# Near wall swimming of helical micro ribbons

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*Abstract*:

We used micro manufacturing techniques to build magnetic helical micro ribbons made of a nickel layer (150 nm) sandwiched between two SiN layers (100 and 170nm) [1]. The ribbon in Fig. 1a is 60$\mu$m in diameter, 150 $\mu$m in width and 740 $\mu$m in length with a helical wavelength of 246 $\mu$m and placed inside a isopropyl alcohol filled chamber of 1cm x 1cm x 0.5cm made of PDMS walls on a microscope glass and covered with another glass at the top. Three pairs of Helmholtz coils are used to generate a rotating magnetic field around the chamber to exert a magnetic torque on the ribbon to rotate it synchronously with the field. A piezo actuator is attached to the microscope glass and driven by 1 and 10 kHz frequencies in the experiments. A three-dimensional CFD model is developed to obtain the velocities of the ribbon using steady Stokes flow assumption around the swimmer due to its rotation and translation. Rotation frequency is fixed in the model, and translational velocities are obtained from force-free swimming conditions. The swimming velocities of the ribbon from the experiments and the CFD model results are shown in Fig. 1b&c. In the simulations, the distance between the swimmer and the bottom wall is varied. According to results, first, there is a mild slow down in both axial and lateral velocities when the piezo-actuator is turned on. Second, the model results agree well with the swimming velocities in the axial direction of the helix but there is a large difference in lateral velocities. The discrepancy could be attributed to magnetic forces due to nonlinearities in the field, or small impurities, such as chipped SiN layers, at the surface of the swimmer that causes traction and hence higher velocities. However, the CFD model is useful to observe interesting behavior under ideal conditions; namely, according to model results the ribbon swimmer slides in the opposite direction to rolling when the gap between the swimmer and the wall is very small. The sliding behavior in close proximity to the wall is because of a large pressure gradient around the nip region when the swimmer is almost in contact with the wall, similarly to the behavior of rotating spheres in cylindrical channels [2]. Lastly, in order to understand the effects of the vibrating plate, a transient model compressible model is developed. Model results indicate that especially a standing wave pattern with a slight nonuniformity can lead to slow-down or speed-up in both components of velocity.

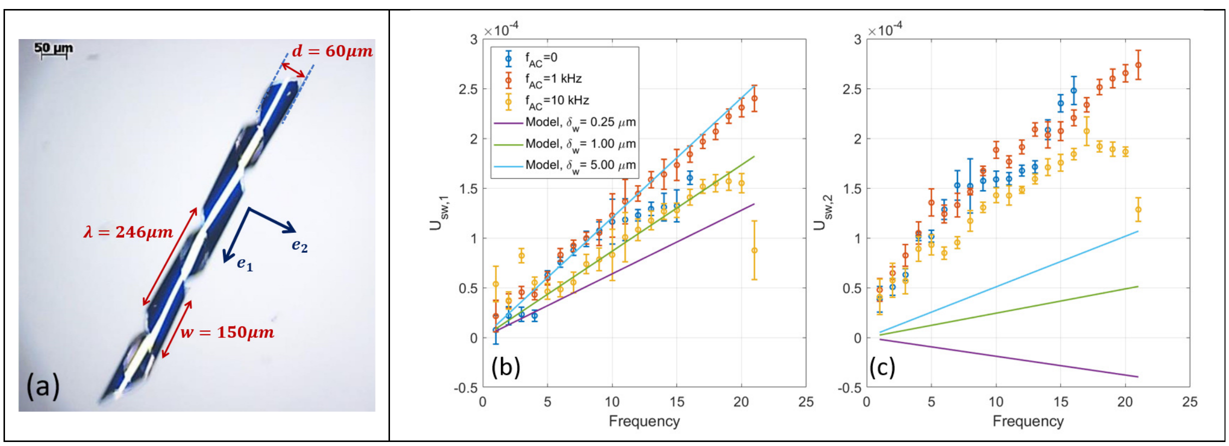


***Figure 1***: (a) Helical micro ribbon. (b) Comparisons of experiments and model results for the swimming velocity in the axial and lateral directions with respect to the swimmer.

## References

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