But while the improved performance, efficiency and durability benefit road car customers, the tighter tolerances can be a headache for race engine builders. “With old engines, you frequently had a lot of material to play with in the inlet and exhaust ports,” says Hill. “Today the quality of the castings has improved and they are much closer to the final part. The standard of road engines is so much higher now, but they are getting more difficult to modify extensively.”

The greater focus of modern road engines also limits changes to the engine’s core geometry. “For example, the bore-to-stroke relationship,” says Hill. “It may be advantageous to increase the bore and reduce the stroke, even if you’re keeping the nominal capacity the same, to increase valve area and reduce piston speed. But that may not necessarily

The 2.5-liter road-going Audi TT RS (left) ***has a larger engine capacity than the LMS race version*** (above)

Fast five: LMS Audi TT RS

LMS Engineering won the VLN championship in 2012 with the Scirocco GT24 powered by a four-cylinder engine based on the Audi S3 EA113. With the mandatory 1.4 bar boost and 38mm air restrictor, the engine produced 375hp but was at the limit of its development. To replace it, LMS built a racing version of Audi’s 2.5-liter five-cylinder engine from the TT RS.

Audi had already developed a race TT RS for the 2.5-liter SP4T class, but high torque output caused gearbox failures. LMS reduced the stroke from 92.8mm to 74.5mm, to reduce the capacity to 2.0 liters. The lower maximum torque helped preserve the gearbox, and the engine was now eligible for the 2.0-liter SP3T class. Other changes included lighter Pankl pistons, longer Arrow conrods, and 153.5mm between the bearing centers instead of 144mm. The water and oil pumps were upgraded, along with the alternator/water pump drive belt and tensioner, and racing spark plugs were used. Everything else, even the turbo, was standard.

In 2014, and running with the regulation 1.4 bar boost limit and 38mm restrictor, the five-cylinder engine produced up to 385hp. In 2015, further development saw the engine break 400hp for the first time, while optimized ECU mapping reduced fuel consumption.

Similar detail work has to go into the engine internals. Some engine builders add low-friction coatings, and a common aim is to lengthen the conrod to reduce angularity and so minimize internal friction between the piston and cylinder wall.

"Frequently there are small geometric changes that you want to make, which mean that you have to replace the base part," says Hill. "You may need to increase the gudgeon pin diameter by a millimeter for durability, which would mean you couldn't use the standard rod any longer. You probably wouldn't want to retain the production valve collet system, so you end up changing the valves. Many production engines will have a cast piston. Clearly you're not going to have a cast piston in a race engine for various reasons, so immediately you're into a different material for that. And that's also largely true for things like connecting rods and crankshafts."

A decision to switch to different materials may be made to allow a more optimal design, but it is also often driven by a change to the manufacturing techniques required for a low production run. Forged crankshafts, for instance, are uneconomic in low volumes, so race engines often use crankshafts machined from steel billets. Component life is another key question, as Hill explains: "A production crankshaft may be quite inexpensive to buy because you can get them in large volumes from the manufacturer. However it may need replacing every build, whereas a bespoke race crankshaft in a vacuum remelted steel such as an S132 material, which is much more expensive, will probably last three, four or five times longer. When you look at the full story, it's quite often beneficial to change to a bespoke part rather than use a production part."

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JASON HILL, HEAD OF NEW ENGINE DEVELOPMENT, ASTON MARTIN RACING

be possible with a production engine now, because there's so little scope in the base block to accommodate such changes. In the past we'd machine the blocks out, fit different liners and increase the bore size, but that's becoming harder – particularly with die-cast blocks."

The greater sophistication of engine control systems also makes the motorsport engineer's job a lot harder, Lautner says, with systems such as direct injection and variable camshaft timing placing extra demands on engine management systems. They also greatly increase the burden of test and development. Developing engine control systems for the first direct injection Audi motorsport engines in 2008, using a Bosch MS4 ECU, took six months of research and what Lautner calls "a lot of budget".

With displacement reduced from 2.5 to 2 liters, the TT RS qualifies for the SP3T class

When a production part is retained, it is essential that quality control is at a higher standard than production standards. “During my time as technical director at Volkswagen Motorsport, we x-rayed all the pistons for the Scirocco GT24 engines,” Lautner recalls. “Nearly 50% of the pistons didn’t conform to our quality requirements. That doesn’t mean VW/Audi use poor-quality pistons, but for a racing application I would highly recommend using parts without any material impurities.”

At Aston Martin Racing, Hill believes a key change in recent years has been customer expectations for reliability. “You don’t expect a road car to break down these days, and people don’t want a race engine to fail either.” However, the increase in durability standards comes with no let-up in performance, and just the same pressure on cost. The solution comes from far greater use of computer modeling to predict failure modes.

“We run finite element analysis on pretty much every part that’s considered at any kind of risk. That gives you a better understanding of how the part is going to operate and what’s likely to cause it to fail before you ever make it,” says Hill. “And you’re able to test it more thoroughly than you were previously. There’s a lot more work done now in terms of rig testing and durability testing of parts, and also the machining and control of parts is so much better than it was.”

LMS Engineering won the 2012 VLN championship with the VW Scirocco GT24, powered by a four-cylinder Audi S3-based engine (top and above)

Lautner believes that manufacturers with big budgets will increasingly develop clean-sheet ‘world engines’ for series like the WRC and WTCC, rather than rely on redeveloped production engines. “You are able to consider from the beginning only the power, weight and durability for your application, and you do not have any compromise with production line, emission regulations, costs and so on.”

But outside world championships and factory teams, production-based engines will still play a major role. “For basic motorsport with amateur or semi-professional drivers, the production-based engine is the best solution, because the development costs are much lower.”

Hill also believes that production-based engines will prosper: “You will see more production-based engine formulas. There’s been a lot of drive in recent years from regulatory bodies to make engines more production based – GT3 was a good example of that. GT3 engines are largely production based.” <

Technology transfer

Motorsport provides an opportunity to test production components under stresses they would never likely see in normal service, and works race teams routinely feed back information to road car engineers, which helps to improve the durability of production parts for road cars. Competition also helps engineers to develop new technologies, which eventually feed through to production.

Titanium valves were the preserve of F1 15 years ago, but are now being used in production engines after considerable refinement of both materials and manufacturing techniques. Direct injection for gasoline cars was also pioneered in racing, and diamond-like coatings had their first automotive applications in motorsport – both are becoming commonplace in road engines.

What will be next? “One of the things I was surprised never made it into production was pneumatic valve control,” predicts Jason Hill, head of new engine development for Aston Martin Racing. “That will probably migrate to production at some point.”