# 방사광 X선 PIV 기법을 이용한 혈액유동의 특성연구

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# Hemodynamic study on blood flows using synchrotron X-ray PIV technique

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## 1. Introduction

Rapid expansion of the BT (biotechnology) and biomedical industries has led to heightened activity in research works on circulatory diseases, which has recently ranked as the most fatal disease. Circulatory diseases have been known to be mainly caused by outbreaks on hemodynamic force in blood vessels(1). Hemodynamic information such as the spatial distributions of flow velocity, shear rate, and shear stress are essential to the early detection of circulatory system abnormalities such as atherosclerosis, aneurysms, poststenotic dilatations, and arteriovenous malformations(2).

For investigating hemodynamic information in detail, more detailed and quantitative data about fluid-dynamic characteristics of blood inside the vessels of several millimeters in diameter are required because most fatal vascular diseases have been occurred in such blood vessels. To do this, we have to visualize and analyze real blood flows not only with spatial resolution less than several tens micrometer but also with temporal resolution less than several tens millisecond.

## 2. Method and Results

In this study, we used the synchrotron X-ray PIV technique in which a synchrotron X-ray (7B2 beamline at Pohang Light Source, Korea) was used as a light source for the PIV method(3). For establishing this synchrotron X-ray PIV system, we have to consider how to acquire pertinent X-ray flow images based on various synchrotron X-ray imaging mechanisms.

When a blood sample is illuminatedwith a coherent synchrotron X-ray, speckle patterns are formed due to the propagation based phase contrast and interference-based enhancement method. In general, the speckle patterns become clearer as the sample-to-scintillator distance (d) and thickness of the blood sample (t) are increased (see Fig. 1A). Seven X-ray images for different hematocrit were also obtained to investigate the effect of blood composition of RBCs and plasma (see Fig. 1B).

We investigated a blood flow inside an opaque tube having a circular cross-section using the synchrotron X-ray PIV method for analyzing the non-Newtonian characteristics of real blood flows(4). The spatial resolution between adjacent velocity vectors was 43.3 x 43.3 μm2in physical size. For finding the significance of this measurement technique for studying blood flows, we compared the measured velocity profile with several hemorheologic models for blood flow. Figure 2 shows that the measured velocity profile is well agreed with the velocity profile suggested by Casson model(5). The typical parabolic velocity profile of Newtonian flow has some discrepancy with the experimental result.

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In the central region of the tube, a potential region in which no velocity gradient exists is formed due to the yield stress of blood by $r_c / R$ = 0.044(6).

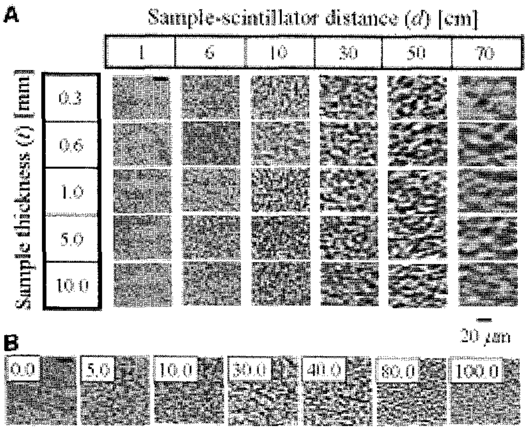


Fig. 1 Speckle patterns of blood samples. A, X-ray images with respect to d and t. B, X-ray images with respect to H.

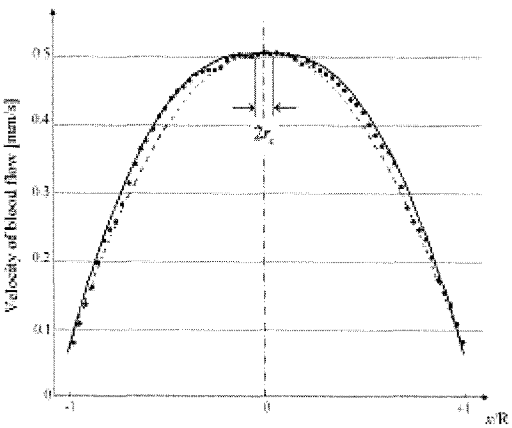


Fig. 2 Streamwise mean velocity profiles for comparing hemodynamic model.

: velocity profile of experimental data;

: parabolic curve fitting profile;

: Casson model fitting profile.

## 3. Conclusion

In this study, the synchrotron X-ray PIV method wasused to obtain quantitative hemodynamic information of whole blood flows without any contrast media or seeding tracers. The X-ray PIV method can be used to investigate various hemodynamic phenomena experimentally and would be used for measuring the volumetric flow rate of blood invasively.

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