About the Development of Russian Engine Building for Railway Traction Rolling Stock

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Abstract. The article analyzes the current state of engine building in Russia. The market volume of railway transport engines at all stages of the life cycle has been determined. Results of the implementation of the subprogram “Development and organization of production of new generation diesel engines and their components in the Russian Federation in 2011–2015” regarding the design of railway traction rolling stock diesels are presented. There are provided the ways to solve problems of piston engine building, proposed at the all-Russian cross-industry “Engine of Russia” Forum.

1. Introduction
The importance of internal combustion engines (ICE) for the economy and the country's defense is difficult to overestimate. This is one of the most important units of vehicles, power plants, military vehicles, constructional mechanisms, agricultural and other equipment [1]. The importance of internal combustion engines is also invaluable for railway transport: the work of the railway industry directly depends on its reliability, efficiency and environmental safety.

Developed engine building ensures the independence of the most important domestic infrastructure facilities and defense equipment from foreign supplies [2]. The Soviet Union had the developed engine building along with the USA, Germany, France, Great Britain, Italy, Switzerland, Finland and Japan. This provided the most important economy sectors – railways, autonomous and backup energy, and the defense industry – with their most important resource, power plants. The share of USSR exports in the “Machinery, Equipment and Vehicles” segment in 1986 was about 15% of total exports, and in 1986, the USSR received slightly more than 7% of all export earnings for the oil and oil products export. From 1971 until the collapse of the USSR, tens of thousands of military and civilian units of equipment were exported, and almost all of them were equipped with domestic engines [3, 4].

During 1990–2010, Russia lost its independence in the field of engine building. There has been a transition to ready-made imported foreign equipment and replacement of Russian components with imported ones. Even if engine components are manufactured in Russia, according to the drawings of Russian enterprises, often the key components (crankshafts forgings, metal for injectors, complex casting) are imported. There is a risk of possible sanction pressure, since the railways are the basis of the country’s strategic security.

2. Railway engines
Diezel engines are mainly used for the railway traction rolling stock. Today, about 12,000 diezel engines with an output of more than 500 kW and approximately 5,000 of lower output are in operation
by Russian Railways and industrial enterprises with their own railway lines. (This number does not include the engines of stand-alone power plants, cars and other non-track maintenance vehicles.) The share of imported engines on mainline diesel locomotives is insignificant, on shunting diesel locomotives and track machines – about 50% (Figure 1).

The key producers of internal combustion engines for railways in Russia include JSC “Kolomensky Zavod”, JSC“Penzadizelmash”, LLC “Ural Diesel-Motor Plant”, CJSC “Volzhskiy Dizel Imeni Maminih”, PJSC “Zvezda”. At present, medium-speed diesel engines manufactured by JSC “Kolomensky Zavod” D49 of dimension 26/26, 12- and 16-cylinder models, are mainly used on mainline diesel locomotives.

On diesel locomotives 2TE116UD, the US GEVO 12 medium-speed diesel engine manufactured by GE of dimension 25/32, 12-cylinder model, is used. A limited batch of 2TE25AM diesel locomotives has been manufactured with a high-speed diesel engine 20V4000R43 of the company MTU of dimension 17/21. A series of 2TE25K2M diesel locomotives with a GEVO 12 diesel engine is in the process of production.

JSC “Kolomensky Zavod” has developed and created prototypes of medium-speed diesel engines of the new generation D300 of dimension 26/28 and D500 of dimension 26.5/31. The stated characteristics of the new D300 and D500 diesel engines mainly correspond to the goals for the introduction of innovative rolling stock in accordance with the Strategy of Innovative Development of JSC “RZD”. There is a decrease of specific fuel consumption, oil consumption through burning, an increase of resource parameters in comparison with the used engines of foreign and domestic production (Table 1).

In terms of specific fuel consumption at the locomotive, modern Russian diesel engines are at the level of the best foreign models. And the stated efficiency of new diesel engines manufactured by JSC “Kolomensky Zavod” is higher than western models.

During its life cycle (and this, as a rule, about 20 years of operation), a diesel engine, in addition to the small maintenance services 2, goes through another 215 maintenance services to the extent of maintenance services 3, 67 routine maintenances (first – 54, second – 9, third – 4), 2 medium maintenance and 1 overhaul repair. The total cost of maintenances and repairs is 7.5 times the initial cost of the engine.

**Figure 1.** The ratio of diesel engines of domestic and foreign production on the traction rolling stock of the Russian railways.
Table 1. Characteristics of diesel engines of high-power diesel locomotives.

| Parameter                                              | Diesel engines |
|--------------------------------------------------------|----------------|
| Designation according to GOST 10150-2014               | 12ChN25/31     |
| Producer                                               | JSC “Kolomensky Zavod” (Russia)                  |
| Cylinder output, kW/cyl                                | 368.0          |
| Cylinder capacity, l                                   | 17.09          |
| Engine aggregate capacity, kW                          | 4,416          |
| Rated speed, min⁻¹                                     | 1,000          |
| Specific effective fuel consumption according to ISO 3046-1, g/kW-h | 184             |
| Specific oil consumption, g/kW-h                       | 0.35           |
| Service life before overhaul, h                        | 72,000         |
| 16LDG300                                               | 220.6          |
| 16ChN26/28                                             | 14.90          |
| 16ChN26/26                                             | 3,530          |
| 18-9DG                                                 | 2,650          |
| 16ChN26/26                                             | 1,000          |
| GEVO 12                                                | 191            |
| 12ChN25/32                                             | 1,050          |
| 12ChN25/32                                             | 186            |
| 12ChN25/32                                             | 0.60           |
| 12ChN25/32                                             | 45,000         |

As part of the implementation of strategic government tasks to expand the use of natural gas as an engine fuel, JSC “Russian Railways” is actively taking efforts to introduce gas engine locomotives and develop technologies for their operation. The first LNG gas turbine locomotives with a capacity of 8300 kW were built and operated. In 2013 there was built the first shunting diesel locomotive TEM19 running on liquefied natural gas and since 2015 it is in operation (Figure 2, Table 2). As an engine of the power plant a piston gas engine with a capacity of 880 kW was used on this diesel locomotive. Variants of gas and gas-diesel piston engines use on mainline diesel locomotives are considered. The development of gas locomotives is restrained only by the lack of mass-produced diesel gas piston engines [5].

For mainline diesel locomotives in 2017 – 105 diesel engines were produced, in 2018 – 145 diesel engines, in 2019 and 2020 – 150 and 166 diesel engines should be produced, respectively.

Total costs for the purchase of new engines in diesel locomotives and track machines operation, excluding generators and other electric machines, are about 4 billion rubles per year. The total cost of the maintenance and repair of engines, that are in operation as part of diesel locomotives and track machines, excluding generators and other electric machines, is 65.5 billion rubles per year.

Taking into account the fact that all engines for railway rolling stock can be produced in Russia and from Russian components, from the annual total cost of engines of 69.5 billion rubles, 13.9 billion rubles will be returned to the Russian budget as taxes, 18.9 billion rubles will go to private funds, including pension funds and health insurance, and 36.6 billion rubles will ensure the lives of tens of thousands of workers as salaries and wages.
3. Russian engine building today

In order to improve the situation in the piston engine building industry, the Ministry of Industry and Trade adopted the subprogram “Development and organization of the production of new generation diesel engines and their components in the Russian Federation in 2011–2015” (hereinafter the subprogram) as part of the federal target program “National Technological Base” for 2007–2011. The total amount of financing for this subprogram was 16.1 billion rubles, including 8.1 billion rubles from non-budgetary sources.

The objectives of the subprogram are:

- development and mastering of production of competitive standard-size lines of new design diesel engines;
- conducting research and development work to maintain the competitiveness of the Russian diesel building in the long term;
- launching into manufacture of at least 11 basic modifications of new generation diesel engines.

During the implementation of the subprogram, research and development work was carried out to design a number of advanced diesel engines. Scientific experimental and bench facilities were created for development of new design decisions in the field of diesel engine building. To date, the subprogram has been implemented, the results of the stage of creating prototypes of advanced diesel engines have been adopted by the state.

As part of the implementation of this subprogram the following models of new engines were designed which in the future (after refining and launching into manufacture) can be applied to the railway traction rolling stock:

- new generation engines D300 (ChN26/28) with power 2,600–3,500 kW and D500 (ChN26.5/31) with 3,500–7,500 kW (JSC “Kolomensky Zavod”);
- new generation engines D200 (ChN20/28) with power 500–1,500 kW (JSC “Penzadizelmash”);
- new generation engines DM-185 (ChN18.5/21.5) with power 750–4,800 kW (LLC “Ural Diesel-Motor Plant”);
- high-speed multipurpose diesel engines M150 (ChN15/17.5) in the power range of 400–1,700 kW (PJSC “Zvezda”).

At the finishing stage of the subprogram, the Ministry of Industry and Trade of Russia together with Bauman Moscow State Technical University and other research and educational institutions with direct involvement of representatives of internal combustion engine and component manufacturers prepared a draft document “Strategy for the development of piston engine building in the Russian Federation” which, unfortunately, has not yet been adopted, not approved and needs to be improved. Russian manufacturers on their own are trying to compete with leading world corporations. Refinement and serial production of new engines designed under the subprogram “Development and organization of the production of new generation diesel engines and their components in the Russian Federation in 2011–2015” are delayed.

At the same time, the world’s leading firms spend 8–12% of their annual revenues on the creation of new advanced engines what allows them to compete in the market for engine building. Additionally, in a number of countries, there is state support for the development of this knowledge-intensive sector of the economy with a long cycle of creating new types of engines. World practice shows that designing of a new standard-size line of engines requires financial costs in the amount of $ 200–500 million, and the creation period is 5–7 years. During this time, technical documentation is developed, individual units and prototypes of piston engines are manufactured and examined, and pilot specimens are built and subjected to comprehensive bench and operational tests.

In October 2018, on the initiative of a team of young engineers and leading industry specialists, an expert council of veterans in the field of piston engine building of the Russian Federation (Council of Elders) was established which prepared holding of the all-Russian cross-industry “Engine of Russia” Forum. “Boiling point” of the Agency for Strategic Initiatives was chosen as the launch site, the chairman of the supervisory board of the Agency for Strategic Initiatives is the President of the Russian Federation V. V. Putin.

In December 2018, piston engine building experts, component suppliers, engine consumers, representatives of operating organizations and businesses, as well as leading universities and state scientific centers discussed the problems of domestic engine building and ways to solve them at 10 sites in Moscow, St. Petersburg and Chelyabinsk. Strategic sessions were held on the development of: power plants for land, marine and river transport; power plants based on piston engines for air transport; stationary and mobile power plants, standby power units, units for nuclear power plants; power plants for railway transport and heavy transport engineering; power plants for special purposes; power plants for agricultural machinery (in particular, using biofuel); production of components for power plants and advanced technologies; hybrid power plants, the use of alternative fuels and optimization of working processes; youth engineering initiatives in the field of engine building and automotive engineering.

The participants of the sites analyzed the current state of the Russian engine building, formed the image of its future, to which it is necessary to strive, and indicated the barriers that must be overcome to achieve a favorable future. The mission was accepted not only for each group, but also for each of its members; its actions in the near future are defined. The roadmap was approved – a visual representation of a step-by-step action plan and events, the scenario for the development of the Russian engine building industry and interaction with the state authority. The first stages of the launch scenario of the program for the development of the Russian engine building industry are the update and approval of the “Strategy for the development of piston engine building in the Russian Federation”.

According to the results of the forum, the main directions of work of the Council of Veterans in the field of piston engine building of the Russian Federation and the Association of piston engine building engineers [5] are defined:
• updating the draft strategy for the development of piston engine building and submitting it for approval to the Government of the Russian Federation;
• development and implementation of the production growth program of domestic engine components, the program provides sustainable progression of the engine building and related industries taking into account import substitution;
• promotion of the organization initiative of the Federal Engineering Centre for piston engine building;
• promotion of the idea of necessity to establish a division in the Ministry of Industry and Trade of the Russian Federation, coordinating the work of all areas of the piston engine building industry;
• creation of the common information space of piston engine building as an element of digital training of specialists, as well as an electronic catalogue of three-dimensional images of the available and future engines and their components in order to use them in the design of final products (automobile, ship, locomotive, generator, etc.);
• facilitating the establishment of the Federal Student Engineering and Technology Corporation.

4. Conclusions
Currently, there is an active work on the self-organization of industry specialists. The membership of the Association of piston engine building engineers is being formed, and it is open to new members. The joint activities of veterans and young professionals in the framework of the association’s work should lead to the fulfillment of the tasks formulated at the “Engine of Russia” Forum.

5. References
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