Study of Rotation of Ellipsoidal Particles in Combined Simple Shear Flow and Magnetic fields

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Introduction: Jeffery's theory describes the periodic rotation of ellipsoidal particles in a simple shear flow at vanishing Reynolds number limit[1]. A 2D fluid-structure interaction (FSI) model is created to study the effect of magnetic field and particle aspect ratio on the period of rotation and symmetry of ellipsoidal paramagnetic particles.

Computational Methods: The fluid field, **u**, is governed by the continuity equation and Stokes equation:

$$\nabla\cdot\mathbf{u}=0$$

$$\rho\frac{\partial\mathbf{u}}{\partial t}=\nabla\cdot\left[-p\mathbf{I}+\eta_f\left(\nabla\mathbf{u}+(\nabla\mathbf{u})^T\right)\right]$$

The velocities of top and bottom walls are set to have the same magnitude but opposite directions. The periodic flow conditions are set to the left and right boundaries of the computational domain.

The governing equations of the uniform magnetic field are given as:

$$\mathbf{H}=-\nabla V_m$$

$$\nabla\cdot\mathbf{H}=0$$

The magnetic potential difference is set on the top and bottom walls. Magnetic insulation boundary condition is applied on the left and the right boundaries of the computational domain.

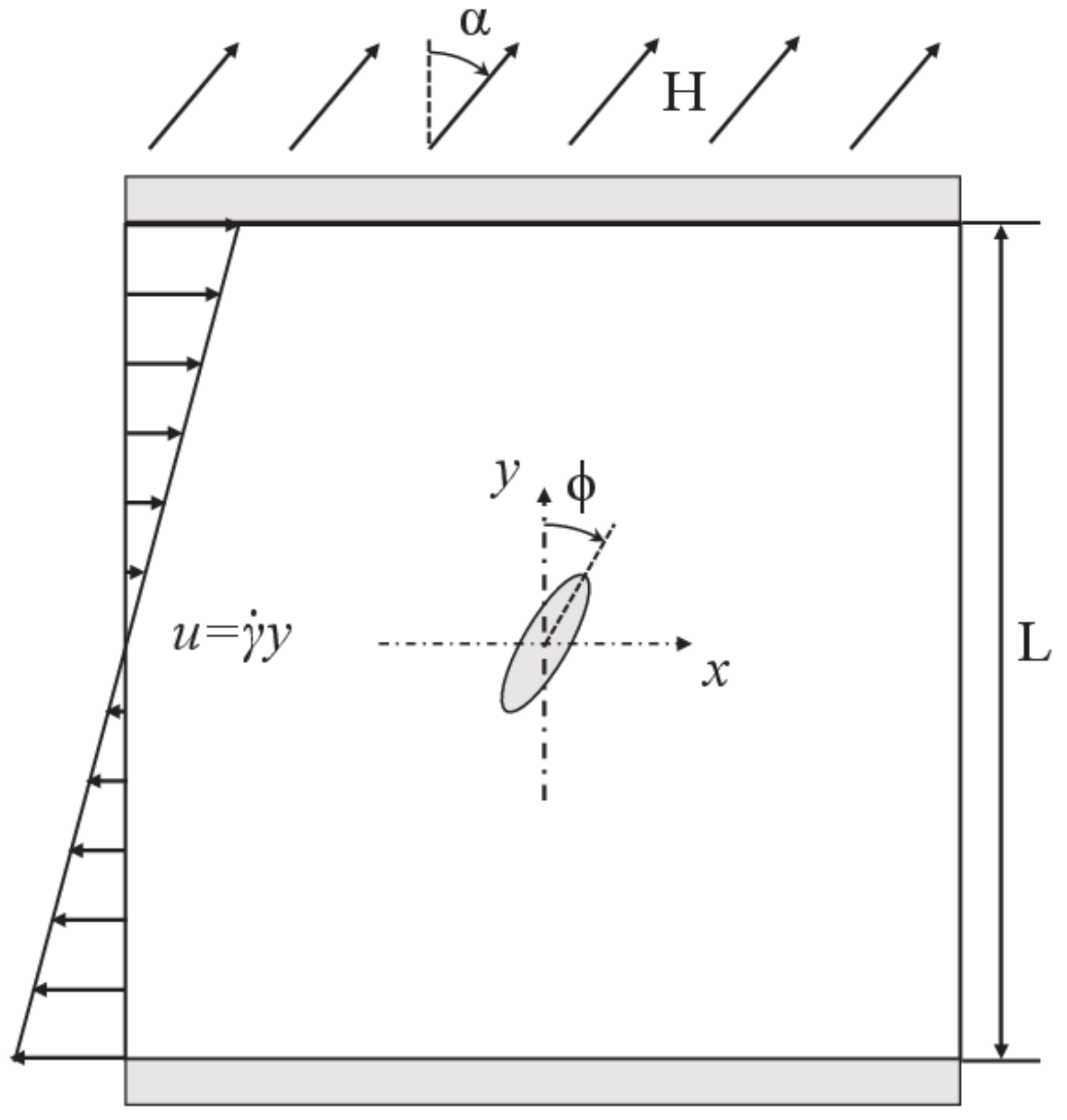

Figure 1. An ellipsoidal particle suspended in a simple shear flow and under a magnetic field **H**, which is directed at an angle α.

Results: Magnetic and flow fields

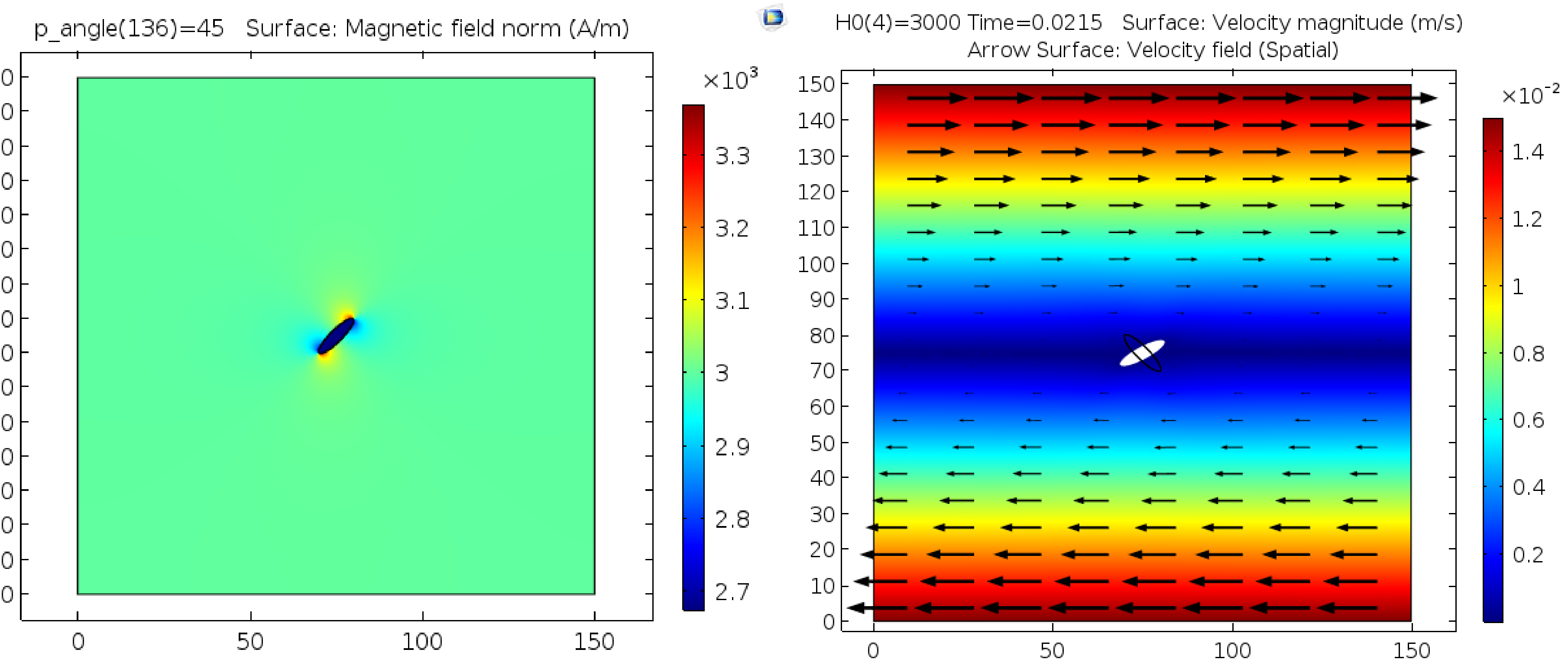

Figure 2. (a) Magnetic field around the particle under the uniform magnetic field of H_0=3000A/m at ϕ=45° .(b) Velocity field in a simple shear flow at a shear rate of $\dot{\gamma}$=200 s^{-1}.

Results: The effect of the strength and direction of magnetic field and particle aspect ratio

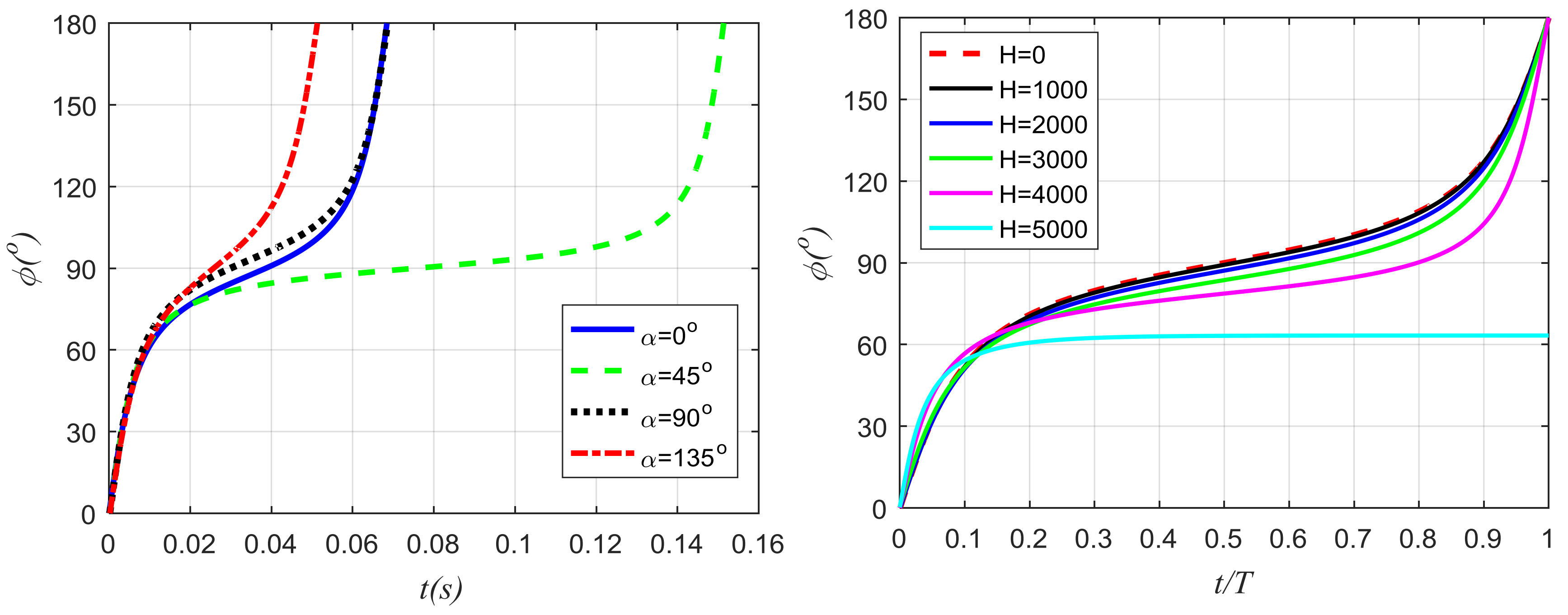

Figure 3. The effect of magnetic field strength H (A/m) on the rotation period and asymmetry of the particle rotation. The magnetic field is applied at angle strength (α=0°).

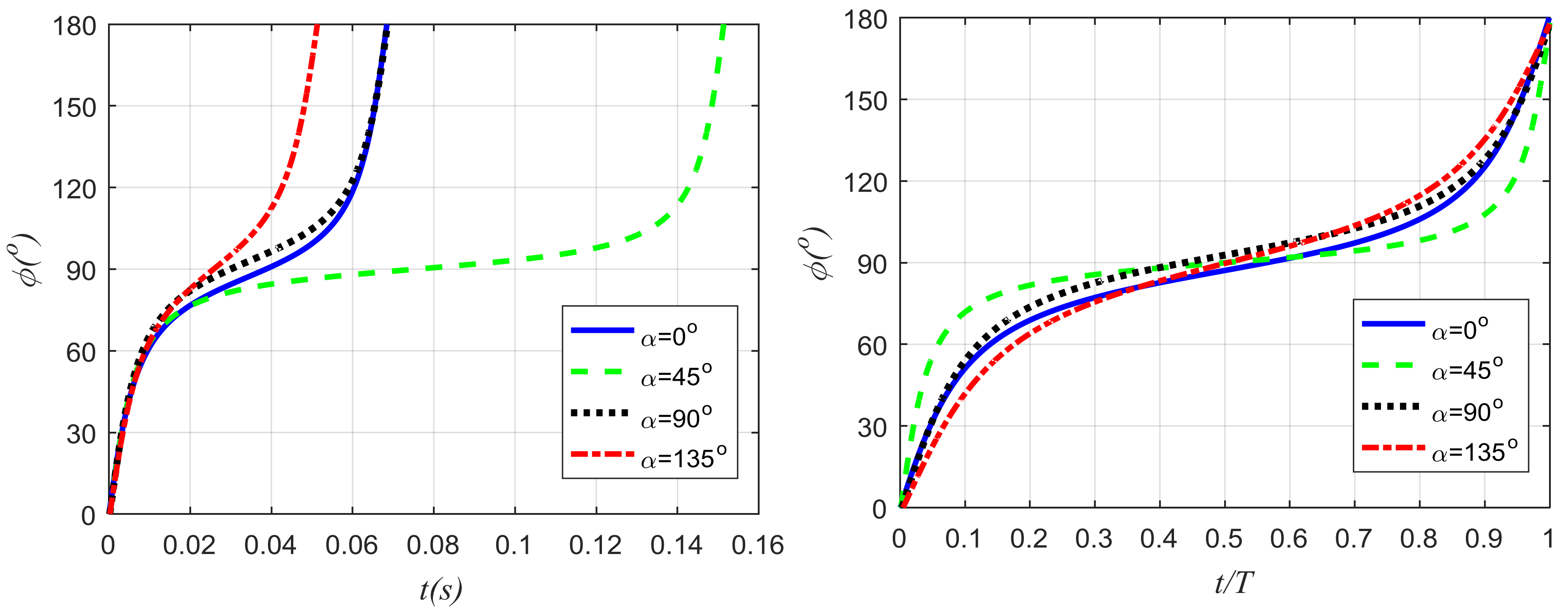

Figure 4. The effect of the direction of magnetic field at a fixed strength (H=2000A/m) on the rotational period and asymmetry of particle rotation.

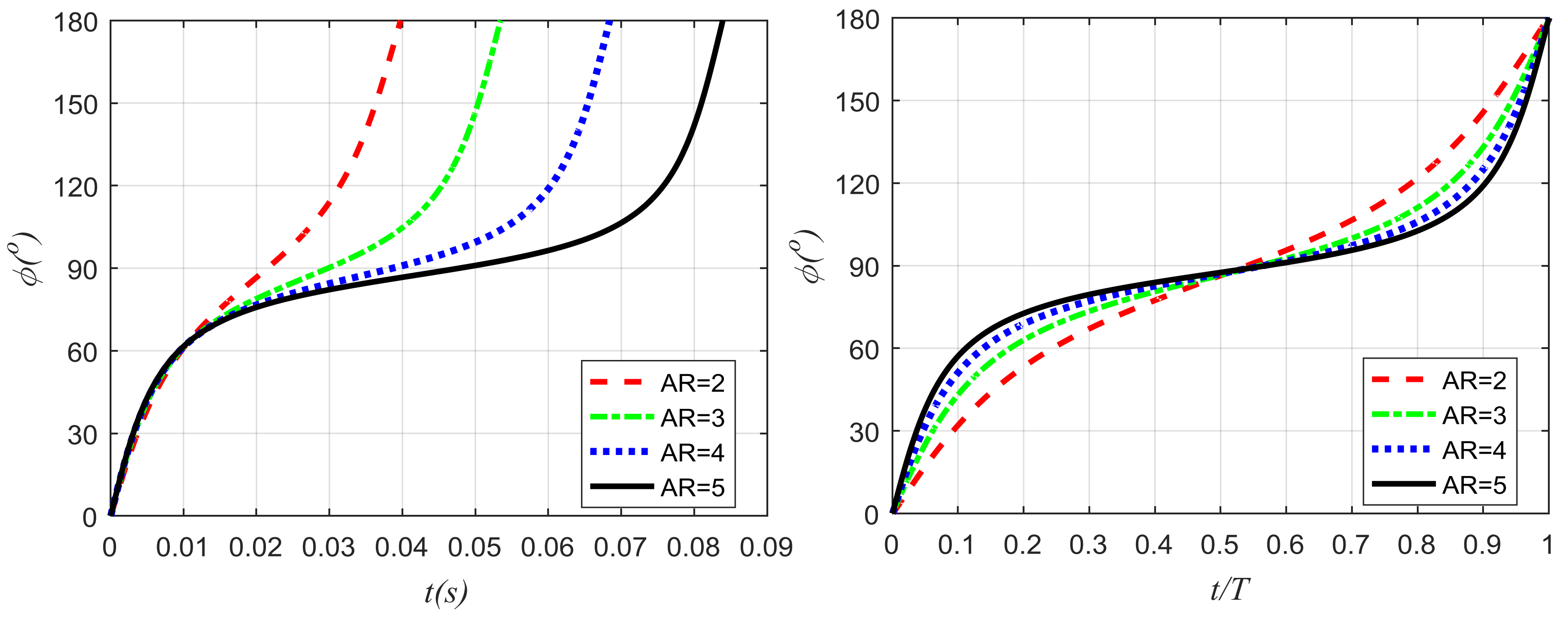

Figure 5. The effect of particle aspect ratio on the rotational period and asymmetry of particle rotation at (H=2000A/m, α=0°).

Conclusions: The magnetic field strength has a significant effect on the period and asymmetry of rotation of particle. As the magnetic field strength increases, the rotation period of particle increases and the asymmetry of rotation becomes more pronounced. The direction of magnetic field modifies both the period and asymmetry of rotation of particle.

References:

1. Jeffery GB. The Motion of Ellipsoidal Particles Immersed in a Viscous Fluid. Proceedings of the Royal Society A: Mathematical, Physical and Engineering Sciences; **102**(715):161–179 (1922).