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CONVERTING EXHAUST HEAT TO ADDITIONAL POWER

There are various potential means to reclaim energy from heat rejected to coolant or to the exhaust. We have mentioned in the past the BMW “Turbosteamer’ and we have looked more deeply at the Woodward Super Turbocharger (RET 020). At the Engine Expo French company heat2power revealed its patented exhaust heat regeneration system, giving us a further taste of the technology we can expect to see in the next decade, when Formula One takes another step in energy recovery system development.

In essence the heat2power system uses a supplementary ‘hot air’ engine. In such an engine there is no fuel and no internal combustion, the piston is driven by the expansion of air that has been heated by an external source. The heat2power system sets a turbo-supercharger and a heat exchanger into the primary engine exhaust system. The turbo compresses air that charges the secondary heat engine while the heat exchanger downstream is used as the external heat source.

Sceptics might wonder if the post-turbo primary engine exhaust gas is significantly hotter than the compressed charge supplied to the heat engine. heat2power has done a lot of analysis of rival systems and of this new approach it claims that it works better than known alternative technologies, for example the Organic Rankine devices. For example : the use of air makes the heat2power system simple and avoids negative effects of piston blow-by on lubrication. It reports that the effectiveness of its system has been confirmed by simulations undertaken by “a major OEM”. So far we don’t have the evidence of physical testing of the heat2power system applied in a race engine environment. In the absence of that, we will accept the figures offered by heat2power as an indication of what heat recovery technology might be capable in the future. Even sceptics will find it food for thought.

So the heat2power exhaust energy regeneration system links an existing primary engine to a secondary heat engine, which exploits exhaust gas energy otherwise wasted and in fact need one or more cylinders, depending on the powerlevel. In this system all of the exhaust gas exiting the primary engine passes through a turbocharger’s turbine and then the heat exchanger, which causes a marginal loss of performance through increased backpressure and compromise of exhaust tuning potential. However, if heat2power’s calculations are accepted that is far more than offset by the power delivered with the secondary heat engine.

The turbine is part of a conventional turbo-supercharger unit that supplies compressed air directly to the secondary heat engine rather than to the IC engine itself. A heat exchanger is part of a separate ‘hot air’ circuit serving the heat engine. The heat exchanger is akin to the air-air device routinely used to cool the charge in a conventional turbo system but, rather than passing air from the atmosphere so as to cool a ducted charge airflow, this device passes exhaust gas so as to heat air circulating within the hot air circuit thereby providing the required external heat source.

The heat engine’s single cylinder has four valves. It has a conventional piston that in turn drives a conventional crankshaft, from which power is added to the primary engine drivetrain and from which the timing drive is taken. One of the four valves admits air from the turbo-compressor another sends spent gas to the primary engine exhaust system downstream of the turbine and heat exchanger. The other two are transfer valves, one of which sends air from the cylinder to the heat exchanger while the other completes the hot air circuit, readmitting the air heated by passage through the heat exchanger.

The heat engine has four operating cycles with normal exhaust and intake events controlled by the respective valves. During the heat engine’s compression stroke not only is the intake air having been compressed by the turbo but it is further compressed by the piston. This happens before the hot air circuit comes into play. The hot air circuit valves are operated so that a slug of air is sent around that circuit, through the heat exchanger. This heated air having been readmitted to the cylinder, it is the expansion of hot air that drives the piston on the power stroke.

The heat engine is not throttled and is always operating at full power, so long as the primary engine's throttle is open, generating a flow of exhaust gas. However, a constantly variable transmission system is used to regulate the heat engine's input to the drivetrain. Under deceleration, with the primary engine throttle closed the drivetrain can power the heat engine, due to the direct connection between the two. The heat engine can therefore add to the engine braking effect and it can be used to generate and store air pressure for subsequent reapplication. The heat2power system can also be used in conjunction with a KERS, each complementing the other. Exhaust heat recovery is effective when the throttle is open; KERS is more appropriate when exploiting closed-throttle time.

heat2power remarks that in the case of a race engine the ratio of ICE crankshaft power to thermal power loss through the exhaust can be as high as 1:1.8. In other words, a 500 bhp race engine can actually reject 900 bhp worth of energy through its exhaust. heat2power claims that its system can reclaim up to 30% of this loss at low engine speed. When the engine is operating between peak torque speed and peak power speed (the normal operating window of a race engine) the gain can still be as high as 20%.

Thus, heat2power claims that its system has the potential to reclaim under normal operating conditions some 20% of the 900 bhp otherwise wasted from a 500 bhp engine. In other words it can be expected to transform a 500 bhp race engine into a 680 bhp unit, through the addition of a heat engine with supporting turbo and heat exchanger systems. Note that no fluids are required for this simple secondary engine – perhaps not even lubricant if advanced coatings are fully exploited. heat2power reports that its system weight is of the order of one kilo per 1.6 bhp generated. A gain of 180 bhp therefore equates to a system weight of 112 kg. Clearly there are weight and packaging disadvantages but the whole point of the system is that performance is increased for no increase in fuel consumption.

On the face of it a regular turbo-supercharger system likewise recaptures energy spent through the exhaust to increase performance and even with charge aftercooling system taken into account it represents a lot less additional weight. However, the difference is that the conventional turbo system is designed to compress the charge air so that more fuel can be handled, thereby to increase power. The heat2power system doesn't just exploit exhaust gas energy. It recaptures it so as to reduce the amount of energy wasted. It is equally applicable to a turbo engine as to a naturally aspirated engine. Moreover, it doesn't know what sort of engine it is dealing with; can be used with any type – compression ignition, two stroke, four stroke, rotary, alternative fuel and what-have-you. And important in the opinion of heat2power is the efficiency at part load which makes it fully transposable to road-applications.

So, if heat2power's calculations are indeed correct, what might be the impact of the system upon a Formula One car?

Let us disregard for a moment the fact that the arrival of heat energy recovery systems is likely to coincide with new engine regulations. If we take the example of a contemporary Formula One car, this weighs 605 kg and exploits around 760 bhp. The same car hypothetically fitted with a heat2power system that reclaims 20% of spent energy as described above in theory would produce 1034 bhp while pushing weight to 776 kg. Nevertheless, the car's power to weight ratio would have gone up, from 1.256 bhp per kilo to 1.332 and this for no increase in fuel consumption.

In practice, for reasons of safety the FIA is expected to peg power output at around the current level when this type of technology is introduced. It will do so by means of new engine regulations. So we can expect smaller, less powerful primary engines supplemented by kinetic and heat recovery systems to maintain today's performance level for significantly less fuel consumption. In fact there might well be a fuel flow metering device to govern this new generation of power plant. That will really sort the effectiveness of the potential energy regeneration systems as part of an integrated drivetrain package.

Race Engine Technology was established in 2003 and now published eight times a year, Race Engine Technology is a unique, high quality review of contemporary racing powertrain technology. It is widely read by design and development engineers and others involved professionally in this worldwide industry and just as avidly by those interested in a subject that has a huge 'enthusiast' following. It reaches the majority of all competition engine builders right across the globe – the heart of its readership. Visit www.highpowermedia.com for more information.