Experiments with the Hydrodynamic Turbulence Experiment

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Abstract

During the summer of 2015, the Hydrodynamic Turbulence Experiment (HTX) was used to study two phenomena: zonal flow generation and differential centrifugation. The study of zonal flow generation is essential to plasma physics since zonal flows can be a result of turbulence. Zonal flows appear in tokamaks and studying zonal flows will lead to a better understanding of turbulence. As for centrifugation, the HTX reduces secondary circulation, allowing for better separation of materials during the centrifugation process. Differential rotation allows for a stronger centrifugation. Background, collected data, and results of these experiments are presented in this poster.

Hydrodynamic Turbulence Experiment (HTX)

Background

- 15 gallon cylinder used for spinning water
- Divided into three parts which rotate independently: inner cylinder, inner ring, outer cylinder
- Rotation controlled by Labview
- Centrifuge experiments use solid body and differential rotation
- Zonal flow experiments use only solid body rotation
- Princeton Instruments camera used for measuring centrifugation in centrifuge experiments
- Laser Doppler Velocimetry (LDV) used for measuring angular speed in zonal flow experiments
- Jets used to introduce turbulence during zonal flow experiments

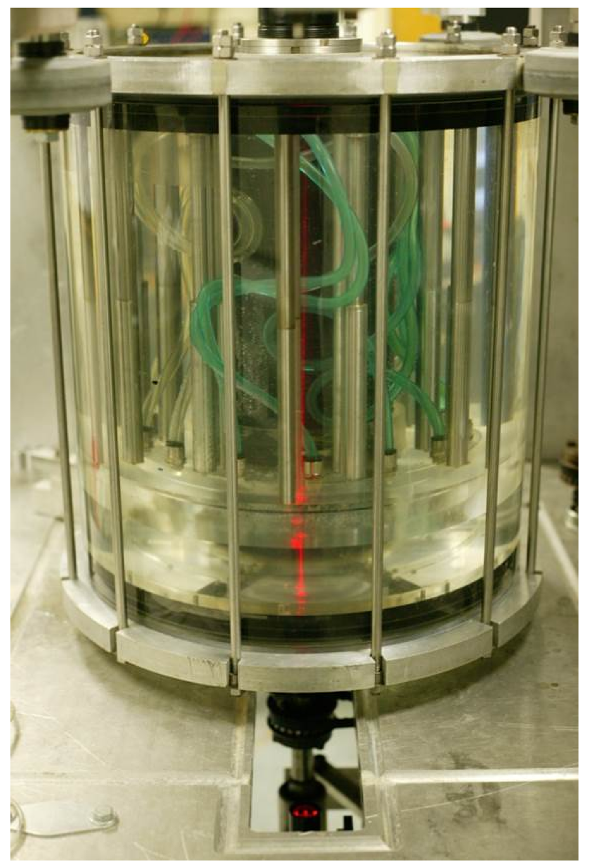

Figure 1: HTX apparatus. The black inner cylinder can be seen behind the jets. The LDV laser can be seen from the bottom. Picture courtesy of Dr. Michael Burin.

Zonal Flows

Background

- Rise out of turbulence
- Specific to the polar direction
- Experiments done characterize the flow radially
- Sloped roofs are used
- Slope of the roof referred to as β
- Zonal flow dependence on β characterized
- Jets in $m = 1$ configuration (six adjacent inlets, six adjacent outlets)

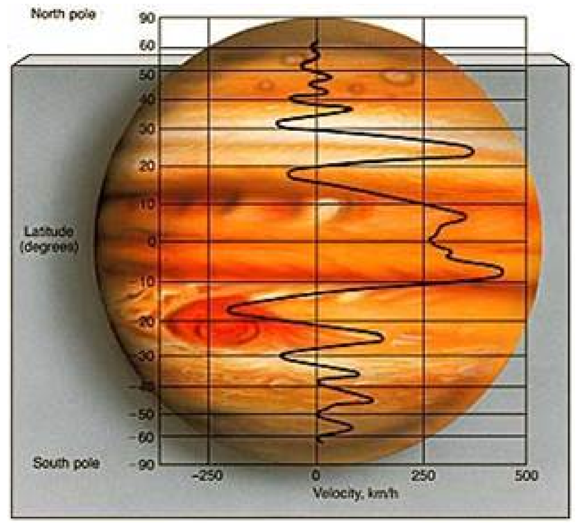

Figure 2: Jupiter's zonal flows. Picture courtesy of Dr. Michael Burin.

Research

- Height of rotating fluid placed at 20 cm
- Roof either sloped upward or downward ($\beta = 0.18$ for upward, $\beta = -0.18$ for downward)
- β measured in cm in height per cm in radius
- Angular speed measured at eleven different radii for five different heights per value of β
- Difference in mean flow with pump on and pump off examined to show dependence on β

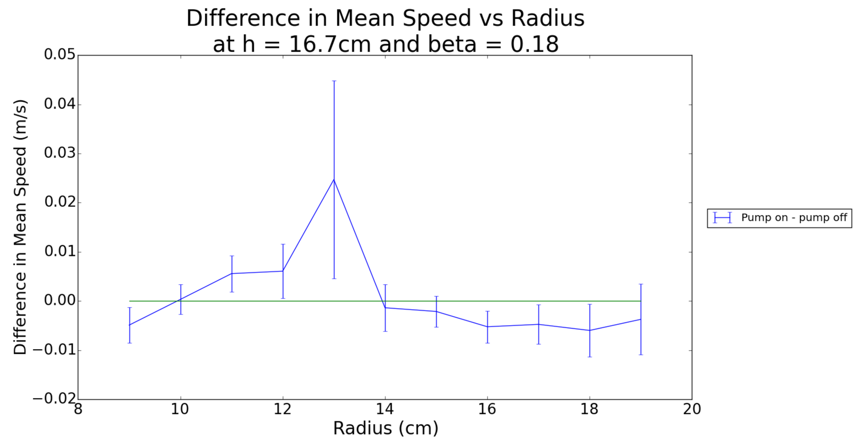

Figure 3: Difference in mean speed while the flow is turbulent and while the flow is stable for positive β

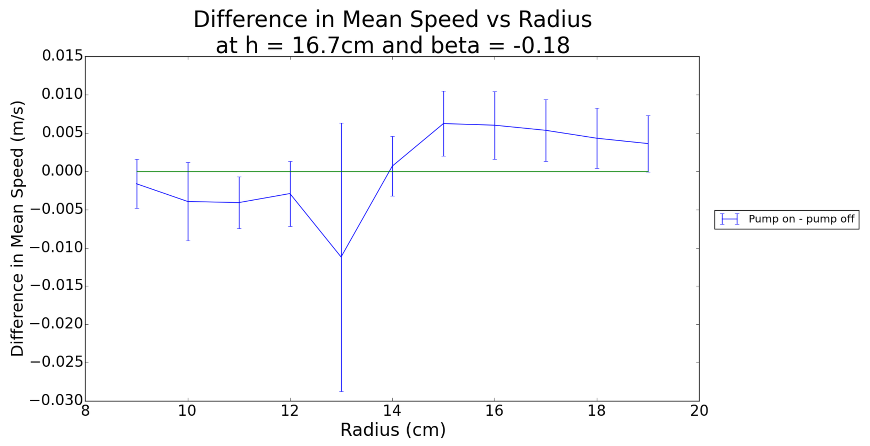

Figure 4: Difference in mean speed while the flow is turbulent and while the flow is stable for negative β

Zonal Flows cont.

Results and Future Work

- Plots positively suggest the β-dependence on the sign of mean flow
- Error bars represent the standard deviation of measurements at that point, divided by the square root of the number of measurements
- Error makes it hard to distinguish the two curves, except at large radii
- Higher pump rates should be examined in order to make this difference more distinguishable

Centrifuge Experiments

Background

- Full height of HTX used (40 cm)
- Titanium Dioxide, TiO_2, (200 nm size) inserted into HTX
- HTX rotates and pushes TiO_2 outward due to centrifugal force
- Three cases of solid body rotation and two cases of differential rotation examined

Solid Body Rotation

- $v_\theta = \Omega r$
- $g_{\text{eff}} = \Omega^2 r$
- $\Omega = 100$ rpm, 150 rpm, 200 rpm used for measurements

Differential Rotation

- $v_\theta = Ar + \dfrac{B}{r}$
- Quantities A and B are constants of the system dependent on inner and outer radii and angular speeds
- $g_{\text{eff}} = A^2 r + \dfrac{2AB}{r} + \dfrac{B^2}{r^3}$
- If A and B are picked correctly, differential rotation will produce better centrifugation than solid body rotation

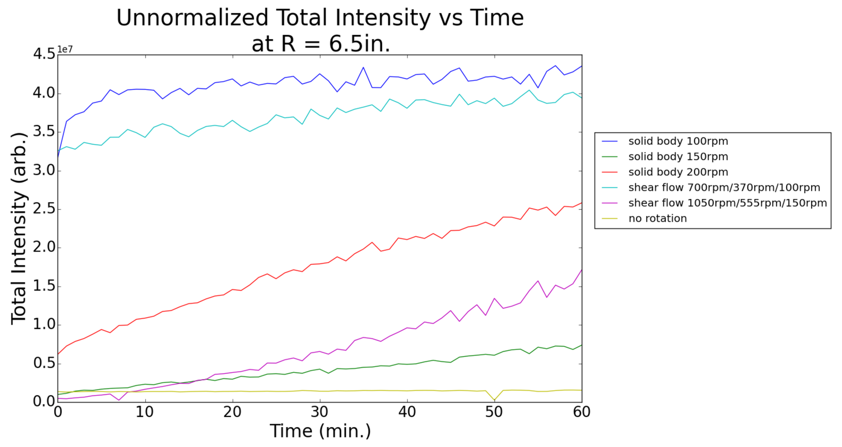

Figure 5: Centrifugation of TiO_2 at outermost radius

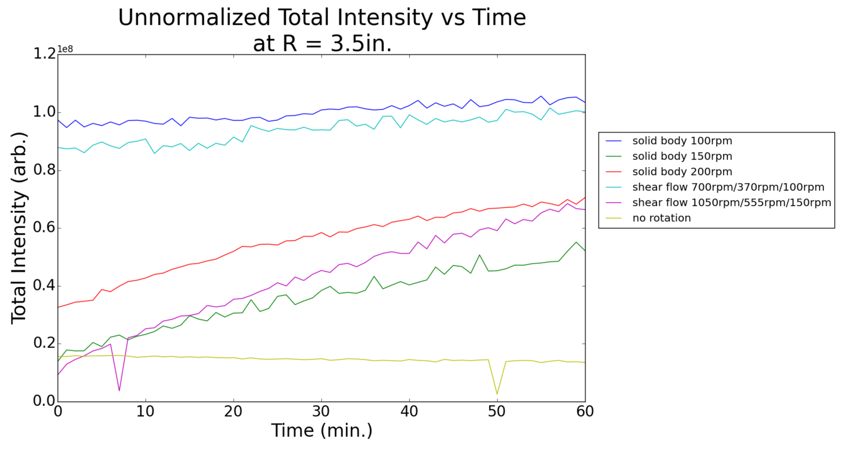

Figure 6: Centrifugation of TiO_2 at innermost radius

Centrifuge Experiments cont.

Research

- Four lasers shine through the bottom of the machine and are captured by Princeton Instruments camera
- Intensity of the lasers measured every minute over sixty minutes
- Intensity growing implies TiO_2 centrifuging outward
- Initial amount and distribution of TiO_2 is major problem

Results and Future Work

- Plots suggest that differential rotation is more effective than solid body
- Experiments need to be repeated with a better control method for the initial amount of TiO_2
- Future experiments should run until 80% removal of TiO_2 achieved
- Potential modifications to the HTX for centrifugation include an inlet for 'dirty water' and removal system for 'dirt' while HTX is spinning

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