Diesel versus diesel & diesel versus gasoline

Source: Race Engine Technology

Publication Date: 11th August 2008

Diesel versus diesel

At Le Mans in 2007 Peugeot had a slight edge over Audi in qualifying but it had to turn down its horsepower on race day to take the strain off, not only its engine but also its transmission, its wheel bearings and so forth. It wasn't surprised to have to play second fiddle to Audi and was more than happy to get a car home in second place.

In 2008 it was different. Peugeot had some additional horsepower in qualifying but more significantly it had the ability to race at its 2007 qualifying pace. There was no inherent reliability issue and its race pace was slightly superior to that of Audi. Not enough to dominate in the manner of qualifying; just enough to stay ahead, at least in the early stages. As the race progressed two other factors came into play. One was rain, which nullified the Peugeot speed advantage while the other was inferior fuel efficiency, which cost Peugeot more time than Audi in pit lane.

Audi's race day speed was sufficient to keep Peugeot in its sights in the dry. That is to say, the most competitive of its trio of R10s, could keep in sight the least competitive of the trio of Peugeot 908s. As it transpired, that was the only 908 to have a trouble-free run. The rain came shortly after half distance and at that stage the eventual runner up held the lead, on the same lap as the eventual winner. The precipitation soon reversed those positions yet the outcome remained in doubt until the final hour.

Audi's open cockpit R10 has a superficially similar 5.5 litre V12 turbodiesel engine to that of the closed cockpit Peugeot 908 and on this occasion both Le Mans Prototype engines looked to be exploiting around the same amount of horsepower (700-plus), at least in the race. Both engines are excessively heavy by race engine standards – in excess of 200 kg – and that means neither car is ballasted to the minimum permitted LM P1 900 kg and that neither has an ideal weight distribution. Both Michelin shod cars have more weight than is ideal on the rear, the 908 to a lesser extent thanks primarily to a slightly more forward engine location.

In dry conditions the 908 makes slightly closer to optimal use of its Michelin tyres. However, on this occasion once rain had reduced lateral grip, the R10's more rearward weight bias was no longer a disadvantage, if anything it was the opposite, enhancing longitudinal grip at a time when the cars are most prone to wheelspin. Theseturbodiesels have vast amounts of horsepower at low road/engine speeds and getting that to the ground once grip levels deteriorate is a major issue.

At the same time with the rain initially occurring in the dark, the superior visibility then afforded by the R10's open cockpit was an advantage over the full enclosure of the 908. Moreover, the Audi was running more compliant suspension settings, which paid dividends once the grip level fell while the spray caused the 908's radiators to clog with rubber and dirt debris, leading to uncomfortable oil and water temperatures. The drivers were told to 'take it easy'; the mechanics lost vital seconds purging the radiators. So it was that inclement conditions over the second half of the race nullified Peugeot's edge in terms of pure speed and ensured that Audi's advantage in terms of fuel efficiency could pay dividends. But where did that advantage come from?

The 908 has had just as sophisticated aerodynamic development as the R10: there is nothing to suggest that it is any less efficient in this respect. When it comes to mechanical grip, the 908's more forward weight distribution is what the tyres need; reduces sliding.

On the other hand since the R10's weight distribution can reduce wheelspin let us call this aspect quits in terms of fuel expenditure. Likewise there is nothing to suggest that either car suffers more pronounced losses through its powertrain. All of which suggests that the R10's superior fuel efficiency is the product not of chassis but of engine development.

When it came into the LM P1 arena, Peugeot not only followed Audi in exploitation of a 5.5 litre V12 turbodiesel, it likewise went to Mahle for its pistons and to Bosch for its common rail fuel system. The technology of the piston and of the fuel system are at the heart of turbodiesel engine development. Initially Mahle supplied an aluminium alloy piston but for 2008 it has made available a steel alternative – lighter and more heat resistant. For Le Mans Audi stayed with its proven technology whereas Peugeot embraced the new steel piston.

Peugeot's development around the steel piston netted it superior ultimate horsepower, which, combined with its superior weight distribution (better use of essentially the same Michelin tyres) made for an easy run to pole. However, to feel comfortable about its ability to finish only its second ever Le Mans of the modern era, Peugeot turned down the wick for the race. The steel piston was no longer a factor.

Meantime, it appears that Audi has taken the lead in the exploitation of higher fuel pressure. Bosch initially supplied both Audi and Peugeot with a 2000 bar system but more recently it has developed a system that can cope with 2500 bar. That was a major technical challenge, and for the engine engineer, it isn't just a case of bolting on the new system and enjoying the benefits of higher pressure. It is a case of developing the engine around higher pressure, which can net higher power and/or superior fuel efficiency. Audi has taken the efficiency route, which paid off at Le Mans to the extent that it could routinely run 12 laps to the 11 of Peugeot.

It was a very close run thing, though. The winning Audi made only routine stops for fuel and tyres; likewise the second position Peugeot. But over the course of 24 hours that 908 needed four more stops than the R10. Each stop implies a 25 second refuel plus time lost stopping and restarting and running the speed restricted pit lane; in total each stop costs around a full minute. So the second place Peugeot, which was only 4.17 seconds behind at the flag, had actually lost four minutes in the pits. Thereby was the race won and thereby was the race lost.

Diesel versus gasoline

The Peugeot 908's aerodynamics have been honed using the Fond Tech 'Aerolab' moving ground plane, scale model wind tunnel in Italy. This highly sophisticated tunnel was used by the Toyota Formula One team until its second in-house facility came on stream at the end of 2007. The point is that many Grand Prix teams nowadays find it fruitful to run concurrently a pair of state of the art tunnels to maximise aero investigation. Aerodynamics are no less significant in the world of Le Mans Prototypes. It is just that outside of the major manufacturers – Peugeot and Audi – there isn't a lot of budget to pursue it.

Pescarolo took the third podium position in the 2007 Le Mans 24 Hour race but its gasoline-fuelled, naturally aspirated 5.5 litre Judd V10-engined car was way off the pace of the Audi and Peugeot 5.5 litre V12 turbodiesels, which exploit at least a 100 bhp power advantage due to respective ACO air intake restrictor sizes. This year the best Pescarolo-Judd in qualifying clocked 208.533 seconds versus 198.513 seconds for the pole winning Peugeot but how much of that 10.02-second gap was down to horsepower inferiority?

Where the pole sitting 908 was the fruit of a dedicated moving ground plane scale model wind tunnel programme, the Pescarolo 01 had enjoyed no wind tunnel testing at all. The only aerodynamic development that Pescarolo does revolves around a tiny amount of 'coast down' testing – better than nothing at all, but compared to the Peugeot programme, like a dodo alongside a bird of prey.

A better indication of the current difference between turbodiesel and gasoline engine potential was given by the Lola-Aston Martin, which qualified in 205.158 seconds – some 6.645 seconds from pole and quick enough to outrun the slowest of the trio of Audi turbodiesels. This coupe, which qualified just 1.311 seconds adrift of the quickest Audi, is the fruit of a serious moving ground plane wind tunnel programme, using Lola's sophisticated in house wind tunnel. At the same time this car has more horsepower than the Judd V10 – thanks to its GT1 base, its naturally aspirated, 6.0 litre Aston Martin V12 is afforded air restrictor sizes that on paper give it something like a 25 bhp advantage over the Judd.

In fact, it would seem that the Lola-Aston Martin was exploiting around 670 bhp, the Audi perhaps 770 bhp and the pole Peugeot perhaps 800 bhp. All three cars enjoyed excellent aero and all three were running to a 900 kg limit with the Lola-Aston ballasted up to that and the turbodiesels slightly over it. More significantly, the gasoline car had a superior front:rear weight distribution; better use of its Michelin tyres almost overcame its power disadvantage, at least against the Audi.

Significantly, Jason Hill, the Prodrive Chief Engineer – Race Engines, who oversaw development of the stock block Aston Martin V12 in the Lola says that he would happily trade the air restrictor advantage it has over the Judd for the opportunity to design instead a pure race engine. Notwithstanding the impressive performance of the Prodrive-run Lola coupe, Hill feels that a brand new race engine (for which there wasn't the budget) should be the basis of an even quicker car.

All this puts the perception of the speed differential of the turbodiesel and gasoline LM P1 cars in a new light. What if a third manufacturer enters the fray with a brand new fully optimised gasoline car, as Honda may well do in 2009?

The Audi qualifying pace was much closer to race pace than that of Peugeot. The evidence of the lone Lola-Aston Martin (which quickly crashed on race day but nevertheless was repaired to finish ninth) is that a manufacturer gasoline car wouldn't necessarily be so far off turbodiesel race pace, if having no real hope of pole. Are the current restrictor sizes really as unfair as team owner Henri Pescarolo has suggested?

But we also have to consider long-term development potential. A manufacturer might gain a little more speed from a gasoline car than that shown by the impressive Lola coupe but there isn't a lot of scope from which to find such gain. A pure race engine might make for a better overall package but only at the cost of some horsepower. Given the mandatory air restrictors and the maturity of gasoline engine technology there isn't scope to find a significant increase in horsepower. The use of direct gasoline injection might help overall race pace but even that gain would only be at best marginal.

On the other hand, turbodiesel racing engine technology is far from mature. Steel pistons are replacing aluminium alloy and injection pressure is increasing. These and other factors mean that the ultimate limit of turbodiesel horsepower given the current restrictor area hasn't yet been explored. At the same time, Peugeot has admitted that if it has the budget to produce a brand new engine, from what it has learned so far it is confident that it can save a lot of engine weight for no compromise on performance. In other words, the scope exists to significantly improve the overall car package.

The ACO is well aware of this; well aware that if Honda does turn up with an optimised gasoline car, it might find that the turbodiesels have taken a significant step further forward. Keen to attract a third manufacturer, the ACO is looking to rule changes that keep the turbodiesels in check. In fact, it is looking to slow all of the prototypes. At the pre-race test Marc Gene was hospitalised after he lost control of his Peugeot in the Porsche

Curves. It was a huge crash that underlined the ACO's concern that the cars currently are simply too quick. In fact, even before the 2008 cars had run on the Le Mans circuit the ACO had talked about reducing speed, saying that the 2007 pole time of 206.344 seconds was, in its opinion, on the wrong side of 210 seconds. By that token the 2008 pole time was over ten seconds quicker than the ACO feels comfortable with. If it does move to slow the cars this much, that provides considerable scope to alter the balance between diesel and gasoline.

There will also be moves to address the danger of the cars 'flying' – there have been incidents this season that suggest there is further need to address high speed aerodynamic stability when extreme angles of yaw are encountered, for whatever reason. On top of this, there is another twist and that is the ACO's willingness to accommodate energy recovery systems from 2009. Formula One will have Kinetic Energy Recovery Systems (KERS) in 2009 and it is likely that the same sort of technology will be exploited at Le Mans, albeit under different rules in terms of the amount of energy that can be stored and reapplied. The ACO is also likely to follow the lead of the American Le Mans Series in embracing a higher level of bioethanol – moving from the current E10 to E85 and perhaps pure bioethanol in due course.

All in all, it is clear that the Le Mans Prototypes of the near future will be very different from the current breed and with that we can anticipate much closer battles between turbodiesel and gasoline or even bioethanol powered cars.