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RHEOLOGY OF A RED BLOOD CELL SUSPENSION COMPUTING WITH A BOUNDARY ELEMENT-FINITE ELEMENT COUPLED METHOD

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Blood is a suspension of red blood cells (RBCs) and its rheology is important when discussing the physiology of the cardiovascular system. In this study, we performed a numerical investigation of the rheological properties of an RBC suspension from the dilute to semi-dilute regime.

An RBC has no nucleus and consists simply of a cell membrane and the cytoplasm of the hemoglobin solution. To model the RBC membrane, we use the Skalak constitutive law [1], and the membrane equilibrium equation was solved by a finite element method. Due to the small size of the cell, typical particle Reynolds number becomes much smaller than unity. Thus, we assumed that motion of the liquid is governed by the Stokes equation and solved by a boundary element method.

In this study, we calculated the bulk stress of the RBC suspension from dilute to semi-dilute regime. In the dilute limit, cell-cell interactions can be omitted and the bulk stress was calculated by the stresslet generated on a single RBC. The resultant effective viscosity of the suspension are strongly dependent on the viscosity ratio of the cytoplasm and outer liquid. In low viscosity ratio regime, deformation of the cell was suppressed with the viscosity ratio and the inclination angle also becomes larger as the viscosity ratio increases. Accordingly, the effective viscosity of the suspension becomes smaller with the viscosity ratio. In more high viscosity ratio regime, however, the RBC motion qualitatively changes from tank-treading to tumbling motion, which yields high effective viscosity of the suspension.

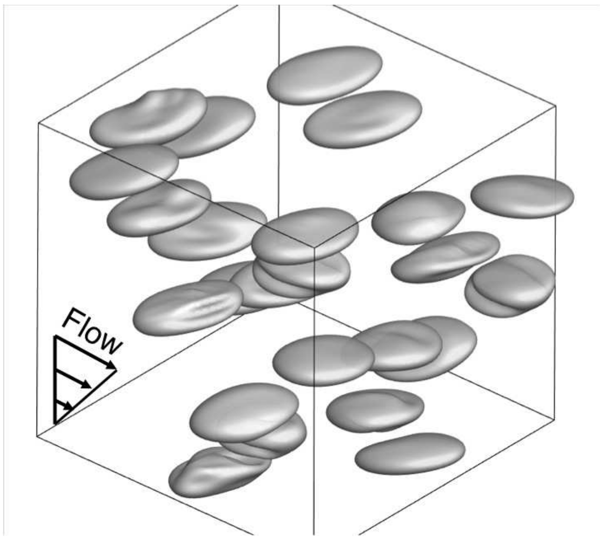

Figure 1: RBCs in a simple shear flow with volume fraction 0.1.

We next investigated the rheological properties of the suspension in the semi-dilute regime. In the semi-dilute limit, the cell-cell interaction cannot be neglected and the hydrodynamic interaction of the cells must be concerned. Then, we simulated multiple flowing RBCs in shear flow (cf. Figure 1), and calculated the particle stress tensor generated by deforming RBCs. Due to the cell-cell interaction effect, the apparent viscosity of the suspension increases non-linearly with respect to the volume fraction c, when $c \geq 0.1$. To strengthen the theoretical understanding of the cell-cell interaction effect, we also conducted order estimation using pairwise interactions. The result suggests that the apparent viscosity increases quadratically with hematocrit in the semi-dilute regime [2]. These findings of the present study will be helpful for gaining a better understandings of complex phenomena in blood rheology, especially *in vitro* experiments.

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