

The free and forced librations of the Moon with liquid shell and solid core

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In report we present our results of the study of lunar physical libration of the Moon on the base of its two and three layers models. On the base of analytical solution for two layers model (the Moon with liquid core) and empirical theory of the Moon's rotation (Rambaux, Williams, 2011), we have identified period, amplitude, and the initial phase of the fourth mode of free libration of the Moon, caused by liquid ellipsoidal core. Preliminary results of studies of three-layers model of physical librations of the Moon have been obtained on the base of some simplified approach for the problem of rotation of the Moon with liquid and rigid cores. The plans for future studies of the Moon rotation are discussed.

The modern view of internal structure of the Moon planet takes into account a complex two- or three-layer model. In our work the analytical theory of lunar physical libration based on its two-layer model consisting of a non-spherical solid mantle and of the ellipsoidal liquid core has been developed. The Moon moves on high-accurate perturbed orbit in the gravitational field of the Earth and other celestial bodies. On the base of two layers model of the Moon we have fulfilled systematic studies of the Moon physical librations. And in first we have presented a solution of the problem in components of vector of angular velocity of the Moon. An analytical presentation of LOD of the Moon with high accuracy in form of trigonometric series has here the progressive value. In first we have determined the fourth mode of free libration of the Moon caused by the influence of the liquid core oscillations of pole axis of rotation of the Moon (its mantle), with a long period in 205.7 yr, with an amplitude of $0''$ 0395 and the initial phase of -134° (for the initial epoch 2000.0). This oscillation reflects the so-called phenomenon of free oscillation of the liquid core. The estimates for the dynamic (meridional) oblatenesses of the ellipsoidal liquid core of the Moon: 0.000442 and 0.000283 have been obtained. These fundamental parameters of geodynamics of the Moon could be determined only on the base of data of observations. Earlier the attempts to determine the period of free core nutation undertaken. Our results were obtained by comparing of the developed analytical theory of lunar physical libration with empirical theory libration of the Moon, constructed on the basis of laser observations in last about 40 years (Rambaux, Williams, 2011).

Preliminary results of studies of three-layers model of physical librations of the Moon have been obtained on the base of some simplified approach for the problem of rotation of the Moon with liquid and rigid cores. We have analyzed the Cassini's motion of the decoupled solid core and its librations in longitude to compare with the Moon motions. On the base of Getino, Ferrandiz et al. approach we give estimations of the periods of free librations of this system. We have constructed differential equations of rotational motion of three layers Moon from positions of the Hamiltonian formalism with application of Andoyer's and Poincaré's variables. Now we construct analytical theory of rotation of the Moon system consisting from the non-spherical mantle, ellipsoidal liquid core and solid core.

Keywords: Moon rotation, free libration, liquid core, solid core