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DESIGNS AND DEVELOPMENT OF RUSSIAN SCIENTIFIC SCHOOLS IN THE FIELD OF CROSS-COUNTRY GROUND VEHICLES BUILDING

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ABSTRACT

In the paper reviewed the main development trends of Russian scientific schools in the field of all-terrain vehicles development. Presents original designs of all-terrain vehicles, created by domestic enterprises. The tendencies of Russian all-terrain vehicles development are considered.

Keywords: all-terrain vehicles, running gear, exploitation characteristics, computational and experimental technology.

INTRODUCTION

The beginning of intensive scientific researches and design developments of the domestic cross-country vehicles refers to 1918 and is connected with creation of Scientific Automobile Laboratory in the USSR.

The development of scientific and design schools and industrial production facilities (capacities) for creation of cross-country vehicles in pre-war and post-war years led to the forming to the beginning of the 1990th of the entire research and production discipline on a scale of the Russian Federation, uniting the industry research institutes (NAMI, NATI, VNIITransmash, TsAGI), higher education institutions (BMSTU, NNSTU n.a. R.E. Alekseev (Gorky Polytechnic Institute n.a. A.A. Zhdanov), MADI, MAMI, MSIU (VTUZ-ZIL) etc.), plant design offices (GAZ UKER (Design & Experimental Works Directorate), SDB ZIL n.a. V.A. Grachev, SKBM (Special Machine Building Design Bureau) of Kurgan etc.), plants' pilot and serial productions (GAZ, ZIL, UAZ, VAZ, URALAZ, ZZGT (Zavolzhsky Crawler Vehicle Plant) of Zavolzhye, Kurganmashzavod, Ishimbaytransmash, Kirov Plant, Rubtsovsk Machine Building Plant, CTZ), the Scientific Research Engineering Institute of the Ministry of Defence of the Russian Federation (21 - Bronnitsy, 38 - Kubinka, 15 - Nakhabino), the SET institute of the MIA RF (Figures 1-3). The creation of cross-country vehicles and training of specialists in this area for the benefit of economy and security of the country were the major national objectives.

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The created designs satisfied the needs of individual owners, environmental and extractive industries, power structures and rescuers.

The scientific & technical and personnel capacity served for emergence of numerous small facilities producing cross-country vehicles: from single "hand-mades" to the series of several hundred samples per year. The most known enterprises of this type are: "Arctictrans", "Trecol", "NAMI-service", "ZVM", "Transport", "SpetsTech", "Bronto", "Avtoros", "OKB VTS", "Petrovich", "Staratel" etc.

The main embodiments of the cross-country vehicles can be classified by the running gear type: wheeled (including the ones with the extra-low pressure tyres), caterpillar (including the ones with the band caterpillars and the pneumatic caterpillars with the "aerol" running gear), step (including the wheel-step ones), vehicles with partial balancing by the air pillow, rotary screw ("screw-propelled vehicles"), snowmobiles (with ski and air pillow); by the transmission type: mechanical, hydraulic, electric; by the vehicle weight parameters: from extra light to super heavy road trains; by the purpose: cargo, passenger, cargo-passenger, technological [1].

The design concept of the cross-country vehicles is defined by pre-determined geographical reference. However, the common operational properties, aimed at safety (in particular environmental) and energy efficiency provision, for all types of the cross-country vehicles are: high mobility (support passability (flotation) and profile passability, amphibiousness, rapidity, steerability (controllability) and stability, independence), reliability, habitability, environmental friendliness (first of all in terms of exposure on the support base).

With growth of the cross-country vehicles' market the requirements for ecological properties become first-priority. The main large consumers can be arranged by extent of reduction of requirements to the ecological properties of the cross-country vehicles in the following order: The Ministry of Natural Resources and Environment, the Ministry of Agriculture, the Ministry of Transport, extractive industries, the Ministry of Emergency Situations, the Federal Security Service, the Ministry of Defence. Besides, tough operation conditions, numerous emergency situations, connected with people deaths and loss of valuable cargo, define safety as one of the major operational properties. In this regard, the national scale task is to create Regulations on safety of the cross-country vehicles, which can be developed on the basis of the "Green Car", Technology platform with the involvement of all interested parties: manufacturers, customers, design office personnel and industry research institutes.

Figure-1. Designs & development of Russian scientific schools in the field of cross-country ground vehicles building.

Figure-2. Designs & development of Russian scientific schools in the field of cross-country ground vehicles building.

Figure-3. Designs & development of Russian scientific schools in the field of cross-country ground vehicles building.

THE MAIN DIRECTIONS FOR THE DEVELOPMENT OF THE CROSS-COUNTRY

The main directions for the development of the cross-country vehicles are completely agreed with the List of critical technologies of the Russian Federation and Priority directions of development of science, technologies and equipment in the Russian Federation (Decree of the President of the Russian Federation dated 07.0711 No. 899): energy efficiency and safety increase by design improvement by use of new materials and energy resources; intellectualization of power trains,

transmissions and running gears; unmanned transport creation; economically actual vehicles' development.

The solving of the abovementioned problems assumes development of the scientific disciplines and conducting of the researches based on the theoretical developments, bench and natural experiments.

One of the effective methods of prospective design creation is application of innovative calculation and experimental technologies.

The modern theory of the cross-country vehicles' driving is oriented first of all to optimization of the running gears' design, power supply plant characteristics' definition and transmission type selection. The achieved mobility parameters of the cross-country vehicles prove high efficiency of the existing scientific developments.

Further development of the driving theory assumes intellectualization of the cross-country vehicles [2, 3] by use of the onboard information and control systems (OICS).

Let us consider, for example, the creation algorithm of intelligent system of power flow distribution between the individual running gears that contact the support base (Figures 4, 5):

a) Assume that the running gear type for the cross-country vehicle is theoretically substantiated and the design parameters are optimized (modern theory allows to describe the running gear behavior mathematically and to confirm the efficiency parameters by experimental researches on benches of "soil channel" type for different operating conditions);

b) A transmission (of mechanical, electric, hydraulic types) and OICS are created, allowing to control the power supplied to individual running gears, - modern assemblies, units and electronic resources allow to implement it from the technical point of view [4];

c) According to the results of experimental researches in the "soil channel" for possible cases of rectilinear and curvilinear motion with different number of "passes", as well as for soil conditions (sand, bog, snow of different types, etc.), we will determine the required supplied power for obtaining the optimum characteristics of energy consumption, free traction, environmental impact on the base. I.e. the running gear and drive "are trained" by set of operational conditions with use of the neural network technologies. Thus, the database required for the optimum power distribution will be obtained [5].

d) Further, the OICS will "recognize" driving conditions and implement the optimum power distribution on each running gear for the real object using sensors (sensors of vehicle angular position, of drive angular speed, of accelerations and angular speeds of the vehicle, force measuring (dynamometrical) wheels, quick-response penetrometers, etc., including the inertial systems) and neural network technologies.

At the same time, there is a method of vehicles' creation, which basis is, first of all, the economic efficiency. It is the developed technology of the wheeled vehicles of high passability (WVHP) based on the chassis of the series all-wheel drive vehicles with a load-carrying capacity starting from 2 tons (Figures 6,7) [6].

The conducted analysis of traction and dynamic properties of the series vehicles and possible layout solutions showed the efficiency of use of the base chassis during the WVHP development.

Such approach has a number of advantages in comparison with development of the WVHP "from scratch":

a) reduction of the WVHP development time and cost;

b) reduction in expenses for the manufacturing organization: the base chassis (assembly kit) is serially manufactured on a factory assembly line, and re-work into the WVHP can be performed in the repair factories or factories specializing in installation of different equipment on the series chassis;

c) possibility of application of the serially manufactured modules ("crew buses", vans) and technological superstructures installed on the base chassis with the minimum improvements;

d) use of the existing spare parts' supply network and existing repair facilities for the WVHP maintenance;

e) minimum time and resource expenditure for driver retraining;

f) providing the base chassis manufacturers with additional orders.

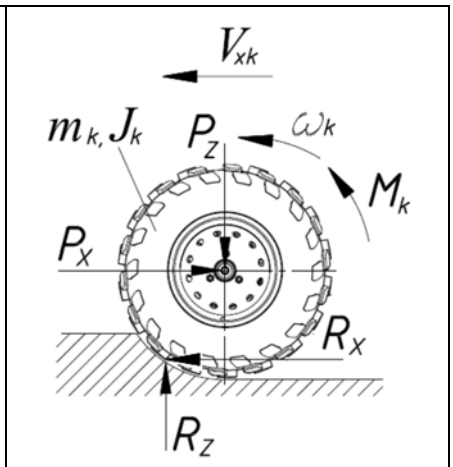
At the moment, efficiency of such approach is confirmed by numerous simulation computer experiments with use of the vehicle dynamics simulation mathematical modeling and demands creation of prototypes, as well as conducting of wide-range experimental researches [5].

The basic parameter defining the WVHP flotation (support passability) is the wheeled running gear soil pressure, which is decreased, with other things being equal, with increase of the wheel dimensions (diameter and width). In this regard under the WVHP creation, determination of rational dimensions of the wheeled running gear - the low-pressure tyres - is of special importance.

The outer tyre diameter selection is defined by the following conditions: diameter shall be as large as possible for providing larger contact area with the support surface and the road clearance, and upon that, the WVHP height shall not exceed 4 meters so that it could drive under bridges and overhead roads. At the same time, the tyre outer diameter increase leads to decrease of the steering wheels' maximum rotation angles that may be compensated by the WVHP wheel span increase or switching to another turning scheme (for example, by means of the articulated frame). The tyre width increase influences positively the flotation, however it can lead to the WVHP driving resistance increase, and it also limits the maximum angles of the wheel rotation.

It is necessary to consider that installation of the extra large wheels on the base chassis can result in need of additional reducers to be introduced into the WVHP transmission to preserve the acceptable traction parameters, which complicates the design and contradicts the accepted concept.

The tyres of the 1500 … 1800 mm outer diameter and 650 … 1100 mm width correspond to the abovementioned conditions. In Russia and in the CIS the tyres of such dimensions are serially produced for installation on agricultural vehicles. For example, the VL-41 tyre produced by OJSC "Voltyre-Prom" (Volgograd) has the 1722 mm outer diameter and 728 mm width; the SB-1 tyre produced by OJSC "Dneproshina" (Ukraine) has the 1650 mm outer diameter and 1052 mm width. For decrease of the transmission load the agricultural tyre tread can be improved.



$$\begin{cases} m_k \cdot \dot{V}_{xk} = \varphi \cdot P_z - P_x; \\ J_k \cdot \dot{\omega}_k = M_k - (f_w + \varphi) \cdot P_z \cdot \dfrac{V_{xk}}{\omega_k}. \end{cases}$$

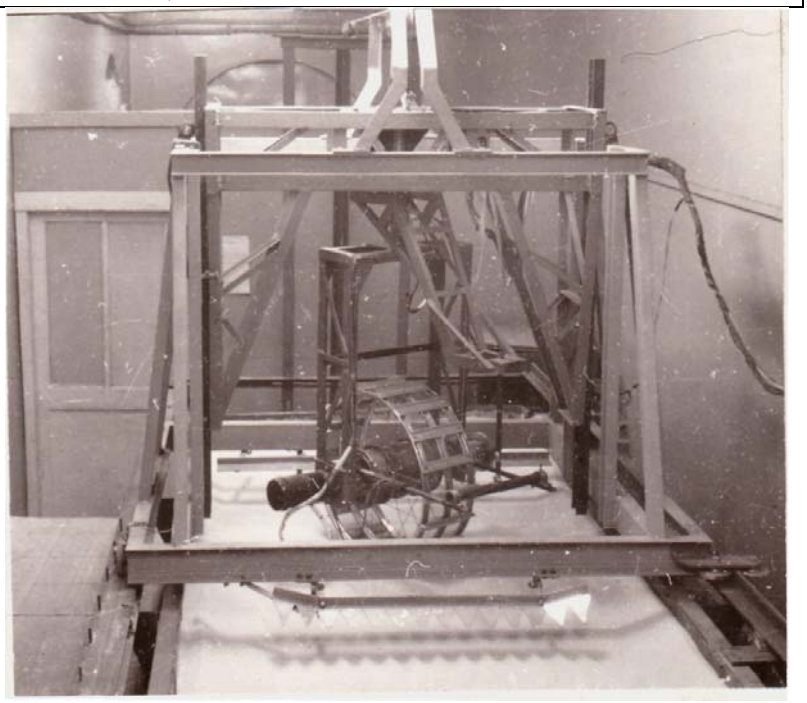
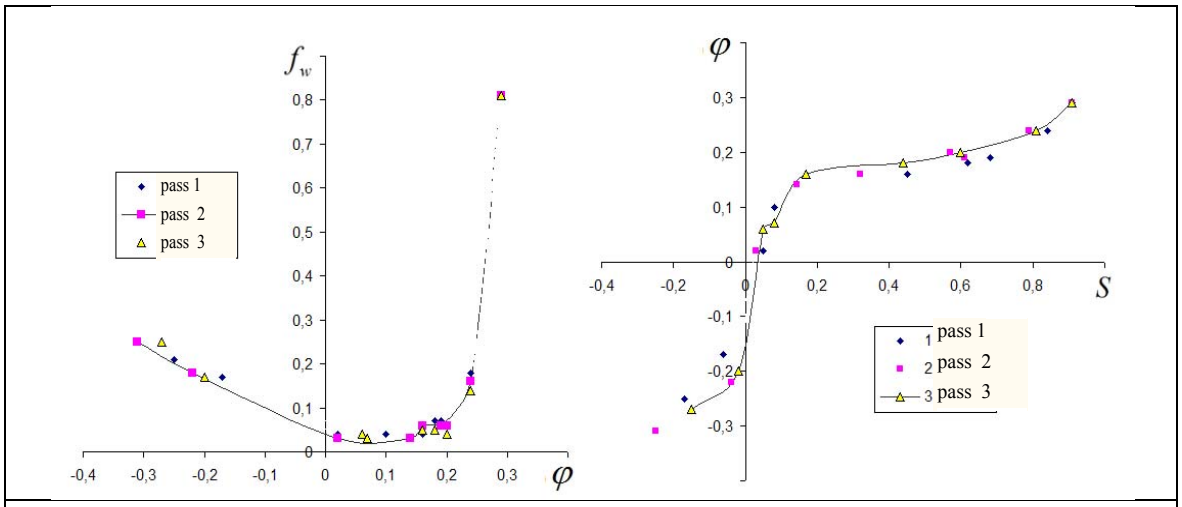


Figure-4. Experimental and theoretical researches of traction and power characteristics of the running gears.



$$m_C \cdot V_{X_c} = 2 \cdot \sum_{i=1}^{3} P_{X_i} - (m_C \cdot g \cdot \sin(\alpha) + P_{KP})$$

$$I_{ki} \cdot \omega_{ki} = M_{K_i} - (1 - S_{Bi})(fw_i + \varphi_i) \cdot R_{Z_i} \cdot r_{Ko}$$

$$m_{K_i} \cdot a_{X K_i} = \varphi_i \cdot R_{Z_i} - P_{X_i} - m_{K_i} \cdot g \cdot \sin(\alpha)$$

$i=1..3.$

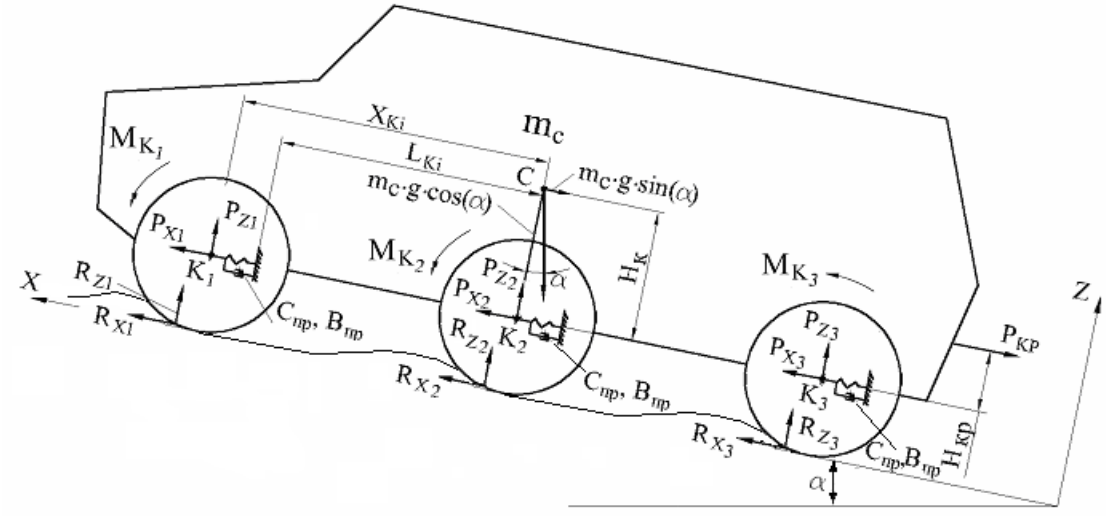


Figure-5. Theoretical researches of traction and power characteristics of the cross-country ground vehicles.

It should be noted that specified modifications of the base chassis design leads to load increase of the transmission elements, suspension system, load-carrying system, WVHP control systems and, therefore, to reduction of the vehicle service life in general. Increase of the time share of the vehicles' operation in severe road conditions and in cross-country conditions also leads to the WVHP service life reduction compared to the vehicles with the base chassis. In this regard the vehicles' amortization period shall correspond to the cross-country vehicles, but not to the basic vehicles.

For implementation of this technology the series all-wheel drive vehicles' chassis produced by the main domestic plants were selected as basic ones: GAZ-3308, Ural-4320, Kam AZ-6560. By now, the WVHP prototypes (more than one hundred units in total) have passed the tests, in particular in the Yamal Peninsula conditions, and the under-control operation at the facilities of OJSC "Gazprom" [7].

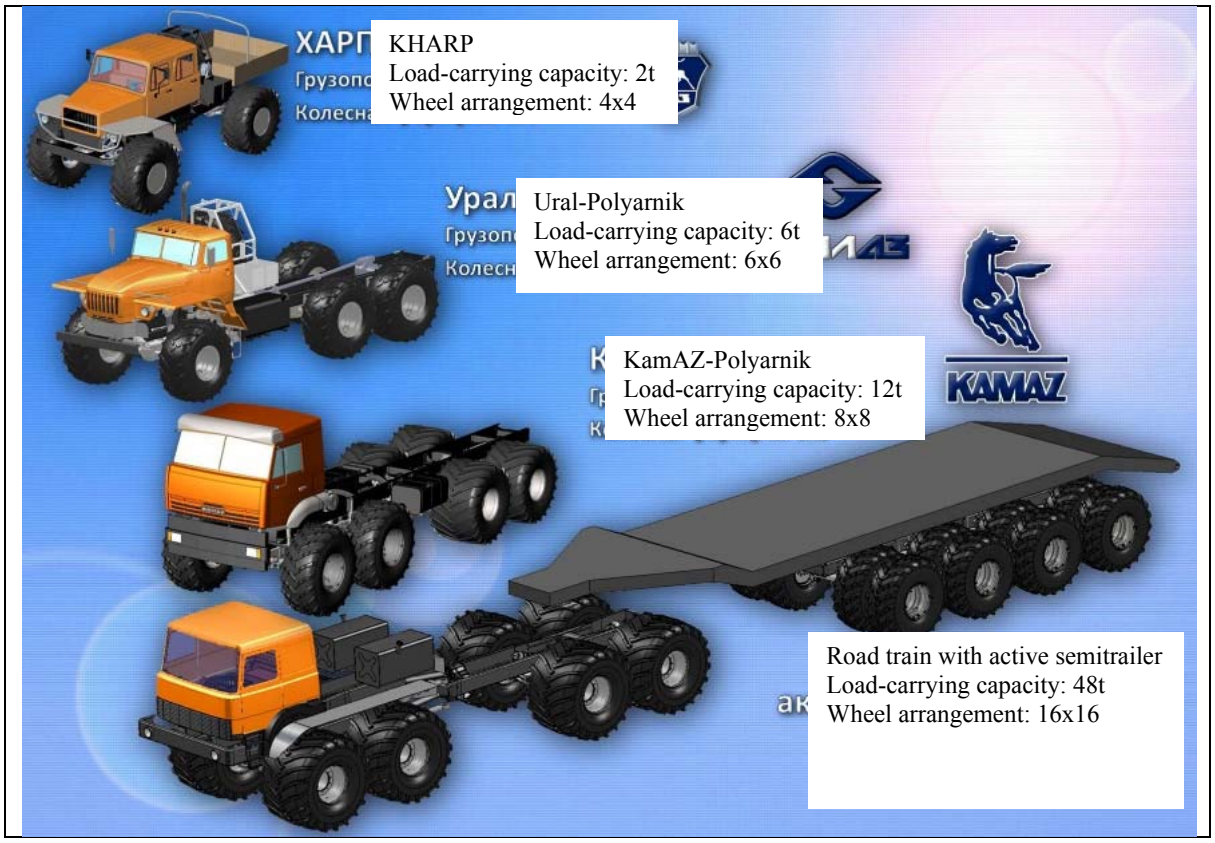


Figure-6. Technology of the wheeled vehicles of high passability based on the series all-wheel drive vehicles' chassis.

Figure-7. Technology of the wheeled vehicles of high passability based on the series all-wheel drive vehicles' chassis.

The conducted researches and tests of the developed samples showed that when driving on soil and snow roads the WVHP have approximately the same technical and operational parameters as such of motor transport, at the same time the WVHP off-road driving is possible at the medium speeds providing the acceptable economic parameters of freight and passenger traffic.

There are activities connected with creation of the articulated vehicles (Figure-8), which are under development at the moment.

Figure-8. NAMI-0127 carrier with the articulated frame.

The main peculiarity of such design is the turning method which consists in change of the front and rear section folding angle by their forced turning. Such design solutions allow to create the WVHP with high cross-country properties and at the same time keep them as road users, unlike the WVHP families presented in Figure-6.

Figure-9 presents the WVHP with 6x6 wheel arrangement and articulated frame, which is the road user.

Figure-9. Wheel vehicle of high passability with the articulated frame.

CONCLUSIONS

In the conclusion, it should be noted that creation of new cross-country vehicles is not possible without the specialized centers (analogs of NICIAMT in different climatic zones) for research, testing and design setting-up, as well as training in driving methods and operation rules.

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