USB memory stick.

Name		Company	
Address		E-mail	

1. On a scale of 1 to 5, how well does the content of HTi meet your interests?

(Low) 1 2 3 4 5 (High)

2. Do the following meet your requirements?

	1 = Want less		3 = Currently OK		5 = Want more
Technical Content	1	2	3	4	5
Detail of Technical Content	1	2	3	4	5
Product Information	1	2	3	4	5
Company News	1	2	3	4	5
People Articles	1	2	3	4	5
Market Updates	1	2	3	4	5

3. Please rate our technical articles on ease of understanding.

Ease of understanding (Easy) 1 2 3 4 5 (Difficult)

4. Would you like HTi to be available in different languages?

Yes No If yes, which languages? _____

_____

5. In your view, what else would you like to see in HTi?

_____

_____

Please fax your reply to + 44 1484 511680. Alternatively, you can complete this survey on our new OE Marketing Portal at www.cummins.com/turbos

Turbo Technologies

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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