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# MEASURING SMALL FORCE/MASS USING FLOATING OBJECT WITH SHADOW METHODS

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**Abstract:** A micro/nano force measurement method is proposed in this paper. Viscous damping is introduced to optimize system stability and reduce interference from mechanical vibration. The resolution of the shadow method was approximately 4 nN.

**Keywords:** micro/nano force, shadow, damping, hydrophobic.

## 1. INTRODUCTION

Small force measurement was concerned especially when the Atomic Force Microscope were introduced to explore the world in nano-scale. The deflection of the AFM cantilever magnified by the reflection of the beam focused on the head represents the force acted on the tip. Accuracy of measurement both in stiffness and in the deflection will be impacted by the vibration from the environment. Since the force measurement system is widely constructed based on the response of the elastic materials to the external force, the external disturbance significantly impacts the measurement, especially when the force is not above micro newton.[1-3] In this paper the viscous media, together with hydrophobic material and shadow methods are introduced to establish the prototype of a micro/nano force measuring system. Based on the updated Archimedes' principle, the shadow area of the floating object was considered as the response to the different force acted on itself. [4-5]

## 2. THE MEASURING SYSTEM

Floating on the surface of the water in the vessel with high transparent bottom, a thin polydimethylsiloxane (PDMS) plate (diameter 8mm, thickness 0.5mm) generated a circular shadow, captured by the CCD camera with a resolution of 5472 × 3648 in pixels. The LED white light source was placed right above the vessel. The measuring system is shown in Figure 1.

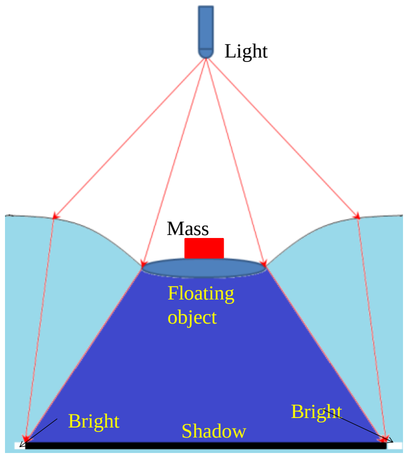


Figure 1. The small force measuring system based on shadow methods

A typical shadow of the plate and the edge of the shadow is shown in Fig. 2A and B, respectively. The first and second order derivative of grey in boundary are shown in Fig. 2 C. The grey of shadow and brightness change slowly, which means first order derivative at this part is almost zero. The grey of the transition section of shadow and brightness changed sharply which means first order derivative at this part is very large. The second order derivative of grey is used to determine the direction. The positive derivative indicates the shadow while the negative indicates the brightness. The position where second order derivative is zero could be used to identify the edge.

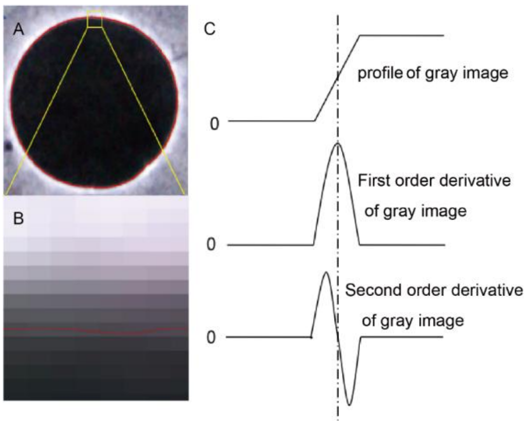

Figure 2. Edge extraction of the shadow. (A) A typical shadow of the PTFE. (B) Edge of the shadow. (C) The first and second order derivative of grey image.

## 3. THE CALIBRATION OF SHADOW METHOD

The calibration of the shadows method is by applying different mass and measuring relative shadow area. While applying the mass, the shadow was simultaneously captured to theoretically calculate the floating force through the above shadow method. The relationship between the weight and shadow area is shown as Figure. 3.This verified the effectiveness of the proposed shadow method.

## 4. THE RESOLUTION TEST OF SHADOW METHOD

The measurement system and the resolution of the shadow method were characterized by applying mechanical forces of known magnitude via loading weights of calibrated mass. The resolution of the balance was characterized by measuring the calculated force noise from the area output. In this way, the noise from the environment and area measurement were accounted for. A continuous picturing shadow of plate showed very stable values with a standard deviation of the weight measurement within 40 Pixel as shown in Figure. 4. Hence, the resolution of the shadow method was approximately 4 nN according to Figure. 3.

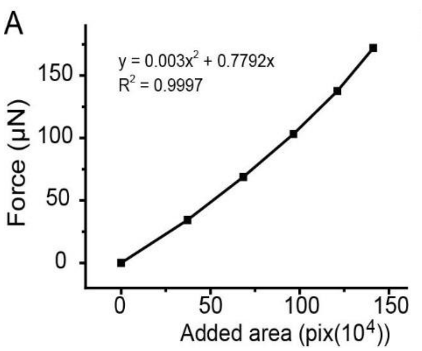


Figure 3. The weight measurement based on shadow method.

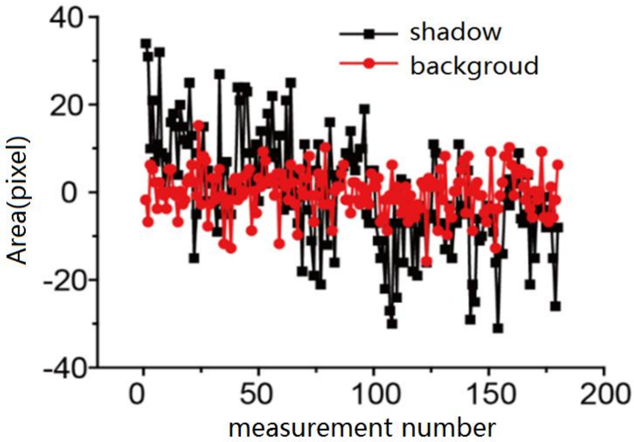


Figure 4. Resolution test of the shadow method.

## 5. ACKNOWLEDGEMENT

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