New 4B11 Turbocharged Engine

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Abstract

Mitsubishi Motors Corporation (MMC)'s newly developed inline 4-cylinder turbocharged engine for the LANCER EVOLUTION X is introduced. This new 4B11 turbocharged engine (2 L) attained the 12.5 kg weight reduction thanks to an aluminum die-cast cylinder block and direct-acting valve train. A variable valve timing device MIVEC (Mitsubishi Innovative Valve-timing Electronic Control System) is equipped not only at the intake side but also at the exhaust side in this engine. This makes it possible to set the best valve timing for overall engine speed and improve performance, fuel economy and exhaust emissions. Furthermore, the low- and middle-speed torque and the response are dramatically improved by reducing pressure drops in the intake and exhaust systems and by revising the turbocharger specifications. Regarding environmental aspects, this engine achieved the 50 % reduction level (3☆) requirements of Japan's 2005 Emission Standard by means of a high-performance metal catalyst, etc.

Key words: *Gasoline Engine, MIVEC, Turbocharger, J-ULEV*

1. Objectives of the development

The main objective set forth for the development of the 4B11 engine was creating a new turbocharged engine that is excellent in performance while meeting the needs of the times for environmental compatibility. In line with this objective, an aluminum die-cast cylinder block was newly developed with the aim of reducing the weight of the engine. The cylinder block in development also featured a rear exhaust layout, which is the first of its kind to be introduced for MMC turbocharged engines. The measures employed for better fuel economy included the Mitsubishi Innovative Valve-timing Electronic Control System (MIVEC) and a high-efficiency alternator. Started by setting "superiority of performance in the motor sports field" as one of the concepts to be embodied in the engine, the development had generous technical feeds from the motor sports know-how or DNA that MMC had cultivated and accumulated through World Rally Championship (WRC) experiences. This know-how was incorporated into this production engine.

2. Major specifications

Table 1 compares the major specifications of the two MMC turbocharged engine models, the new 4B11 and the previously developed 4G63.

3. Features

The following part of this section introduces the technologies and components adopted to attain the above-mentioned objectives of the development. Many of the technology and component items contribute to two or more improvements as shown in **Table 2**.

3.1 High performance engine consuming less fuel

The technologies adopted to undertake the challenge of creating a high performance engine consuming less fuel included the MIVEC system applied to both intake and exhaust valve mechanisms (this configuration of the MIVEC system was first employed in the 4B1 model engines) and optimization in the shape of the intake manifold as well as of the intake and exhaust ports. Adoption of these technologies provided the effect of distributing an equal amount of air to every cylinder, which in turn enabled the idling speed to be lowered without compromising the high-speed performance of the engine. In addition, the use of an aluminum die-cast cylinder block with improved cooling efficiency made it possible to further advance the ignition timing and consequently to reduce the fuel consumption rate. Also, the friction-caused loss of energy was reduced by the use of full-floating piston pins and through-holes made in the bulkhead of the cylinder block to lower pressure in the crankcase. Another improvement adopted for higher fuel economy was the use of a high-efficiency alternator, the first of its kind to be used by MMC. On the one hand, while it brought about higher vehicle performance, the application of these improvements, on the other hand, successfully achieved a fuel economy level equivalent to or higher than that of the LANCER EVOLUTION IX MR, despite the LANCER EVOLUTION X being 100 kg heavier than the former model.

Fig. 1 shows the performance curves of the engines on these two vehicle models.

3.2 Weight reduction and durability

The 4B11 engine has an aluminum die-cast cylinder block of reduced weight. The biggest challenge with regard to the employment of this aluminum die-cast

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Table 1 Major specifications

		LANCER EVOLUTION X	LANCER EVOLUTION IX MR (Reference)
		4B11 (2.0 L)	4G63 (2.0 L)
Displacement (cc)		1,998	1,997
Cylinder bore (mm)		86	85
Stroke (mm)		86	88
Stroke/bore (S/B) ratio		1.00	1.04
Bore to bore pitch (mm)		96	93
Big-end to small-end length of connecting rod (mm)		143.75	150
Compression ratio		9.0	8.8
Red zone speed/over-revolution fuel cut speed		7,000 / 7,600	
Fuel used		Unleaded premium gasoline	
Turbocharger		TD05HA-152G6-12T Titanium-aluminum alloy turbine wheel and aluminum alloy compressor wheel combination	TD05HRA-155G6C-10.5T Titanium-aluminum alloy turbine wheel and aluminum alloy compressor wheel combination
	Option	TD05H-152G6-12T Inconel turbine wheel and aluminum alloy compressor wheel combination	TD05HRA-155G6mC-10.5T Titanium-aluminum alloy turbine wheel and magnesium alloy compressor wheel combination
Cylinder block material		Aluminum die-casting	Cast iron
Camshaft drive		Silent chain-driven	Timing-belt-driven
Valve train		Direct-acting DOHC, 16 valves, continuously variable MIVEC applied to both intake and exhaust systems	Roller rocker arm DOHC, 16 valves, continuously variable MIVEC applied to intake system
Balancer shaft		None	Secondary balancer
Exhaust system layout		Rear exhaust	Front exhaust
Maximum torque ($N\cdot m/min^{-1}$)		422 / 3,500	400 (GSR), 407 (RS) / 3,000
Maximum output {$kW(PS)/min^{-1}$}		206 (280) / 6,500	206 (280) / 6,500
Compliance with exhaust emissions control standard		50 % reduction level (3☆) requirement of Japan's 2005 Emissions Standard	Japan's 2000 Emissions Standard
Engine weight reduction		△12.5 kg*	Base weight

* Reduction in weight of engine main body (not including intake and exhaust system parts)

Table 2 Adopted technologies and their purposes

Technology/component	High performance, low fuel consumption	Compactness, light weight	Low emissions	Low NVH	High reliability
Aluminum die-cast cylinder block		○			
Four-bolt fastened bearing cap	○				○
Semi-closed deck design	○				○
Continuously variable valve timing system (MIVEC) on intake and exhaust sides	○		○	○	
Equal-length, short-port aluminum intake manifold	○	○			
Rear exhaust engine layout	○	○	○		
Compact-size, large capacity, fine spray injector	○		○		
Disuse of balancer shaft		○			
Fuel system refinement (optimization of control fuel pressure)	○		○		
Use of long-reach M12 ignition plug	○				○
High-efficiency alternator	○			○	
High-performance metal catalyst	○		○		

cylinder block was to ensure strength sufficiently durable against operational stress while reducing the weight. The first measure to make this possible was fastening each of all the five bearing caps to the cylinder block with four bolts to assure strength enough to withstand high output operation of the engine. The second measure was the application of a semi-closed shape top deck with bridges to the cylinder block to minimize the bore deformation of the cylinders under stress of high-output operation. Furthermore, a ladder frame structure was applied to the cylinder block, which greatly contributed to the reduction in noise, vibration and harshness (NVH). **Fig. 2** shows the structure of the cylinder block.

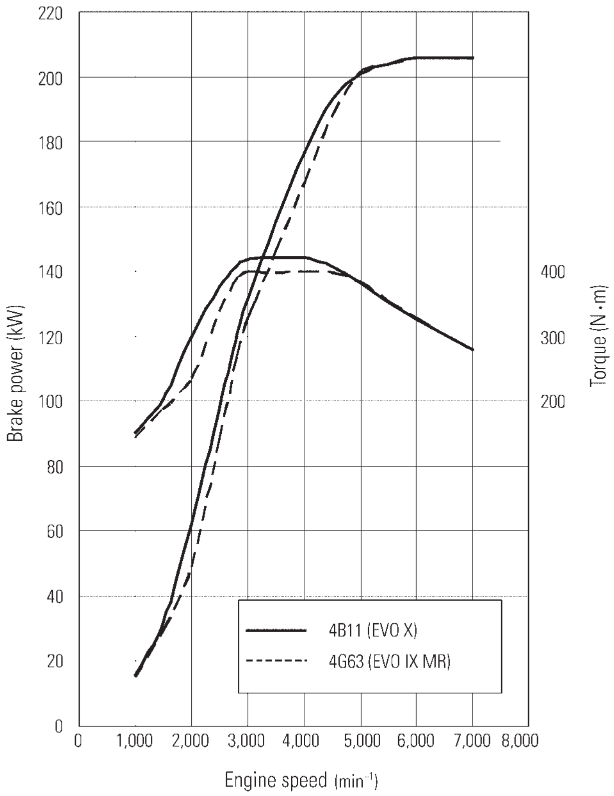

Fig. 1 Engine performance

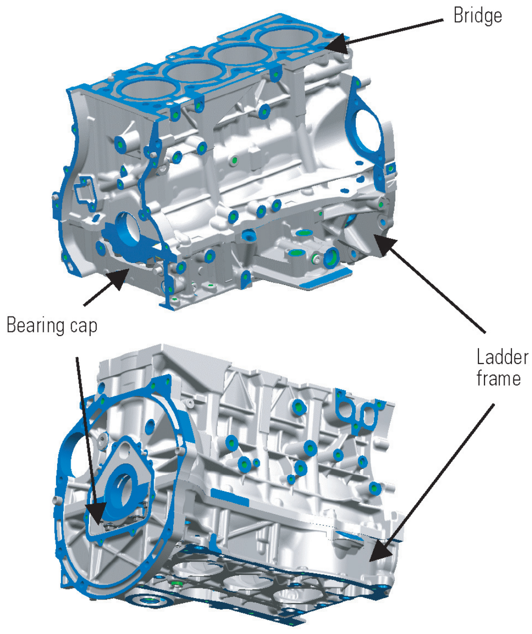

Fig. 2 Cylinder block structure

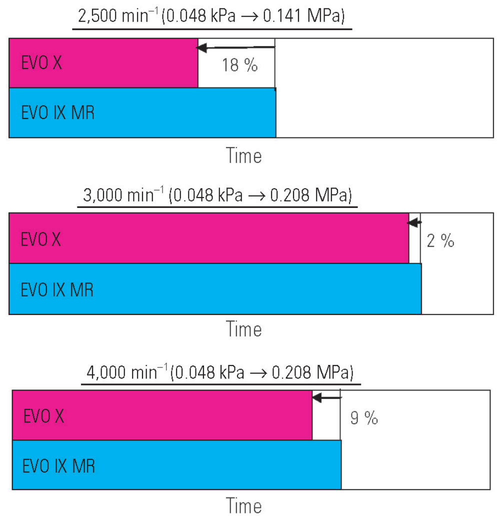

Fig. 3 Engine response

In addition to the above, other weight reduction measures were also applied, examples of which are the adoption of a direct-acting valve train and the disuse of balancer shafts. As a result, the weight of the new engine mechanism could be successfully reduced by as much as 12.5 kg compared with the 4G63 turbocharged engine.

3.3 Low exhaust emissions

The technologies adopted for simultaneously satisfying high performance and low exhaust emission requirements were compact-size fine spray injectors and optimization of fuel line pressure. Application of these technologies enabled improved fuel atomization while maintaining necessary fuel flow rate during high-output operation and eventually ensured clean exhaust emissions while the engine stayed capable of delivering high power. Using these technologies in combination with the rear exhaust layout and a high-performance metal catalyst featuring a shorter activation time, the new engine successfully reduced exhaust emissions of the EVOLUTION X to a level as low as less than 1/4 of the EVOLUTION IX, achieving the 50 % reduction level (3☆) requirements of the Japan's 2005 Emission Standard.

3.4 Improved engine response

An engine's "high performance" is most often represented by large maximum output and torque. In the motor sports field, the engine response is another important performance factor. The 4B11 engine incorporates such improvements as an optimally shaped turbocharger compressor wheel, a straight type intake system and large diameter exhaust system piping featuring heightened response performance which is up to 18 % faster to respond to accelerator operation than the 4G63 turbocharged engine. **Fig. 3** compares the engine response characteristics of the LANCER EVOLUTION X and LANCER EVOLUTION IX MR. **Fig. 4** shows the details of the compressor wheel improvement.

3.5 Higher reliability

Unlike the 4G63 turbocharged engine which uses M14 long-reach spark plugs, the 4B11 turbocharged engine uses M12 long-reach spark plugs that enable the water jackets around the combustion chambers to be expanded for more efficient cooling. This, coupled with the highly heat-conductive aluminum cylinder block,

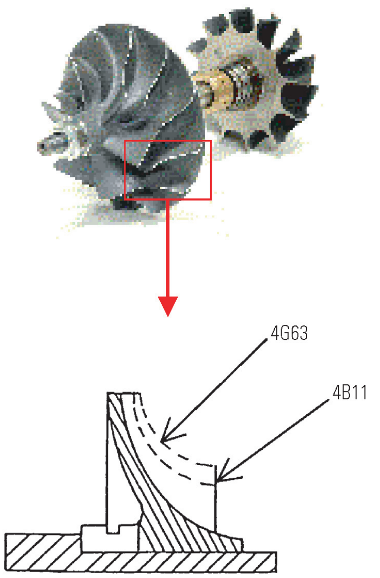

Fig. 4 Compressor wheel improvement

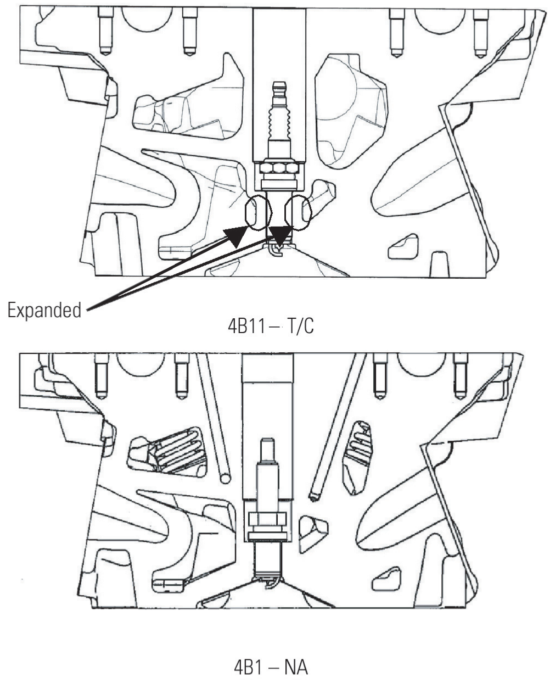

Fig. 5 Cylinder head cross section

lowers the fire-contact surface temperature of the new engine by approximately 50 °C compared with the 4G63 engine, greatly reducing the thermal load upon the cylinder head. **Fig. 5** shows cross sectional views of the cylinder head.

4. Conclusion

Exhaust emissions, fuel economy and other environmental performances of the engine will further increase their importance in the future. The situation will thus certainly impose a challenge of simultaneously nurturing to a still higher level two contradicting factors, namely high performance and environmental compatibility in order for us to make the next evolutionary step in engine development.

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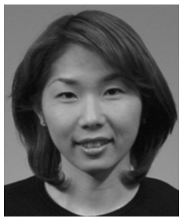

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