Measuring the Fully Turbulent Power Number for Rushton Impellers

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Introduction

Figure 1: Rushton Impeller

- Mixing has many relevant industrial applications, including for bitumen froth treatment, which is a crucial sector of oil sands processing to eliminate water in the final bitumen products. Impeller type and rotational speed are both important factors in determining mixing conditions happening in bitumen froth treatment, and therefore affect the overall the dewatering efficiency.
- Over this summer, we have been doing experiments to determine and verify the fully turbulent power number of the Rushton (RT) impeller, seen in Figure 1 which we are trying to implement in industry.
- The power number is a dimensionless value that estimates how much power is being used by an impeller per unit of area[5]. The power number (N_p) can be expressed by the following equation:

$$N_p = \frac{2\pi T_q}{\rho N^2 D^5} \quad [1]$$

- Where N is the rotational speed of the impeller, D is the diameter of the impeller, ρ is the density of the fluid, and T_q is the torque [1] – a measure of the turning force exerted by the fluid onto the impeller, which increases with the rotational speed.
- The Reynolds number, which is a ratio of viscous to inertial forces is an indicator of the type of flow occurring in a fluid and is expressed by this equation:

$$Re = \frac{\rho V D}{\mu} \quad [5]$$

- Where V is the rotational speed, D is the impeller diameter, ρ is the inertial force, and μ is the viscous force[5].
- In this application of Rushton impellers, fully turbulent flow with a Reynolds number greater than 20,000[5] (in industry- can be lower in the lab) is necessary.

Objective

- To plot the power number as a function of the Reynolds number for Rushton (RT) impellers in the confined impeller stirred tank (CIST).
- To determine the point at which the power number stabilizes (when the flow becomes fully turbulent) by manipulation the rotational speed of the impellers.
- To determine the fully turbulent power number of Rushton impellers.

Methods

- The strain gauge torque transducer in Figure 2 is turned on prior to the experiment so the torque has time to stabilize.
- Once the torque has stabilized, baseline torque measurements are taken first to determine the torque of the shaft in water without the impellers at various rotational speeds, starting from 1000 RPM and incrementally decreasing the speed to 100 RPM

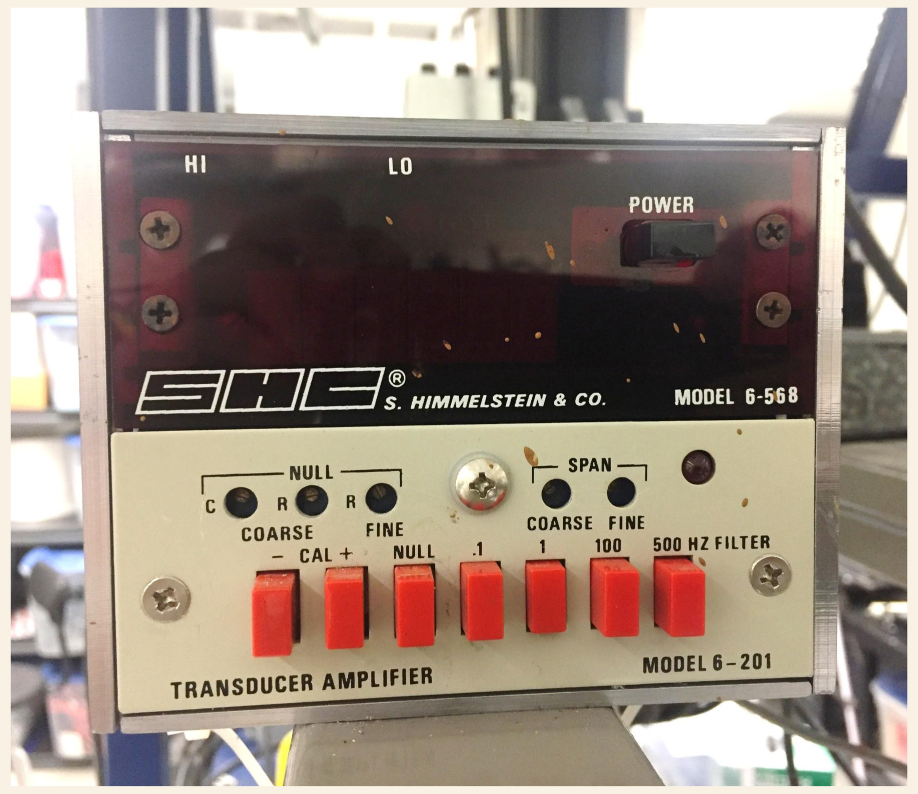

Figure 2: Torque transducer

- The impellers start at a high rotational speed and move down to avoid the stabilizing phase between each different speed.
- Torque measurements are taken with the impellers, shown in Figure 4, at rotational speeds starting at 1000 RPM and decreasing to 100 RPM.
- Figure 3 shows the entire experimental setup [1] (Figure 3 uses a different tank than was used in our experiments).

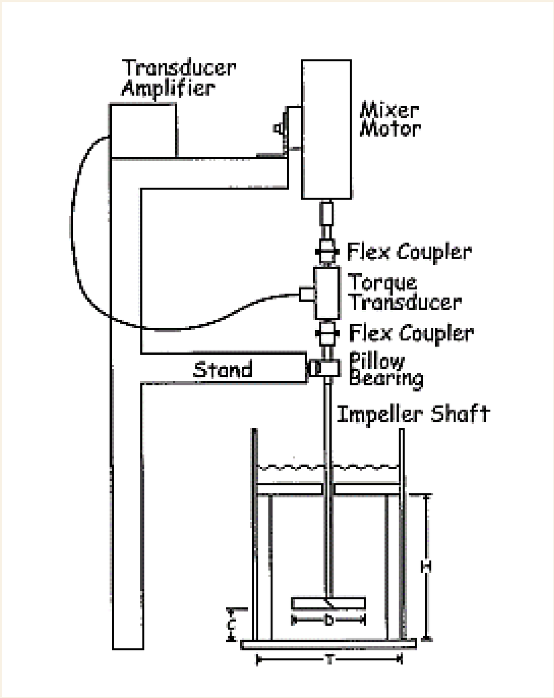

Figure 3: Experimental setup [1]

- The baseline measurement is subtracted from the corresponding torque measurement of the shaft with impellers.
- This data is used to plot the power number as a function of the Reynolds number.
- The fully turbulent power number can be determined from this plot- when the power number becomes independent of the Reynolds number.

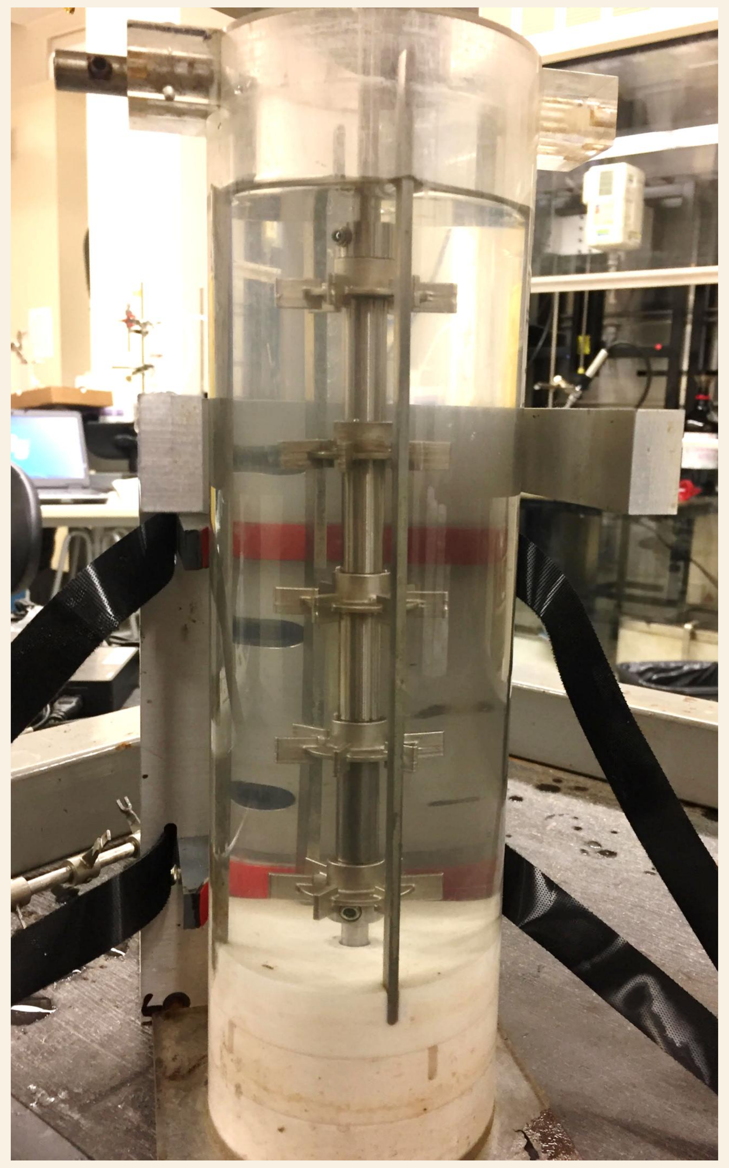

Figure 4: Shaft with Rushton impellers in CIST

Results

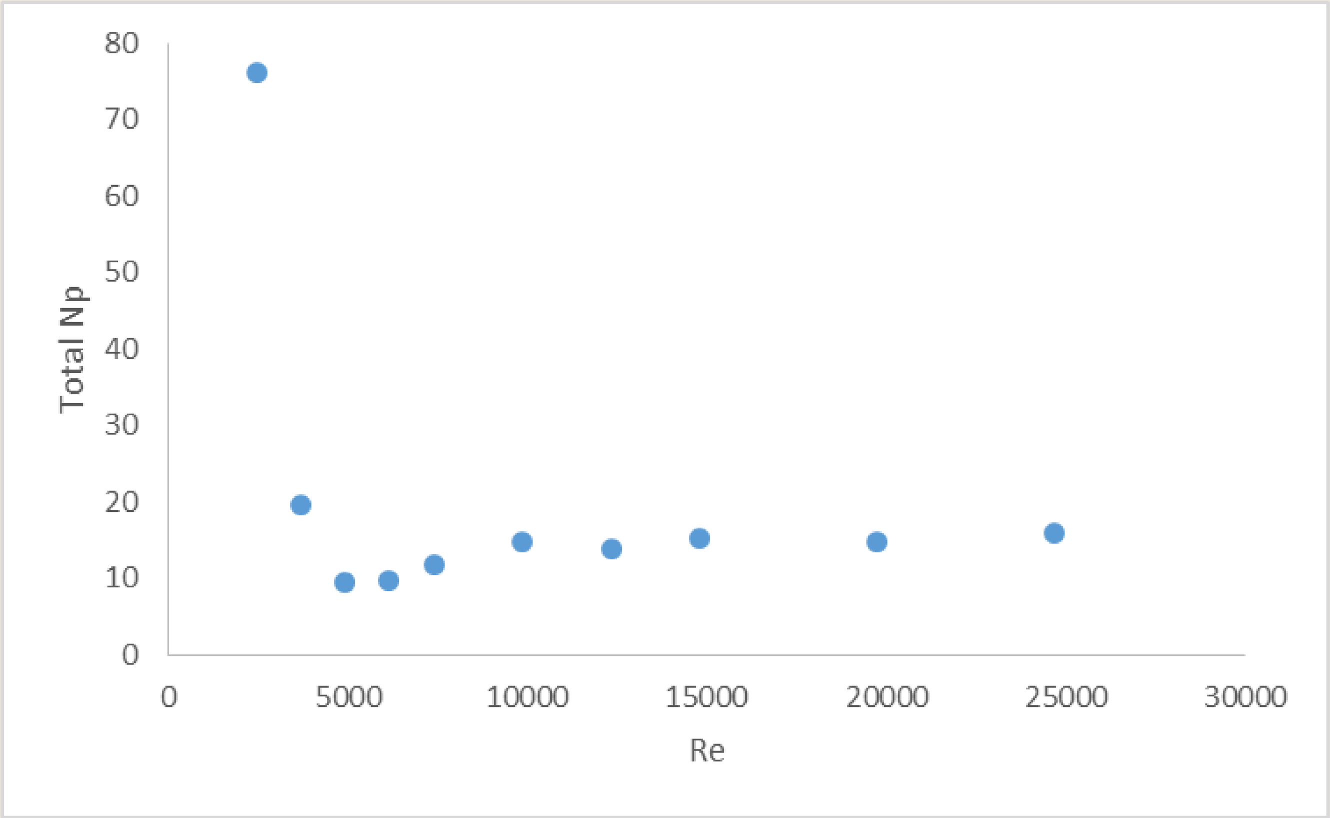

Figure 5: Plot of the power number as a function of the Reynolds number

In Figure 5, total Np is the total power number of the five impellers, and Re is the Reynolds number.

Conclusion

- The plot of the power number as a function of the Reynolds number shown in Figure 5 shows that the power number stabilizes at a Reynolds number of around 10,000.
- The power number is also roughly constant at a Reynolds number of 5,000, but does not completely stabilize until 10,000.
- The total fully turbulent power number of the five impellers used in the experiment was 16
- The power number of each individual impeller is the total power number divided by five = 3.2
- The flow became fully turbulent at a rotational speed of 400 rpm (in water).

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Literature Cited

[1] D. Chapple, S. M. Kresta, A. Wall, A. Afacan, "The Effect of Impeller and Tank Geometry on Power Number for a Pitched Blade Impeller," *Trans IChemE,* vol. 80, pp. 364-372, 2002
[2] François Cabaret, Sylvain Bonnot, Louis Fradette, Phillipe A. Tanguy, "Mixing Time Analysis Using Colorimetric Methods and Image Processing," *Ind. Eng. Chem. Res.,* vol. 46, pp. 5032-5042, 2007.
[3] Marcio B. Machado, Suzanne M. Kresta, "When Mixing Matters: Choose Impellers Based on Process Requirements," *American Institute of Chemical Engineers,* vol 61, no. 7, pp.27-33, 2015.
[4] Murray Gray, Zhenghe Xu, Jacob Masliyah, "Physics in the Oil Sands of Alberta," *American Institute of Physics,* vol. 62, no. 3, pp. 31-35, 2009
[5] Edward L. Paul, Victor A. Ateimo-Obeng, Suzanne M. Kresta, Handbook of Industrial MIxing, Hoboken, New Jersey : John Wiley and Sons Inc., 2004.