FUNDAMENTAL PRINCIPLES OF THE CROSSING (PASSING) CAPACITY FOR WHEEL SPECIAL MILITARY VEHICLES

Cornel ARAMĂ*, Andreea ARAMĂ**

*"Henri Coandă" Air Force Academy
**freelancer

Abstract: *In mountain corps, the combat surprise of the enemy is made, first of all, by mobility. For this, when the horses are not used, the access of vehicles in difficult access areas is sometimes vital because it is a surprise for the enemy, the attacks of special troops of mountaineers can be surprising or the mountain artillery companies can supply their troops better.*
This is the reason why my doctoral research has focused on the influences of ground features on the capacity of crossing, especially in the cold period of the year, because most of the time mountain rangers' corps take action in this kind of conditions.
The tests were made in real conditions, during the missions and the field exercises, in tough climatic and atmospheric conditions, exclusively in mountains in winter.

Keywords: *mobility, stability, crossing capacity, precessional transmission, wheeling characteristic.*

1. THE PASSING CAPACITY OF WHEEL VEHICLES

The passing capacity is the possibility of vehicles to circulate off-road and on bad or bumpy roads and to pass different kinds of obstacles.

The highest requirements are for off-road vehicles (cars and trucks). The passing capacity is characteristic of military heavy vehicles, which, apart from the possibility of moving on the unpaving or bumpy roads, have to be capable to circulate into natural ground, in any meteorological conditions and to be capable to pass some obstacles like unevenness, grooves, fords, snow-drifts etc.

The passing capacity, the basic factor that influences the stability of mountaineers' vehicles, depends on some dynamically and geometrical characteristics and it is influenced by the projection solutions that were adopted for global organization and by the constructive solutions of some parts of vehicle. The stability is not only reliability, but also a practical applying and tactical operative assembly of measures and studies which guarantee the success of the intervention. Briefly, the increasing of the stability of off-road vehicles is the main idea of the paper and the stability is seen not only as fighting stability, but also as global stability.

2. THE INFLUENCE OF THE CONSTRUCTIVE SOLUTIONS ON THE PASSING CAPACITY OF THE VEHICLE

Some constructive and dimensional particularities were solved logical during projection, so, the tendency is to increase the passing capacity according to the requirements and the destination of the vehicle. Some of the most important solutions will pointed out here, in this paper because I have noticed them during mountaineers' field exercises.

The increasing of the number of tires and their position. The moving capacity on bumpy roads and on soft ground is improved if the tire pressure on the ground is low. This is done by increasing the number of tires and their size or by using more than two axles. The solution of disposing the wheels one by one (in tandem) is more favorable than the solution of the two twin wheels on the same part of the axle; the rolling resistance decreases because of the lesser width of wheel track and the adherence of the rear tires increases because they pass on the trace left by the front wheels. That is why it is advisable the width of the front track to be the same with the width of the rear track.

The use of independent wheel suspension. It is necessary that the road normal reactions for drive wheels, in case of moving into soft or uneven ground, to vary as little as possible in order to use a drive force as much as possible because their increase could make the wheel to dip and to skid on the ground. So, the independent wheel suspension has to be used.

The use of drive front axle. Sometimes, in off-road conditions, the military vehicles with a large crossing capacity meet perfect vertical obstacles (balustrades, slopes etc.). The crossing capacity depends on the type of the drive wheels because the vehicle must have front drive wheels or the temporary possibility to connect them, the rest of the time the front wheels being used only for steering and suspension systems.

Favorable construction solutions adopted for the transmission parts. The possibilities of moving in soft ground are increased by hydrodynamic transmission because the drive force is smoothly applied to the wheels. In this case, the slippage of the tires is eliminated. This is one of the reasons why the hydrodynamic transmissions are used for military vehicles.

3. THE OPTIMIZING OF THE TRANSMISSION SYSTEM BY USING PRECESSIONAL TRANSMISSION [3]

A way of developing transmissions is the drawing up of new types of mechanical drive lines. The harmonic transmission has appeared this way.

Cinematically and constructively speaking, the harmonic transmission has many tangent points with the planetary transmission. It is one of its modifications. The flexibility of one of the pinions is the main difference.

The harmonic transmission is compact, has high lifting capacity and assures high cinematic precision and the possibility of sending power into watertight medium – the basic advantage of harmonic transmission.

The disadvantages are: low reliability of the flexible element (and low reliability of transmission in general), reduced capacity to work on high speed and some technological difficulties.

These disadvantages do not occur in case of the precessional planetary transmission. This was known before the harmonic transmission but it was not used too much because of the inadequate using of internal evolventic gear. This gear does not take into consideration the influence of the particularities of the spherically-spatial movement of satellites to the transmission function.

The increased multiplicity of precessional transmission (till 100% teeth pairs in gear simultaneously) provides a high lifting capacity and a cinematic accuracy and moreover low overall size and mass. Other advantages could be: large cinematic possibilities, high efficiency, low acoustic emission, the possibility of sending the movement into watertight medium and the possibility of solving all technological problems.

In conclusion that is why the precessional transmission has large possibilities to be used in mechanical engineering.

Depending on the structural scheme, the precessional transmissions are two basic types: K-H-V and 2K-H. Starting from these two basic types, a large range of constructive solutions with large cinematic and functional possibilities can be drawn up. They could have the possibility to work as reduction or multiplicity gear, differential, auto break system etc.

The gear-train diagram of precessional transmission K-H-V (look to the figure 1 a) consist of four elements: planet carrier *H,* satellite wheel *g*, central wheel *b* and body.

The satellite wheel *g* and the central wheel *b* are into internal gear and their teeth generating lines cross each other in one point; this point is named center of precession.

The satellite wheel *g* is placed on the planet carrier *H* which is built like an inclined crank. Its central axle together with the axle of central wheel forms an angle θ. The inclined crank *H,* because of its rotation, send to satellite wheel *a,* a spherically-spatial movement as against the ball joint from the center of precession.

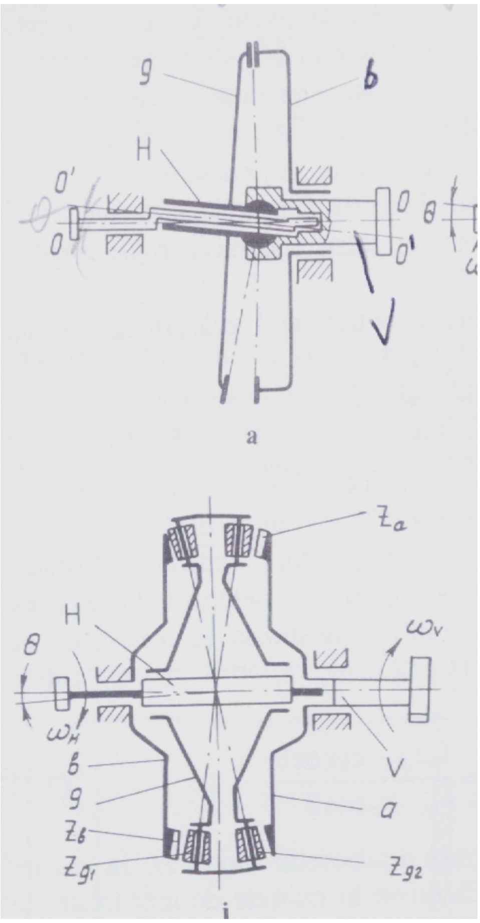

Fig. 1 The precessional transmissions

The precessional transmission 2K-H (fig1i) has higher performances mainly in cinematic plan. It consists of the satellite wheel *g*, with two crown gears Z_{g1} and Z_{g2}, which are in gearing with two central wheels: one is mobile *a* and the other one is immobile *b*.

Both types of precessional transmissions have not been used in automotive industry yet, but, considering their performances, they can be successfully applied for differentials, gear boxes, reduction boxes, drive wheels, particularly for "off-road" vehicles.

Implications of changing the classical drive lines (planetary or/ and rigid axis mechanisms) with precessional transmissions.

Straight implications:

The global mass of transmission (vehicle) decreases → m ↓; If it is necessary the conversion ratio of power unit could increase → i ↑;

Compact transmission that bring about increasing of protection level;

The transmission efficiency increases → η_{tr} ↑; The possibility to use precessional transmission as drive wheels, differentials and high watertight gear and reduction boxes.

Indirect implications:

The wheel torque increases because: $M_r = M_e \cdot i_t \bullet \eta_t$;

The wheel tangential force increases because: $F_r = M_r/r$;

The traction force increases because:

$$F_t = \frac{M_e \cdot i_t \cdot \eta_t}{r} \qquad (3.1)$$

The general dynamic of vehicle increases because of mass decreasing;

It is easier for the vehicle to be used on the stable area of traction (adherence) characteristic mainly for the most difficult moments, starting and low speeding moments, because driveline connection is done without jerking (it is a feature of the precessional transmission), so, without high sliding; this thing is very difficult or impossible to be done by classical transmission.

4. EXPERIMENTAL RESEARCHES TO ESTABLISH THE CROSSING CAPACITY OF MILITARY VEHICLES

The necessity of obtaining of an as good as possible stability of military vehicles for fulfilling the combat missions at optimal parameters implies the optimization of tire-road interaction. The process is more complex in off-road conditions as it usually happens in mountain areas.

This is the reason why my doctoral researches has focused on the influences of ground features on the capacity of crossing, especially in the cold period of the year, because most of the time mountain corps takes action in this kind of conditions. Also, wooden growth has the a lot of importance, because it can block the access of vehicles in some areas, many times the military fighting against the actions of external agents because of the low protection level of some components of the body of vehicles.

The tests were made in real conditions, during the missions and the exercises field, in tough climatic and atmospheric conditions, exclusively in mountains in winter. The results were very interesting, because by using them we can improve the capacity of crossing of military vehicles that were checked: DAC 665 T, DAC 887 R and R 16215 FA. The geometrical parameters, the functional parameters of the capstan and the static pressure of the tyres of testing trucks were established. It was noticed that the dates obtained by measuring the specific pressure on the ground, for the front right tire of the testing trucks, are at the low limit for the values established for the trucks. This is good for military vehicles because they are used mainly "off-road". The aim of these preliminary researches was to establish if the trucks, after an intensive exploitation, observe the initial working parameters.

In the second part of the test, the limit crossing capacity for snow pack was established. We noticed an important difference between the results obtained on light (fresh) snow at low temperatures (-20^{0}C↔-5^{0}C) – the first situation – and the results obtained on wet snow with temperatures around 0^{0}C – the second situation. The wet snow has the characteristic to create tracks easily. In an extreme situation, this can cause the blocking of the wheel in the holes which are created, especially when the tire does not have a ground adapted profile (tractor profile). The wet snow has a higher resistance to advancement. So, the driver has to be very careful not to hasten the wheel, because, if this happens, the wheel could get stuck.

Because, during missions and field exercises, camps have to be installed in wild places with abundant underwood, the studies have to be focused on the possibilities of vehicles to pass through these types of areas, mainly for body down level. Because there are not any estimated perfect methods of access possibilities through underwood wild areas, we have to draw up new methods to estimate the passing capacity for forest exploitation and military interventions, but also to go deep into the existing methods taking into account, as an original item, the level of protection of the military vehicles subassemblies. If the tanks and armored personal carriers, from other reasons, NBC protection and the necessities of floatability and tightness, had a good level of protection, the military trucks, mainly the ones used by Mountain Corps, are neglected, in many cases unwanted events taking place and causing their immobilization from minor reasons which could have been avoided by using very simple methods.

The justification of the practical necessity to elaborate a calculation procedure of the protection level for vehicle subassemblies when passing through woods or through a general wild zone: During personal activity as vehicle exploitation and maintenance officer, I encountered many situations, mainly during missions and field exercises, with the relative “fragility” of the exposed parts of the vehicles used during these activities (R 16215 FA, DAC 665 T, and DAC 887 R). I refer to the inferior part of the chassis because, in a few situations, some vehicles, very well adapted to the difficult conditions in leaf-bearing forests but also in coniferous woods from the mountain areas where the mountaineers work, became suddenly non-operating or it was impossible to force them.

The method used was that of taking minute photos of vehicles, insisting upon the “delicate” parts. The components already protected (headlights with protection grid, the radiator with a special shield, etc) and the ones which, by constructive solidity, could support, when necessary, the weight of the vehicle (springs, axles, gear boxes, switchgear distributing boxes …) were not taken into account. We insisted upon plastic and rubber components and the wiring of the electrical equipment.

We studied almost the whole car park and we noticed the most numerous deteriorations which could be the result of the described situations.

The classical method of drawing up the felling coefficient

- ➢ This method refers only to the capacity of vehicles in general to pass through wild areas, but it does not offer us some details about the protection level of subassemblies situated in an exposed position of the vehicle body.
- ➢ There have been arranged three underwood routes :

I zone: maximum thickness for the most of undergrowth: 95 mm;
II zone: maximum thickness for the most of undergrowth: 70 mm;
III zone: maximum thickness for the most of undergrowth: 50 mm.

- ➢ The formula for felling coefficient: $m = d_c / G_t$, where:

G_t – full load of testing vehicle [t];
D_c – maximum thickness of the most of undergrowth from testing zone [cm].

Testing Conditions

Table 1

Preparation of vehicles	Fuel and oil full load, indicated tire pressure
Load conditions	The testing will be made in three situations: body weight, partial load and full load
Testing place	Babarunca-Grohotis zone
Temperature	Aprox. 12^0C
The minimum length of arranged route	Aprox. 3,5-4 length of trucks
Underwood density	Aprox. 45 pieces/m^2
The distribution in percents of underwood thickness	10% maximum thickness 25% medium thickness 65% below 30 mm thickness
The vehicle working conditions	The gear box in first speed, reduction gear box on "force" speed, the engine speed at maximum power

Felling Coefficient *m* for DAC 887 R

Table 2

Load [t]		I zone	II zone	III zone
body weight	13,5	0,70	0,51	0,37
partial load	16	0,59	0,43	0,31
full load	21	0,45	0,33	0,23

Drawing up a formula that can show the protection level of vehicles subassemblies as well as possible [1]

➢ There are some factors that are to be taken into account when suggesting a formula for the protection level of a vehicle :

- the vulnerable surfaces which need 1,2,3,4 protection level;
- the importance of the necessary protection level;
- the number of 1,2,3,4 level components and the surfaces covered by them;
- the position of unprotected parts: front, behind, lateral and inferior (down level);
- level of self-protection because of constructive solidity;
- if the components could be protected from working position;
- level of self-protection because of the basic material of the components.

The Suggested General Formula

$$K = 100(N_1 \cdot S_1 \cdot \alpha_1 + N_2 \cdot S_2 \cdot \alpha_2 + N_3 \cdot S_3 \cdot \alpha_3 + N_4 \cdot S_4 \cdot \alpha_4) \quad (4.1.)$$

where:

K – exposure level; it shows to what extent the vehicle can be affected by the physical agents of the environment; as we can deduce from the formula , the ideal value of K is 0.

N – the number of subassemblies which need the protection level 1,2,3 or 4.

S – the surface covered by the subassemblies with a certain protection level; it is a part of the total surface where, due to the intervention of the environment against it , the vehicle can be damaged because of the deterioration of one of those elements. We can also use S without the index number in order to indicate the whole exposed surface and then $S = S_1 + S_2 + S_3 + S_4$;

α – the necessary protection level coefficient; it has got a certain value, one found intuitively for every protection level.

The general formula can be used for every exposed surface and that's why we can calculate a global exposure level. The inferior part of the vehicle body is considered the most important one because it includes the most "delicate" components which have a direct influence on the durability of the vehicle. That's why I'm going to introduce the experimental results found when calculating the exposure level regarding the inferior part of the vehicle body for DAC 665 T, R 16215 FA and DAC 887 R. One of the first conclusions is that these vehicles do not function properly regarding the way some components were located (projecting deficiency) and regarding the careless way these components were set and/or taken care of.

In order to apply these theories, we'll introduce the results obtained when calculating the protection level for the vehicles mentioned before. Because the inferior part of the chassis is very important, we will find the exposure levels for this part of the vehicle body.

5. CONCLUSIONS

As we could see, the first part pointed out the importance of basic constructive solutions adopted by off-road vehicles for the increasing of crossing capacity, the way it was shown within my research. In the second part it was proved the importance of applying of new kinds of mechanical drive lines, as it is the precessional transmission which could improve the adherence between tire and road by increasing driver car handling.

The final conclusion is that a good theoretical understanding of practical phenomenon, which could be met during fields exercise, can be realized by detail analyzing of wheeling (adherence) characteristic.

In short, the necessity of obtaining as good a stability as possible of military vehicles to fulfil the combat missions at optimal parameters implies the optimization of tire-road interaction, seen as a mechanic system.

The process is more complex in off-road conditions as it usually happens in mountain areas because we know that the dynamic performances of vehicles, especially for military vehicles used off-road, are limited by road adherence (grip conditions).

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