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THE MODEL OF TERRESTRIAL VEHICLE WITH INERTIAL PROPULSION

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ABSTRACT

The work presents the physical and mathematical model of a vehicle with inertial propulsion. On unequipped way a vehicle with wheels and with classical propulsion moved with great difficulties. On economical basis is not founded in all situations to built communication way on any pieces of land. A universal vehicle, able to go on any pieces of land, their complexity and costs are not prohibitive can offer an alternative for this cases.

1. Introduction

The terrestrial vehicles with self-propulsion moved because of a force between driving part (wheel, caterpillar chain) and way (road, rail, cable), named driving force. The engine transmits to driving part the movement and an effort corresponding of the necessary driving force. This driving force is efficient for the movement of the vehicle if only the friction force between driving part and way is greater as the necessary traction force. This particularity creates problems in the cases of the uneven way or with small adherence. A pulled vehicle, even from a low power tractor device, can be moved on any way. For example a car pulled from a horse pair moved on any uneven way, mostly inaccessible for same car equipped with his own engine.

Our natural environment has evolved under the influence of more natural laws, one of his is the adaptation at the environment and the selection of the best adapted. If we observe the existent movement media in the nature, the entire world of the beings has not selected the wheel as movement device. From the simple to the complex being we found as terrestrial movement possibilities the crawl or the stepping (in this last we include and the jumping). On uneven way the vehicles with self-propulsion are disadvantageous opposed to pulled vehicle and opposed to any moving beings. Only after very long time we shall build devices similar to moving organ of the beings and technologies for his manufacture. Up until then, on any equipped or unequipped way (asphalt, soil, grass, marsh, mud, snow, uneven or smooth) a good alternative better as the wheel offers the vehicles with inertial propulsion. At these vehicles the propulsion force appears not between wheel (or moving device) and way, but developed inside of the vehicle and bring this directly in movement. The way takes part in this action only as friction contact surface, without any moving being from nature can not move.

2. The principle and the modelling of the vehicle.

As inertial propulsion device can be chosen the generator of the one-direction forces based on the centrifugal force. This propulsion device can be easily adapted on the mostly used engines from today, respectively the rotational thermal engines. The assembly engine-propulsion device can work or in vertical or in declivous plane. These two possibilities will be analysed lower.

From begins we put the working hypothesis:

- the way is considered stiff, respectively his deformations change not essential the model; this fact was tested from the authors on theoretically and practically model;
- the friction between vehicle and way is necessary, the friction has an important role in movement and must be used correct and exactly;

- the inertial maximal force must not lift the vehicle from the way;
- we consider the movement oneself, not the performance as at rally.

2.1. Inertial propulsion device in vertical plane.

Figure 1 shows a construction of the vehicle. The way is considered stiff, the movement is not possible on vertical direction. On the vehicle with total mass *M*, two masses m rotated in against senses with angular speed *ω*, on coplanar circular trajectories from radius *R* and produce inertial forces. The mass *m* can have different angular phases, in principle adjustable.

For the dynamic equations we chose as origin of the rotation the vertical axis to up for the mass from left, the horizontal axis to right for the mass from right. Because the angular phase s relative between the mass *m*, we consider that only mass from right have an angular phase α, positive upper horizontal axis, negative under the axis.

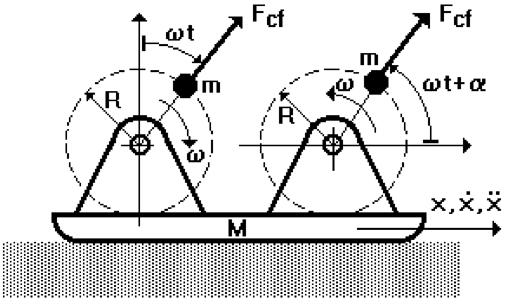


Fig. 1. Inertial propulsion in vertical plane with parallel axis.

Between vehicle and way exist friction, the friction coefficient has the form [4]:

$$\mu = \mu_o e^{a|\dot{x}|} \tag{1}$$

where μ_o is the adherence coefficient, *a* is an influence coefficient, $|\dot{x}|$ is the module of the instantaneous speed. The movement equation of the vehicle is:

$$M\ddot{x} + \mu \begin{Bmatrix} Mg - \\ -2m\omega^2 R \begin{bmatrix} \cos(\omega\ t) + \\ + \sin(\omega\ t + \alpha) \end{bmatrix} \end{Bmatrix} \operatorname{sgn}(\dot{x}) =$$
$$= 2m\omega^2 R[\sin(\omega\ t) + \cos(\omega\ t + \alpha)] \tag{2}$$

In (2) the total mass *M* includes and the mass *m*. The function "*sgn*" amount to "the sign of..." and $g = 9{,}81 ms^{-2}$.

In order to apprehend better the movement of the vehicle, we consider that the angular phase α is null and the movement begins at the moment *t*=0 from the positions as upper. At *t*=0 the inertial force on the mass from left reduce the pressure of the vehicle on the way and the inertial force on the right mass pulls this to right. This effect decreases in time ad *t=T/4*, *T* = the period of the movement, *T=2π/ω.* Now the inertial force on the right mass reduces the pressure on the way and the inertial force on the left mass push the vehicle forward. Hereinafter, at *t=T/2* the left mass increases the pressure on the way and hereby the friction force. The pushing force to back of the right mass can not move the vehicle. Same action appears at t=*3T /4,* but the left and right mass change their role. In conclusion, on the first half of the period of the circular movement appear propulsion forces to forward (to right in our example), greater as the friction forces, on the last half period appear propulsion forces to back with same values as to forward but the friction forces are greater. The vehicle has two different actions on one period: moved forward with a certain distance on the first half of the period and bides on the last half or, if the centrifugal forces are greater, moved forward with a certain distance on the first half of the period and moved back with a littler distance on the last half. The propulsion to right is possible for certain values of the mass *m*, angular speed *ω* and radius *R*. If the maximal centrifugal forces are greater as the minimal friction forces (inferior limit) and lift not the vehicle (superior limit), the vehicle can be moved in one certain direction. The

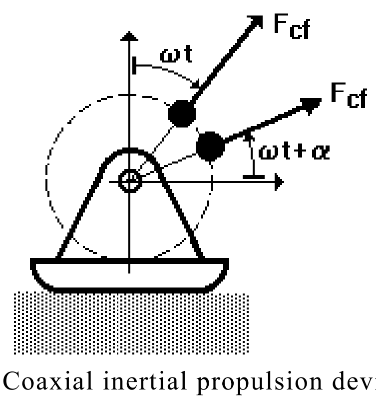


Fig. 2. Coaxial inertial propulsion device in vertical plane.

movement is not continuous. In one period the vehicle goes forward on certain times and bides on another times or goes forward and backward with different distances, backward littler as forward. This periodically movement repeated at each period.

An another variant of the inertial propulsion is to see in the figure 2. The mechanically complexities are greater as in the anterior case but the vehicle is compact.

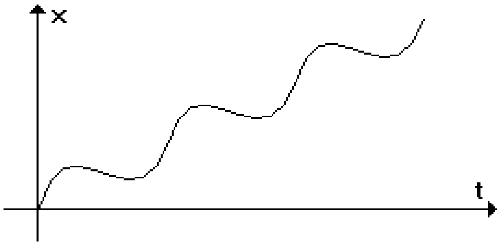


Fig. 4. Typically form of the position **x** as function of the time.

The equation (2) solved heavy on the analytically way [6], we prefer the numerically methods. But we give not the solutions for this case because this propulsion has certain disadvantages. If the friction quotient between vehicle and way is not constant along of the way or the way is uneven, the parameters of the propulsion device must be continuous adapted at the different working conditions. The adaptation consists in the adequate values for the centrifugal force (different mass *m* or different radius *R* but easier through the change of the angular speed ω even during of the movement) and in the adequate value for the phase angle α, very difficult to make. This last adaptation is unconditional necessary in order to have invariably the best movement parameters as speed and power.

2.2. Inertial propulsion in declivous plane.

The propulsion device is assembled in an all-angle plane at the angle α, figure 3 [2]. The movement equation of the vehicle is given from

$$M\ddot{x} + \mu\begin{bmatrix} Mg - \\ -2m\omega^2 R\cos(\omega\ t)\sin(\alpha) \end{bmatrix}\mathrm{sgn}(\dot{x}) = \\ = 2m\omega^2 R\cos(\omega\ t)\cos(\alpha) \quad (3)$$

It is easy to demonstrate that for the value of the angle α given from

$$\alpha = artctg(\mu) \quad (4)$$

the propulsion force F, figure 3, has the littlest value.

The solution of the equation (3) obtained easier on numerical methods [1], [3], [5] and we have chosen this way. The results give the law of the movement (position $x(t)$, speed $v(t)$ or $\dot{x}(t)$, acceleration $\ddot{x}(t)$ as functions of the time) and the values of the power $P(t)$ during of the movement.

$$P(t) = \mu\begin{bmatrix} Mg - \\ -2m\omega^2 R\cos(\omega\ t)\sin(\alpha) \end{bmatrix}\cdot|\dot{x}(t)| \quad (5)$$

where μ comes from (1).

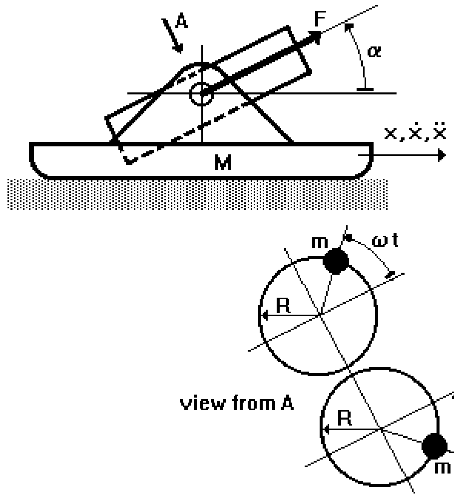
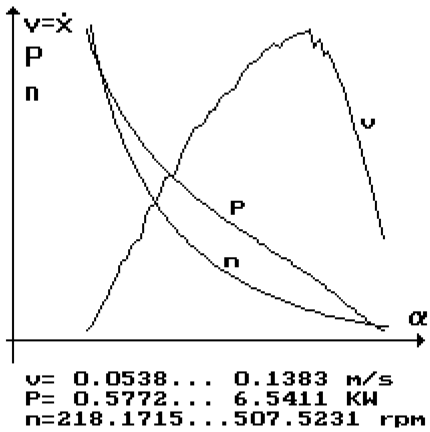


Fig. 3. Inertial propulsion in declivous plane.

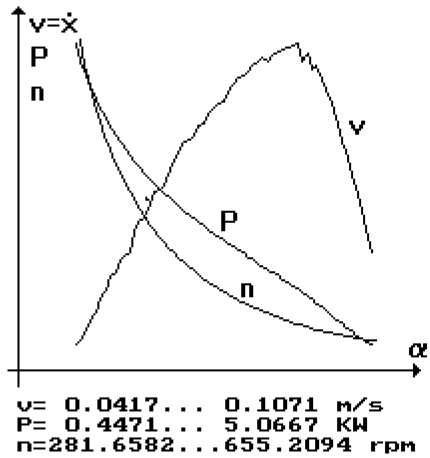
In opposite with the formula (4) the maximal effect is not for from this given value of the angle α, the surveys on the model show another results.

The figure 4 shows a typically form of the law of the position, $x(t)$. The influence of different factors on the movement laws is presented in figure 5. We have chosen $M = 5000\,Kg$, quotient *a=0* (Coulombian friction), angle $\alpha \in \left[10^o \cdots 70^o\right]$. The values of the rotation speed *n* in r.p.m. ($n = 30\omega/\pi$, ω = angular speed in rad/sec) are determined as maximal values, dependent from α, in order to maintain the vehicle on the way

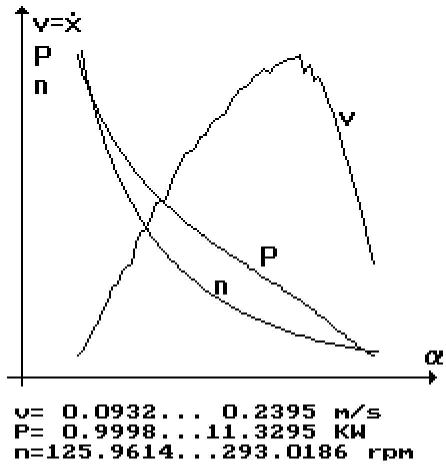
$$2m\omega^2 R\cos(\alpha) \le Mg \qquad (6)$$



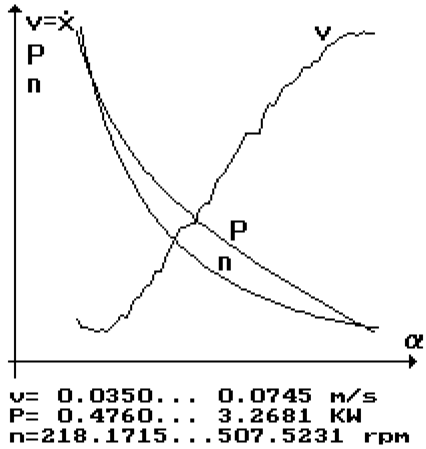
R=0,5 m; m=100 Kg; μ_O=0,2;



R=0,3m; m=100 Kg; μ_O=0,2



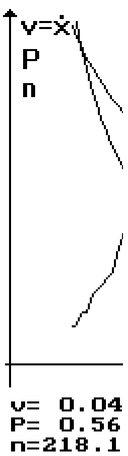
R=0,5 m; m=300 Kg; μ_O=0,2;



R=0,5 m; m=100 Kg; μ_O=0,1;

Fig. 5. The laws of the movement in different conditions

From figure 5 is to see that the friction between the vehicle and way influences in large measure the efficiency of the movement, but at great power. For same centrifugal force (propulsion force) the efficiency is greater for greater mass *m* and radius *R* and sometime at lower rotation speed *n*. The influence of the exponent of the friction *a* is to see in the figure 6. We have chosen a negative value, like for really dry friction.



m=100 *Kg*; *R*=0.5 *m;* $\mu_0 = 0.2$

Fig. 6. The case *a= -0,4.*

3. Another specifications.

The vehicle with the propulsion device in declivous plane has more advantages. It is possible to change two parameters during of the movement: the rotation speed *n* and the angle α. The modify of the value for the angle α has the same effect as the modify of the phase angle for the anterior propulsion mode and his values influence in large measure the efficiency of the movement, see figure 5 and 6. If the vehicle need go back, this fact is possible through the corresponding values of the angle α. Difficult is the change of the movement direction. In order to make this fact, the propulsion device can be movable around of the vertical axis and this possibility directs the propulsion force in the desired direction. A better solution consists in two propulsion devices, synchronised and phased, independent movable around theirs vertical axis. In this case the vehicle can be rotated even on the spot.

4. Vehicle with friction dependant from one way.

The contact surface between vehicle and way can have friction forces dependant from one way. As example can be chosen a system from more wheels with independent suspension, with free forward movement and obstructed to backwards. In this case appear little friction forces forward (rolling friction) and great friction forces backward (sliding friction). The figure 7 shows the results for R=0,5 m, m=100Kg, a=0, $\mu_O = 0{,}2$ backwards and $\mu_O = 0{,}01$ forwards.

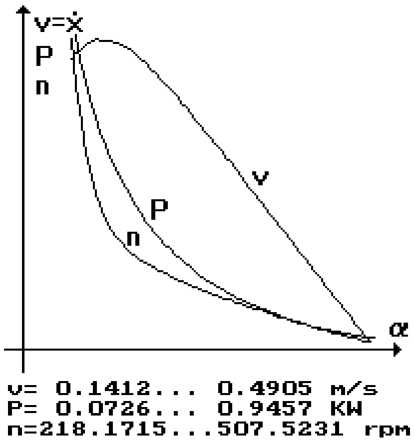


Fig. 7. Vehicle with friction forces dependent from one way

The ratio speed / power is very advantageous and the maximal effect appears for little values of α, in other words the propulsion forces appear on the movement direction.

The disadvantage of this vehicle consists in the impossibility to go back only through the change of the angle α. The change of the direction can be made similar to upper vehicle.

5. Conclusions.

The vehicle with inertial propulsion represents a good alternative on uneven way. The construction is relative easy, without transmissions, gearbox etc., the propulsion device can be coupled directly at the engine. The vehicle needs in return greater power and offers a very jerky movement. This last characteristic makes impossible to place a driver on board, the driving can be made only from distance through remote control. Such vehicle can be driven without constructions modify from a way on another, from asphalt on sand or soil, from marsh on grass or snow but can not pass over obstacle. The speed is little but the possibility to go on each pieces of land make from this vehicle a universal vehicle on any unequipped way.

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