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About the potential energy of two electric resonators during ponderomotive interaction

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Abstract
The paper shows the existence of several stationary states of an electromechanical system of resonators connected by all types of electrical connections. An analytical expression is obtained for the energy of the ponderomotive interaction of the electromechanical system. A model of the mechanism of homeopolar coupling is proposed, since the process of formation of a hydrogen molecule can be considered as a grouping into a single mechanically stable formation of two electric resonators.

Keywords: Ponderomotive interaction, resonator, coupling, mechanical motion, charge, inductive, capacitive, ohmic, frequency, hydrogen atom

Introduction

In case of ponderomotive interaction electrically connected resonators under certain conditions, it is possible to group them into a single mechanical stable formation [1]. Let us consider electromechanical system of resonators connected by variable inductive and capacitive, as well as by constant ohmic connections [2, 3].

We investigate the mechanical motion of resonators under external electrical action. With slowly changing parameters of mutual relations, the oscillatory motion of the electromechanical system can be represented by the following differential equation:

$$\left.\begin{array}{c}\beta_{11}\ddot{x}_1+\mathcal{E}_{11}\dot{x}_1+\alpha_{11}x_1+\beta_{21}\ddot{x}_2+\mathcal{E}_{12}\dot{x}_2+\alpha_{12}x_2=\Phi^1(x_1,x_2;t)\\ \beta_{21}\ddot{x}_1+\mathcal{E}_{21}\dot{x}_1+\alpha_{21}x_1+\beta_{22}\ddot{x}_2+\mathcal{E}_{22}\dot{x}_2+\alpha_{22}x_2=0\\ \beta_{33}\ddot{x}_3+\mathcal{E}_{33}x_3+\frac{d\beta n}{dx_3}(\dot{x}_1\dot{x}_2)+\frac{d\alpha_{12}}{dx_3}(x_1x_2)=0\end{array}\right\} \quad (1)$$

where x_1 and x _ 2 are charges in the first and second resonators;
x_3 - distance between resonators;
β_ik,α_ik Ɛ_ik (i, k = 1, 2) - eigen- and mutual coefficients
correspondingly inductance, capacitance and resistance;
β_33 and Ɛ_33 - mass and friction coefficient of the movable resonator.
Equation (1), which is fundamental for the problem under consideration, describes processes in the ponderomotive interaction of resonators. A general solution to this equation is generally impossible with varying parameters.

We will investigate the interaction of high-quality resonators with small values of communication coefficients and the same constant parameters. Equations for electrical oscillatory motion in the system write to view

$$\left.\begin{array}{c}\ddot{x}_1+2\delta\dot{x}_1+n^2x_1+\gamma_1\ddot{x}_2+2\delta\kappa\dot{x}_2+n^2\gamma_2x_2=\Phi(x_1,x_2;\,t)\\ \gamma_1\ddot{x}_1+2\delta\kappa\dot{x}_1+\gamma_2n^2x_1+\ddot{x}_2+2\delta x_2+n^2x_2=0\end{array}\right\} \quad (2)$$

here $n = \sqrt{((\alpha_{11})/(\beta_{11}))}$ is the partial frequency of the resonators;
$\delta = (\mathcal{E}_{11})/(2\beta_{11})$ - damping of resonators;
γ_1, γ_2 and κ - coefficients inductive, capacitive and ohmic
Links that may vary within:

$(-1\leq\gamma_1\leq1)$, $(0\leq\gamma_2\leq1)$, $(0\leq\kappa\leq1)$

under laws:

$\gamma_1=(k_1)/x\_3$, $\gamma_2= - k_2\ x\_3$, κ=const.

Constant k_1 and k_2 depend on the geometry of the resonators and the properties of the medium in which the interaction occurs.

Under the influence of external force F (x_1, x_2; t) forced electric oscillations are excited in electromechanical system of resonators with frequency ω; ponderomotive forces occur at the same frequency [omega] and between resonators.

The natural frequencies of the electromechanical system depend on the mechanical coordinate of the x_3 in a complex way. The first natural frequency with an increase in the distance between the resonators x_3 decreases non-monotonically, which is important when grouping the resonators into a single mechanically stable formation, since this effect is realized under the condition [omega] < n. [4].

Knowing changes in the natural frequency of the electromechanical system, it is possible to predict resonant phenomena at all values of the frequency of external influence.

Solving the equations of motion, for the energy of the ponderomotive interaction of resonators we will have:

$$U = M^2\left[\frac{(n^2-\omega^2)}{2}\left(\frac{k_1^2\beta_{11}\omega^4}{x_3^2}+k_2^2\alpha_{11}n^2x_3^2\right)-4\delta^2\kappa\omega^2\left(\frac{k_1\beta_{11}\omega^2}{x_3}+k_2\alpha_{11}x_3\right)\right], \quad (3)$$

where M is a constant depending on parameters of resonators, amplitude and frequency of external influence.

The curve of dependence of potential energy of ponderomotive interaction on distance between resonators has several minimums. These minima correspond to the same frequency of external exposure. This means that stable mechanical equilibrium of the electromechanical system for the same frequency is possible at several values of the resonator coupling energy.

From the expression (3) for equilibrium distances, we obtain the following equation:

$$(n^2-\omega^2)k_2^2\alpha_{11}n^2x_{30}^4-4\delta^2\kappa\omega^2k_2\alpha_{11}x_{30}^3+4\delta^2\kappa\omega^4\beta_{11}k_1x_{30}- - (n^2-\omega^2)k_1^2\beta_{11}\omega^4=0,$$

which is the solution

$$\left.\begin{aligned} x_{30}^{(1)} = R_0, \text{где } R_0 = \frac{\omega}{n}\sqrt{\frac{k_1}{k_2}};\ x_{30}^{(2)} = \frac{R_C-\sqrt{R_C^2-4R_CR_L}}{2} \\ x_{30}^{(3)} = \frac{R_C+\sqrt{R_C^2-4R_CR_L}}{2} \end{aligned}\right\}, \quad (4)$$

where, R_L and R_C are equilibrium distances for electromechanical systems of resonators inductively connected by ohmic and capacitive-ohmic connections, respectively. They have the following expressions:

$$R_L = \frac{k_1(n^2-\omega^2)}{4\delta^2\kappa},\ R_C = \frac{4\delta^2\kappa\omega^2}{k_2n^2(n^2-\omega^2)} \quad (5)$$

The equilibrium state of the system at x_30^ ((1)) is basic, since it does not depend on any additional conditions. The energy corresponding to the main equilibrium state, i.e. the depth of the main minimum of potential energy characterizing the coupling energy of the two resonators, is determined by the formula:

$$U_{min}^{(1)} = M^2\alpha_{11}\omega^2(k_1\,k_2)^{1/2}\left[(n^2-\omega^2)\sqrt{k_1k_2}-8\delta^2\kappa\frac{\omega}{n}\right]. \quad (6)$$

The condition for the existence of two other local equilibrium states, which is performed only at certain ratios of communication coefficients and system parameters, is:

$$R\_C>4R\_L. \quad (7)$$

At some relationship of communication values, the depth of local minima may be comparable to the depth of the main minimum. In this case, the electromechanical system has three stable equilibrium states. In the absence of fluctuations, the system, being in one stationary state, cannot move to another without any external effects. Small random effects lead to the fact that the system begins to make minor fluctuations near one of the stationary states and from time to time changes from one state to another [3]. The probability of such a transition depends on the magnitude of the fluctuations and the depth of the potential minimum.

Knowing the analytical expression for potential energy, and considering the electromechanical system of resonators like a harmonic oscillator near the equilibrium point, we can find the frequency of mechanical oscillations in the first approximation [5]. Let's notice. That we are talking about the relative movement of the center of mass of resonators. In zero approximation, the fast system is a reservoir of potential energy for slow.

The frequency of mechanical oscillations of the electromechanical system depends on its parameters and the frequency of external electrical action:

$$\Omega_0 = 2Mk_2n^2\sqrt{\frac{\beta_{11}}{2\beta_{11}}}\sqrt{(n^2-\omega^2)-(k_1k_2)^{-1/2}2\delta^2\kappa\frac{\omega}{n}}. \quad (8)$$

Note that the maximum absorption of electromagnetic energy by mechanically stable uniform formation of resonators corresponds to external frequencies close to their own. At the same time energy of electrical oscillations of the system is transferred to energy of mechanical ones.

Suppose that a hydrogen atom in the basic state can be considered as a linear oscillatory system with one degree of freedom, according to classical representations. Therefore, the process of forming a hydrogen molecule can be considered as grouping into a single mechanically stable formation of two electric resonators.

Based on our results of the study of the ponderomotive interaction of two electric resonators, comparing the oscillations of the linear harmonic oscillator (with a frequency corresponding to the electron velocity in the first Boron orbit) with the free state of the hydrogen atom, the following dissociation energy of the hydrogen molecule D = 4.05 eV is obtained for the interaction energy of two hydrogen atoms corresponding to the inter-nuclear distance R = 0,741 A °, which is well consistent with the experience data. The agreement of known experimental and calculated values confirms the correctness of qualitative reasoning when considering the homeopolar bond of diatomic molecules.

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