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ALTERNATIVE WAYS FOR VEHICLE ICE DEVELOPMENT

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ABSTRACT

The article considers the alternative ways of improving vehicle engines developing by the State Scientific Center "NAMI". The work describes the traverse power mechanism, which allows controlling the movement of the pistons, changing the compression ratio and the working displacement. The construction of traverse engines allows them to be manufactured together with the serial engines with a partial modification of the standard equipment. The research shows that it is possible to significantly increase the boost pressure in a diesel engine with a regulation of the compression ratio, thereby increasing the power. As well it is possible to save the previous level of power, reduce the working volume (the number of cylinders), while improving fuel efficiency, reducing the mass and cost of the engine. A gasoline engine allows increasing the boost pressure without detonation, with a reduction in the compression ratio, while increasing the liter capacity with improving the fuel economy in the high load modes. With an increase in the compression ratio, fuel efficiency will improve on low-load conditions.

Keywords: internal combustion engine, adjustable compression ratio, adjustable working volume, throttling loss, Otto cycle, Diesel cycle, cycle time control

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1. INTRODUCTION

Numerous predictions of engine technologies prospects show that in the next decades piston engines will remain dominant in their traditional application sectors (road transport, diesel locomotives, shipbuilding) while expanding the use in special transport systems. Piston engines are constantly being improved in terms of environmental and economic parameters, liter capacity, mass dimensions. However, in recent years, the pace of improvement of the core engine parameters has decreased significantly. Therefore, the attempts to create new types of piston engines, in particular with controlled piston motion, which allow regulating the compression ratio and the working volume, become actual.

2. MAIN PART

Innovations implemented in modern engines relate to the improvement of its systems and units, primarily the elements of fuel equipment, in order to improve the flow of work processes. However, the motion laws of the pistons remain rigidly specified and depend only on the invariable parameters of the cranking mechanism. This circumstance does not allow us to use such powerful working process parameters optimization reserves in the whole range of its operating modes, such as regulation of compression ratio and working volume.

Until recently, it was considered axiomatic that the compression ratio is a constant design variable, such as, for example, the diameter of the cylinder. Indeed, in traditional engines, the magnitude of the compression ratio is uniquely determined by the size of the cranking mechanism, the height of the piston, and also the location of the cylinder head relative to the axis of the crankshaft.

It is known that the power and fuel efficiency of the engine increase with an increase in the compression ratio due to an increase in the indicator efficiency. When the values of the compression ratio reach 13-14, the improvement of the engine performance is stopped due to the inevitable growth of mechanical losses. Therefore, the indicated values of the compression ratio are optimal.

At the same time, the value of the compression ratio designed in the engine differs from the optimal one. In gasoline engines, the compression ratio is less than optimal one and is limited by detonation. In diesel engines, the compression ratio is more than optimal one and is selected considering the reliable self-ignition of the fuel when the cold engine starts.

Numerous calculations and experimental studies demonstrated that for a gasoline engine and for a diesel engine, the compression ratio regulation can provide approximately the same improvement in fuel efficiency by 20%, although the reasons causing this and the compression ratio algorithm are different. A diesel engine with a regulation of the compression ratio allows significantly increase the boost pressure, thereby increasing the power. As well it is possible to save the previous level of power, reduce the working volume (number of cylinders), while improving fuel efficiency, reducing the mass and cost of the engine. A gasoline engine with a reduction in the compression ratio allows increasing the boost pressure without detonation, while increasing the liter capacity with all the concomitant positive effects, including improved fuel economy in high load modes. With an increase in the compression ratio, fuel efficiency will improve on low-load conditions.

The possibility of adjusting the working volume is even more valuable for the engine performance than the regulation of the compression ratio. A large working volume of existing engines is needed only for driving a car with a speed close to maximum. These modes do not exceed 10% of the total time of the car movement. Most of the time, for example, when driving in the city – it requires an economic engine with a small working volume. Both regulation of compression ratio and working volume open up wide prospects for creating a new type of engine with controlled piston motion. It is an "elastic" engine that flexibly adapts its volume and compression ratio to the conditions of the car's movement. For example, when more power is needed, this engine is equivalent to a 6-cylinder engine. If a large power is not required (city traffic mode), it will correspond to a 4-cylinder and even a 3-cylinder engine. Whereas, a significant reduction in fuel consumption is ensured.

By now, a fairly large number of methods for regulating the compression ratio ε and working displacement are known. The classification is given in Figure 1.

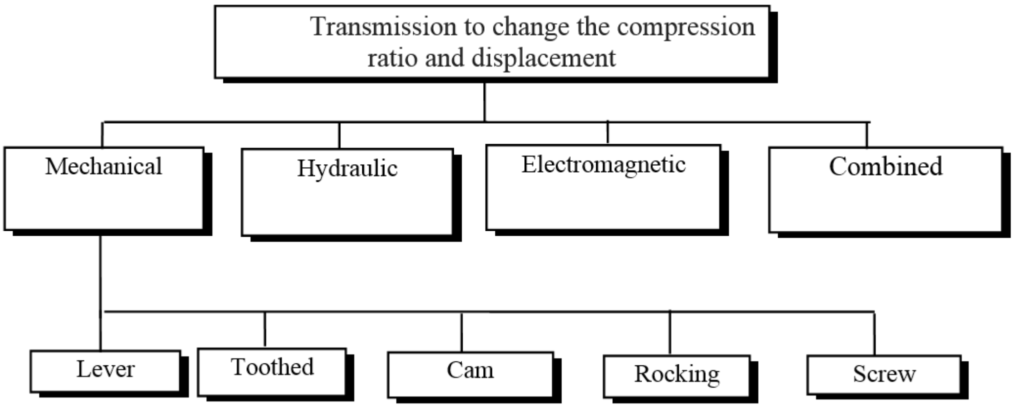


Figure 1 Classification of gears and mechanisms for regulating the compression ratio and working volume

The number of proposed designs that allow us to adjust the compression ratio and engine displacement is very big. However, the vast majority of them, allows solving the set tasks for control ε and V_h h, while are not suitable for practical implementation because they are impossible to provide an acceptable engine performance, or are inapplicable for technological reasons. Therefore, only a limited number of engines were embodied in metal and only single designs were manufactured.

In the early 90s of the 20th century, the SSC FSUE "NAMI" proposed a conversion mechanism called a traverse mechanism, which allowed controlling the movement of the pistons, changing the compression ratio and engine displacement [1-3]. Technical solutions for the NAMI traverse mechanism are protected by patents of different countries. Since the beginning of the XXI century, works on engines with traversal converting mechanisms are actively carried out by Peugeot, Nissan and HONDA [4-12]. SSC NAMI produced more than a dozen traverse engine models with controlled piston motion on the basis of the VAZ, YaMZ and DaimlerChrysler serial engines. Some of them are shown in Figures 2, 3, 4. All samples are traverse engines.

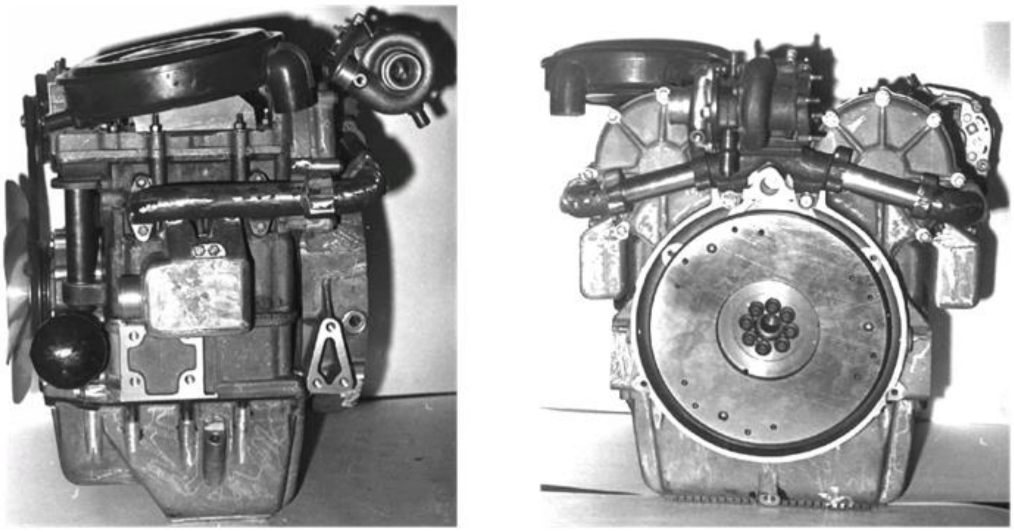


Figure 2 Traverse diesel TB-48 (iV_h = 1.9 l) based on Elko 3.82.92T engine from Elsbett-Konstruktion (Austria)

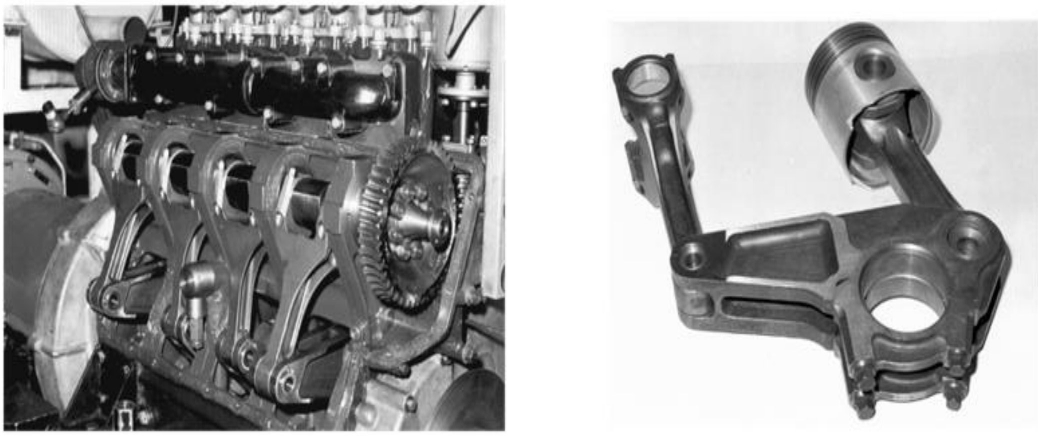
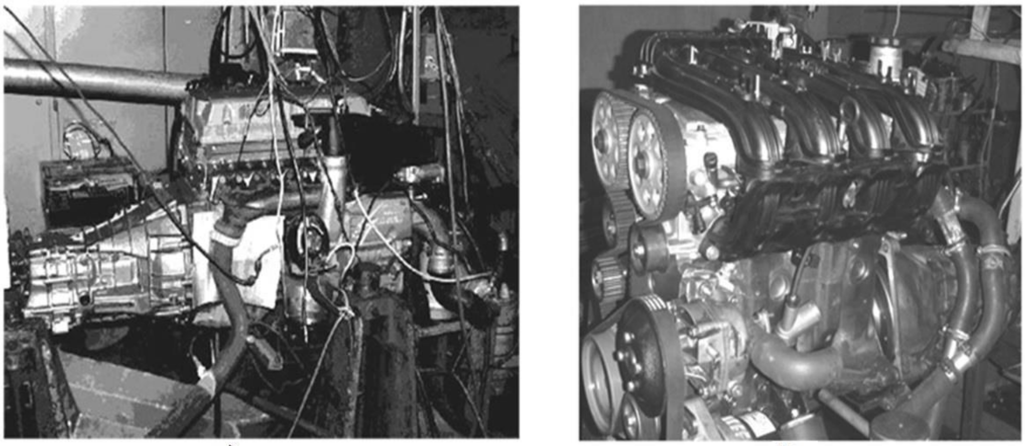


Figure 3 Traverse diesel T-01 (iV_h = 9,1 l) and its movement details based on the YaMZ-8424 engine

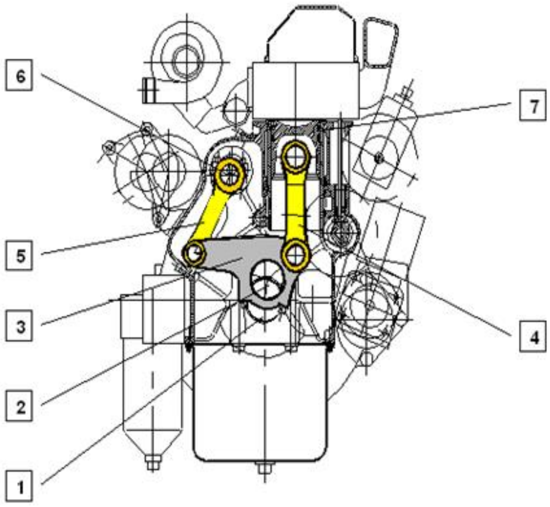


a) b)

Figure 4 Traverse engines with spark ignition: a) - VE111 (iV_h = 2 l) on a DaimlerChrysler engine M111 base, b) - VAZ 11194VE (iV_h = 1.4 l) based on VAZ 11194 engine

The NAMI traversing mechanism works as follows (Figure 5). The axis of the crankshaft 1 is offset relative to the axis of the cylinders. The crankpin 2 of the crankshaft is connected to a crosspiece 3 having two more cylindrical hinges: one is connected to the connecting rod 4 and another is connected to the rocker arm 5. The upper end of the rocker arm is connected to the wobbler shaft 6 located in the diesel engine case, and the upper end of the connecting rod 4 is connected to the piston 7. When the crankshaft rotates, the piston reciprocates. The distance from the plane of the cylinder head to the bottom of the piston (when it is in the TDC), determining the degree of compression, depends on the coordinate of the rocking axis of the rocker arm. This coordinate and, therefore, the compression ratio of the motor is controlled by rotating the wobbler shaft.

The engine compression ratio is maximum when starting and running on idling and small loads. As the load increases and, consequently, the boost pressure increases, the compression ratio decreases smoothly when the wobbler shaft is turned. At the same time, the maximum combustion pressure is limited to a constant level, the maximum under the conditions ensuring the performance of the power mechanism bearings in the diesel engine, or the absence of detonation in the gasoline engine.



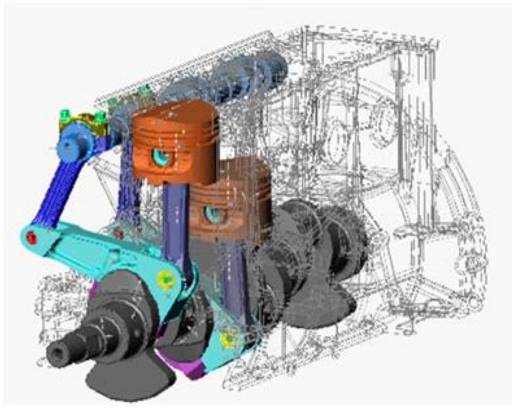


Figure 5 Traverse mechanism of NAMI engines

One of the main tasks set for the creation of traverse engines was to provide maximum constructive, technological continuity and unification with a basic engine.

Parts and assemblies of the engine with controlled pistons movement can be divided into three groups: standard, variable and additional (Figure 6) [13]. The standard products include the following products of the basic series engine: cylinder head, inlet and outlet manifolds, flywheel, flywheel housing, oil pan, crankshaft bearings and covers, oil and water pumps, engine mounts, fuel and ignition systems, starter, generator.

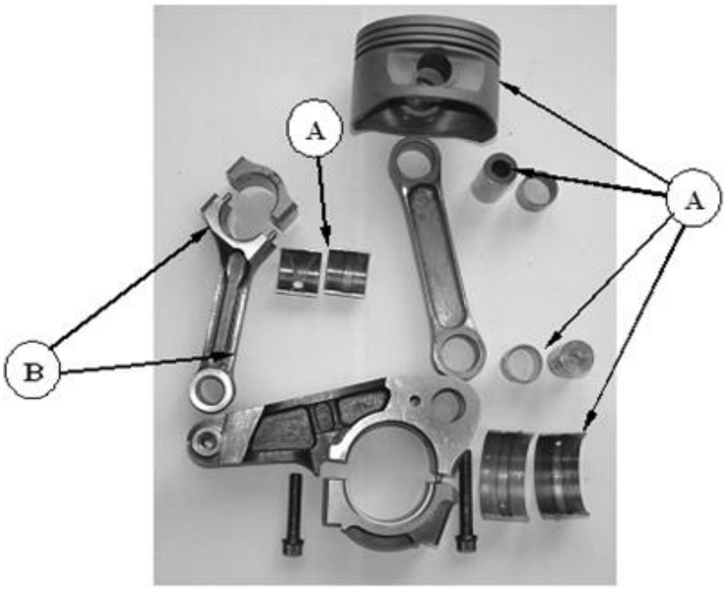


Figure 6 Details of the conversion mechanism of the traverse engine: A - standard parts; B - additional parts (manufactured according to standard technologies and from traditional materials)

The main variable part is the cylinder block, which has a structural and technological continuity with the cylinder block of the basic engine (Figure 7). Due to the fact that the inter-cylinder distance does not change, the processing of the cylinder block can be performed on the production equipment of mass production.

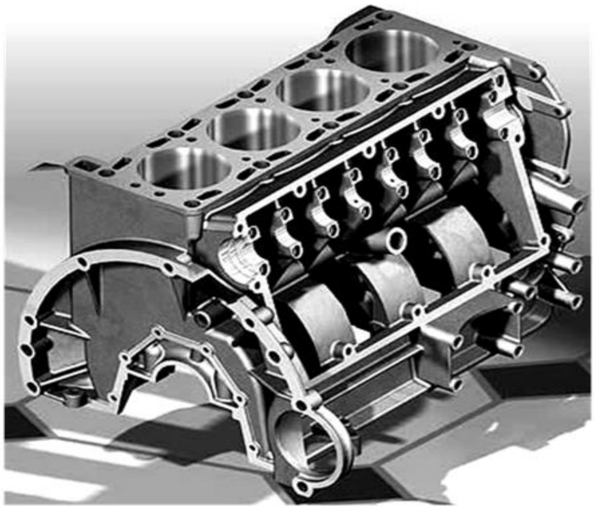


Figure 7 The cylinder block of traverse engine

The crankshaft in the design and manufacturing technology is unified with the crankshaft of the basic engine and differs from it only by a reduced crank radius. Its processing is also performed on standard equipment. The length of the shaft, the dimensions of the crankshafts, the diameter of the connecting rods, their coordinates in the longitudinal section are the same. The design of the front part of the shaft and the flywheel attachment assembly is also retained. The crankshaft material is the same as the base engine has.

Additional parts of the traverse engine are elements of the conversion mechanism - traverses, rocker arms and a wobbler shaft (Figure 6). The design of the traverse is close to the design of the connecting rods of aircraft engines. The bearing of a cranked bearing of a cranked shaft is executed similarly to the basic engine. According to the design and materials used, the rocker arm is close enough to the connecting rods of traditional engines. The upper and lower heads of the connecting rods are identical to the upper end of the connecting rod of the basic engine. The connecting rods of the engine with controlled piston movement does not have a connector in the lower heads and, therefore, are simpler than the serial ones. The technology of manufacturing a wobbler shaft is similar to the technology of manufacturing a camshaft of a basic engine.

The design of the traverse motors allows them to be manufactured together with the serial engines in the current production line with a partial modification of the standard equipment.

The transverse conversion mechanism was originally developed for engines with a variable compression ratio (Variable Epsilon - VE) and practically unchanged piston stroke. Further works since the late 90s of the last century were aimed at designing an engine with adjustable working volume and compression ratio (Variable Displacement & Epsilon - VDE).

Using multi-parameter optimization modeling, a VDE engine mechanism was developed (Figure 8) [2, 13]. When introducing changes into the design of the traverse mechanism, it can be modified into a powerful mechanism that allows increasing the working volume of the engine by 40% with a reduction in the compression ratio by twice.

In VE and VDE engines, the compression ratio in the maximum load modes is reduced, allowing the boost pressure to be increased without detonation. At the same time, 4-cylinder traverse engines are capable of developing the same power as a standard 6-cylinder engine. In addition, in medium and low load modes in the VDE engine, the working volume is reduced by 24% and the engine is “transformed” from a 4-cylinder to a 3-cylinder engine with a corresponding improvement in fuel economy.

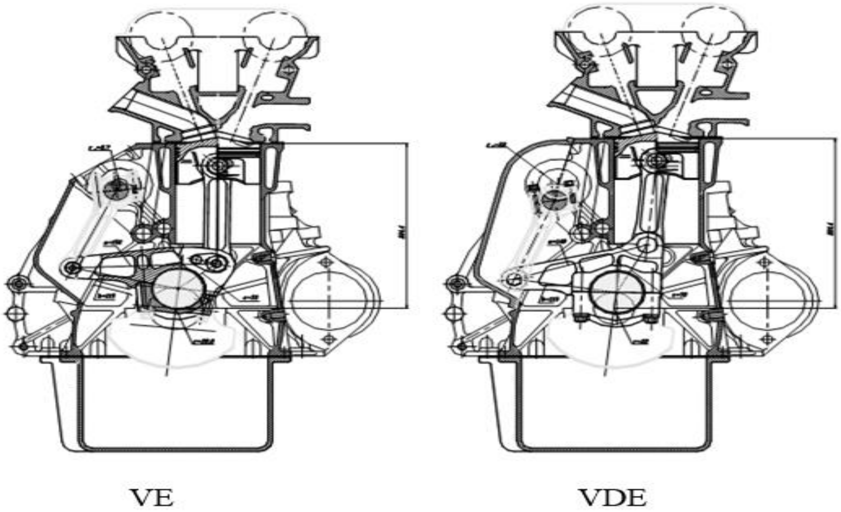


Figure 8 Cross sections of engines with adjustable working volume and/or compression ratio.

The change in the components of the effective efficiency of the 4-engine VE and VDE in relation to the parameters of the 6-cylinder basic engine at a power of 15 and 60% of full load is shown in Figure 9.

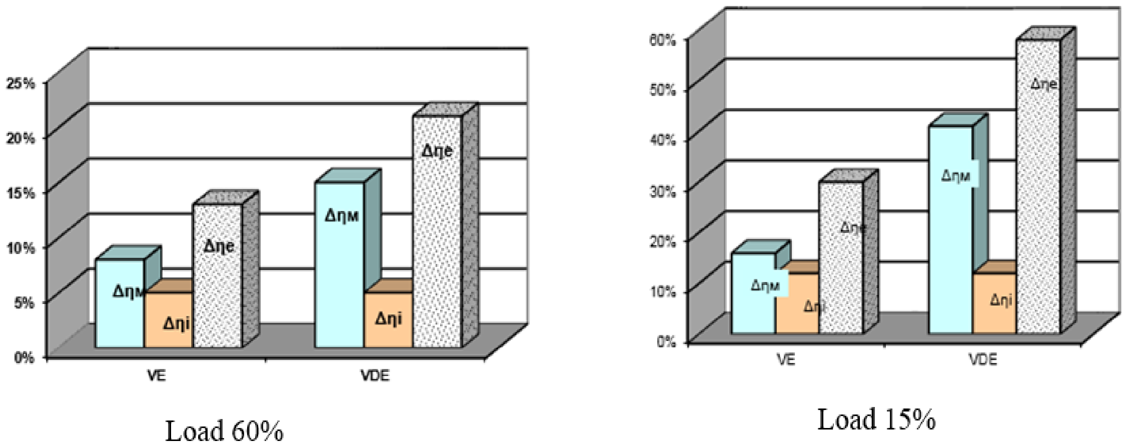


Figure 9 Increase the efficiency of engines with adjustable working volume and/or compression ratio.

Figure 9 shows that small and medium loads regimes the adjusting of both compression ratio and working volume provides a 1,5-2 times greater improvement in fuel efficiency in comparison with only the compression ratio regulation.

3. CONCLUSIONS

The study testifies that the piston motion control allows to significantly reduce the vehicle fuel consumption, especially in urban traffic, and to reduce greenhouse gas emissions. While the construction of the traverse motors does not require a significant change in the existing production. It is possible to manufacture them together with the serial engines with partial modification of the standard equipment.

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