
Development of a New 5.6L Nissan V8 Gasoline Engine

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**Reprinted From: New Spark Ignition Engine and Component Design,
and Spark Ignition Combustion
(SP-1828)**

ISBN 0 7680 1423-9



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SAE *International*[™]

**2004 SAE World Congress
Detroit, Michigan
March 8-11, 2004**

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ISBN 0-7680-1319-4
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Printed in USA

the changes noted here, displacement of 5552 cc was achieved for the new engine.

REDUCTION OF INTAKE/EXHAUST MANIFOLD FLOW RESISTANCE

A 3-D model was used to conduct flow analyses for designing such components as the intake manifold, exhaust manifold and cylinder head ports, in order to achieve highly efficient intake and exhaust flows.

Intake Manifold

The use of flow analysis in designing the intake manifold resulted in an intake port diameter of 44 mm and an intake port length of 560 mm, thereby achieving the required torque curves. With regard to the bend radius of the intake manifold ports, it is known from previous results that an R/D ratio of 2.0 is the optimum value. Amid the restrictions placed on the VK56DE engine by the required intake volume and vehicle mountability requirements, a port configuration was studied that would secure the optimum port length and diameter while satisfying the necessary intake volume. It is known that a port shape with a long horizontal section tends to provide a better η V characteristic than one with a long vertical section. The reason for that is thought to be that a long horizontal section allows a larger bend radius on the inside of the port, which inhibits separation of the airflow to improve Cv.

In determining the shape of the intake manifold of the VK56DE engine, the distribution of the port flow was first made clear. It was found that the main flow region of the intake air was on the outer side of the port. Based on that result, a D cross-sectional shape was adopted that improved the η V characteristic, though the R/D ratio was 1.8, and the required torque curves were thus obtained. The inlet of the intake manifold ports was designed with a bellmouth shape that was optimized on the basis of a steady-state flow analysis. At the initial stage of the design study, it was found that the thermal housing of the #1 cylinder required a recessed shape on account of the engine mountability requirements. On the basis of an analysis, an optimum shape was found that improved the K value by approximately 15%, and that shape was adopted for the VK56DE engine. Moreover, the use of these various analytical techniques made it possible to reduce the number of times prototype parts had to be produced.

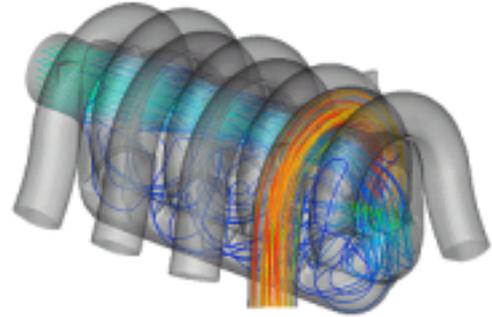


Fig. 3 Analysis Model of intake manifold

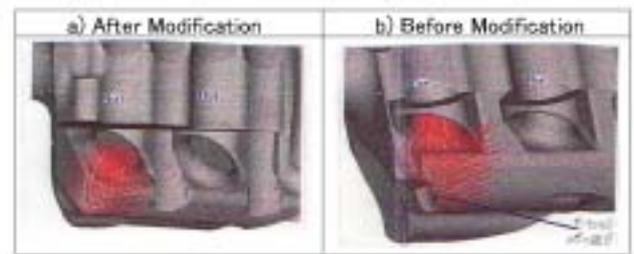


Fig.4 Result of analysis at the intake manifold

Cylinder Head

The intake ports in the cylinder head were designed on the basis of those of the VK45DE engine, and the design was further optimized to emphasize the low-end torque characteristic. The valve train system continued the DOHC design of the base engine, and an intake valve diameter of 37 mm was adopted. That valve size was the result of emphasizing improvement of the intake air flow velocity in the low speed range, rather than simply adopting the largest valve size allowed by the cylinder bore diameter. The optimum intake port geometry was formed by trimming the top of the port edge and thickening the bottom so as to achieve a high tumble ratio combined with the desired Cv characteristic.

The exhaust ports were also designed with the optimum geometry without any airflow separation by making the port cross-section round and by increasing the bend radius at the bottom of the throat.

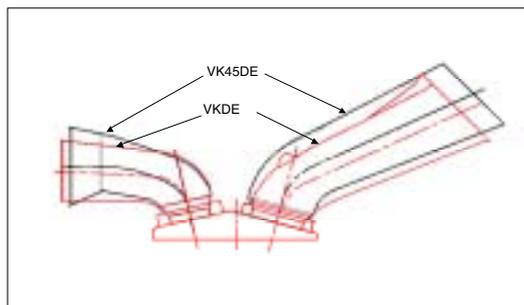


Fig.5 Comparison Cyl-Head port

Exhaust Manifold

A stainless steel exhaust manifold integrated with the catalytic converter was adopted to reduce the weight. In order to reduce the flow resistance in the exhaust manifold, flow analyses were conducted to determine the optimum port for every cylinder. In addition, the shape of the catalytic converter inlet was also optimized to achieve an exhaust manifold with little flow resistance. Previously, component reliability related to the exhaust gas temperature has been a major issue in the design of exhaust system components. For the VK56DE engine, the heat distribution in the engine compartment was analyzed, taking into account the airflow produced by the movement of the vehicle. The distribution of the exhaust manifold temperature was then estimated under the condition in which the engine would be mounted in the vehicle, and the results were used in designing the exhaust manifold shape. As one example, this approach made it possible to consider flow resistance and thermal fatigue simultaneously in selecting and determining the optimum shape for the joints of the ports, which are the places where thermal fatigue is the severest. Based on the results of the measures described here, the exhaust manifold was designed so as to strike an optimum balance among weight, performance and cost considerations.

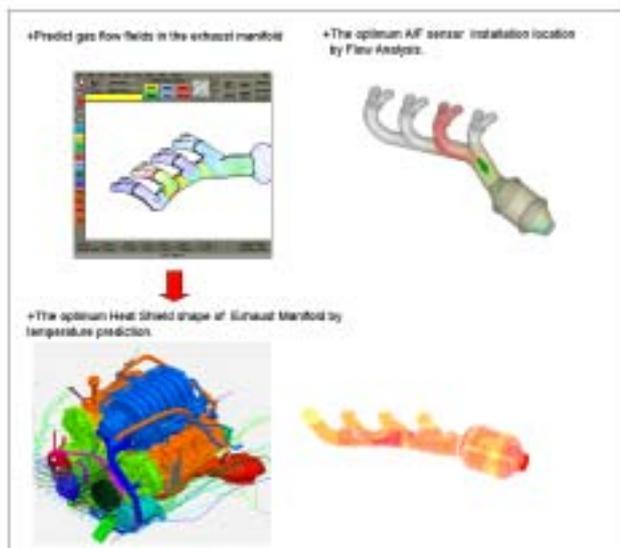


Fig.6 Analysis Model of exhaust manifold

COMBUSTION CHAMBER

Pistons

The compression ratio was set at 9.8:1 to meet the requirement for use of regular gasoline with this new engine designed for full-size vehicles. With regard to the combustion chamber configuration, a top land height of 4.2 mm was adopted to reduce the dead volume of the piston top land for the sake of lowering hydrocarbon (HC) emissions. A dish-shaped combustion chamber was selected for the VK56DE engine as the optimum configuration for meeting these requirements.

For the purpose of lightening the weight, the compression height was set at 31.63 mm, continuing the same specification as the VK45DE engine, and the results of finite element analyses (FEA) of the various parts were effectively utilized to keep the piston height at 52 mm. The inner diameter of the piston pin was tapered to achieve a weight reduction of 16 g per cylinder compared with the VK45DE engine. The combined weight of the piston and piston pin is 531 g per cylinder, achieving a K value of 0.563. The application of an epoxy resin-graphite coating to the piston skirt to reduce friction was carried over from the VK45DE engine.

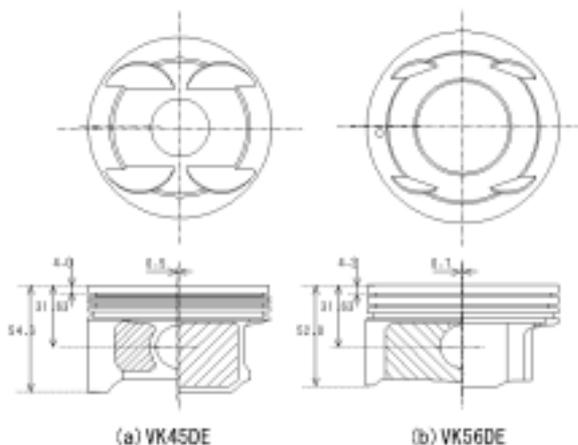


Fig.7 Piston Specification

Coolant Flow Around Combustion Chamber

With the aim of improving resistance to knocking, the coolant passages throughout the entire engine were re-examined, and a 3-D flow analysis was used in designing the coolant flow around the combustion chamber. The area of the water jacket around the spark plug tower where the wall thickness was decreased was expanded by approximately 70% on the intake side and by approximately 35% on the exhaust side. As a result, the coolant flow rate around the plug tower was improved by approximately 20% compared with the specification of the initial design study. Along with the adoption of long-reach spark plugs, sufficient anti-

knocking performance has been achieved even with a large bore diameter of 98 mm.

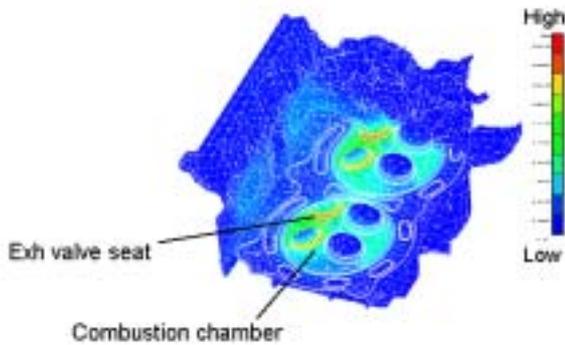


Fig.8 Analysis Model of coolant flow

REDUCTION OF FRICTION

A DOHC design was adopted for the new engine for the purpose of securing high power output, but one drawback of this type of valve train compared with SOHC or OHV designs is increased friction. To reduce friction in the valve train, the camshaft was microfinished for an improvement in surface roughness. Shim-less valve lifters were adopted to reduce both the weight and the part count. The crown of the valve lifters is given a gas nitriding treatment that reduces friction. In addition, the tension and loading of the valve springs were optimized. As a result of these measures, valve train friction was reduced by approximately 1%.

For the main moving parts, a full counter crankshaft with microfinished crank journals was adopted, which together with the application of the epoxy resin-graphite coating to the piston skirt works to reduce friction.

By incorporating these various friction reduction measures in the VK56DE engine, its typical fuel economy level was improved by approximately 3% compared with the initial design study specification.

As a result of making the improvements explained here, the VK56DE engine generates maximum torque of 379 lb-ft/3600 rpm and maximum power of 305 hp/4900 rpm, along with delivering approximately 330 lb-ft of brake torque, representing 90% of its maximum torque, at 2500 rpm.

VEHICLE POWER PERFORMANCE

The above-mentioned torque characteristics provide power performance suitable to a full-size pickup truck and a full-size SUV, including low-end acceleration in city driving, freeway on-ramp acceleration and passing acceleration, and hill-climbing capability and passing acceleration when towing. This engine output combined with a five-speed automatic transmission delivers hill-climbing power performance among the best in this vehicle class on all types of grades.

Although the engine produces its maximum power at 4900 rpm, it has been designed to operate in the high-speed range up to 6000 rpm. The level of shifting smoothness achieved in concert with the shift schedule of the automatic transmission is thought to be without precedent in the full-size vehicle market.

Moreover, the adoption of an electronically controlled throttle facilitates fine-tuned control to provide smooth driving performance that is expected to meet drivers' demands.

QUIETNESS

With the aim of making the VK56DE engine one of the quietest in its class, it continues the noise-reduction measures applied to the VK45DE engine, and it also adopts an aluminum front cover, an aluminum oilpan and a plastic intake manifold. These and other components for reducing noise were designed through efficient use of various analytical tools.

SUPER SILENT CHAIN SYSTEM

The super silent timing chain used for the VK45DE engine on the Infiniti Q45 sedan has also been adopted for the VK56DE engine to mitigate the impact energy produced by the meshing of the chain and the sprockets. Compared with a conventional roller chain, the super silent chain reduces high-frequency noise for a dramatic reduction in chain meshing noise. Moreover, the chain's small pitch also contributes to a lighter weight because it allows a more compact cylinder head design.

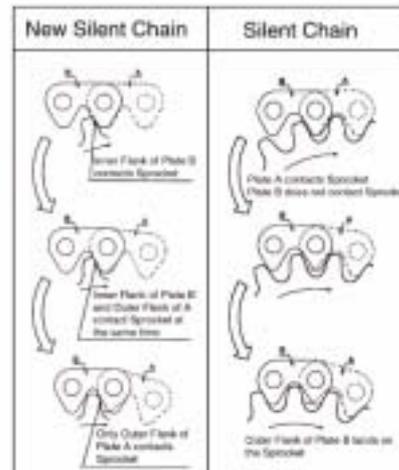


Fig. 9 Mechanism of noise reduction

ALUMINUM FRONT COVER

The VK56DE engine adopts a sprocket cover and a front cover. The application of analytical tools made it possible to find the optimum shapes for both covers to ensure quiet operation. As specific examples, ribs were effectively placed on the front cover, and the cam sprocket cover was suitably rounded to obtain sufficient

weight of 231 kg, even though the displacement was substantially increased over that of the VK45DE engine. An engine weight comparison is given in Fig. 13.

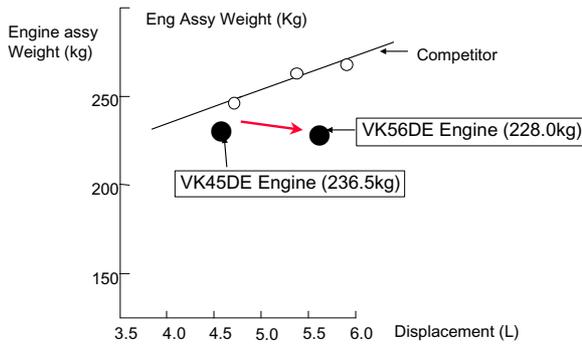


Fig. 13 Comparison Engine weight

EXHAUST EMISSION PERFORMANCE

The adoption of a thin-film ceramic-based catalytic converter integrated with the stainless steel exhaust manifold promotes faster catalyst light-off. In addition, an air-fuel ratio sensor was adopted to improve response and facilitate large-scale purging of evaporative emissions for compliance with the ULEV regulations. In determining where to install the air-fuel ratio sensor, an investigation was made of the exhaust gas flow, taking into account the firing sequence of each cylinder. The results of that investigation were used to improve the response of the air-fuel ratio sensor.

RELIABILITY

Previously developed products had also met the durability requirements for the full-size vehicle market. However, the engines of full-size pickup trucks and SUVs are used more frequently in driving situations involving severe operating conditions, such as climbing hills when towing something. The need to assure durability in such driving situations was considered in the design of every engine component, and rigorous tests were conducted throughout the development process to confirm the reliability of the new engine.

CYLINDER HEAD GASKET

A principal issue involved in increasing the bore diameter was to ensure bore sealing performance by the head gasket. To secure the required bore sealing performance, the VK56DE engine adopts a three-layer, two-bead metal (SUS) head gasket, with a wave-stopper bead used for the intermediate layer. The axial force of the head bolts was also adjusted, among other improvements made to enhance the potential for

securing bore sealing performance suitable to full-size vehicles.

ENGINE COOLING SYSTEM

A 21-stage water-cooled oil cooler, with a heat exchange capacity of 5.0 kW, was adopted to meet the severe operating conditions imposed on the engine in various driving situations for full-size vehicles, such as hill-climbing when towing something.

The entire engine cooling system was re-examined, including the pulley ratio of the water pump and the engine-driven fan. As a result, the water jacket of the cylinder block was designed with a depth of 75 mm, and a cooling system with a U-turn flow design was adopted, which had the effect of reducing the temperature difference between the engine coolant and oil by approximately 5 deg. C. As a result of implementing the changes described here, the thermal performance potential of the engine was improved over that of the base engine.

CONCLUSION

This paper has described the development objective set for the VK56DE engine along with its performance and technical features. This engine has been developed for use on a full-size pickup truck and a full-size SUV in the North American market. Every previously applied engine technology was re-examined to achieve an optimal balance of performance suitable for these vehicles, including overwhelming power, low noise and vibration, and also reliability for use under severe operating conditions such as towing. As a result of the cumulative improvements made to thoroughly enhance its basic character, the new engine was successfully designed and engineered to meet the development objective.

1. The engine achieves not only high power output but also a flat torque characteristic from the low rpm range. Development efforts were mainly dedicated to the intake and exhaust air flow improvement by fully utilizing CAE analysis.
2. The engine achieves best-in-class quietness' and lightweight, to reduce engine noise in addition to the CAE approach to enhance engine rigidity.