Calculation and analysis on axial acoustic radiation force of a Bessel beam on sphere particals

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Abstract

There have been numerous theoretical investigations of the acoustical radiation force of plane traveling waves incident on spherical objects in an inviscid fluid. Some research suggests the possibility of trappingsmall objects (such as biological cells) near the focus of a single traveling wave. This is in part because ultrasonic beams might provide an alternative to laser beams for trapping objects of biological or medical interest and because of potential applications in reduced gravity associated with space flight. In either the acoustic or electromagnetic case an important property of focused beams is that conditions have been predicted where the radiation force is in the opposite direction of the beam propagation even in the absence of significant dissipation.

In this paper, the axial acoustic radiation force of fluid sphere and elastic sphere illluminated by Bessel wave calculated by partial waves series expressions (PWSE) is studied. By means of the the harmonic expansion of Bessel beam and the scattering form function of sphere partical, the expression of the axial acoustic radiation force can be derived. The Bessel beam is characterized by the cone angle β of its plane wave components where $\beta = 0$ gives the limiting case of an ordinary plane wave. Through the inspection of scattering form function of different scattering angle, the scattering into backward hemisphere is significantly depressed in the Bessel beam case where the acoustic radiation force Y_p is negative. Negative axial forces are found to be correlated with conditions giving reduced backscattering by the beam. This condition may also be helpful in the design of acoustic tweezers for biophysical applications. Other potential applications include the manipulation of objects in microgravity. In the other hand, the effect of the thickness ratio of double layers fluid sphere is analyzed. Meanwhile, through series of combiantions of materials and thickness for elastic sphere and elastic shell, a wider frequency range and higher magnitude of negetive Y_p could be achieved, and the radiation force of elastic sphere may be affected by the reasonance of sphere elastic modes. Low frequency approximations to the radiation force are noted for rigid, fluid, and elastic solid spheres in an inviscid fluid.

Keywords: Bessel beam; acoustic radiation force; fluid sphere; elastic sphere