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MOTION OF ROTATING SPHERICAL PARTICLES TOUCHING A WALL

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Abstract: *The paper deals with an analysis of motion of rotating spherical particle in calm water, when the particle is in contact with a smooth, horizontal wall. The motion was visualized by a fast digital camera at 1000 frames/second. Based on software analysis the particle trajectories as well as rotational velocities were determined. Values of vertical, horizontal and rotational velocities were used as input parameters for numerical model and the results are compared with experimental data. Experiments were performed with glass particle of diameter 25 mm, initial values of rotational speeds varied from 500 to 3000 revolution per minute.*

Keywords: ***Particle rotation, particle trajectory, Magnus force.***

1. Introduction

Particle motion and particle-wall collision play an important role in many industrial processes involving suspension flows. The collisions affect particle accumulation and dispersion and inter-phase transport and mixing. Compared to a dry collision the kinetic energy of a particle in a liquid environment is dissipated by viscous stresses in the liquid and by inelasticity during collision (Li et al., 2012). The ratio of particle inertia to viscous forces is quantified through the Stokes number, $St = (1/9)(\rho_p/\rho_f)Re$, where Re is the particle Reynolds number based on an impact velocity. Although many papers deal with the particle-wall collision a little is known about the collision when the particle rotates. The aim of this contribution is to analyze a movement of the rotating particle, calculate a theoretical trajectory of the particle and compare it with the experimental observation.

2. Experimental set-up

The experiments with rotating spherical particle were realized in a water tank of dimensions 40 x 28 x 20 centimeters. The tank was filled with water up to a level 60 mm above the bed. The bed was formed by a glass plate of thickness 19 mm. The particle was a glass sphere of diameter 25 mm and density 2470 kg/m3. Water temperature was 24°C. The particle movement in water was recorded with a frequency of 1000 frames per second using a digital video camera NanoSence III+. Hairlines were drawn along two perimeters of the particle to make it possible to determine the particle rotation. The initial values of rotational velocities were 500, 1000, 2000 and 3000 rpm. The particle always rotated in counter-clockwise direction. Only experiments in which the plane of the particle trajectory was parallel to the plane of the video camera objective were chosen. To analyze the particle movements functions implemented in Matlab Image Processing Toolbox were applied. If the position of the particle center is known the translational velocity components can be easily calculated.

3. Discussion of the results

The particle motion in fluids is described by a set of ordinary differential equations taking into account interaction of several forces like submerged gravitational force, drag force, force due to the added

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mass, Magnus and history forces and torque acting on a rotating particle. History force was not considered due to the relatively large particle diameter and high Reynolds numbers (Re > 6000). As we know the particle trajectories and the translational and rotational velocities just after the impact we could solve the differential equations. The Magnus force coefficients, C_M, were determined for each jump to obtain the best coincidence between the measured and the calculated trajectories. A dependence of coefficient C_M on initial values of non-dimensional angular velocity Γ_0, ($\Gamma_0 = 2Re_{\omega out}/Re_{out}$) is shown in Fig. 1, from which an approximation curve can be drawn in the from

$$C_M = \frac{0.523}{3.49 + \Gamma_0} \tag{1}$$

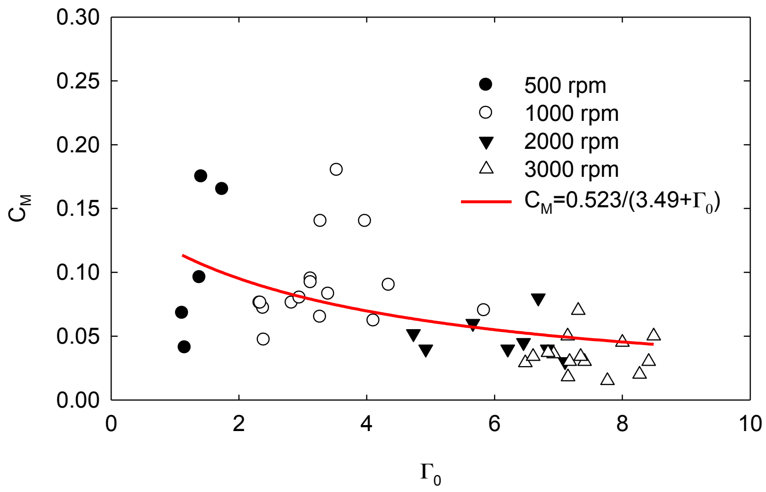

Fig.1: Dependence of Magnus force coefficient on non-dimensional angular velocities

4. Conclusion

Movements of the spherical particles rotating in calm water and touching the horizontal bed were visualized and analyzed. Due to very low values of dynamic friction coefficients no changes of the angular velocities were observed during collision process. The angular velocities monotonically decreased during time and the drag torque acting on the particle could be described by a moment equation, where a modification of the Sawatzki drag torque coefficient is suggested according to the equation $C_\omega = 1.3\ C_{\omega\ Sawatzki}$.

Measured values of the translational and angular velocities just after the collision were used as initial parameters for numerical simulations of particle movements. The Magnus force coefficients were determined for each jump to obtain the best coincidence between the measured and the calculated trajectories. The Magnus force coefficient can be approximated by the Equation (1).

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