# EXPERIMENTAL INVESTIGATION OF GEOMETRY ON TORQUE HYSTERESIS BEHAVIOUR OF TAYLOR-COUETTE FLOW

Melika Gul[1], Gerrit E. Elsinga[1] & Jerry Westerweel[1]
[1]*Laboratory for Aero & Hydrodynamics, Delft University of Technology, Delft, The Netherlands*

*Abstract* This study investigates the effect of the Taylor-Couette geometry, namely the aspect ratio, $\Gamma$, and the gap width ratio, $\eta$, on the torque hysteresis reported by [1]. Measurements were taken at two shear Reynolds numbers, $Re_s$, of 5.5x10$^4$ and 9x10$^4$.The torque was recorded while decreasing or increasing the rotation frequency ratio $a$=-$f_o/f_i$, keeping the rotation frequency difference $f_i$-$f_o$ constant, where $f_o$ and $f_i$ are the outer and inner cylinder rotation frequencies, respectively. Results obtained for $\Gamma$=22 and $\eta$=0.917 at $Re_s$ of 5.5x10$^4$ and 9x10$^4$ show hysteresis occurring in the torque data. Interestingly the hysteresis behaviour is opposite to what was reported before [1], ie. torque is highest for decreasing $a$. Further studies will be performed to understand whether this hysteresis is due to the geometry itself and whether there is a relation between the this phenomenon and the flow structures of the Taylor-Couette flow.

## EXPERIMENTAL SETUP

Torque measurements conducted by Huisman et al.[1] in Taylor-Couette flow reveal that hysteresis occurs with a high probability within a certain range of values for $a$, which is defined as $a$ =-$fo/fi$, where $fo$ and $fi$ are the outer and inner cylinder rotational frequencies, respectively. They relate this difference in the torque values to different turbulent states occurring in the Taylor-Couette flow. However, further studies are needed to understand this phenomenon. Also, questions remain on how the hysteresis behaviour depends on $\Gamma$ and $\eta$. Thus, the aim of this study is to perform experiments to better understand the hysteresis behaviour of the Taylor-Couette flow and to investigate the effect of the geometry on this phenomenon.

Experiments were performed in the Taylor-Couette setup of the Laboratory for Aero & Hydrodynamics in Delft University of Technology. This set up is identical to the facility used by Ravelet et al. (2010). A picture of the Taylor-Couette setup is given in Figure 1. The Taylor-Couette system consists of two independently rotating coaxial cylinders. The inner cylinder has a radius of $r_i$=110 ± 0.05 mm and the radius of the outer cylinder is $r_o$=120 ± 0.05 mm, which results in a gap of $d$=10 mm between the two cylinders and a gap width ratio of $\eta$=0.917. The inner cylinder has a length of $L$= 220 mm and therefore the axial aspect ratio is $\Gamma$=$L/d$=22. The system is closed at both ends with the end plates rotating together with the outer cylinder and the working fluid is water. The torque measurements were performed by a torque-meter attached to the inner cylinder shaft.

**Figure 1.** Picture of the Taylor-Couette setup.

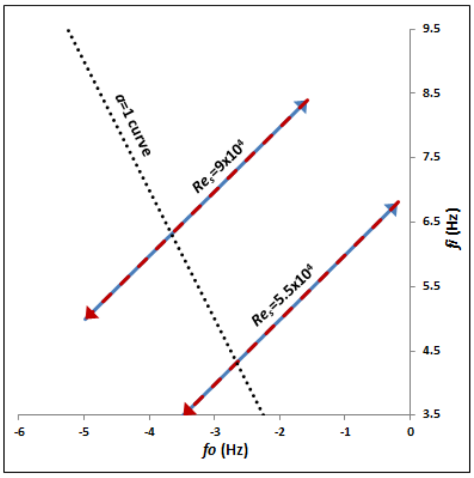


**Figure 2.** Sketch of the trajectories followed for the torque measurements for $Re_s$=5.5x10$^4$ and $Re_s$=9x10$^4$.

During the torque measurements the outer cylinder was always counter-rotating with respect to the inner cylinder at several $fo/fi$ frequency ratios, where $fo$ and $fi$ are the outer and inner cylinder frequencies, respectively. The difference in the frequencies of the two cylinders ($f_i$-$f_o$) was kept constant, that is, 7 Hz for the $Re_s$=5.5x10$^4$ case and 10 Hz for the $Re_s$=9x10$^4$ case, where $Re_s=2|\eta Re_o-Re_i|/(1+\eta)$ is the shear Reynolds number.

In order to investigate the hysteresis phenomenon in the torque measurements, we first followed a trajectory in the decreasing *a* direction (blue line) and then repeated the measurements in the increasing *a* direction (red line). Figure 2 demonstrates these trajectories for these two cases.

In our Taylor-Couette setup the temperature of the working fluid, water, cannot be actively controlled. Thus, at the start and end of each data set the temperature was measured and the change in temperature is observed not to be greater than 0.6K for the $Re_s$ of 5.5x10$^4$ case and the average temperature change is 0.3K. For the $Re_s$ of 9x10$^4$ case the maximum and the average temperature change is 1 K and 0.6 K, respectively.

## RESULTS

The results of the torque measurements performed at several *fo/fi* frequency ratios at 5.5x10$^4$ and 9x10$^4$ shear Reynolds numbers are presented in Figure 3 and Figure 4, respectively. Blue marked data was obtained when measurements were conducted in the decreasing *a* direction and red marked data was obtained when the trajectory of increasing *a* was followed. As it is seen in these figures there exists hysteresis in the torque measurements around *a*=0.4. Also, these figures show that the torque values in the hysteresis regime is higher when measured in the decreasing *a* direction, which is contrary to the behaviour found by Huisman et al.[1]. Further study will be conducted to understand the hysteresis phenomenon and the effect of the geometry involved.

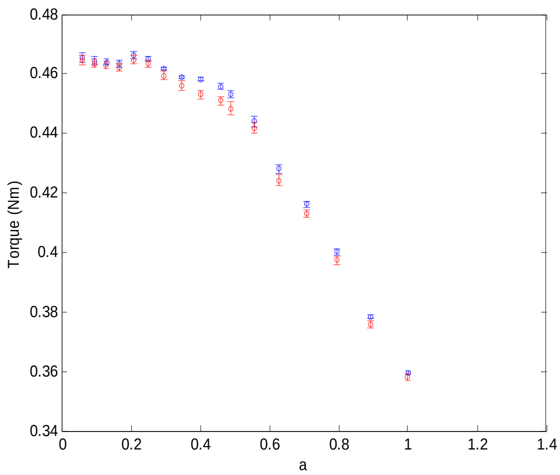


**Figure 3.** Torque measurements obtained at $Re_s$ of 5.5x10$^4$ showing the hysteresis.

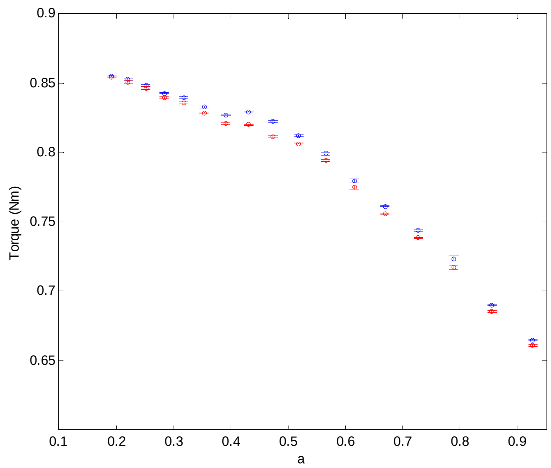


**Figure 4.** Torque measurements obtained at $Re_s$ of 9x10$^4$ showing the hysteresis.

## References

[1] S. G.. Huisman, R. C.A. van der Veen, C. Sun and D. Lohse. Multiple states in highly turbulent Taylor–Couette flow. *Nature Communications* **5**(3820), 2014.

[2] F. Ravelet, R. Delfos, and J. Westerweel. Influence of global rotation and Reynolds number on the large-scale features of a turbulent Taylor-Couette flow. *Physics of Fluids* **22**(5), 055103-1 055103-8, 2010.