EXCELLENCIA
INTERNATIONAL MULTI-DISCIPLINARY JOURNAL OF EDUCATION
Volume 02, Issue 07, 2024 ISSN (E): 2994-9521

Analysis of Mechanical and Electrical Vibrations in the Engines of Military and Combat Vehicles on the Basis of Differential Equations

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Abstract:

This article discusses methods for analyzing mechanical and electrical vibrations that occur in military equipment, which is one of the topical issues, using differential equations.

Keywords: oscillation, equation, differential equation, constant coefficient.

It is known from the laws of mechanical motion that the vibration of a rigid body with mass can be free or forced. Free vibration equations are characterized by damping and consist of a homogeneous differential equation. Usually, in internal combustion engines, continuous oscillations are formed that are not necessarily damped. The reason for this is that external force periodically affects the system. In internal combustion engines, as a result of the explosion of fuel, mechanical vibrations (vibrations) are generated, and it is natural for electric vibrations to be generated in the electric circuit and electric motor (generator)[1]. Mechanical forced vibrations are represented by second-order inhomogeneous special differential equations with constant coefficients. Forced vibration is generated under the influence of an external force and its general formula is given in the form (1).

$$m\frac{d^2x}{dt^2}+\lambda\frac{dx}{dt}+kx=f(t) \qquad (1)$$

where ***m*** - the mass of the body (object) (kg),

x- is the function representing the law of motion, the deviation of the points on the surface of the engine from a certain position (m),

k- uniformity (stiffness) of the elastic system,

λ - proportionality coefficient,

$f(t)$ - external force or driving force, - acceleration of the system,

$\frac{d^2x}{dt^2}$ - system speed.

This differential equation is derived from Newton's second law, one of the fundamental laws of dynamics[2]. Any moving object comes under the influence of this law. In turn, the rotational vibration of the flywheel on the axis is also expressed by equation (1). Only, x instead of the law of motion φ, the angle of rotation of the flywheel (rad), instead of the mass m, the moment of inertia of the flywheel is replaced I $\left(kg\cdot m^2\right)$, instead of the torque k, the angular velocity ω of the axis is replaced, and as a result, the following equation (2) is formed.

$$I\frac{d^2\varphi}{dt^2}+\lambda\frac{d\varphi}{dt}+\omega\varphi=f(t) \quad (2)$$

Equation (2) is called a special form equation with a second-order constant coefficient on the right side. In addition, it is possible to analyze the mechanical vibrations (vibrations) occurring in alternating synchronous three-phase generators (including asynchronous motors) using equation (1).

One of the factors (physical process) that causes the most damage to the techniques is vibration. The factors that create it are mechanical and electrical vibrations. We use the differential equations branch of mathematics to bring the mechanical or electrical vibrations in this phenomenon to the limit of human knowledge. Suppose a non-branched alternating current circuit connected in series is given (Fig. 1).

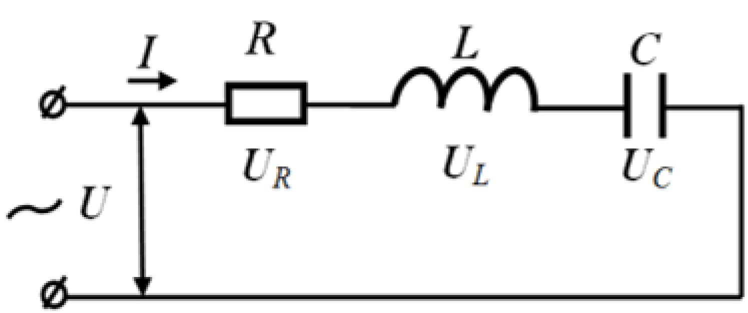

Figure 1. Unbranched alternating current circuit.

The main reason for this is that alternating current $i(t)$ is produced in synchronous generators, which are considered the primary (main) source of electricity. The above simple electric circuit consists of *L*- inductive coil, *R*- resistance, *C*- capacity (capacitor), *E*- electric driving force. The current in the electric circuit $i(t)$, the capacitor charge q, and the voltages are respectively denoted by U_R, U_L and U_C. Since the elements in the electric circuit are connected in series $E = U_R + U_L + U_C$, the total voltage is equal to. When evaluating any complex branched electric circuit, it is evaluated by its equivalent simple electric circuit. For this reason, our main goal R is L, C, E to scientifically check a simple electric circuit formed by connecting the current $i(t) = \frac{dq}{dt}$ elements in series[3]. We create the following differential equation from the equality of current $U_L = L\frac{di}{dt}$, voltagees, and $U_C = \frac{q}{C}$.

$$L\frac{di}{dt} + Ri + \frac{q}{C} = E \quad (3)$$

(3) by differentiating the differential equation once with respect to time and dividing both parts of the equation by L, we form the second-order non-homogeneous linear differential equation with the following constant coefficients.

$$\frac{d^2i}{dt^2} + \frac{R}{L}\cdot\frac{di}{dt} + \frac{1}{LC}\cdot i = \frac{1}{L}\cdot\frac{dE}{dt} \quad (4)$$

The differential equation (4) is the oscillation formula in which R, L, C s are fixed numbers, for convenience $R = 2,\ L = 1,\ C = \frac{1}{5}\ \frac{1}{L}\cdot\frac{dE}{dt} = \sin t$ by performing the substituton, we get the following equation

$$i''_t + 2i'_t + 5i = \sin t \quad (5)$$

(5) of the differential equation $i(0) = 1$ va $i'(0) = 2$ we find a general solution that satisfies the initial conditions.

To solve the equation, first homogeneous $i''_t + 2i'_t + 5i = 0$ we find the general solution of $\tilde{i}(t)$.

We find the solution of a homogeneous differential equation with constant coefficients of the second order $i = e^{\lambda t}$ we look for it. Taking first and second order derivatives $i' = \lambda e^{\lambda t}$ $i'' = \lambda^2 e^{\lambda t}$

$$\lambda^2 e^{\lambda t} + 2\lambda e^{\lambda t} + 5e^{\lambda t} = 0$$

$$e^{\lambda t}(\lambda^2 + 2\lambda + 5) = 0$$

$$e^{\lambda t} > 0,\ \lambda^2 + 2\lambda + 5 = 0$$

$$\lambda_{1,2} = -1 \pm 2i$$

$$\alpha = -1,\ \ \beta = 2$$

$$\tilde{i}(t) = e^{\alpha t}(C_1 \cos\beta t + C_2 \sin\beta t) = e^{-t}(C_1 \cos 2t + C_2 \sin 2t)$$

the private solution of the inhomogeneous part of the differential equation is $i^*(t) = A\sin t + B\cos t$ looking in the view[4]. first on $i^*(t)$ dan t bo'yicha birinchi we take the First-Order and second-order derivatives over dan (5) and take them to the differential equation.

$$-A\sin t - B\cos t + 2A\cos t - 2B\sin t + 5A\sin t + 5B\cos t = \sin t$$
$$2A\cos t + 4B\cos t + 4A\sin t - 2B\sin t = \sin t$$

$$\begin{cases} 2A + 4B = 0 \\ 4A - 2B = 1 \end{cases} \Rightarrow \begin{cases} A = \dfrac{1}{5} \\ B = -\dfrac{1}{10} \end{cases}$$

$$i^*(t) = \frac{1}{5}\sin t - \frac{1}{10}\cos t$$

(5) the total solution of the differential touch $i = \tilde{i} + i^*$ was equal to.

$$i(t) = e^{-t}(C_1 \cos 2t + C_2 \sin 2t) + \frac{1}{5}\sin t - \frac{1}{10}\cos t$$

Using the boundary conditions C_1 and C_2 finding the values of the constants[5]. Using the boundary conditions and finding the values of the constants[6-9].

$$1 = C_1 - \frac{1}{10} \Rightarrow C_1 = \frac{11}{10}$$

$$i'(t) = -e^{-t}(C_1 \cos 2t + C_2 \sin 2t) + e^{-t}(-2C_1 \cos 2t + 2C_2 \sin 2t) + \frac{1}{5}\sin t - \frac{1}{10}\cos t$$

$$2 = -C_1 + 2C_2 + \frac{1}{5} \Rightarrow C_2 = \frac{29}{20}$$

(5) the general solution of the differential touch satisfying the initial condition $i(t) = e^{-t}(\frac{11}{10}\cos 2t + \frac{29}{20}\sin 2t) + \frac{1}{5}\sin t - \frac{1}{10}\cos t$ (6) is in view.

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