# PREVENTION OF PUMP THROMBUS USING CIRCULAR VIBRATION OF MAGLEV IMPELLER —OPTIMIZATION OF VIBRATION CONDITION—

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## Introduction

Centrifugal blood pumps used in extracorporeal membrane oxygenation (ECMO) as well as ventricular assist devices (VADs) are composed of engineering materials and have a risk of thrombus when blood has contact with their material surface. Although pump geometries based on fluid dynamics, biocompatible materials, and anti-thrombogenic coatings have been developed, complete anticoagulation-free prevention of thrombosis has not yet been achieved. To solve this issue, we have developed an anti-thrombogenic technology in which a magnetically levitated (maglev) impeller is vibrated in orbital motion to inhibit adhesion of blood components to the impeller surface [1]-[3]. This technology can be used in combination with above-mentioned conventional anti-thrombogenic technologies and is expected to reduce the use of anticoagulants. In this study, we conducted in vitro experiments to determine the optimum vibration conditions for preventing pump thrombus.

## Methods

Two maglev centrifugal blood pumps [4] are connected in parallel to a mock circulatory loop consisting of a reservoir and a flow resistance, and filled with porcine blood anticoagulated with heparin. One pump was operated without circular vibration, and the other was operated with vibration of an amplitude $A$ of 5 µm to 30 µm and a frequency $f$ of 70 Hz to 280 Hz. The experiments were conducted twice under all vibration conditions. The 10 points marked on the impeller surface were photographed using a microscope before and after the experiment, and the brightness was set to a threshold value so that the areas of adhesion of blood components were black and the areas exposed on the impeller surface were white. The blood adhesion prevention rate (*BAPR*) was calculated using $S_{w/o}$ (areas of blood components adhered without vibration) and $S_{w/}$ (areas of blood components adhered with vibration) by the following equation.

$$BAPR = (S_{w/o} - S_{w/}) / S_{w/o} \qquad (1)$$

## Results

The experimental results showed that either the larger amplitude $A$ or the higher frequency $f$ of the vibration increased *BAPR*. Physically, the inhibition of blood adhesion is thought to be due to a change in the shear rate acting between the material surface and the blood. As shown in Figure 1, the relationship between the "shear acceleration" (the rate of change of shear rate), which can be expressed as a function of $A$ and $f$, and *BAPR* was investigated. The results show that regardless of the values of $A$ and $f$ separately, a high *BAPR* was obtained when the shear acceleration exceeds 8000 $s^{-2}$.

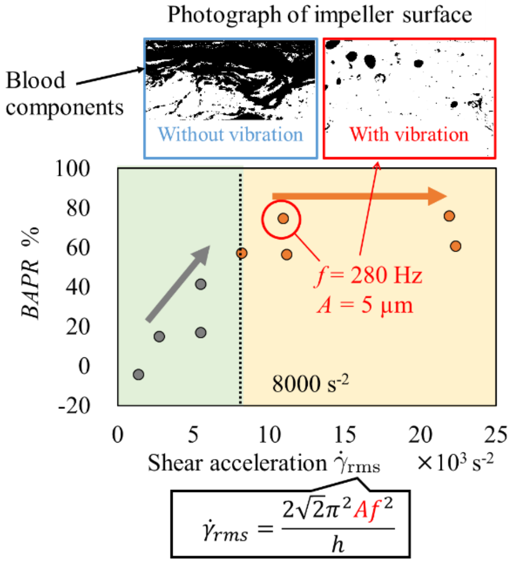


*Figure 1: BAPR against shear acceleration generated by maglev impeller vibration. High BAPR was achieved when the shear acceleration was higher than 8000 $s^{-2}$.*

## Discussion

Shear acceleration of 8000 $s^{-2}$ or higher was identified as a vibration parameter that can achieve a high *BAPR*. This result suggests that not only blood pumps but also any material in contact with blood can be subjected to a certain level of microvibration from the viewpoint of "shear acceleration" to prevent blood adhesion. The outcome is also considered to be a highly versatile result.

## References

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