SOME ASPECTS TO BE CONSIDERED DESIGNING ENVIRONMENTAL FRIENDLY ALL-TERRAIN VEHICLES

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Abstract

While creating all-terrain vehicles (ATVs) for off road operation, peculiarities of natural climatic conditions especially ones of the far Northern areas where the subsoil is permafrost are often ignored. One of the most common human interferences in the nature of the North is damage to vegetative cover by transport vehicles in the summer time, resulting in thermokarst formation. More than 70% of top-soil cover destruction of the tundra ecosystem is caused by the existing ATVs. The regeneration of the destroyed soil will take decades and even hundreds of years. The issue of ecological balance conservation is closely related to the well-being of 26 native peoples of the North.

The contradiction between the transport exploitation of the far North and the necessity to conserve the ecoregions must be solved by creating on-land all-terrain motor vehicles with the reduced impact on the bearing surface.

The current stage of development of all-terrain vehicles and, in particular, wheeled vehicles intended for use in severe road conditions can be characterized by a variety of their types and lay-out solutions and, in particular, by different steering arrangements. The choice of the steering arrangement for transport machines designed for applications on soft soils must be made by consideration minimized negative impacts on the bearing surface, providing the tangential stresses in the contact of the wheel with the soil do not exceed the soil resilience values. Therefore, the assessment criteria of curvilinear motion of such ATVs can be the minimized tractive forces necessary to perform a turn.

From the standpoint of energy consumed by turning and impact on the bearing surface, the wheel steering arrangement can be regarded as the most favourable, and the worst arrangement is differential.

Keyword: *transport, terrain vehicles, severe areas operation, environmental impacts, wheel steering*

Speaking about negative environmental impacts of motor vehicles, we first of all mean the engine exhaust emission as the most severe pollution, as well as the noise. In recent time effects of motor vehicles on environment has been regarded as applicable to the full life cycle of a product, comprising processes of production, use and recycling. While creating all-terrain vehicles (ATVs) intended for off road operation, peculiarities of natural climatic conditions especially ones of the far Northern areas where the major part of subsoil is permafrost are, as a rule, ignored. The subsoil there contains 60 - 90% of permanently frozen water in the surface layer of 20 - 30 meters deep. The thaw of permafrost under the influence of various factors results in formation of thermokarst, hummocks, hollows and soil movement.

One of the most common human interferences in the nature of the North is damage to vegetative cover by transport vehicles in the summer time. More than 70% of top-soil cover destruction of the tundra ecosystem is caused by the existing ATVs. One kilometre journey of a tracked vehicle with ground pressure of about 50 kPa would result in the destruction of 10 km² of the tundra surface. The channels dug by the tracked carrier would turn into streams within several days which two or three years later would form thermokarst erosive gullies. Even lightest tracked carriers destroy the melted surface layer of the tundra. The natural regeneration of the destroyed soil and vegetative cover will take decades and occasionally, hundreds of years. The issue of ecological balance conservation is closely related to the well-being of 26 native peoples of the North whose traditional economy includes reindeer raising, fishing and hunting. Moreover, the area of the Russian North alone acts as a producer of almost 1.5 billion tons of oxygen annually. Its vital importance within the global climate system has not been appreciated yet at its true value.

The contradiction between the transport exploitation of the far North and the necessity to conserve the ecoregions must be solved by means of the wide employment of scientific and technological achievements and, in particular, creating on-land all-terrain motor vehicles with the reduced impact on the bearing surface.

This is conditioned by the fact that the other environmental protection activities, such as banning the use of ATVs in the summer, designing route maps showing the most sensitive to human interference areas, revegetation, are far from being sufficient while the intensity of exploitation of the Northern regions is growing. Therefore, besides having off-road capabilities, ATVs must comply with rigid environmental requirements and, in particular, requirements with regard to minimized negative impacts on the bearing surface. At the same time, common environmental requirements for road vehicles must not be forgotten. As long as it does not matter where the harmful emissions occur, in any case, they make their contribution to the common atmospheric pollution. Excessive noise disturbs the local species, many of which have been registered in the Red Book, driving them off their habitat and very often causing reduction of their populations.

Minimized negative environmental impacts of ATVs are mostly determined by bearing capacity $\boldsymbol{q_s}$ and slip resistance $\boldsymbol{\tau_s}$ of the bearing surface. When designing ATVs and considering the most common types of terrain, as a reference, it is possible to take the following limit values of practicably achievable pressures and tangential stresses in the contact of the mover with the bearing surface:

- for clay and loamy soils: $\boldsymbol{q_{MAX}} \leq 10$ - 30 kPa, and $\boldsymbol{\tau_{MAX}} \leq 60$ kPa,
- for sandy soils: $\boldsymbol{q_{MAX}} \leq 30$ kPa, and $\boldsymbol{\tau_{MAX}} \leq 38$ kPa,
- for marshland: $\boldsymbol{q_{MAX}} \leq 10$ - 15 kPa, and $\boldsymbol{\tau_{MAX}} \leq 10$ -14 kPa,
- for snow: $\boldsymbol{q_{MAX}} \leq 20$ kPa, and $\boldsymbol{\tau_{MAX}} \leq 10$ - 20 kPa.

These values of pressure on the bearing surface are quite correspondent to the generally accepted environmental requirements applied to ATVs used in summer on soft soils of the Northern areas providing they use the same route once or twice within the season; the soil pressure from on-land vehicle movers must not exceed 20 kPa.

The current stage of development of all-terrain vehicles and, in particular, wheeled vehicles intended for use in severe road conditions can be characterized by a variety of their types and lay-out solutions and, in particular, by different steering arrangements. Among conventional steering arrangements three main types can be distinguished: wheel steering (by means of turning the wheels of one or more axles), articulated steering (by means of changing the angle between the front and rear halves) and differential steering (by means of varying the relative rate of rotation of the right and left side wheels. The combination of steering arrangements is also possible but it is not applied very often for its design complexity. The choice of the steering arrangement is determined by the specific operating conditions of the concrete vehicle, the overall dimensions of the wheeled mover, the required maneuverability of the vehicle, the complex design of the steering mechanism, etc.

The choice of the steering arrangement for transport machines being designed for applications on soft soils must be made by consideration minimized negative impacts on the bearing surface providing the tangential stresses occurring in the contact of the wheel with the soil do not exceed the soil resilience values. Therefore, the assessment- certification of barriers manufactured nationally or imported in accordance with the requirements of the Product Certification System for Building (РДС –10-232);

criteria of curvilinear motion of such ATVs can be the minimized tractive forces necessary to perform a turn.

In order to evaluate one or the other steering arrangement from the standpoint of required tractive forces, as a quite conventional case, we can consider the case of the turn with radius ***r*** of machines with the four axles, all-wheel drive and wheel steering, articulated steering and differential steering. To simplify the calculations let us presume that in all cases the axles are equidistant and the distance between them is equal to ***a***, the wheelspan of all machines is the same and equal to ***b***, the normal wheel load is the same and equal to $\boldsymbol{G_K}$, the radii of all wheels are the same and equal to $\boldsymbol{r_K}$, the turning is stable and even with minimum speed performed on the firm horizontal bearing surface. For the setups with wheel steering and articulated steering the driving mechanism of all wheels is differential, the friction in the differential mechanisms is ignored.

- for turning with the steerable wheels:

$$P_K = G_K \left(f + \frac{2a}{\zeta}\varphi\right) \qquad \text{– regardless of the wheel slip,}$$

$$P_K = G_K f + \frac{1}{8} K_Y \left(\frac{a}{r}\right)^2 \qquad \text{– allowing for the wheel slip,}$$

- for turning with the articulated steering:

$$P_K = G_K \left(f + \frac{4a}{\zeta}\varphi\right) \qquad \text{– regardless of the wheel slip,}$$

$$P_K = G_K f + \frac{1}{5} K_Y \left(\frac{a}{r}\right)^2 \qquad \text{– allowing for the wheel slip,}$$

- for turning with the differential steering:

$$P_{Kmean} \approx \left(f + \frac{6a}{\zeta}\varphi\right) G_K \qquad \text{– regardless of the wheel slip,}$$

$$P_{Kmean} = G_K f + \frac{5}{4} K_\delta \left(\frac{a}{r}\right)^2 \qquad \text{– allowing for the wheel slip.}$$

Substituting the numerical values for the vehicle turning with 10 m radius and values

$\boldsymbol{\alpha}$ = 2;
$\boldsymbol{\varphi}$= 0.7;
$\boldsymbol{f}$ = 0.022,

we obtain:

$\boldsymbol{P_K} = \mathbf{0.057}\ \boldsymbol{G_K}$ **–** for turning with the steerable wheels,
$\boldsymbol{P_K} = \mathbf{0.092}\ \boldsymbol{G_K}$ **–** for turning with the articulated steering setup,
$\boldsymbol{P_K} = \mathbf{0.127}\ \boldsymbol{G_K}$ **–** for differential steering.

The given expressions are confirmed by the experiments conducted with the wheeled machine 8x8 type that have shown that the differential method of turning involves 50% deterioration of energetic properties of maneuverability in comparison with the conventional turning.

From the standpoint of energy consumed by turning, as well as from the standpoint of impact on the bearing surface, the wheel steering arrangement can be regarded as the most favourable, and the worst arrangement from that point of view is differential.

As long as coefficient of side-slip resistance $\boldsymbol{k_y}$ depends on the design of a concrete tyre (height and width of the profile, orientation of the reinforcing threads, layers, etc.), width of the rim, air pressure in the tyre and wheel load, it is more convenient to use formulae ignoring the wheel slip for designing purposes.