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MAIN RESISTANCES TO MOTION IN GATLING WEAPONS

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A b s t r a c t :

The paper deals with resistances against rotation of barrel group at Gatling weapons: feeding and husking of cartridge from belst, locking or unlocking of breec, inserting of cartridge into chamber on the rate of fire and their infuences on required power. Computed results are compare with measuring on 12.7 mm Gatling machine gun. The mathematical model will be published in following paper next time.

1. Introduction

The Gatling Gun type of machine gun provides very high rate of fire by being capable of what may essentially be called simultaneous loading, firing, extracting and ejecting and still overexpose any one barrel to the effects of rapid, continuous fire. Each of the above four functions are performed in separate barrels during the same interval thus fixing four as the lower limit for the number of barrels, to the gun.

The principle is explained in Fig. 1, see [1]. Each of four barrels must complete one revolution of the barrel group to complete the functional cycle. The breech blocks move axially along a guiding groove in the weapon casing. During one revolution of the barrel group each breech block moves backwards and forwards in turn with delays at the front locked position for firing and at the rear position for case ejection and feeding the next cartridge. Breech block movement is controlled by a cam formed as a groove in the inner surface of the weapon casing. Each of the breech blocks is provided with a guide with a roller which moves along the groove of the cam as shown in Fig. 1.

The main resistances acting against moving barrel group will be discussed. As an example was chosen 12.7 mm Russia machine gun 9-A-624, see Fig. 2, which was adapted from a gas operation to an electric drive. The base conditions and rearrangements are explained in [7]. DC motor **P2ZX525** was chosen with 1100 W power at 2800 min^{-1} revolution for the experimental weapon. The torque is 5 Nm at 2750 min^{-1} revolution. The maximum torque during acceleration is 14 – 17 Nm, as it was verified at the manufacturer. Between the motor and a barrel group was put in the gearbox **MTC22** with the transmission ratio equalled 10, Fig. 3.

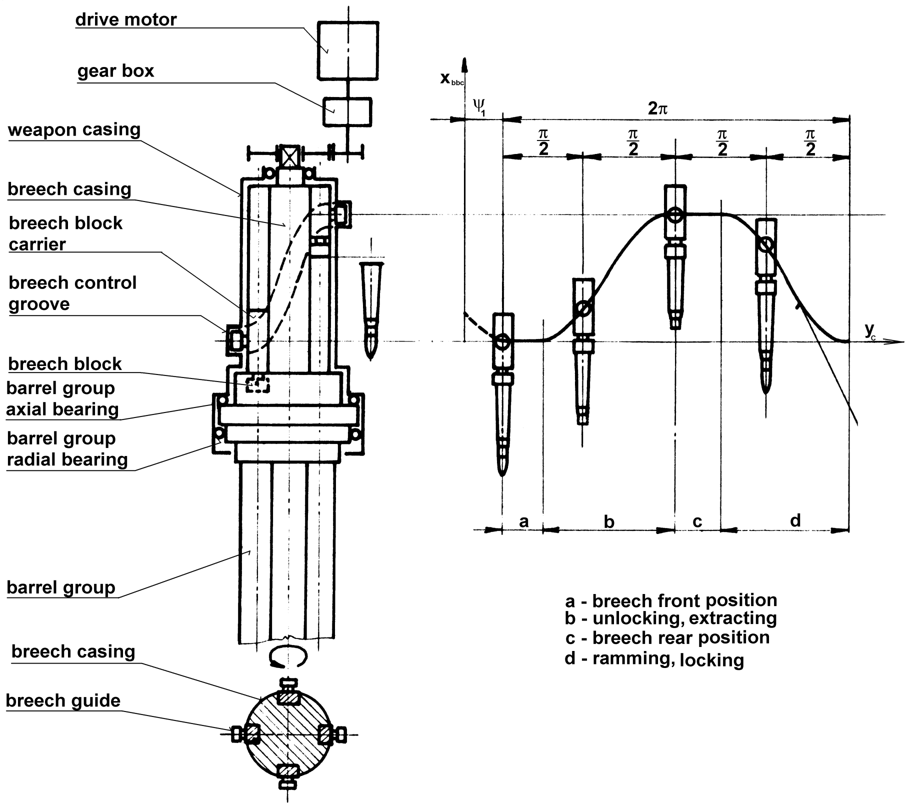

Fig. 1 Gatling system – principle

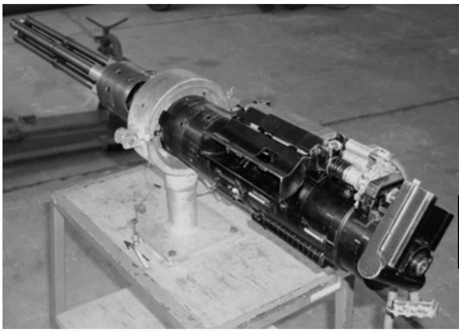

Fig. 2 Original Gatling machine gun

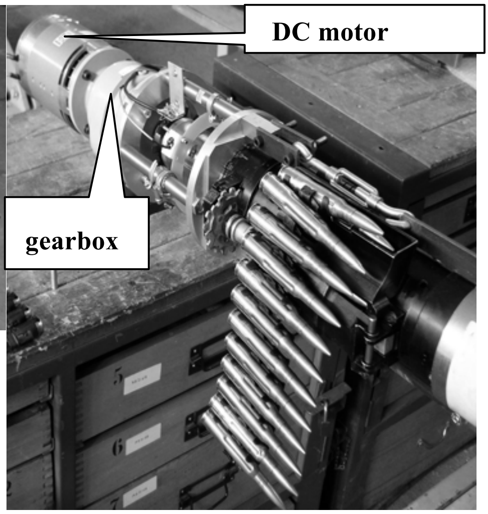

Fig. 3 Experimental weapon

The investigation of weapon parameters was made by measurement of revolutions and torque of the barrel group. The revolution was measured by the TCST1103 optoelectronic element. The torque was measured by the strain gauge 3/120-XY21-HBM with telemetric transmission system MANNER, see Fig. 4.

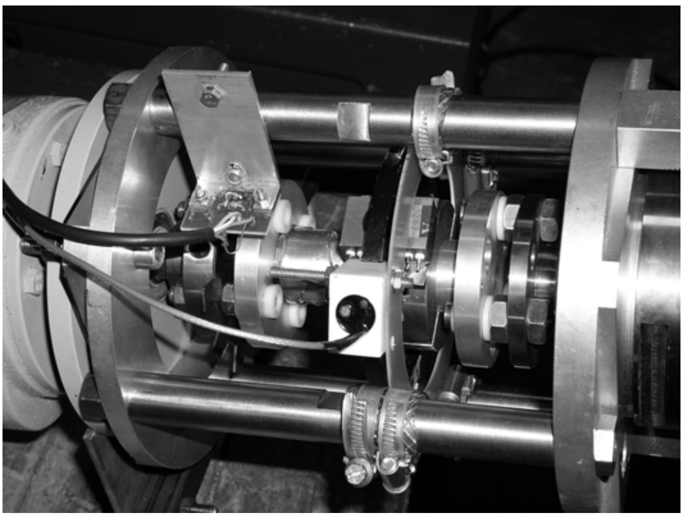

Fig. 4 Gauges for measurements

On the base till published measurements it is possible to say that this system is accelerated during the whole operation period. It is not typical course such as it is known in the "normal" machinery where drives have a zone of stabile revolutions. It follows from it that automatic weapons have a very short time of their action – mostly 1 or 2 seconds.

2. Results of measurements and calculations

The outputs of investigations show that the main influences acting on the rate of fire and required power are see [7]:

- feed moment M_{feed} – 22,7 % of required power,
- damping (friction) moment M_{D} – 6,6 % of required power,
- extracting and ejecting moment M_{E} – 9,7 % of required power,
- breech moment for locking and unlocking M_{B} – 54,5 % of required power,
- breeches kinematics moment M_{K} – 6,5 % of required power.

The main motion equation is written as

$$I_{\mathrm{BG}}\ddot{\varphi}_{\mathrm{BG}} = M_{\mathrm{T}} - M_{\mathrm{feed}} - M_{\mathrm{D}} - M_{\mathrm{K}} - M_{\mathrm{E}} - M_{\mathrm{B}} \qquad (1)$$

where

I_{BG} - system inertia mass moment with respect to rotation axis [kg.m^2],

$\ddot{\varphi}_{\mathrm{BG}}$ - barrel group angular acceleration [rad.s^{-2}],

M_{T} - driving torque on the barrel group [N.m], its characteristics is in Fig. 5.

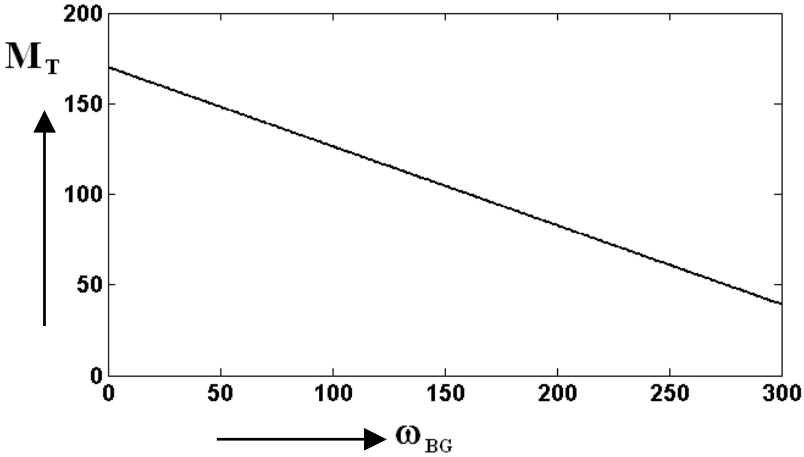

Fig. 5: Driving torque on the barrel group

This characteristics is linear decreasing of torque depending on angular velocity as is usual for permanent magnet excitation DC motor.

The motion equation is usually solved with an independent variable as the time. In the doctoral thesis [9] there is independent variable the angular displacement $d\varphi$ of the barrel group. It follows from it that these moments acting against the movement depend on $d\varphi$. The whole revolution (2π) is divided into 4000 steps – it means $d\varphi$ = 0,00157 rad. The time transformation is done as well.

The moments against the movement of barrel group entering into equation (1) were obtained by measurements on the experimental weapon. The parameters are given with division one revolution into 400 steps – one step is equalled 0,0157 rad, i. e. approx 0,9°. This attainable accuracy is possible by means for measurement on the weapon.

The summary moment acting against the driving torque M_{T} is draw in Fig. 6. (without an influence of inertia moment $I_{\mathrm{BG}}\ddot{\varphi}_{\mathrm{BG}}$).

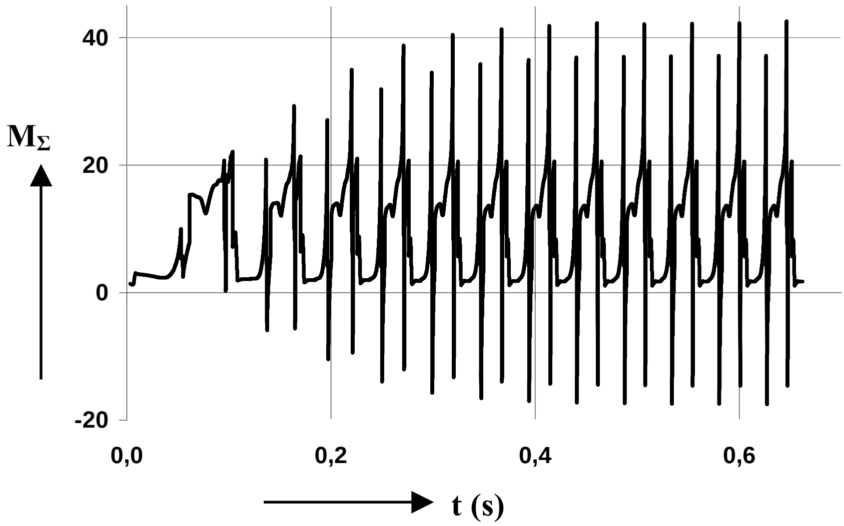

Fig.6 Summary moment

Now the components of summary moment will be explained.

The whole feed moment M_{feed} course is shown in Fig. 7 (during ¼ of revolution of barrel group). This case is when friction factors between a cartridge and husking device is 0,125. When the friction factor is 0,1 then the maximum value of M_{feed} is 14 N.m. The husking force was determined by measurement on the ZWICK/Z100 tensile machine and the link rigidity (k_l = 135 kN/m) as well.

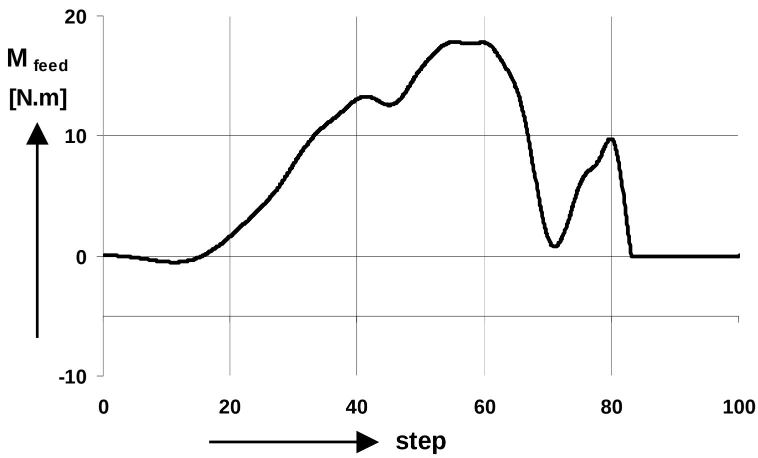

Fig.7 Feeding moment

Damping moment was determined as sum of all friction moments against barrel group rotation with feed mechanism but without cartridges and breeches. Its value can be approximated from equation (2) - for the 9-A-624 machine gun - and the course interesting values of us is shown in Fig. 8.

$$M_{\mathrm{D}} = 0,0004\omega^2 - 0,005\omega + 1,266 \tag{2}$$

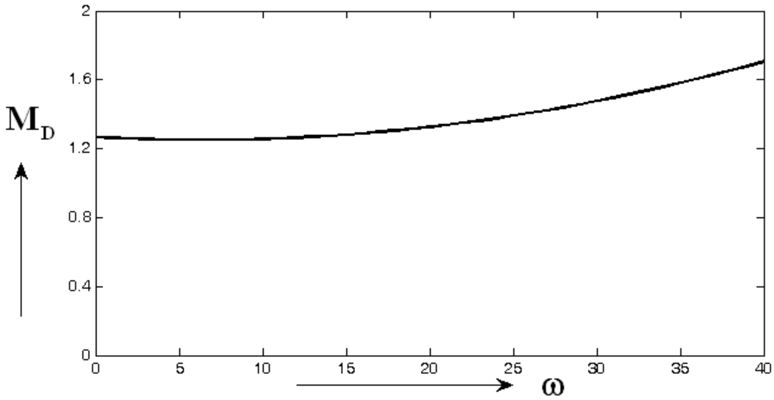

Fig. 8 Damping moment

Measurements were provided at four different voltages and different driving motor characteristic. The maximum angular velocity was obtained from our experimental weapon. This velocity is equalled 40 rad/s. These results were not published in book [6] and they are new as results about feed moment. The function $M_{\mathrm{D}} = f(\omega)$ gives a new view on problems which are connected with dynamics of weapon where is assumed only dry friction, not viscous friction as damping.

The moment of the cartridge or case ejected from weapon was calculated from relation (derived in [7])

$$M_{\mathrm{E}} = r_{\mathrm{ni}} F_{\mathrm{i}}\,, \tag{3}$$

where

F_{i} - tangential force acting on the case,

r_{ni} - radius of case centre mass.

Tangential force depends on radial and transverse acceleration of the case, its mass, slope angle of the ejector and friction factors between case and ejector and between case and breech guidance.

The course of ejecting moment is shown in Fig. 9. The minimal value is about 37 N.m and maximum at the end of ejection is 104 N.m. The energy necessary to eject a case is approx 3 J but the power 1830 W.

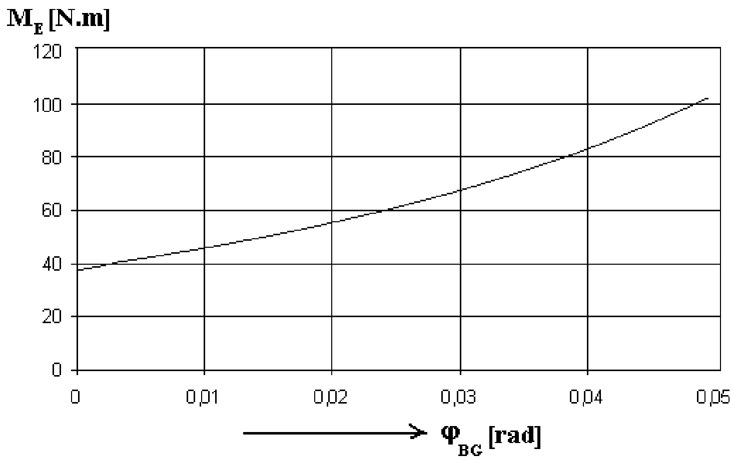

Fig. 9 Cartridge or case ejecting moment

The breech moment for locking and unlocking M_{B} was determined by static measuring with new and spent practice cartridges. This moment act for very short interval (and time as well) and its values are:

- new cartridges 53 – 56 Nm for locking and 28 – 32 Nm for unlocking
- spent practice cartridges 27 – 33 Nm for locking and 18 – 23 for unlocking.

The ramming force of cartridges varies from 200 N for spent practice cartridges and 300 N for new one.

This result is very important for designers and users because moment M_{B} and ramming force together create more than 50% of the required power. This problem should be solved in future more.

The last moment is the breeches kinematics moment shown on Fig. 10. This figure describes M_{K} increasing of 1st and 3rd breeches for example. Four moments for every breech would be unclear in one diagram.

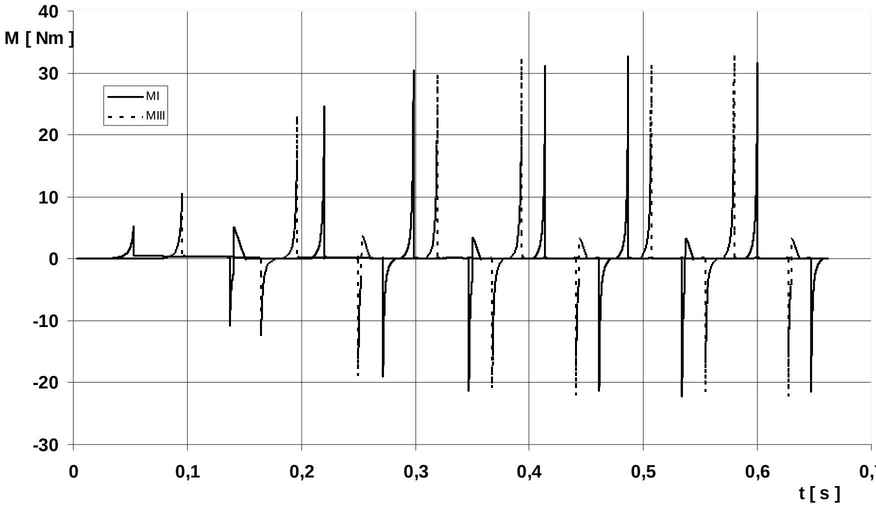

Fig. 10 Breeches kinematics moment – an example for 1st and 3rd breech

The equation (1) was solved by way variable separation, where the integration step is 0, 00157 rad. The computation was made in Microsoft EXCEL programme, which needs approx 170 Mb memory depending on required outputs and their numbers. If we suppose firing 25 rounds then 58 000 rows are used (from 65 536 potential rows).

The comparing of measured and calculated results are shown in Fig. 11 where are the angular velocities of the barrel group (M – measured, C – calculated).

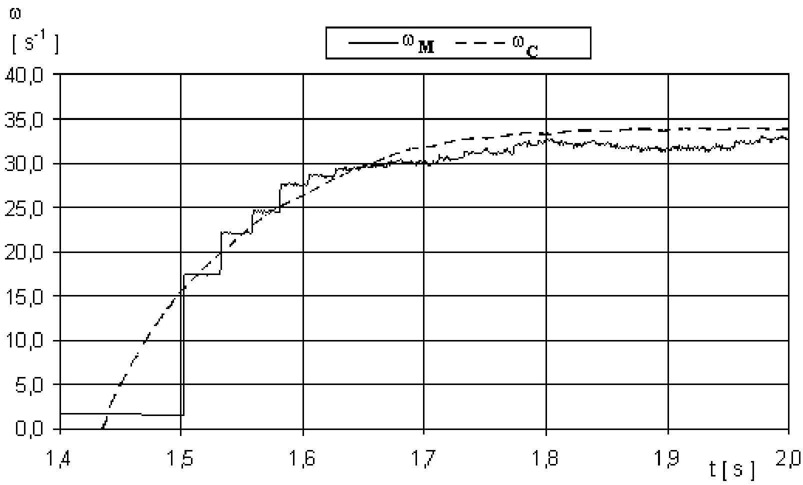

Fig. 11 Measured and calculated angular velocity

The attained angular velocity ensures the maximum rate of fire 1200 rds/min. The different between measured and calculated values are suitable for other using.

The rate of fire (number rounds per seconde) for the number j barrels is obtained from the following relation

$$k = \left(\frac{j\omega}{2\pi} \right). \tag{4}$$

The breech velocities (obtained by the calculations) are shown in Fig. 12 where is evident the main advantage of Gatling system with comparing of classical powered systems. The breech velocity is four times lower than the gas operated system with same calibre. The accelerations are below 1000 m/s^2 as it is published in [7].

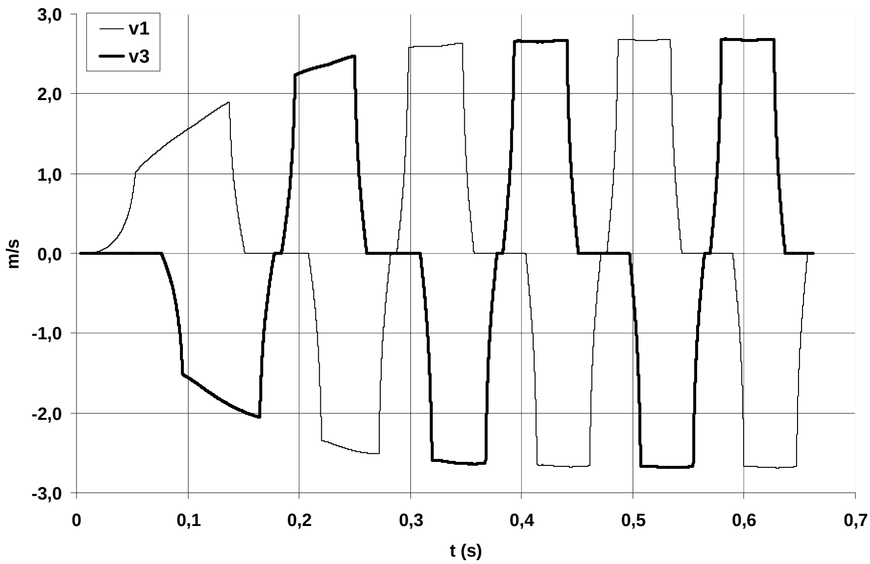

Fig.12 Breeches velocities No. 1, 3

3. Conclusion

The nominal required rate of fire was achieved at the voltage approx 24 V. It is 1200 rds/min and it corresponds to the angular velocity of the barrel group over 31 rad/s. This rate of fire was obtained during 0,25 s and it is after 3 simulated rounds. At the voltage 32 V was obtained the rate of fire 1400 rds/min during 0,3 s. The maximum

rate of fire for really weapon 4000 rds/min can be achieved by using a drive with the power 5,7 kW and after acceleration during 0,3 s this power is 3,7 kW, see Fig. 13.
In the Fig. 13 are:

P_T - power of drive (W),

P_R - required power of the weapon without acceleration (W),

k - rate of fire (rds/min) and

φ - angular displacement of the barrel group (rad).

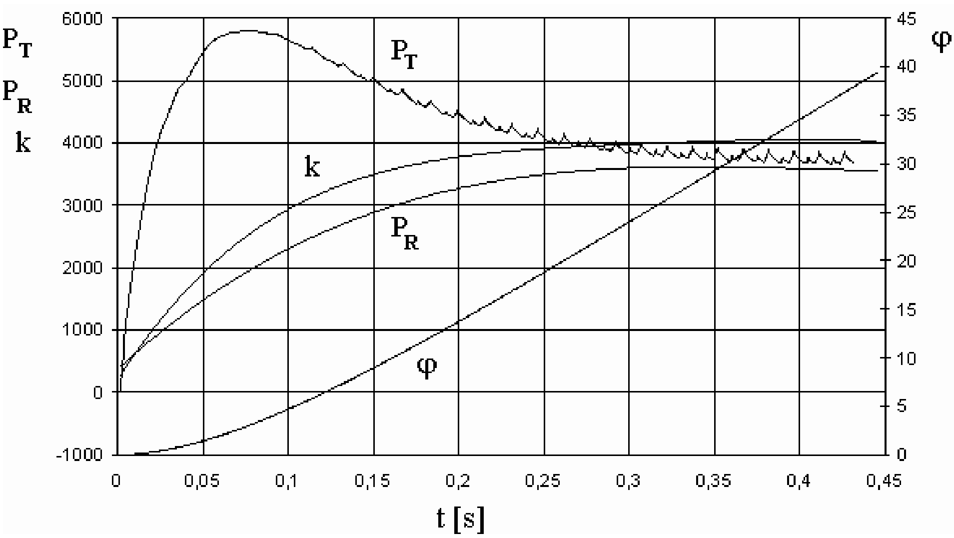

Fig. 13 Simulation of 4000 rds/min

Another calculations in [7] have shown that by way decreasing of transmission ratio between motor and gearbox it is possible to achieve a higher rate of fire then 1200 rds/min (with same DC motor) because system inertia mass moment will be decreased at 55 %. But the rate of fire 1200 rds/min will be achieved two times quickly – after 0,2 s.
These and other simulations were published in thesis [7] and will be explained in the next part as a continuation of this paper.

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