INFLUENCE OF THE DIFFERENT CAPACITOR CONFIGURATIONS OF THE SUPPLY SYSTEM ON THE EFFICIENCY OF THE RAIL ACCELERATOR

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Abstract

An influence of the capacitor configuration in the pulse supply system for rail accelerator on its efficiency was investigated in the paper. Two different configurations were compared: the first one with parallel connection of capacitors, and the second one with parallel-series connection. In both cases the same number of capacitors was assumed. All other parameters of the device were kept constant, i.e. mass and dimensions of the projectile, rail length and stator geometry. A field-circuit model was used to analyze numerically the transients for different capacitor configurations and voltage values.

1 Introduction

The interest in the subject of rail accelerators is increasing, especially in military applications [1]. However, there is an increasing interest observed in other applications e.g. geological research (impact measurements) and measuring of impact resistance of materials (for space shuttle covers, satellites and airplanes). Conventional drive systems do not allow to obtain the demanded parameters [2, 3].

The costs are also a problem. Although they are relatively low for accelerator itself, the power supply system including control and monitoring systems could be very expensive. Thus, there are carried out investigations to increase the efficiency of the system. One of possibility is to increase the magnetic flux in the armature volume [4]. Another one is changing the supply system, e.g. by using X-RAM generator [5].

In the presented work the supply system based on capacitors was used and two different connections were analyzed. The connection influences the current waveforms (the pulse duration and its amplitude), which can directly influence the accelerator performance. Increasing the efficiency could lead to decreasing the costs.

2 Mathematical model

For the analysis of the efficiency, the previously verified field-circuit model was used [4], which block diagram is shown in Figure 1. The field calculations were performed in the ANSYS Maxwell magnetostatic module. The parameters of the circuit model were kept constant. This simplification was necessary to compare the influence of the capacitor connection on the accelerator efficiency.

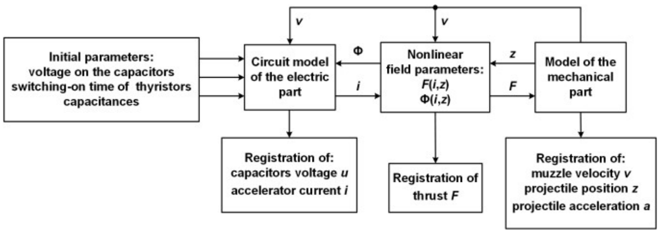

Fig. 1. Block diagram of the field-circuit model [4]

The capacitor bank was divided into three sections (symmetrical in terms of capacity), which were triggered simultaneously from separate thyristor keys. This configuration was similar to the physical one, which will be used for extended measurement verification. The total power capacity assumed is 300 mF for a parallel connection and 75 mF for a series-parallel connection. In order to maintain a constant energy accumulated in the supply system, the initial voltage for the series-parallel connection system was twice as high as for the parallel one. The comparative parameters were the calculated muzzle velocity and efficiency of the whole system (accelerator + supply system).

3 Calculation results

The analysis was carried out for four different input energy values (Table 1). For lower energy values (1.5 kJ and 6 kJ), the more effective connection is a parallel one. For higher energy values, the more effective system is a series-parallel connection. From Fig. 2 it is visible, that both connection configurations give the same result for approx. E=10 kJ. In the range from 1.5 kJ to 12 kJ there is only a slight difference between two analyzed connections visible. For higher input energy values, the parallel-series connection is more effective (allows to reach higher muzzle velocity).

Figure 3 shows the current waves for two cases form Table 1 i.e. the lowest and highest energy value. For parallel connection of capacitors, the current pulse has a longer duration and a smaller maximum value comparing to parallel-series connection. It is due to higher capacitance and lower voltage value. In Fig. 3b the time moment of leaving the rails is visible as the abrupt current value decreasing.

Connection arrangement	*C* [mF]	*U* [V]	*E* [kJ]	v_{cal} [m/s]	*η* [%]
parallel	300	100	1.5	86.89	1.82
parallel-series	75	200	1.5	75.61	1.40
parallel	300	200	6.0	248.7	3.72
parallel-series	75	400	6.0	233.8	3.34
parallel	300	300	13.5	404.0	4.47
parallel-series	75	600	13.5	421.4	4.81
parallel	300	400	24.0	539.9	4.86
parallel-series	75	800	24.0	610.4	5.67

Table 1. Calculation results

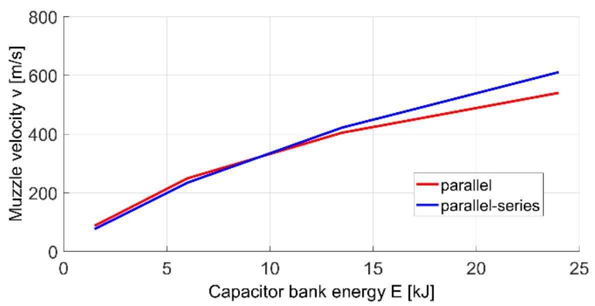

Fig. 2. Calculated muzzle velocity vs. capacitor energy

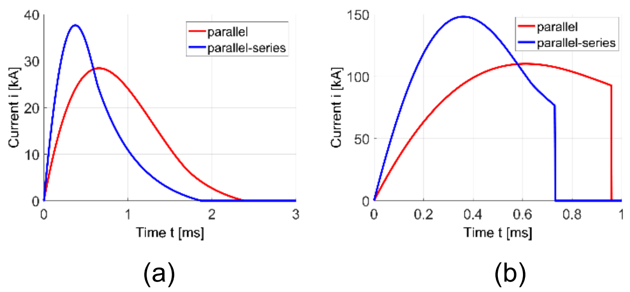

Fig. 3. Excitation current vs. time: a) 100V/200V, b) 400V/800V

Along with the amplitude of the current, the values of the thrust are increasing. Thus, the acceleration increases and the muzzle velocity could be higher (Fig. 4). The parallel-series connection, due to higher voltage and maximum current value, allows to reach higher muzzle velocities for supply energy values above 10 kJ (in our case) comparing to parallel connection.

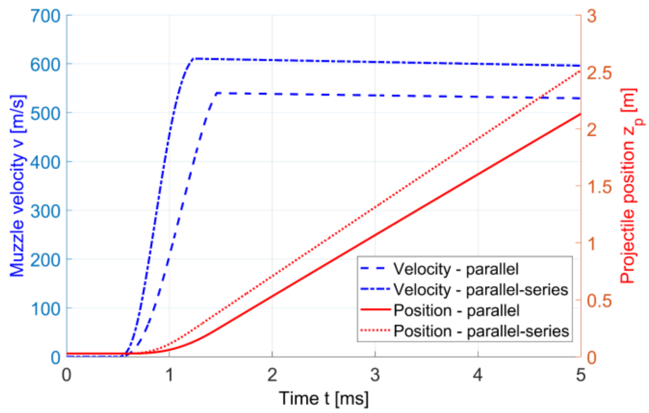

Fig. 4. Projectile velocity and position waves for 400V/800V

4 Conclusions

Based on the numerical calculation results, the following conclusion were formulated:

a) The type of capacitor connection system used affects the efficiency of the accelerator.
b) For accelerators with relatively short rails (300 mm), in case of a higher energy levels (in the presented model above 10 kJ), it is reasonable to use a series-parallel connection.
c) The selection of the capacitor configuration should take into account the length of the rails.

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