

# Mechanical Engineering Doctoral Defense

Determination of propulsion matrix from microscale Brownian motion

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## Abstract

The propulsion matrix provides a compact description of the locomotion of a single flagella molecular motor in a low Reynolds number environment. The locomotion properties of individual flagellar motors are central to bacterial behavior, including chemotaxis, pathogenesis, and biofilm formation. However, because conventional hydrodynamic measurement approaches require applied forces, torques, or fluid flows, it is not possible to directly measure the propulsion matrix for an individual microscale helical filament. Here, we overcome the limitations inherent to conventional measurement approaches using a combination of theoretical, experimental, and computational advancements. First, we derive the relationship between the elements of the propulsion matrix with translational and rotational Brownian motion using the fluctuation-dissipation theorem. Next, we perform volumetric fluorescent imaging using high resolution oblique plane microscopy with sufficient spatio-temporal resolution to resolve both translation and rotation of individual helical filaments isolated from *E. coli*'s flagellar motor. Finally, we develop a computational framework to track individual helical filaments across six degrees of freedom, extract diffusion coefficients, and quantify the temporal correlation between translation and rotation. We determine the maximum propulsion efficiency to be  $\sim 1.7\%$ . Direct measurement of propulsion efficiency generally agrees with the ensemble and large-scale measurements previously performed using conventional hydrodynamic measurements. Our findings suggest that the approach described here can be extended to more complex in-vitro experiments that evaluate microscale molecular motors. For example, evaluating sperm motility without inducing chemotaxis or utilizing a microfluidic setup.



May 12, 2022; 10 AM;

Zoom Link: <https://asu.zoom.us/j/2530678256>