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CAE drives super car engine design

Three words – greenest, cleanest and meanest – succinctly sum up the new McLaren M838T V8, designed and developed in collaboration with Ricardo and making good use of Ricardo portfolio of CAE software; greenest, because it establishes a new yardstick for low CO_2 emissions within its class; meanest, because it is the most powerful engine in that class; and leanest because of the high-efficiency, bespoke manufacturing facility built to produce it

Supercars may have a reputation for being anything but environmentally friendly, but the M838T V8 in the McLaren MP4-12C sports car has changed all that, setting new standards for CO_2 emissions – yet at 600 PS also emerging as the most powerful in its class. "Something that was absolutely key for us," explains Ricardo project director for the M838T, Tim Yates, "was to ensure we had simultaneous engineering between the development team and the manufacturing team." This involved defining the entire approach from the outset, from the capital investment in buildings and equipment to the number of man-hours needed per engine. From the very beginning a 'no faults forward' strategy was adopted, together with 100 percent data storage and traceability of all components.

Design and analysis – key ingredients

As usual in the design or development of any engine by Ricardo, the company's world-class software tools had a major role to play. WAVE was used to simulate engine performance and 1D gas dynamics, VALDYN to model the valvetrain and drive system dynamics, RINGPAK for piston ring dynamic analysis, VECTIS for CFD work, PISDYN for analysing piston skirt lubrication and piston secondary dynamics – and FEARCE and ENGDYN for crankshaft and cylinder block structural analysis.

The M838T in detail

At 3.8 litres the M838T is substantially downsized compared to most of its market competitors, yet it is significantly more powerful than any of them. Smaller capacity is a fundamental pre-condition for higher efficiency: both pumping and frictional losses are reduced through the smaller volumes and reduced surface areas. The mass of reciprocating parts is also reduced, as is the total mass of the engine – to a remarkable 200 kg. All of this serves to improve the efficiency and dynamics of the vehicle as a whole.

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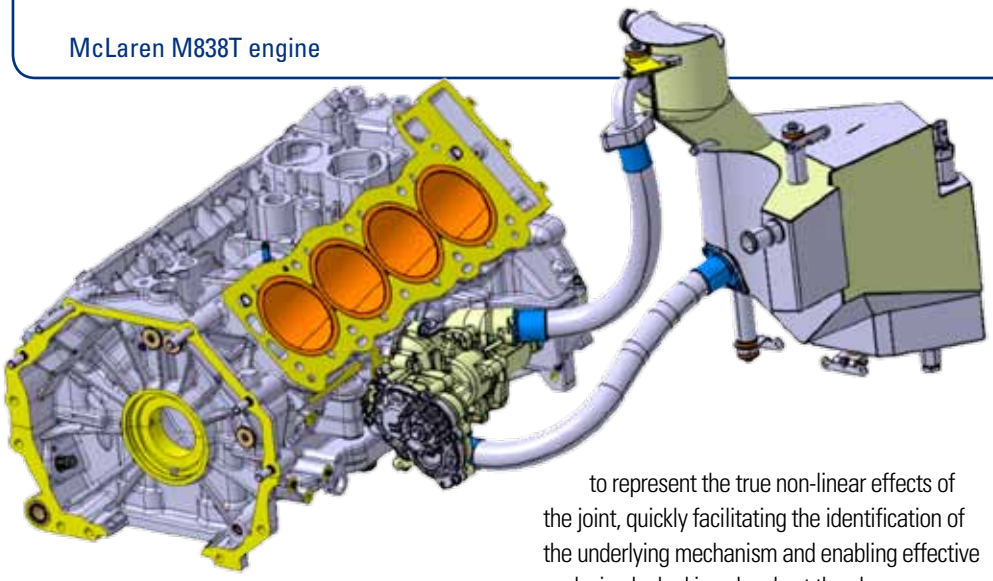


In some ways the M838T is a classic design – a 90° V8 with a flat-plane crank and four valves per cylinder. But despite that superficial orthodoxy and despite its extraordinary robustness, there is nothing ordinary about specifications of the new McLaren V8: in fact, it is cutting edge in almost every respect. The engine has the lowest CO_2 emissions in its class – just 279 g/km – and meets both EU5 and ULEV2 emissions standards. Power output is a thrilling 600 PS at 7500 rev/min, matched by 600 Nm torque at 3000 rev/min.

Thanks to clever fundamental design the compact cylinder block has an exceptionally low mass: not only are the main and lower bedplate crankcases sand cast in aluminium alloy, but so are the top-hung, wet cylinder liners, a feature which saves an additional 4 kg compared to conventional cast iron liners. Careful targeting of the sand cores helps keep the weight down too, and the finished assembly comes in at just 36 kg. The flat-plane crankshaft allows a smaller counterweight radius and, combined with the short stroke, this allows a low block height of just 201 mm and a crank-to-ground centre line height – important for road-holding – of only 121 mm. Dry-sump lubrication also allows low positioning of the engine in the chassis and this helps create the lowest possible centre of gravity for the MP4-12C.

The Ricardo Software CAE tools played a crucial role in designing a high-quality and robust engine, and their use in the development of the cylinder block is a particularly good example. "We did encounter some difficulties and we are quite open about that," admits Yates. What is important, though, is how those inevitable hurdles were identified and quickly overcome. Early on in the development phase there were some instances of liner cracking, for example. As a part of the cylinder block analysis the contact area between the liner and block was modelled to represent the true non-linear effects of the joint, quickly facilitating the identification of the underlying mechanism and enabling effective re-design by looking closely at the clearances, the support and how the liner was loaded and clamped. All of this was made inherently easy using Ricardo's FEARCE powertrain FEA platform.

Top end design

The cylinder head is one of the most important assemblies in any engine, and its design makes a particularly important contribution to the performance, emissions and fuel consumption characteristics. In this case, each of the two cylinder heads has double overhead camshafts, each camshaft being fitted with its own phaser. Like the block, the cylinder heads are optimized for weight, single-piece plastic cam covers giving a net weight saving of 2.3 kg and an aluminium rocker carrier and thin-wall spark plug tube saving a further 2.5 kg. The narrow included valve angle reduces the width (and weight) of the head and an integrated housing for the variable valve timing gear enables compact oilways and minimises the overall length of the heads. Again, from the perspective of quality and robustness, single-plane oil sealing rules out oil leaks.

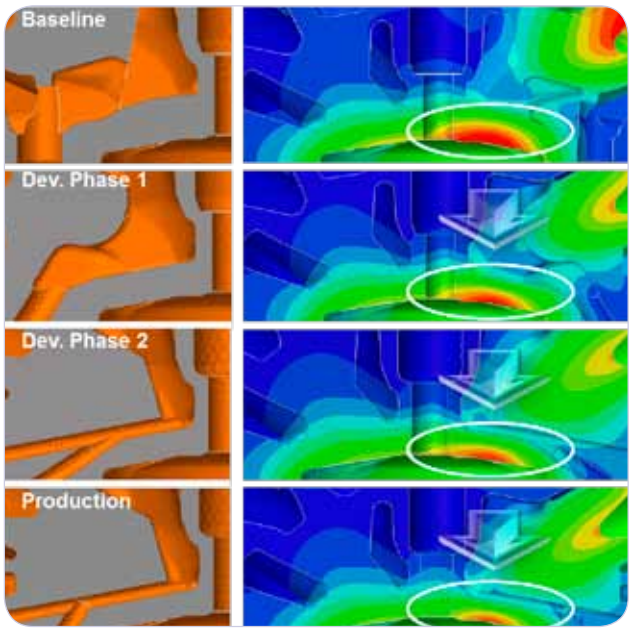
Needless to say, the head design is minutely optimized to maximise performance and minimise fuel consumption and CO_2 emissions. Exhaust valve size is maximised to avoid gas flow restriction and to increase the available turbine energy. Intake ports are designed to provide excellent gas flow while retaining good tumble characteristics for efficient fuel-air mixing. The high flow rate reduces pumping losses and the tumble helps low-speed combustion as well as improving fuel economy at high speed. The quadruple cam phasers improve response, torque, power and fuel economy throughout the engine speed range.

The valvetrain features end-pivoted finger followers and a single 'beehive' design of valve spring, the low mass and high stiffness of which provides accurate valve control at high speed while keeping forces – and thus frictional losses – to a minimum. The cam profiles were also designed to improve these characteristics, with the use of VALDYN at the design stage helping eliminate any risk of loss of contact with the camshaft, spring surge or valve bounce.

The head casting went through a number of development phases after analysis of the first version revealed the potential for excessive temperatures in the exhaust bridge. Thermo-mechanical finite element analysis using FEARCE made it possible to evolve the design of the cooling passages and head gasket shaping to optimize the targeting and velocity of coolant jets, as well as making components easier to manufacture.

Sound quality of crucial importance

Clearly, the sound quality of a supercar engine is crucial and a considerable amount of work was carried out to get the balance just right. WAVE was used extensively in order to capture precisely the desired sound quality both inside and outside the vehicle. Because turbochargers significantly mute the wave form of intake noise, a sound transmission system incorporating a resonator was included to pipe sound to the cabin. The design of the exhaust system also took into account sound



quality as well as efficiency. This aspect of the work, based heavily upon WAVE simulation, was featured in the BBC TV documentary *How to build a super car,* which described the development of the McLaren MP4-12C, and was first screened in the UK on November 20.

Just 18 months from the start of the CAE-intensive collaboration with Ricardo, a unique new engine was born, possessing spectacular performance and emissions and easily meeting the high-level goals set by McLaren based on the exacting expectations of its very discerning customer base. The MP4-12C that it powers defines a completely new segment within the premium sports car market. To build a brand new car is a challenge; to build a brand new high-performance sports car that is ground-breaking, efficient, high-quality, lightweight, practical, dynamic, safe, comfortable, and visually arresting is a greater challenge still. McLaren – with help from Ricardo and other highly innovative supply chain partners – looks to have achieved this in considerable style.

New customers

Ricardo Software is pleased to announce that global aerospace, security and advanced technology company Lockheed Martin and German consulting group Sidion have both joined the expanding family of WAVE licensees. In addition, Chinese automaker SGMW has selected a range of Ricardo Software CAE products for its powertrain engineering operations.

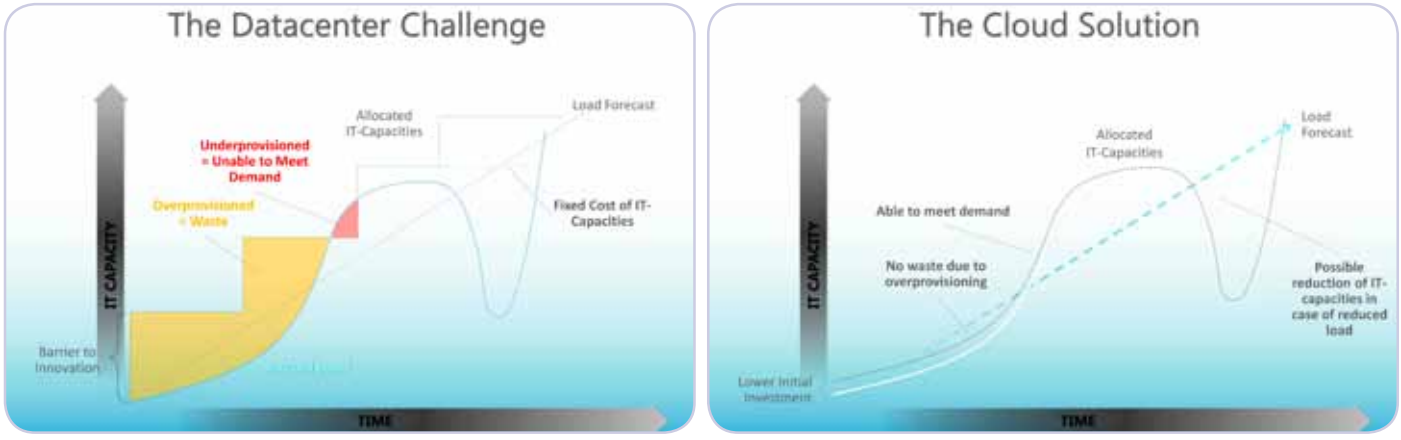
New products

Ricardo Software has recently released a large number of product updates, including full releases of WAVE (8.4) and PISDYN/RINGPAK (5.2). These releases, along with updates to FEARCE (8.1p2), R-Desk (1.5) and ISIS (1.7), represent a large collection of features and capabilities added to the Ricardo Software suite of products.

WAVE 8.4 was released on November 18, incorporating significant enhancements to WAVE, WAVE-RT, WaveBuild, WaveBuild3D, and WavePost and well as minor enhancements and corrections for WaveMesher and Diesel3D. New features include cylinder geometry defined per-cylinder, multi-component Wiebe combustion sub-model actuators, new turbocharger sensors, 'send/receive' control system elements, summary data tables in the WavePost Results tree, and move/rotate CAD-imported geometry in the WaveBuild3D Complex Component editor.

Users are encouraged to visit the Ricardo Software customer support secure web site at https://www.software.ricardo.com to review release notes and download the new versions of their products.

Opportunity in the cloud



With the ever-increasing demand for software applications and processing resources, it is small wonder that many CAE software providers and users are turning to cloud-based computing solutions – here we explain the latest efforts to port Ricardo Software products to Microsoft's Azure cloud platform.

In the earliest days of engineering the test lab was king. Product designs were produced based on simple calculations and hypotheses of how new innovations might work. The process was one of design, prototype build, test, and inspect, followed by redesign iterations as necessary to achieve the desired performance and durability. In more recent years CAE has moved to take centre stage in the design process with increasing use of testing for confirmation and validation/homologation purposes only; the iterative aspects of design optimization are being carried out in software rather than hardware.

In parallel with this shift in emphasis in favour of CAE as the driver of design optimization has come an almost insatiable appetite for processing power. While typical individual run times for many forms of simulation have been dramatically reduced, the need for far more detailed modelling and much greater numbers of individual analyses has acted to significantly increase the demand on in-house IT systems. The use of Design of Experiments (DoE) methods for optimization purposes has, in particular, resulted in frequent peaks in demand by CAE teams and consequent demand for processing power.

Where processing demand is static or increasing in a relatively predictable manner, and is relatively stable throughout the working week, the traditional IT model of providing in-house resources is an acceptable solution. However, with the sporadic demand levels of modern CAE applications this is far from efficient; if resource is scaled to maximum demand then capital investment is ineffectively employed whereas if it is scaled for average

demand, delays are an inevitable consequence of demand fluctuations.

Enter the cloud

Cloud computing offers a potential solution whereby software applications and resources are provided via a large network of computers hosted by the cloud service provider, with users accessing applications via a web interface. Cloud platforms – such as Microsoft Azure – allow corporate users to maximize the benefits of demand flexibility across a range of computational assets, be they in-house owned and operated, run externally by the cloud provider, or a mixture of the two.

To the user, the operation of applications in a cloud environment is essentially unchanged. Although they may be completely unaware of the fact, most users of web based e-mail systems such as Hotmail and Gmail, are already well used to using cloud-based applications. Other than when accessed via a mail client, users simply run a browser in order to access a web-enabled version of their chosen e-mail software; the application residing on the cloud platform as opposed to their own PC or smart phone. The real advantage of cloud-based applications for large commercial CAE users and IT system managers is the ability to accommodate bursts in demand for both processing power and software licences.

Case study: VALDYN

Recognizing that cloud computing is potentially attractive to its customers, Ricardo Software has participated in a pilot study to port its VALDYN product to run on Microsoft's Azure cloud. "We realized that cloud-based systems offer some very attractive advantages for our customers around the world," explains Ian Hubert, global development manager of Ricardo Software. "As such we thought that it was important to carry out some initial validation testing to demonstrate the advantages that this new web-based IT technology can bring."

The team chose VALDYN for this validation exercise, as Hubert goes on to explain: "VALDYN is a product with very short individual run times, but it can also typically require very large numbers of calculations for DoE based optimization. Through its run distribution capability, it was also an ideal candidate for cloud-based evaluation as it is already structured to allow easy distribution of multiple jobs."

The validation exercise involved two models. In order to demonstrate the basic functionality of VALDYN operating in the Azure cloud, an existing simple run distribution example was used but expanded to 41 cases. The team found that VALDYN worked 'out-of-the-box' on Azure which meant that no core software development was required. Three main scripts were used to control the run distribution job – originally developed for use in an in-house Windows HPC Server environment, these required only minor adaptation to perform the necessary utility functions for operation in Azure.

Evaluation of a full DoE example

Having proven that VALDYN could operate in the Azure environment, a full-scale DOHC valve train and chain drive model with 28 cases across a full speed sweep from 850 to 7500 rev/min was used. This model was deployed in a DoE study to investigate two chain-flap parameters with a total of 5 values each, hence requiring the assembly and solution of a full matrix of 700 runs. This DoE analysis was run back to back on a conventional 12 core machine as well as on the Azure cloud. The conventional approach required 33 hours solution time plus a further 24 minutes to recombine the results in to a single 46 GB file. In comparison, the Azure solution was run across 62 nodes in a run time of just 2.5 hours plus 8 hours for recombination and transmission of results – over 3x speed-up from the baseline (in-house) solution.

Next steps

Ricardo Software is keen to talk to customers interested in exploiting the potential of cloud-based application of its CAE products, as Hubert continues: "The work we have carried out on VALDYN clearly demonstrates the advantages of cloud-based applications and we are keen to roll this capability out to our customers. We anticipate that WAVE will offer very similar benefits to those demonstrated for VALDYN, as will future run distribution capable versions of PISDYN and RINGPAK. VECTIS is likely to represent a different form of implementation challenge and we need to understand more about the costs and opportunities of this form of solution-intensive and large file size application.

I would encourage Ricardo Software customers interested in exploring the potential advantage of cloud-based CAE application to contact us so that they can collaborate on the evaluation of this very promising technology."

Customers interested in talking to Ricardo Software about cloud based applications should contact Ricardo Software at: RS_support@ricardo.com.

User conferences

The very successful annual calendar of Ricardo Software user conferences has been extended in 2011 to include events in China, India and Japan in addition to the longer established European and North American events. September's North American event was particularly informative and interesting for delegates, with presentations from Honda R&D and Faurecia respectively on the prediction of piston slap using 3D motion simulation, and the simulation of linear and non-linear transmission loss in exhaust mufflers. In addition to the usual mix of presentations on the latest Ricardo Software product features, research and applications, the afternoon of the event was given over to a workshop presented by Matt Maunder (whose work was covered in the BBC documentary described in the main feature) on intake and exhaust acoustics and engine structure vibro-acoustics.

Details of upcoming events can be found on the Ricardo Software web site – including, for example, details of the 2012 European conference to be held on March 27 at Ludwigsburg, Germany. Information on past events is also available including details of the presentations given and in some cases downloads. Customers are recommended to keep a watch on the events section for details of the latest conferences in their region.

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