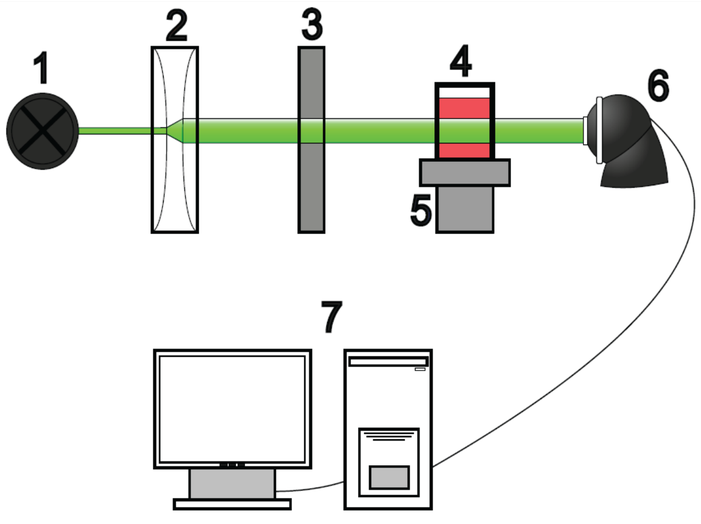
THE PROCESS OF ERYTHROCYTES GROUPING BY ULTRASOUND STANDING WAVE

Doubrovski V.A.[1], Markov S.V.[1, 2], Torbin S. O.[1]
[1]Saratov State Medical University, [2]Saratov State University

Abstract

In this work, experimentally and theoretically (mathematical modeling), the donor blood erythrocytes grouping process by a standing ultrasonic wave is considered. The phenomenon under investigation was recorded by obtaining the process photographic images with their subsequent computer processing. The time duration required for erythrocytes grouping in ultrasonic standing wave nodes was experimentally determined for the given experimental conditions. A mathematical model of erythrocytes grouping process in ultrasonic field was developed on the base of their collective motion analysis. The experimental and simulation results comparison revealed a fairly high level of their correspondence, in particular, such a characteristic of this process as the erythrocytes grouping time duration, as well as the process dynamics itself.

Experimental setup



1 - LED lamp;
2- lens system;
3 - neutral light filter;
4 - cuvette;
5 - couvette attachment with US source;
6 - digital camera;
7 - PC.

Mathematical model

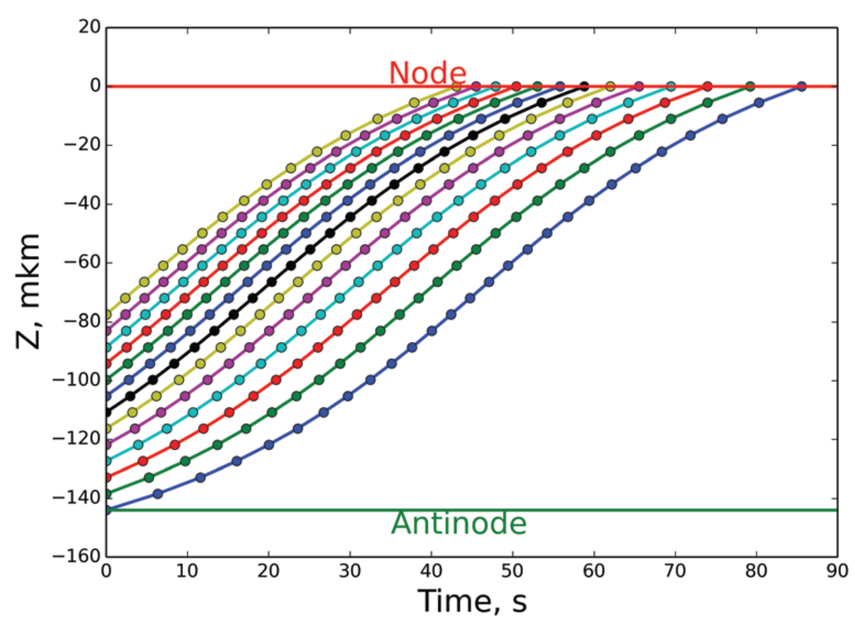
$$v_0 = \frac{A + g - B}{D} \qquad D = \frac{32\eta\pi c^{\frac{1}{3}} r_{er}^3}{\rho_d \, q^{\frac{11}{9}}}$$

$$A = \frac{cF_{r.er}}{\sqrt[3]{q}\,\rho_d} \qquad B = g\frac{\rho_l}{\rho_d}$$

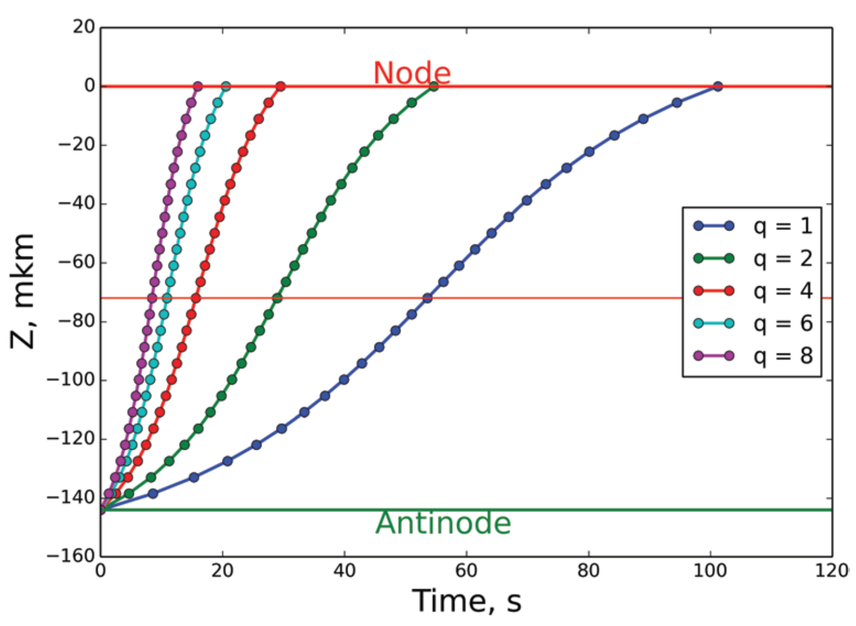
$$\rho_d = \rho_l + \frac{1}{\sqrt[3]{q}} \cdot \frac{4}{3} \cdot \pi r_{er}^3 c\left(\rho_{er} - \rho_l\right)$$

v_0 - layer movement speed;
c - RBC concentration;
$F_{r.er}$ - radiation force for a single RBC;
q - RBCs amount in an aggregate;
ρ_d - layer density;
ρ_l - liquid density;
ρ_{er} - RBC density;
η - liquid viscosity;
r_{er} - RBC radius;
g - gravity acceleration.

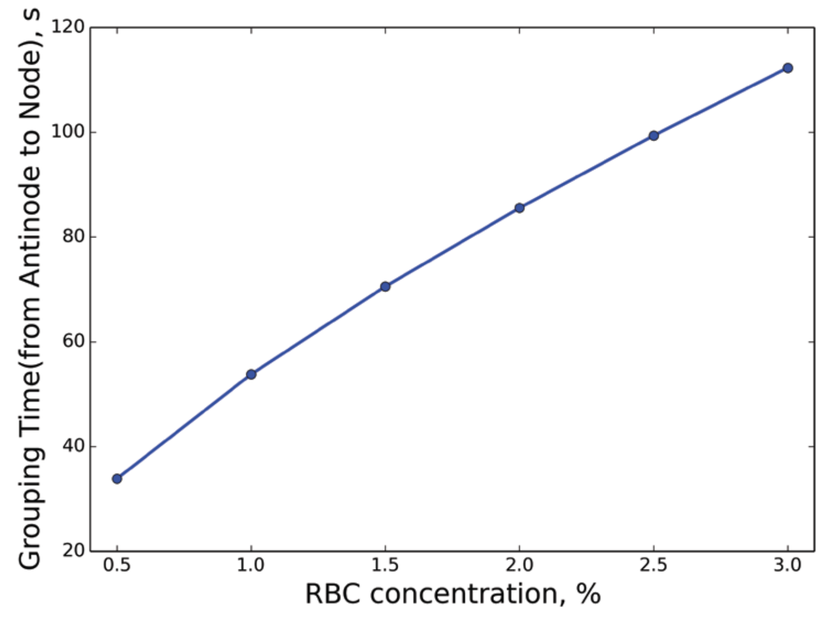
RBC layer coordinate dependence on time at different initial position (from node)



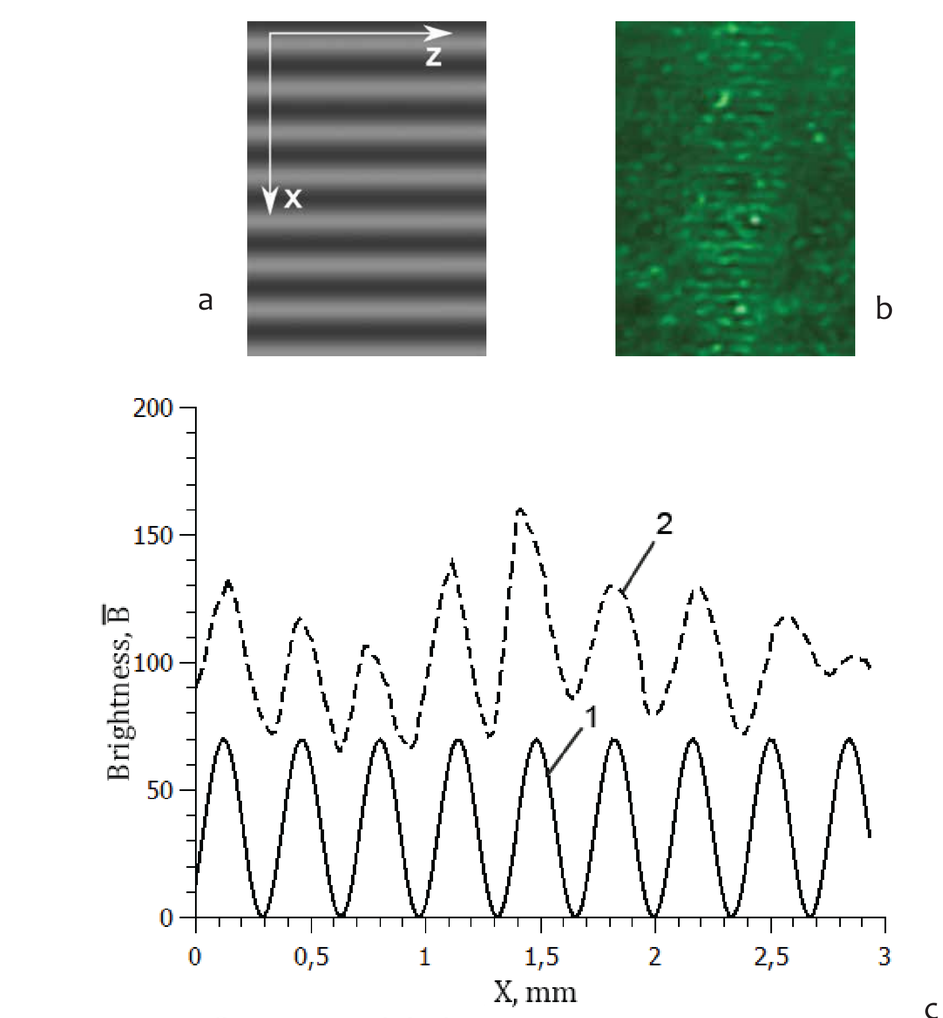
RBC aggregates layer coordinate dependence on time at different q (erythrocytes amount in an aggregate)



RBC grouping time dependence on its concentration in samples

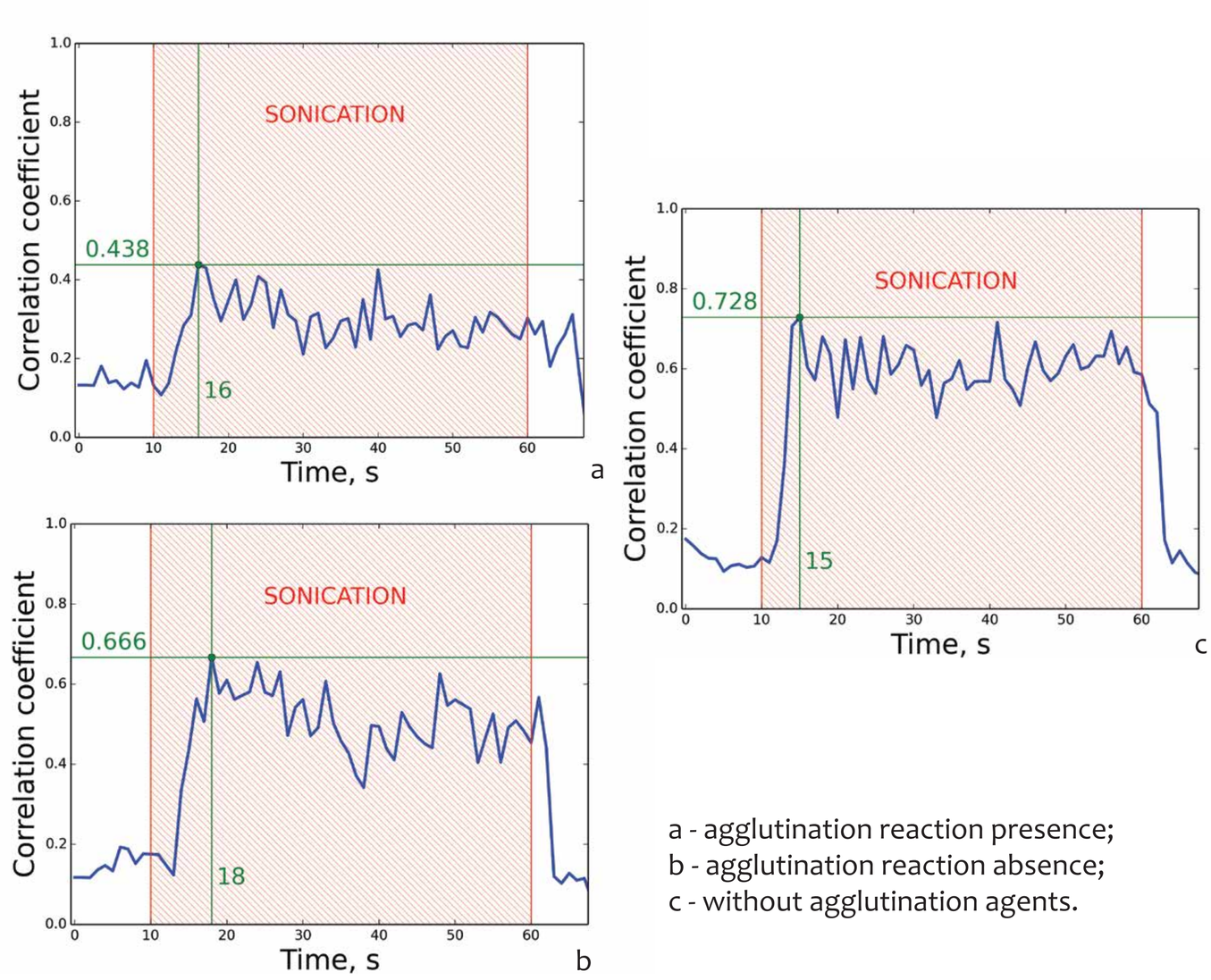


Experimental image and Fourier analysis results



a - RBC stratification modeled image;
b - RBC stratification experimental image;
c - experiment and model comparison (1 - model, 2 - experiment).

Correlation analysis results



a - agglutination reaction presence;
b - agglutination reaction absence;
c - without agglutination agents.

Conclusion

Work results: a mathematical model of RBCs and their aggregates grouping in the ultrasonic standing wave field was built, experimental and theoretical results comparison showed the adequacy of this model; the "periodicity" of RBC stratification in ultrasonic standing wave field is shown; images for the cases of the presence and absence of the agglutination reaction analysis showed a significant difference between them. The bottom line is that the impact with an ultrasonic standing wave on the blood sample contributes to a more accurate determination of an agglutination reaction presence, and, therefore, is a key element in the austo-optical blood typing method development.