Development of vehicles to be operated on rough roads and in off-road conditions

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Abstract. The article presents the results of a study on the demand for goods vehicles along rough roads. It analyzes the main existing approaches for driving on surfaces with non-hard coatings. The main problems are associated with either roads or existing vehicles to be operated in having no hard-surface roads territories of the Russian Federation. The main directions to develop universal vehicles to be used on rough roads are defined.

1. Introduction

The development of the territory is an important task for many regions of the Russian Federation. One of the key issues of improving the comfort of living is the availability of hard-surface road. This problem is not urgent in developed countries, since the territory of Great Britain and France are usually provided with hard-surface roads. In Japan, only 89% of roads are hard-surface ones though in this country the density of roads is the highest showing 3.250 km of roads per 1.000 km²; while in France -1.932 km and in the UK -1.733 km [1]. In the Russian Federation, this indicator is very low, only 87 km per 1.000 km²; 70.6% of which are hard-surface roads.

Statistics for the Russian Federation shows that the length of highways is 1.66 million kilometers, while only 1.16 million kilometers are hard-surface roads, and 7.3% of the total highway length is unsurfaced roads of federal, regional or inter-municipal importance. According to statistics for 2016, the share of rural settlements of the country that do not have surfaced roads for communication with the federal or local road network amounts to 28.2%. This number is high enough to determine the relevance of the research topic. Developing vehicles to be operated on rough roads and agricultural roads to delivery personnel and cargo is of great importance for the development of territories. Therefore, the development of such vehicles is a very important task. The purpose of the study is to find low construction cost technical solutions for movement on rough roads. The study of this problem is connected with economic issues, for example, the lack of hard-surface access roads to small rural settlements results in additional expenditures on transportation along unsurfaced roads, which are 3-4 times higher than using roads with better surface [2]. Approximately 50 thousand rural settlements are not provided with year-round hard-surface road communication that causes a decrease in the economic development of the territory and migration of the population to more developed parts of the country.
2. All-wheel Drive Vehicles
The cheapest implementation of the possibilities of delivering cargo to hard-to-reach areas is an all-wheel drive vehicle; it is much cheaper than air transport and driving on roads without a hard surface is possible [5].

All-wheel drive trucks are type of design of the chassis and transmission of a vehicle, where the supply of torque to all wheels is used. Four-wheel drive is indicated by an axial formula, where the first number is the number of wheels, and the second number is the number of wheels with drive gear. Typical and rare axial formulas are 2х2, 3х3, 4х4, 6х6, 8х8, 10×10, 12×12, and even 24×24. Where absolutely unique 2x2 are motorized single-axle tractors for coupling with equipment, three-axle schemes 3x3 are three-axle special trucks, and 24-24 are multi-axle 12-axle transport systems for heavy loads. The most typical drive gears, commonly used and really efficient, are 4x4, 6x6 and 8x8 drive trucks. In case of heavy loads, drive gears of trucks according to the scheme 8x6 [3] are used. This type of power supply is often the modernization of the vehicle in order to increase a number of characteristics - passability and carrying capacity. Therefore, a 6x6 three-axle cargo all-terrain vehicle is taken as a basis, in which the axle is driven into the axle spacing. Such axle can be lifted (pusher or sloth) and controlled. Using a 6x6 base vehicle makes a drive gear with power supply to the first drive axle, although there are modifications without any first drive axle. In general, these improvements are often performed at auto body shops according to the order of the customer, but sometimes it is the factory type of vehicle, developed exclusively from scratch. The second drive gear, through which the cardan passes, must have a notch in the middle part; for this reason, these vehicles are not always all-terrain vehicles, but only vehicles with off-road capabilities, or characterized by high stability of operation in conditions of slippery surfaces. They are road heavy tractors, cargo evacuators, or utility-harvesting main-line machines.

3. Screw-propelled Vehicles
The use of all-wheel drive vehicles is limited on rural roads and cultivated land roads. In such cases, tacked vehicles are used. But there is an even more efficient technology allowing moving on this type of non-solid surface. Vehicles based on the use of an Archimedean screw were called screw-propelled vehicles [4, 5, 7]. Such vehicles can move on flooded soils, clay, swamps, fields, snow, etc. There are various movement organization schemes using rotating screws. For example, we can speak of several patents registered in the 60s of the twentieth century.

Figure 1. Diagram 8x6, where 1 - power unit; 2 – clutch; 3 – gear box; 4 – transfer case; 5 – power takeoff shaft; 6,8,11 – wheel drive axles; 7,9,10 – cardan transmission.
Figures 2 and 3 present screw-propelled vehicles to move on ground or snow [6].

**Figure 2.** Becker’s Snow Pusher (1960). Californian Alvin Becker patented the original vehicle on the basis of screw-propelled vehicle. Becker’s idea was to create an independent module, equipped with two parallel screw rotors, driven by a common engine. The module can be attached to a sled or even to a skier. [4]

**Figure 3.** Kazmer’s screw-propelled vehicle (1966). To improve the excellent passing ability of screw-propelled vehicle, Kazimir Kazmer came up with an incredible idea. Kazmer’s strange vehicle had 4 independent screws, located at angles of 90 degrees; there was screws cross or a square under the vehicle. The speed was low, but it could move on hard-surface roads.

Nowadays, only one model of a screw-propelled vehicle is mass produced in the world. It is MudMaster, which is produced by Australian company Residue Solutions. Serial production is implemented individually according to an individual order, and this universal platform is used to install various ordered by the buyer equipment. Only about 20 units of equipment are produced per year.
There are several major disadvantages of a screw-propelled vehicle; primarily, low vehicle speed and high fuel consumption; the main disadvantage is the impossibility of movement on hard-surface roads, as either screws or roadways are damaged. Therefore, low-boy trailers are used for their transportation along roads with a hard coating. In general, the cost of both the operation of such vehicle and vehicle itself is rather high that is practically inapplicable for the conditions of the remote areas of the Russian Federation.

4. Proposed Scheme
Taking into consideration all the factors and disadvantages of each traffic across hard-to-reach areas pattern, it is proposed to design vehicles using several transportation technologies at once. The proposed scheme is based on a combination of all-wheel drive car scheme using screw supports at the bottom of the car.

The simulation of a similar vehicle being able to go along various surfaces with a non-hard coating was performed. The system of technical solutions capable to compensate disadvantages of the geometric patency of technology including a wide range of applications has been proposed. BABR system of
technical solutions includes: Front Mounted Hob Modules to compensate angles of approach; Main Pushing Hob Modules to compensate angles of departure; Perpetual Screw Cardan and Active-Passive Rotating Dies of four types to compensate road clearance preventing getting on the axles; Walking Telescopic Pushers to overcome the ice-coated superelevations. Implementation of Alternative Bearing of Towing Capacity provides vehicles with opportunity to bear on the ground of any kind, water and air, that results cumulatively in phenomenal vehicle floatation. Cab suspension provides ability to overcome fordable depth up to 3 meters (Figure 5).

5. Conclusion
The main conclusion of the article is determination of the direction of development of new vehicles to be operated on rough roads and in off-road conditions to overcome the problem of supplying remote settlements, carrying out agricultural work during spring season of bad roads and so on. Solving such problems will increase the economic efficiency of the development of remote territories of the Russian Federation.

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