Features of the distribution of the magnetic field in the vicinity of the erythrocyte membrane

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Abstract. The article considers the problem of generating magnetic fields in a living organism. The movement of red blood cells along narrow capillaries is considered. In such capillaries, red blood cells change their shape, stretch and roll along the capillary. Charges located on the surface of the red blood cell generate a magnetic field. Calculations of the magnetic field strength showed that at small distances from the red blood cell (~ 1 μm), the differences in the distribution of intensity are significant. At large distances from the red blood cell (~ 100 μm), these differences in strength are smoothed out. At large distances from the red blood cell, the distribution of the magnetic field strength is similar to the distribution of the magnetic field of the dipole.

1. Introduction
When red blood cells (RBCs) move through narrow capillaries, they change shape, stretch and roll along the capillary [1-4]. Charges located on the erythrocyte membrane generate a magnetic field [5, 6]. This magnetic field can affect the content of red blood cells, because iron atoms are part of hemoglobin. Also, a magnetic field can affect particles located outside the red blood cell. Therefore, it is necessary to make calculations of the magnetic field in the vicinity of the red blood cell, to evaluate its magnitude and distribution.

2. Mathematical model
If the charge \( q \) moves with speed \( V \), then the magnetic field strength

\[
H = \frac{qV \sin \alpha}{4\pi r^2},
\]

where \( r \) is the distance, \( \alpha \) is the angle [7].

The magnetic field strength created by several moving charges is defined as the vector sum of the strengths created by the charges.

The erythrocyte shape is approximated by a truncated cylinder bounded on one side by a hemisphere [3]. The charges are located on the erythrocyte membrane and move along closed trajectories [8-10].

Calculations of \( H \) were made with the following parameters: the erythrocyte charge is \( 0.32 \times 10^{-11} \) C, the number of closed trajectories on the erythrocyte membrane is 101, the number of charges on the erythrocyte membrane is 38594, the erythrocyte membrane rotation speed is 20 revolutions per second,
RBC radius is 2 μm, RBC volume is 94 μm³, RBC surface area is 135 μm², truncated cylinder are 3.4 μm and 11.5 μm, RBC velocity is 100 μm/s [3, 5].

3. Results and discussion

Figures 1 and 2 shows the distribution of the magnetic field strength $H$ (A/m) in the plane perpendicular to the axis of the RBC (axes X) located at a distance 1 μm and 8 μm, respectively, from the front of the RBC in the direction of travel of RBC. Calculations were made in increments of 1 μm.

**Figure 1.** The distribution of $H$ at a distance 1 μm from the RBC.

**Figure 2.** The distribution of $H$ at a distance 8 μm from the RBC.

Figures 3 and 4 show the distribution of $H$ at a distance 8 μm and 98 μm over RBC (in a plane parallel to the XY plane, the step in space is 1 μm and 10 μm, respectively).

**Figure 3.** The distribution of $H$ at a distance 8 μm from the RBC.

**Figure 4.** The distribution of $H$ at a distance 98 μm from the RBC.

Figures 5 and 6 show the distribution of $H$ (A/m) at a distance 8 μm and 98 μm from RBC (in a plane parallel to the ZX plane, the step in space is 1 μm and 10 μm respectively).

Figures 7-13 show the distribution of the magnetic field strength $H$ (A / m) (ordinate axis) on a straight line parallel to the X axis (μm) located at a distance of 3 μm from the X axis (abscissa axis) at angles from the axis Z equal to 0, $\pi / 6$, $2\pi / 6$, $3\pi / 6$, $4\pi / 6$, $5\pi / 6$, $6\pi / 6$ radians respectively.
Figure 5. The distribution of $H$ at a distance 8 $\mu$m from the RBC.

Figure 6. The distribution of $H$ at a distance 98 $\mu$m from the RBC.

Figure 7. Distribution of $H$ at an angle of 0 radians.

Figure 8. Distribution of $H$ at an angle of $\pi/6$ radians.

Figure 9. Distribution of $H$ at an angle of $2\pi/6$ radians.

Figure 10. Distribution of $H$ at an angle of $3\pi/6$ radians.
Figure 11. Distribution of $H$ at an angle of $4\pi/6$ radians.

Figure 12. Distribution of $H$ at an angle of $5\pi/6$ radians.

Figure 13. Distribution of $H$ at an angle of $6\pi/6$ radians.

Figures 14 and 15 shows the distribution of $H$ (A/m) (applicate axis) at a distance 3 μm and 100 μm from the X axis along the X axis (μm) (abscissa axis) and along the angle $\alpha$ (one division on the ordinate axis is equal to $\pi/12$ radians) (ordinate axis).

Figure 14. Distribution of the magnetic field strength $H$ (A/m) at a distance 3 μm from the X axis.
4. Conclusion

The calculations showed that the magnetic intensity at a distance of 1 μm from the red blood cell reaches 0.001 A / m. The distribution of the magnetic field in the vicinity of the red blood cell shows that the strength in front of the red blood cell and behind it is greater than from the sides. The differences in the distribution of the magnetic field strength are significant at small distances from the red blood cell (∼ 1 μm). The differences in the distribution of strength at large distances (∼ 100 μm) are smoothed. This allows us to conclude that at large distances from the red blood cell, the magnetic field of the red blood cell is similar to the magnetic field of a dipole.

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