Tolerances in Flux Compression Generator Design: Theory

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Abstract— The physical properties of FCG components available on the market (wires, explosives, liners (armatures), etc.) might differ from those that were originally used for FCG design. As a result, the output parameters of the manufactured generator (e.g. maximum output power) could deviate from the pre-calculated values. Simple formulas are derived to enable evaluation of change in maximum output power of a helical flux compression generator due to variations in either wire insulation thickness or detonation velocity of explosive. The obtained formulas establish acceptable tolerances for FCG components produced by a third-party manufacturer.

Keywords-HFCG; FCG; tolerances; insulation thickness; detonation velocity

I. INTRODUCTION

The main features of FCGs invented in the 1950s are now well known [1–3]. The FCG design for a particular task is based on the use of well-developed theoretical models and numerical methods [4–7]. However, the physical properties of FCG components available on the market (wires, explosives, liner, etc.) might differ from those that were originally used for FCG design. As a result, the output parameters of the manufactured generator (e.g. output power) could deviate from the pre-calculated values. That is why, some simple formulas are derived to enable evaluation of change in maximum output power of a helical flux compression generator powering an inductive load due to variations in either wire insulation thickness or detonation velocity of explosive. The obtained formulas establish acceptable tolerances for FCG components produced by a third-party manufacturer.

II. INSULATION THICKNESS

The insulation thickness of wires produced even by the same manufacture can vary along wire length. As a result, wire diameter d and winding density differ from one inductor sample to another. This means that there is some spread in FCG inductance values $L_G(t)$ for different specimens.

Since the current amplification factor is mainly determined by the ratio of the initial FCG inductance L_0 to the load inductance L_l, one should expect a deviation of the generator output parameters from those declared during design procedure. For the exponentially decreasing FCG inductance $L_G(t)=L_0e^{-\alpha t}$ and resistance $R_G(t)=R_0e^{-\alpha t}$, the change in maximum output power ΔP_{max} is given by the following formula

$$\frac{\Delta P_{\max}}{P_{\max}} \approx -2\left(1-\frac{2R_0}{\alpha L_0}\right)\cdot\frac{\Delta d}{d} \tag{1}$$

Here, $\Delta d/d$ is a relative change of wire diameter.

III. DETONATION VELOCITY

A similar situation is observed with parameters of explosive used for liner filling. The detonation velocity might differ in different tests. The dependence of inductance derivative $dL_G(t)/dt$ on the detonation velocity v results in variations of the maximum output power:

$$\frac{\Delta P_{\max}}{P_{\max}} \approx \left[1+\frac{R_0}{\alpha L_0}\cdot\left(1+2\ln\frac{2L_0}{3L_l}\right)\right]\cdot\frac{\Delta v}{v} \tag{2}$$

Here, $\Delta v/v$ is a relative change in detonation velocity.

IV. RESULTS

Simple formulas enabling evaluation of change in maximum output power of a helical flux compression generator due to variations in either wire insulation thickness or detonation velocity of explosive are derived. The obtained formulas establish acceptable tolerances for FCG components produced by a third-party manufacturer.

REFERENCES

[1] A.D. Sakharov et al., “Magnetic cumulation,” DAN SSSR, vol. 165, no. 1, pp, 65–68, 1965.
[2] A.I. Pavlovsky, R.Z. Lyudaev, “Magnetic cumulation” in Issues of modern experimental and theoretical physics, Leningrad, Nauka, 1984.
[3] Magnetocumulatiove generators – pulsed energy sources. vol. 1, eds. V.A. Demidov, L.N. Plyashkevich, V.D. Delemir, Sarov, RFNC-VNIIEF, 2012.
[4] B.M. Novac, M.C. Enache, I.R. Smith, and H.R. Stewardson, “Simple 2D model for helical flux-compression generators,” Laser Particle Beams, vol. 15, no. 3, pp. 379 – 395, 1997.
[5] A.S. Pikar, N.Yu. Deryugin, P.V. Korolev, V.M. Klimashov, “The method for numerical modeling of magnetic field compression in HFCG,” Proc. Russian VI Zababahin's Sci. Readings, Sarov, Russia, 2001, pp. 38:1 – 38:5 [in Russian].
[6] D.E. Lileikis, “Numerical modeling of a helical, explosive flux compression generator,” in Proc. IEEE Conf. Rec. Plasma Sci., May 1997, p. 276.
[7] S.V. Anischenko, P.T. Bogdanovich, A.A. Gurinovich, and A.V. Oskin, “Simulation of helical flux compression generator,” IEEE Trans. Plasma Sci., vol. 46, no. 5, pp. 1859 – 1863.