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:

\[
\begin{align*}
\beta_{11}\ddot{x}_1 + \epsilon_{11}x_1 + \alpha_{11}x_1 + \beta_{21}\ddot{x}_2 + \epsilon_{12}x_2 + \alpha_{12}x_2 &= \Phi^1(x_1, x_2; t) \\
\beta_{21}\ddot{x}_1 + \epsilon_{21}x_1 + \alpha_{21}x_1 + \beta_{22}\ddot{x}_2 + \epsilon_{22}x_2 + \alpha_{22}x_2 &= 0 \\
\beta_{33}\ddot{x}_3 + \epsilon_{33}x_3 + \frac{d\Phi}{dx_3}(x_1, x_2) + \frac{d\Phi}{dx_3}(x_1, x_2) &= 0
\end{align*}
\]

(1)

where \(x_1\) and \(x_2\) are charges in the first and second resonators; \(x_3\) - distance between resonators; \(\beta_{ik}, \alpha_{ik}\) are eigen- and mutual coefficients; \(\epsilon_{33}\) and \(E_{33}\) - 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

\[
\begin{align*}
\dot{x}_1 + 2\delta x_1 + n^2 x_1 + \gamma_1 \dot{x}_2 + 2\delta n^2 x_2 + n^2 \gamma_2 x_2 &= \Phi(x_1, x_2; t) \\
\gamma_2 \dot{x}_1 + 2\delta \gamma_2 x_1 + n^2 \gamma_2 x_1 + \dot{x}_2 + 2\delta n^2 x_2 + n^2 x_2 &= 0
\end{align*}
\]

(2)

here \(n = \sqrt{(\alpha_{ii}/\beta_{ii})}\) is the partial frequency of the resonators; \(\delta = (E_{ii}/2\beta_{ii})\) - damping of resonators; \(\gamma_1, \gamma_2\) and \(\kappa\) - coefficients inductive, capacitive and ohmic.

Links that may vary within:

\((-1 \leq \gamma_1 \leq 1), (0 \leq \gamma_2 \leq 1), (0 \leq \kappa \leq 1)\)
under laws:
\[
g_1 = \frac{(k_1)}{x_3}, g_2 = -k_2 x_3, \kappa = \text{const.}
\]

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 \( \omega; \) 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 [\( \omega \) \(< n \)]. 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:
\[
U = M \left[ \frac{(n^2 - \omega^2)}{4} \left( \frac{k_0 x_1^2}{x_3} + k_1 x_1^2 x_3^2 \right) - 4 \delta \omega^2 \left( \frac{k_1 x_1^2}{x_3} + k_2 x_3 \right) \right] (3)
\]

where \( M \) is a constant depending on parameters of resonators, amplitude and frequency of external influence. The curve of dependence of potential energy of resonators, amplitude and frequency of external influence. The curve of dependence of potential energy of ponderomotive interaction of two electric resonators, comparing the process of forming a hydrogen molecule can be considered as a linear oscillatory system with one degree of freedom. At the same time energy of electrical oscillations of resonators corresponds to external frequencies close to their natural frequency. 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 \( D = 4.05 \text{ eV} \) is obtained for the interaction energy of two hydrogen atoms corresponding to the inter-nuclear distance \( R = 0.741 \text{ Å} \), 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.

References
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