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"Pumping losses can be practically eliminated"

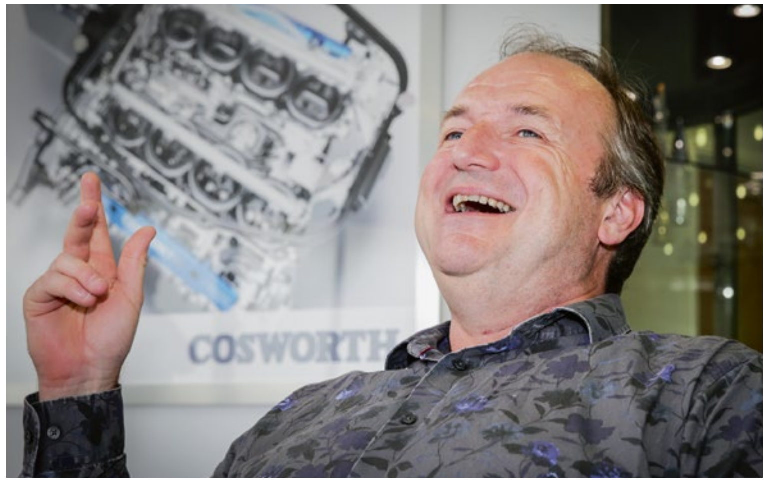
Cosworth has a long heritage in developing and building high-performance engines for motorsports as well as road-going applications. Nowadays, the UK-based company is utilising its knowledge more and more to support the development of highly efficient combustion engines. We sat down with its Managing Director Powertrain, Bruce Wood, to discuss the potential and technologies to further optimise gas exchange as well as supercharging systems.

MTZ _ In a joint development project, Cosworth and further partners have developed a highly efficient gasoline engine. The reduction of pumping losses was one major goal. Which measures have you taken?

WOOD _ I guess you are referring to the ME engine project we undertook in collaboration with CEC / Haitec, for which we have recently published some of the very exciting results we achieved. At the beginning, Cosworth undertook an extensive concept study to look at all the technologies available to reduce parasitic losses within engines. The focus here was to provide our customers with an engine that delivered excellent fuel consumption over a very broad operating area.

In this respect, we looked at several measures to minimise friction and fluid circuit losses, but the greatest benefit to giving a broad operating area of low BSFC was through dethrottling. We considered several systems to achieve this, such as Fiat's Multi-air and BMW's Valvetronic, but in the end decided to use the Pierburg UpValve system being

Bruce Wood was born on 10 December 1964 in Amersham, Buckinghamshire, UK. After graduating from Brunel University with a Bachelor of Science in Mechanical Engineering in 1987, he joined Cosworth with the ambition to design his own racing engine. In 1996, he was promoted to the position of Chief Designer for the XD engine, which was used in the US ChampCar racing series. Afterwards, he oversaw the design, development and racing strategy of all products outside of Formula 1 such as CART, WRC, MotoGP and Le Mans sports prototypes. In the past decade, he has been key in transforming Cosworth from racing engine supplier to OEMs for engine technology. Having progressed to his current role as Managing Director Powertrain through different management positions, he will be celebrating his 30th anniversary working for Cosworth this year.



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developed by Rheinmetall Automotive. This is a mechanical valve actuation system similar to the BMW Valvetronic arrangement, but with fewer components and also capable of providing cylinder deactivation. In this way, with one valvetrain system, two methods of dethrottling could be used, and the compound and synergistic benefits of both systems could be explored.

Variable inlet valve timing is currently in high demand to realise Miller timing under part load. Do you see any realistic road-going approaches other than mechanically-actuated systems?

Early- or late-intake valve closing can be used to very good effect in controlling engine load through regulating the trapped charge without throttling the intake air. In this way, we have demonstrated that pumping losses can be significantly reduced – although not entirely eliminated – at light load. The degree to which this can be achieved depends on the extent to which throttling across the intake valve can be avoided.

The problem with mechanical actuation systems is that the valve lift has to be controlled together with duration in order to maintain acceptable dynamics, and with early intake valve closing (EIVC) systems you reach a point where for very low charge mass the valve lift reduces to the extent that irreversible pumping losses are incurred. Despite this, in our experience these systems offer the best methods for providing charge control through variable valve duration.

Which challenges do you see in other system?

There are a number of alternative systems being presented, including mechanical-hydraulic systems such as the Fiat Multi-air system. However, in our experience, the hydraulic systems give rise to quite significant losses through the need to pump hydraulic fluid through narrow passageways. Also with these systems the work done in opening the valve is lost, and they can result in much greater net mechanical losses than with mechanical systems.

Electro-mechanical valvetrains exist at the concept and prototype level, and provide useful tools for R&D activities. However they remain at a low TRL level due fundamentally to the cost, complexity and weight of such systems.

“Mechanical valve control systems give the best benefit”

In Cosworth’s experience, mechanical valve control systems provide the greatest reliability and robustness, and the weight and efficiency advantages give the best overall benefit.

Miller timing unfortunately places a high demand on boosting pressure in operating ranges where exhaust gas enthalpy is low. What is the most appropriate technology to solve this problem?

The whole concept of the Miller cycle is to improve efficiency by enabling more of the energy released within the cylinder to be extracted as useful work. The more energy extracted within the cylinder during expansion, the less there is available to power turbomachinery. If the situation with road cars where the drive profile is extremely dynamic is added, then the reduced trapping efficiency that Miller cycle systems suffer is also a significant handicap and compounds this effect.

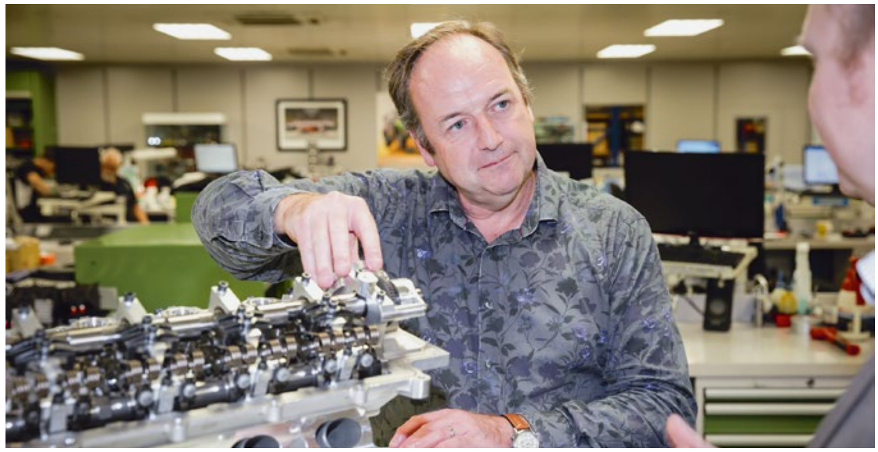
When you look at the current road car applications using the Miller cycle, the ratio of compression to expansion used are certainly a lot less extreme than can be exploited in applications that operate predominantly under steady-state conditions such as in power generation or marine propulsion.

Correct turbo matching and ongoing development with turbomachinery to get the most out of the exhaust enthalpy available becomes imperative to maintain the required engine response. We have seen some very good development in recent years in reducing rotating inertia and end-thrust loads, which can do a lot to improve the transient response of turbomachinery and allow the boost pressure to compensate for the reduced charge trapping in the way that Miller described.

In this field, e-boosting offers some very good advantages. As with all electrical power systems, there is a need to manage the electrical energy balance and to decide on how best to utilise any electrical energy available – either through direct torque or by exploiting the multiplier effect of powering a boosting system. This depends on the application.

Pankl Turbosystems and Federal-Mogul Powertain have recently presented an electrically assisted turbocharger for 48-V power supply. Will this technology be the future of supercharging?
In certain applications I think this is very likely. As with every electric component, there is a cost and weight penalty that needs to be justifiable, and the energy used has to be captured, stored and re-used with efficiency reductions during every step. Notwithstanding this, electrically assisted boosting systems offer a very neat and effective solution to the problems of transient response associated with extreme downsizing and Miller cycle operation. In this respect it is likely that such systems will form a much larger part of automotive boosting systems in the future, especially as higher voltage systems become more commonplace.

In Cosworth's experience, supplementary turbocharger shaft power can give a very good transient response in systems designed for up to 160 kW/l. Above this level, the benefit of electrical assistance becomes limited by the compressor surge boundary, and other forms of boosting are required to give the required low-end torque.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Wood describes that Pierburg's UpValve system has been the enabler to utilise two methods of dethrottling within the ME engine project as it allows both valve actuation as well as cylinder deactivation

Scavenging has been an appropriate measure to improve the low-end torque of engines with high specific power. With the upcoming RDE legislation …
… it is certainly true that the use of excessive over-scavenging during transient operation can short-circuit large amounts of unburned air directly into the exhaust system, which overloads the catalyst with oxygen and reduces the effectiveness of the aftertreatment unit to process NO_x. This is in direct contravention of the spirit of the new legislation, which quite rightly requires that the impact of IC engines on public health and our environment is kept to an absolute minimum.

In practice, however, the key point is to present well-mixed stoichiometric gas to the catalyst in order to ensure efficient processing of the exhaust constituents. With care, this is achievable with some scavenging. It is also the case that the amount of overlap usable is already limited in a lot of applications by factors such as the transient response time of variable cam phasing systems, and the need to minimise catalyst degradation over time. So overall the impact of the RDE legislation in this area is not as severe as is sometimes portrayed.

The important thing always is to consider the most efficient package overall. If over a whole journey, less fuel is burned and less pollutants are emitted by using a more aggressively downsized engine with a slightly larger catalyst formulated to cope with oxygen spikes, this is better for public health and the environment than the approach of not using any overlap and requiring the use of a larger, less efficient engine to provide the same performance.

"Motorsport offers a wealth of knowledge"

Which technologies or methods from developing racing and high-performance engines can help the most to further improve the efficiency of road-going engines?
Cosworth has a very strong heritage of developing highly efficient powertrains based on creative, innovative and original solutions derived from first principles. Over the past fifty years, the company has amassed a lot of experience in reducing losses and maximizing efficiency within internal combustion engines.

Motorsport offers a wealth of knowledge on ways to reduce weight and frictional losses, whilst optimising gas-exchange and combustion processes to make sure that every bit of the fuel energy supplied is used to best effect.

In terms of the technologies that are most applicable to improving road-going engines, there is a lot from our approach to producing lightweight designs that can carry across to good benefit. We have derived some very good road-car combustion systems from the high-efficiency systems developed for motorsport, and these have proven to work very well in giving good stability and low emissions. Another area in which technologies developed for motorsport can be deployed to good effect in road engines is in the use of plasma-spray technologies for lightweight, low friction cylinder bores with very good thermal conductivity. These enable high compression ratios and good downsizing ability.

From your experience, are there also any lessons learned beyond technology?
Perhaps the greatest benefit that Cosworth's heritage has given us is the right approach to solving the engineering problems at hand. As always in engineering, the right solution requires finding the optimum balance between lots of complex interacting factors. The responsible approach is to understand these interactions and the sensitivities of the inputs well enough to bring the best compromises together in an intelligent and informed way such that the negatives of each compromise are minimised while the benefits are maximised.

Mr. Wood, thank you very much for this interview.

INTERVIEW: Martin Westerhoff

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