Availability of the agricultural, municipal and road construction vehicle market with Russian diesel engines

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Abstract. The paper describes the enterprises that produce or produced diesel internal combustion engines for agricultural, municipal and road construction vehicles in the Russian Federation. The main emphasis is made on engines with a capacity of up to 4400 cc and a power of up to 150 kW as the most demanded for the country. The main consumers of such combustion engines are presented. It is shown that one of the main drawbacks is the impossibility of manufacturing the component base of the required quality for the organization of production of diesel engines in Russia.

1. Introduction
One of the most important tasks of the domestic industry is the establishment and further development of own production of agricultural, municipal and special vehicles, as well as components for it, including diesel engines, or it is necessary to create conditions for the localization of technologies of foreign manufacturers on the territory of the Russian Federation. Thus it is necessary to establish interaction between large manufacturers of vehicles, on the one hand, and manufacturers of component base (parts, units, spare parts), on the other hand, the absence of which eventually makes it impossible for them to cooperate in the production of vehicles of various purposes in the country. The Russian market of agricultural, municipal and road construction vehicles currently urgently needs a reliable domestic diesel engine with a capacity of up to 4.4 litres. It has to have a high amount of torque, low weight and compact overall dimensions, have high fuel efficiency and meet modern environmental requirements. The current demand for such ICE is up to several thousand units per year with further forecast for a stable annual increasing number of such products due to the renewal of the fleet of vehicles or basically their absence on some necessary for the country's economy positions.

In connection with the above-mentioned, the aim of the work will be to justify the need to establish the production of a range of reliable domestic diesel engines with a capacity of up to 4.4 litres.

2. Problem setting
On the basis of the analysis of tendencies and a developed situation in the engine building and engine component base to show the necessity of manufacture of a range of reliable domestic diesel engines with a capacity up to 4400 cc and power up to 150 kW which is pretty much in demand for a wide variety of agricultural, municipal and road construction vehicles in Russia.

3. Results
We will consider the proposals of Russian manufacturers on diesel engines for agricultural, special and road construction vehicles with a capacity of up to 4400 cc.
Vyatka machine-building Enterprise AVITEK produced small-size single-cylinder four-stroke diesel engines of VSN series (VSN-6D, VSN-7D, VSN-9D). The manufacturer positioned these engines as a power source for driving autonomous small (mini) power plants, welding units, mini-tractors, pumping and compressor units, as well as for road transport and construction machinery and other small mechanization means. At the moment the production of these engines is discontinued [1].

Engines of similar purpose have been developed by Production association TULAMASHZAVOD, these are single-cylinder four-stroke diesel engines TMZ-450D and TMZ-520D [2], having the following characteristics:

- TMZ-450D with a capacity of 454 cc and a power of 8.0 kW;
- TMZ-520D with a capacity of 520 cc and a power of 9.5 kW.

Head Specialized Design Bureau “Transdiesel” of the Chelyabinsk Tractor Plant has developed and produced a 2-cylinder V-shaped diesel engine V2Ch 8.2/7.8, which has air cooling, power of 8.8 kW and a capacity of 0.8 litres [3].

The main consumers of this ICE were such Russian enterprises as:
- Chelyabinsk Tractor Plant (Chelyabinsk);
- Projector Elektrotekhnika (Moscow);
- Electroagregat (Kursk);
- Elkon (Barnaul);
- Sarapul Electric Generator Plant (Sarapul);
- Kurganmashzavod (Kurgan);
- Proletarsky Zavod (St. Petersburg).

Having studied the demand and market requirements, the design bureau of the plant has developed a project of a family of small-size water-cooled diesel engines covering the power range from 18 to 55 hp. The new family of compact V-type liquid-cooled diesel engines consists of:

- 2-cylinder version with a capacity of 1.17 litres;
- 4-cylinder version with a capacity of 2.34 litres;
- 6-cylinder version with a capacity of 3.57 litres.

At the moment such engines are created only in the form of single prototypes [4].

Among domestic engines with a capacity of 1 to 4.4 litres, the products of Vladimir Motor Tractor Plant (VMTZ), which is currently in the bankruptcy stage, were in demand and popular [5]. The company produced the following diesel engines with air cooling:

D120 is a two-cylinder internal combustion engine with a capacity of 2.08 litres, which produces a power of 15.4 - 22.1 kW. It was installed on mini loaders of Uralvagonzavod, forklift trucks of Kalinin Machine Building Plant, electric units produced in Kursk and Vladimir region.

D130 and D130T are three-cylinder engines with a capacity of 3.12 litres and a power of 29.4 - 47.8 kW. It was installed on the following types of machinery:
- tractors Agromash 50 TK, Agromash 50 SSH, T-45, VTZ-2048;
- welding unit of ADD-4004 type;
- cement carrier TC-21.

D144 - four-cylinder internal combustion engine with a capacity of 4.15 litres and a power of 27.2 - 44.1 kW. It was installed on the following machinery:
- T-40, LTZ-55, T28X4M tractors;
- Forklift trucks 4014D, 40811,40261, 40271,40816;
- road rollers DU-63-1, DU-EZ, DU-47B, DU-94, DU-E6, DU-E7;
- Asphalt pavers DS-63-1, DS-155;
- Concrete mixers 581460, 581462;
- Compressor stations of ZIF and PKSD type;
- welding units of ADD type;
- power plants AD-16-T400-1 VP, ED-16-T400-1 VP;
- track machines PRM and MSSHU.
D145T is a four-cylinder engine with a capacity of 4.15 litres and a power of 41.9 - 55.1 kW. The engine was installed on the following types of machinery:

- tractor Agromash 85 TK;
- diesel generators AD-30, AD30-T400-1 VP, ED30-T400-1 VP, HS250-20/4;
- Concrete mixers 58146C, 58147C.

In July 2018, the company underwent mass layoffs of its working personnel. On 30 June 2019, the arbitration court declared the company bankrupt.

Zavolzhsky Motor Plant. The first technical task for the design of the diesel engine was received by the company in the late 1970s. It was planned to produce a turbocharged diesel engine with a cast-iron cylinder block with a capacity of 2.3 litres and a power of 80-90 hp. Over the past 15 years, the engineers created several different prototypes, conducted a number of tests as part of a car at NAMI proving ground, but the engine has not gone into production. Nevertheless, the idea of its creation was not forgotten and in 1993 the project on the development of a diesel engine on the basis of the produced perspective gasoline engine ZMZ-406 was launched. Later in the autumn of 1995, a two-litre 105 hp engine 406D.10 was tested, which served as the basis for the development of the engine ZMZ-514, which after the refinement of the cylinder head (GBTs) by Ricardo specialists, was put into mass production [6].

The first pilot batch of ZMZ-514 engines intended for GAZelle automobiles was assembled in 2002. But as early as 2004 serial production was stopped. The reason for this was the unstable quality of components and the difficulty of maintaining the accuracy of parts processing at the plant. Having carried out works on the refinement of the new engine, having changed the design of the block, rods, valvetrain timing chains and other parts in November 2005 the shop of small series of the enterprise has begun manufacture of diesel engines with an index ZMZ-5143 [7]. Due to the wrong priorities in the engine design, there were claims to the life of this combustion engine throughout its production.

Zavolzhsky Motor Plant upgraded the ZMZ-5143.10 engine by installing Bosch Common Rail fuel injection equipment to meet environmental standards and improve fuel efficiency and traction characteristics. The new ZMZ-51432.10 CRS engine became more demanding to fuel quality, and the cost of repairing its fuel equipment has increased significantly. Many drawbacks in this engine have passed from the old engine in the form of failures of valvetrain drives and high-pressure fuel pump, short life of the oil pump, impulses in the fuel line of the injection pump, cracks in the cylinder head.

The main reason for the decline in demand for ZMZ diesel engines was the Euro-5 emission standard, which was introduced on 1 January 2018. According to manufacturers' estimates, bringing these diesel engines up to Euro-5 (higher fuel injection pressure, the introduction of diesel particulate filters and more efficient catalytic converters, etc.) increases the final cost of the product only at the plant level by 1,000 - 1,500 euros, which will inevitably affect their demand.

A new plant as part of YMZ-Avtodiesel for serial production of engines of the new family was built and launched. This is one of the most advanced production facilities for diesel engines not only in Russia but also in Eastern Europe. Investments in the project amounted to 11 billion rubles, the estimated production volume is up to 50 thousand ICE per year.

The YMZ-530 engine is a new family of medium in-line four- and six-cylinder diesel engines with power from 130 to 330 hp with the potential to meet Euro-6 emission standard. Up to 400 modifications and configurations of engines with a high degree of unification have been developed. The model range was developed by the engineers of YMZ-Avtodiesel and GAZ Group with the support of the world leader in the field of transport engineering AVL List (Austria). The YMZ-530 engines are equipped with advanced design solutions for layout, control and operation of the main systems. Their production began in 2013.

DieSEL engine YMZ-534 is in-line four-cylinder, which capacity is 4.43 litres. The power range from 100 to 176 kW, and the torque from 420 to 784 N.m. The design uses: cast iron cylinder blocks, cast iron wet sleeves, oil nozzles cooling the bottom of the piston, connecting rods made of steel. The diameter of cylinders is 105 mm, and the steel crankshaft provides a stroke of 128 mm, which provides
the capacity of the internal combustion engine [8]. The engine has a “lower” camshaft located in the cylinder block (Cam-in-Block). The block head has 4 valves per cylinder.

The degree of localization of 530th series ICE components increases every year: in 2015 - 68%, in 2016 - 75%, in 2018 - 80%. GAZ Group has mastered the casting of cylinder blocks, turbo-compressors are manufactured by Turbotekhnika (formerly produced by German Schwitzer), production of pistons has been mastered in Kostroma, KAMAZ supplies crankshafts, and the camshaft is produced by the plant YAZDA, which is located next to YaMZ. They also prepare for the production of high-precision fuel-air pumps. It will produce 2000 bar instead of the usual 1000-1500 bar.

At present, the consumer is inclined to choose an engine which is reliable, efficient, easy to maintain, has high fuel efficiency performance. Due to the fact that the proposals of domestic engine builders are very limited, the scales are tilted towards numerous foreign manufacturers, which are present in the domestic market.

On the territory of the CIS, the factories of Belarus are especially notable in terms of their prevalence. The Minsk Motor Plant (MMZ) with its mass-produced engines due to their cheapness and ease of maintenance, which are in high demand in the post-Soviet space. This is the largest enterprise in Belarus, as well as the leading manufacturer of diesel engines among the CIS countries, it is ranked first in the number of engines for tractors and combines. The market share of this plant is more than 50% of the total fleet of tractors in the CIS. The main products of MMZ are diesel engines D-243, D-245 and their modifications with an in-line arrangement of cylinders and capacity of 4.75 litres. Their number and distribution have led to the fact that the consumer considers these internal combustion engines produced in Russia, but this statement is not true.

Cummins Inc. has localized its production in Russia in the Republic of Tatarstan by establishing a joint venture Cummins Kama to produce diesel engines with KAMAZ in Naberezhnye Chelny [9]. The Cummins “B” series engine assembly line with power from 140 to 300 hp and capacity from 4.5 to 6.7 litres was opened. Since March 2017, Cummins Kama has expanded its product range by launching assembly of L-series engines with a capacity of 8.9 litres and a power of up to 400 hp. Localization of this engine production reaches 60% of its cost.

Unfortunately, the production of Cummins “A” series engines with a power of 31 - 60 hp with a capacity of 1.4 to 2.3 litres and in-line 3- and 4-cylinder series "F" with a power of up to 160 hp with a capacity of 2.8 and 3.8 litres, which are in high demand in the market of light-duty cars, small tractors and municipal vehicles, the company does not plan to move to Russia in the near future. Besides, in the near future, such large foreign manufacturers as John Deere, Caterpillar, Deutz, Perkins do not plan to place their production of diesel engines in Russia yet, but negotiations continue with them [10-13].

At present, the main drawback for the organization of ICE production in Russia is the impossibility to manufacture components of the required quality. Manufacture of such parts for the valvetrain as piston rings, fingers, connecting rods, valves, springs, guide bushings, camshafts, gaskets and glands, causes great difficulties for domestic manufacturers due to high requirements to the quality of manufacturing of component base and ICE. In addition, there are major problems with the manufacture of parts made of aluminium alloys. Even the need for fasteners can be met by up to 50%, but only by “nonresponsible” fasteners. A separate problem is the lagging of Russian enterprises in a wide range of technologies for the production of complex billets by casting from high-strength cast iron and cast iron containing graphite, steel, as well as processing to strengthen the working surfaces of a wide range of parts by chemical-thermal, laser and plasma methods.

In recent years, a lot of attention has been paid to the provision of the agricultural, municipal and road construction vehicle market with Russian-made diesel engines at the highest level. Specialists of the Center of Agricultural Engineering of Central research and development automobile and engine institute NAMI carry out the work to identify the market demand and problem areas for the production of a range of diesel engines, necessary for the needs of the agricultural industry. Together with WDMA (German Engineering Association), a round table on “Development of Component Production and International Cooperation in Russia and the EAU Member States in Agricultural and Road Construction Engineering” was organized at the Agrosalon-2018 in Moscow. The event was attended by key
producers of agricultural, construction and road construction machinery and components in Russia and abroad. Together with the National Agency of Social Communications, work was organized at the Strategic Session of the Russian Engine Forum in 2018. A working group “Agricultural piston engine” of leading manufacturers and scientists was formed.

Figures 1 and 2 show the dependence of the engine power on its weight and the dependence of the engine weight on its capacity. The diagrams show the area of piston internal combustion engine parameters, which has an optimal combination of characteristics and is the most demanded by manufacturers of agricultural, municipal and road-construction vehicles.

**Figure 1.** Dependence of engine power and capacity.
4. Conclusion

When considering the power characteristics of internal combustion engines, it was established that manufacturers in our country need a range of reliable domestic diesel engines with a capacity of up to 4400 cc and a power of up to 150 kW. The analysis of trends and the current situation in the engine manufacturing industry and component base production for them has shown that along with the development of the family of ICE for certain types of vehicles, it is also necessary to develop the production of modern components and systems for them. In that case, machine-building in the Russian Federation will gain significant growth through the development of a considerable number of new advanced technologies. When organizing or localizing production, it will be necessary to pay attention not only to the reliability, efficiency and low noise of engines but also to their environmental friendliness in order to reduce the harmful impact on the environment. Therefore, one of the urgent technologies of the future on the ICE market will be the development and introduction of models operating on both mixed and biofuels and other alternative types of fuel.

Enterprises involved in serial production of diesel engines and components for them will have to master not only new technological processes but also modern methods, equipment and facilities for technical control to improve the quality of production and bring it to conformity with international regulations, requirements and standards. For this purpose, the enterprises to be established will need to employ highly qualified specialists, from workers to engineers and technicians. At present, an active search for partner organizations for these processes is underway. In addition, one of the conditions for consumers is the creation in the country of a widely developed and accessible network of technical support, service and timely delivery of spare parts.

With a proper approach to the problem considered in the work, joint discussion, search and implementation of solutions not only by manufacturers of component base and equipment for various purposes but also by government agencies, scientific institutions, educational institutions, it will be possible to get a quality and competitive product that will allow a breakthrough in the development of engine production.
domestic engine building, reduce the dependence on imports and provide conditions for the supply of Russian engineering products for export.

References

[1] Website of the Institute of Information Technologies and Computer Aided Design, Federal Information Fund of domestic and foreign catalogues of industrial products "Diesel engines of VSN series". [Electronic resource]. URL: http://xn--80aajzhcnfc0a.xn--p1ai/PublicDocuments/0703989.pdf (accessed 13.09.2019)

[2] Official website of the company Tulamashzavod [Electronic resource]. URL: http://www.tulamash.ru/catalog/4 (accessed: 13.09.2019).

[3] Official website of LLC "Chelyabinsk Tractor Plant - UralTRAC", review of products [Electronic resource]. URL: http://chtz-uraltrac.ru/catalog/categories/1.php (accessed: 13.09.2019)

[4] Official website of LLC "Chelyabinsk Tractor Equipment Plant", overview of products [Electronic resource]. URL: http://www.chzt.ru/index.html (accessed date: 13.09.2019)

[5] Official website of the company "Vladimir Motor-Tractor Plant", review of products [Electronic resource]. URL: http://www.vmtz.tplants.com/ru/company/review/ (accessed: 13.09.2019)

[6] Internet edition of “Za rulem” publishing house [Electronic resource]. URL: https://www.zr.ru/content/articles/7772-molodoj_dizel_zhelajet_poznakomitsa/ (accessed 13.09.2019)

[7] Official website of ZMZ, review of products [Electronic resource]. URL: http://www.zmz.ru/Produktciiya/Dvigateli_ZMZ/Semeystvo_ZMZ51410_Dvigatel_ZMZ_5143210_CRS_s_sist (RU) (accessed: 13.09.2019)

[8] Official website of ZMZ, review of products [Electronic resource]. URL: https://www.ymzmotor.ru/catalog/ymz-530/ (accessed: 13.09.2019)

[9] Official website of "Cummins" company, product review, diesel engines [Electronic resource]. URL: https://www.cumminsengines.com/engines (accessed: 13.09.2019)

[10] Official website of John Deere, product overview, industrial diesel engines [Electronic resource]. URL: https://www.deere.com/en/industrial-engines/ (accessed: 13.09.2019)

[11] Official website of the company "Caterpillar", product overview, industrial diesel engines [Electronic resource]. URL: https://www.cat.com/en_US/products/new/power-systems/industrial.html (accessed: 13.09.2019)

[12] Official website of the company "DEUTZ Russia" review of products [Electronic resource]. URL: http://www.deutz.ru/website.ru.html (accessed: 13.09.2019)

[13] Official website of the company "Perkins", review of products, industrial diesel engines [Electronic resource]. URL: https://www.perkins.com/en_GB/products/new/perkins/industrial.html (accessed: 13.09.2019)