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DYNAMIC ANALYSIS OF MOVEMENT OF FIGHTING VEHICLES

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ABSTRACT: In article the method of dynamic analysis of movement of a fighting vehicle is considered. On the example of movement of the tank across, rise and descent from height the power, kinetic energy, speed and time of movement are determined.
Keywords: dynamic analysis, movement, fighting vehicle, power, kinetic energy, speed, time.

INTRODUCTION

In the kinematic analysis of movement of the mechanism the structure and geometry of links of the mechanism is considered, operating forces on links of the mechanism aren't considered.

In case of dynamic analysis of movement of the mechanism two problems are solved.

The first task – the force analysis of the mechanism. Purposes of the force analysis:

1) Determination of the unknown external forces operating on mechanism links;
2) Determination of forces of response in kinematic couples;
3) Equilibrating of mass of the mechanism.

The second task – dynamics of movement of the mechanism. Purposes of dynamic analysis: 1) determination of necessary power for execution of the required movement of the mechanism or the machine; 2) determination of distribution laws of necessary power for execution of the required operation;
3) Determination of performance coefficient and movement of the mechanism or machine under the influence of external forces.

1. MODE OF MOVEMENT OF THE MACHINE

Research of dynamics of movement of the machine consists in the analysis of movement of the machine under the influence of known driving forces and resistance forces. Dynamic analysis is necessary for support of the required movement of the machine.

In case of study of movement of the machine in case of action of the given forces all operating forces are replaced with links using the force on the given link. In such a way the task of dynamics of movement of system of all moving links is provided to the task of dynamics of movement of one given link. Such link is called as a link of coercion of forces and weight or a point of coercion of forces and weight. For example, in fighting vehicles as a point of coercion of forces and weight the point of the center of gravity of the machine is accepted.

The given point is affected by two specified forces:
F_h – the given driving force, N;
F_q – the given resistance force, N.

Force F_h performs work A_h, equal to the work performed by all driving forces or creates power N_h, equal to the power of the machine created by all driving forces.

The specified power is determined by a formula:

$$N_k = \sum_{i=1}^{k} N_i \; ; \qquad (1)$$

where N_k – the power created by the specified force or brought moment, W;
N_i – the power created by force or the moment enclosed and brought to i to a link, W.

The specified power is defined by the following expression:

$$N_k = F_k \, v_k; \qquad (2)$$

where F_k – value of force specified to a point of corecion, N;
v_k – motion speed of a point of coercion, m/s.

Summary time of movement of the machine expresses the following equation:

$$T = T_r + T_u + T_v; \qquad (3)$$

where T_r – running start time, time of increase of speed from zero to average normal speed of the machine;
T_u – time of the set movement, motion speed of the machine fluctuates about average normal speed;
T_v – runout time, modification time of speed of the machine from average normal speed to null value.

Change of kinetic energy for the machine expresses the equation:

$$A_h - A_q = \sum_{i=1}^{k} \frac{m_i v_i^2}{2} - \sum_{i=1}^{k} \frac{m_i v_{oi}^2}{2} \; ; \qquad (4)$$

where m_i – the mass of i of the material point, kg;
v_{oi} and v_i – initial and finite speeds of i of the material point, m/s.

Apparently from the equation (4), during running start the condition is satisfied:

$$A_h > A_q; \; v > v_o. \qquad (5)$$

During running start kinetic energy of the machine increases.

During the set movement the speed of the machine doesn't change or periodically fluctuates near average normal speed. In this the period operation of driving forces is equal to operation of resistance forces:

$$A_h = A_q; \; v = v_o. \qquad (6)$$

During the set movement an increment of kinetic energy of the machine equally to zero.

During runout the following condition is satisfied:

$$A_h < A_q; \; v < v_o. \qquad (7)$$

During this period the kinetic energy which is saved up during running start is spent.

2. DYNAMIC ANALYSIS OF MOVEMENT OF THE T-72 TANK

The fighting vehicle weight m=41 t moves a) across – S_1=10 km;

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b) on rise – km S_2=0,1km; c) on descent – S_3=0,1 km (fig. 1).

Engine capacity of the machine N=780 h.p., efficiency of transmission of the machine η_t=0,75, road type – sandy, coefficient of resistance of the road of f=0,15, slope angle of rise and descent $\alpha = 27^{o}$.

To define a driving force, motion speed, kinetic energy, movement time.

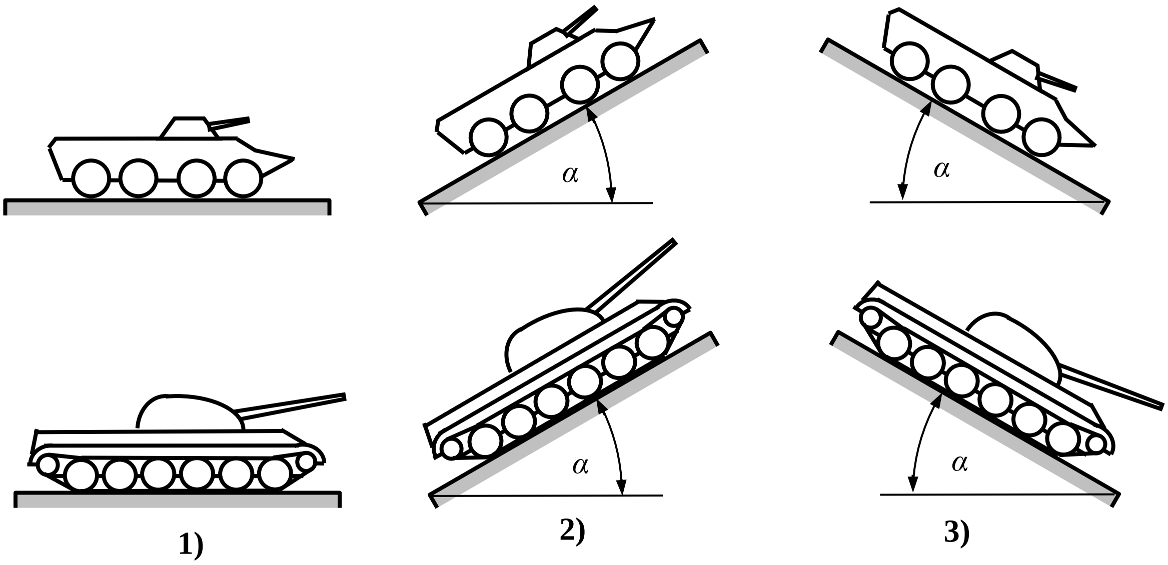

Fig. 1. Movement of a fighting vehicle:
1 – horizontal movement, 2 – movement on rise, 3 – movement on descent

a) Movement of the machine across

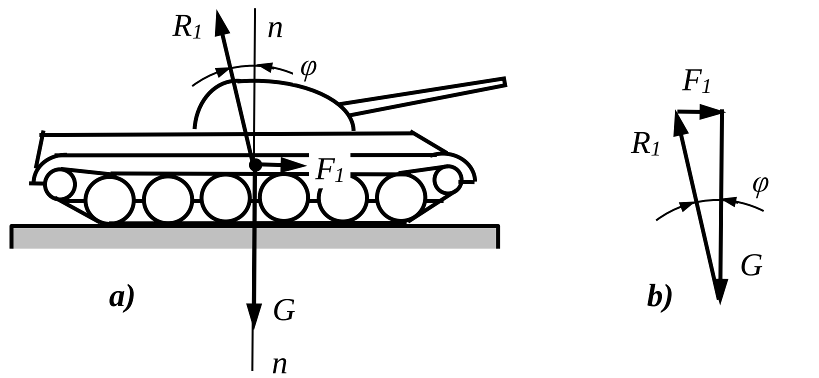

Fig. 2. Movement of the machine across:
a – operating forces on the machine; b – plan of forces

All operating forces on the machine are given to a point of the center of gravity machines. Engine capacity in h.p. it is representable in kW:

$$N_w = N\ 0{,}75 = 780\times0{,}75 = 585 \text{ kW}.$$

The specified power passing through transmission:

$$N_k = N_w\,\eta_t = 585\times0{,}75 = 438{,}75 \text{ kW}.$$

In case of movement of the machine the gravity of G is the useful resistance force (fig. 2). Accepting free fall acceleration of g=9,8 m/c^2, we determine machine gravity:

$$G = m\,g = 41\times9{,}8 = 401{,}8 \text{ kN}.$$

The driving force of F_1 is directed horizontally (fig. 2, a).

In the absence of resistance force of the road, force of response of R_1 is directed vertically, on a normal of *n-n* are rather expensive. In the presence of road resistance force of response of R_1 deviates n-n normal back on an angle φ. Force resulting from friction is harmful (negative) force.

The plan of forces (fig. 2, b). is formed

In case of uniform motion of the machine the vectorial equation of forces will be has an appearance:

$$\overline{F_1} + \overline{R_1} + \overline{G} = 0.$$

The friction resistance angle is defined:

$$\varphi = arctgf = arctg0{,}15 = 8{,}53^o.$$

According to the plan of forces we define a driving force:

$$F_1 = G\ tg\varphi = G\ f = 401{,}8\times 0{,}15 = 60{,}27 \text{ kN}.$$

Possible motion speed of the machine is determined by a formula:

$$N_k = F_1\ v_1.$$

From here speed:

$$v_1 = N_k/F_1 = 438{,}75/60{,}27 = 7{,}28 \text{ m/s} = 26{,}2 \text{ km/h}.$$

Kinetic energy of the machine:

$$W_{k1} = 1086{,}5\times 103 \text{ J} = 1086{,}5 \text{ kJ}.$$

Time of horizontal movement of the machine:

$$T_1 = S_1/v_1 = 10\times 103/7{,}28 = 1373 \text{ s} = 23 \text{ min}.$$

b) Movement of the machine on rise

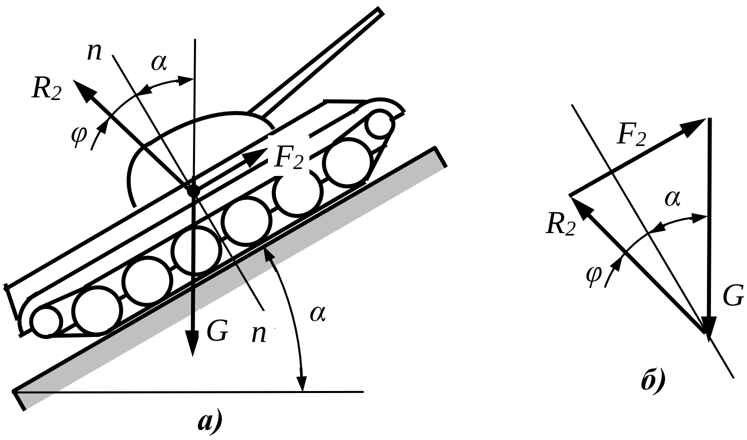

Fig. 3. Movement of the machine on rise:
a – operating forces on the machine; b – plan of forces

In case of movement on rise the driving force of F_2 is directed parallel to a surface of movement of the machine (at an angle α concerning the horizon)
(fig. 3, a). The direction of force of response of Road R_2 concerning a normal of
n-n displaces back on a friction resistance angle φ. Gravity of the machine is the negative force. We make the plan of forces (fig. 3, b). According to the plan of
forces the driving force is defined by the following expression:

$$F_2 = G\ (sin\alpha + cos\alpha\times tg\varphi) = 401{,}8\ (sin27^o + cos27^o\times 0{,}15) =$$

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$$= 401,8\ (0,454+0,891\times 0,15) = 236,12\ \text{kN}.$$

Motion speed on rise:

$$v_2 = N_k/F_2 = 438,75/236,12 = 1,86\ \text{m/s} = 6,69\ \text{km/h}.$$

Kinetic energy of movement of the machine:

$$W_{k2} = 70,92\times 103\ \text{J} = 70,92\ \text{kJ}.$$

Time of movement of the machine on rise::

$$T_2 = S_2/v_2 = 0,1\times 103/1,86 = 538\ \text{s} = 8,96\ \text{min}.$$

c) Movement of the machine on descent

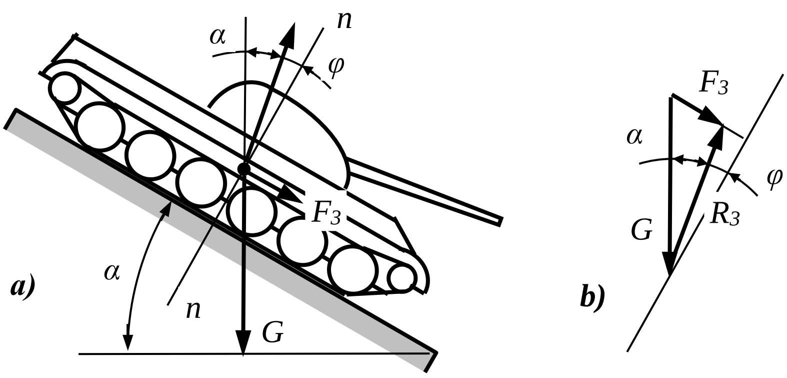

Fig. 4. Movement of the machine on descent:
a – forces operating on the machine; b – plan of forces

In case of movement of the machine on descent the driving force of F_3 is directed parallel to a surface of movement of the machine (at an angle α concerning the horizon) (fig. 4, a). The direction of force of response of Road R_3 concerning a normal of *n*-*n* displaces on a friction resistance angle φ. Gravity of the machine is a driving force. We make the plan of forces (fig. 4, b).

According to the plan of forces in case of movement on descent a driving force is defined by the following expression:

$$F_{30} = G\ (sin\alpha - cos\alpha\times tg\varphi) = 401,8\ (sin27^o - cos27^o\times 0,15) =$$
$$= 401,8\ (0,454-0,891\times 0,15) = 128,71\ \text{kN}.$$

Under the influence of this force the machine spontaneously moves on descent with a speed:

$$v_{30} = N_k/F_3 = 438,75/128,71 = 3,41\ \text{m/s}.$$

Joint speed of movement of the machine:

$$v_3 = v_{30} + v^1 = 3,41 + 7,28 = 10,69\ \text{m/s} = 38,5\ \text{km/h}.$$

Kinetic energy of movement of the machine:

$$W_{k3} = \frac{m\cdot v_3^2}{2} = \frac{41\cdot 10^3\cdot 10,69^2}{2} = 2343\times 103\ \text{J} = 2343\ \text{kJ}.$$

Time of movement of the machine on descent:

$$T_3 = S_3/v_3 = 0,1\times 103/10,69 = 93\ \text{s} = 1,55\ \text{min}.$$

Summary time of movement:

$$T = + T_1 + T_2 + T_3 = 1373+538+93 = 2004\ \text{s} = 33,4\ \text{min}.$$

Average rate:

$v = (S_1+S_2+S_3)/T$ = (10+0,1+0,1) 103/2004 = 5,09 m/s = 18,3 km/h.

OUTPUTS

We output the received results in the table

Type of movement	Driving force F, kN	Speed v, km/h	Kinetic energy W_k, kJ	Time T, s
Horizontal	60,27	26,2	1086,5	1373
On rise	2362,12	6,69	70,92	538
On descent	128,71	38,5	2343	93
Average rate of v=18,3 km/h; summary time T=2004 s				

Dynamic analysis of movement of a fighting vehicle is given (on the example of the T-72 tank). On the basis of the given technique, on a practical training for a specific route taking into account road type beforehand it is possible to define the mode of movement of a fighting vehicle (speed and time of movement). It will provide exact passing of a route with a fighting vehicle.

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