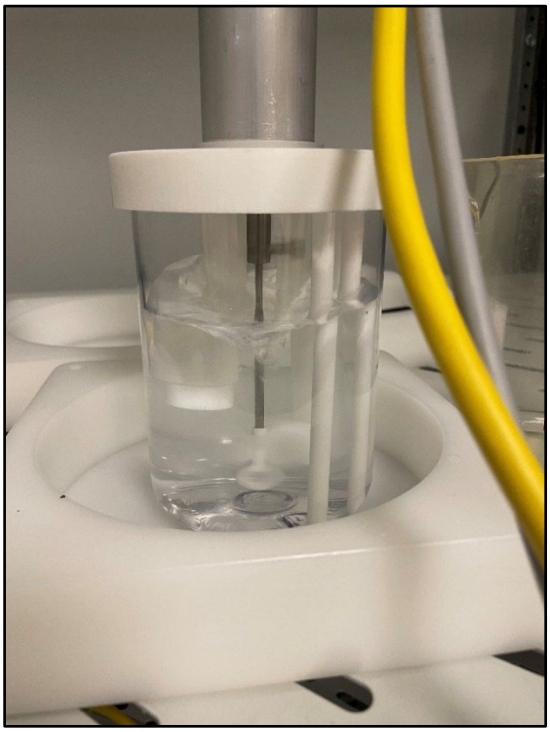
500 ml SUB Power Number



Power Number test on 500 ml CellVessel performed by Jesper Julian Struve Andersen

Company: CerCell A/S

Date: 2022-NOV

Contents

What is Power Number

Power Number is a dimensionless parameter based on the power in Watt consumed by the agitating rotor = impellers for the single use bioreactor and turbines for the single use fermenter.

It can be calculated:

$$Watt = Power\ Number\ x\ Density\ x\ Agitator\ speed^3\ x\ Rotor\ Diameter^5$$

$$P = N_p n^3 \rho D^5 \qquad or \qquad N_p = \frac{P}{\rho n^3 D^5}$$

P = Rotor power, Watt

N_p = Power Number

ρ = Density of liquid, kg/m^3

n^3 = Rotor/agitator speed measured in revolutions / second

D^5 = Rotor/impeller diameters in meters

For better understanding how the Power Number can vary a lot when the Reynolds Number (RPM) is low, we need to look at the graph below that show how Power Number will change a bit in the beginning (low RPM) and stabilize at higher RPM.

Reynolds Number contain viscosity of the fluid, a linear dimension, and a flow speed (RPM), the only thing changing in our test is the flow speed so we can see the x-axis on the graph as RPM.

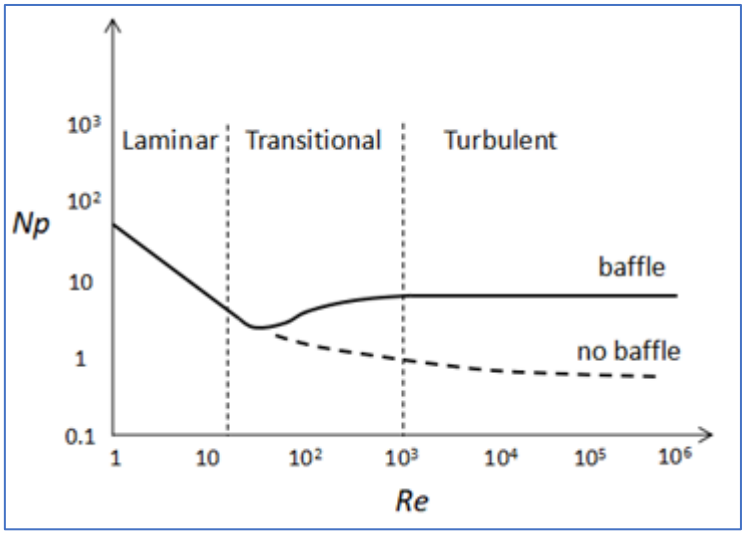


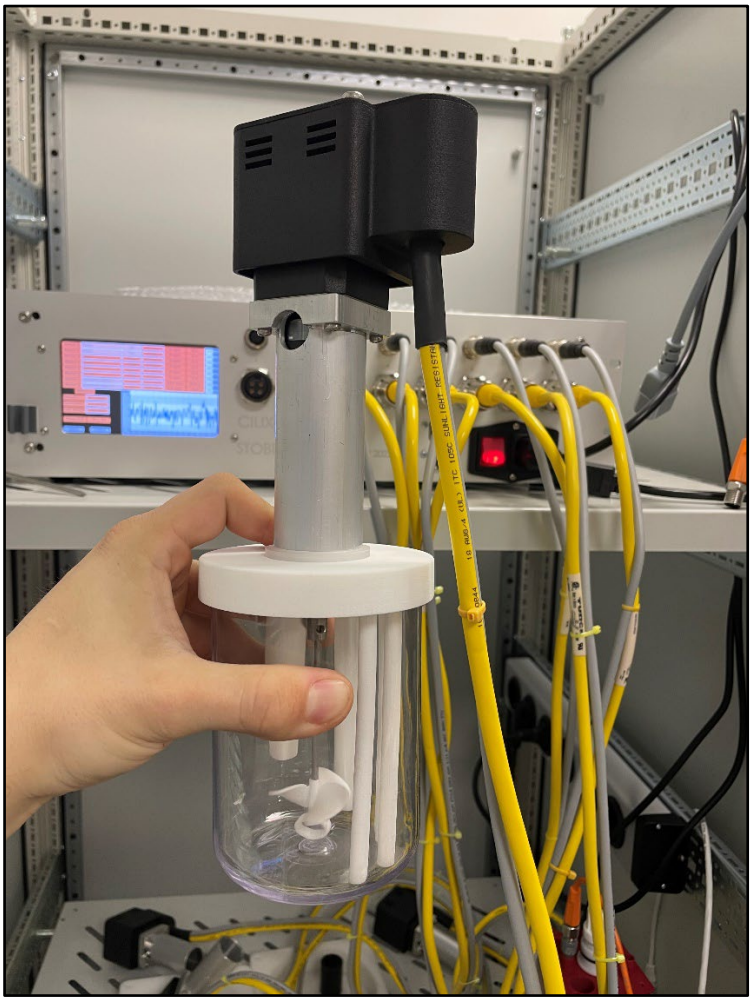
Figure 1: Graph of Power Number ***change according to Reynolds Number (RPM) increasing.***

Test setup

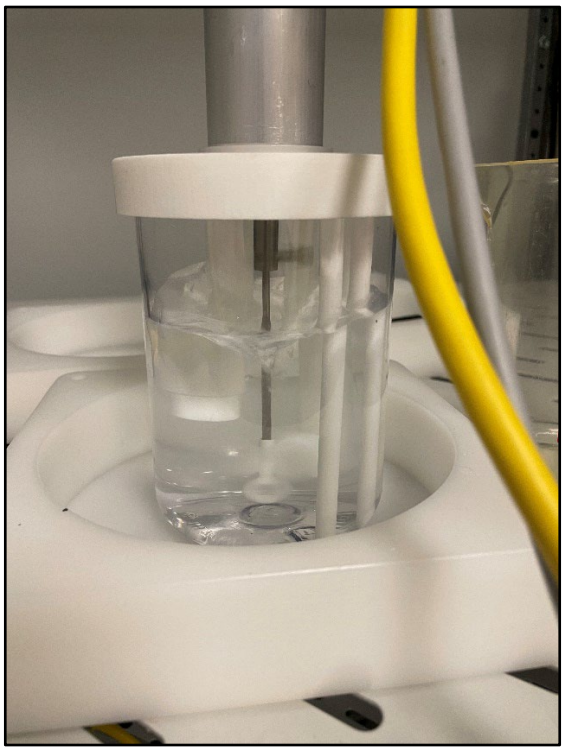
As the 3 pictures below shows the setup was a replica of the size 500 ml 0D 80 mm CellVessel SUB with OD 35 mm impeller prepared specifically for this test.

Steps:

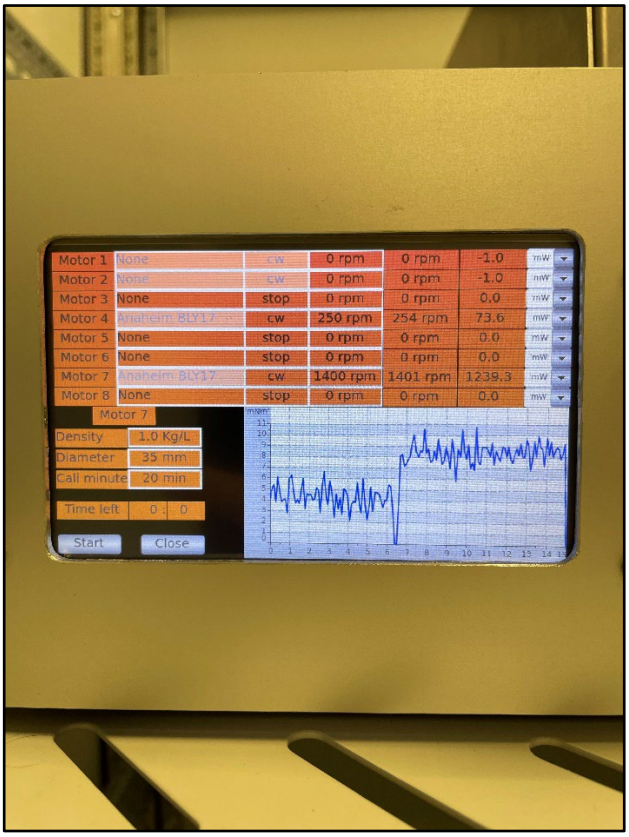
1. Run the impeller in the SUB at the wished tested RPM without water for 20 min heating up the servo motor ball bearings and the Head-Plate-Drive. Which will have an impact on consumed power and increase precision.
2. Read out the consumed motor power (mW) in milli Watt being the motor and HPD bearing friction losses.
3. Run the impeller at the wished tested RPM with water for 10 min, read out the mW power consumed in the total system (motor friction + HPD friction + water resistance).
4. Subtract the 2 numbers and get the power consumed by the impeller (water resistance) and calculate the Power Number.



Picture 1: 500 ml vessel with the NEMA-17 BLDC motor and CILIX-19 drive system in the background.



Picture 2: 500 ml SUB with liquid inside spinning at 1400 RPM.



Picture 3: CILIX motor controller (www.cronus-pcs.com) equipped with a 25 watt NEMA-17 BLDC where the graph indicates the power used running without water and with water in the vessel.

Measured and calculated Power Numbers

P = Watt consumed by the impeller (water resistance)

$$N_p = \frac{P}{\rho n^3 D^5}$$

ρ = 1000 kg/m^3 (demi water is used)

n^3 = $(\frac{RPM}{60})^3$ =Rounds per sec

D^5 = 35 mm impeller is used $0{,}035^5 = 0{,}000000052521875$ Rotor/impeller diameters in meters

RPM	P	N_p	ρ	n^3	D^5
100	0,001	4,1	1000	4,63	0,000000052521875
200	0,0026	1,33	1000	37	0,000000052521875
300	0,0075	1,14	1000	125	0,000000052521875
400	0,017	1,06	1000	297	0,000000052521875
600	0,047	0,9	1000	1000	0,000000052521875
800	0,104	0,835	1000	2370	0,000000052521875
1000	0,203	0,834	1000	4630	0,000000052521875
1200	0,380	0,900	1000	8000	0,000000052521875
1400	0,600	0,899	1000	12700	0,000000052521875

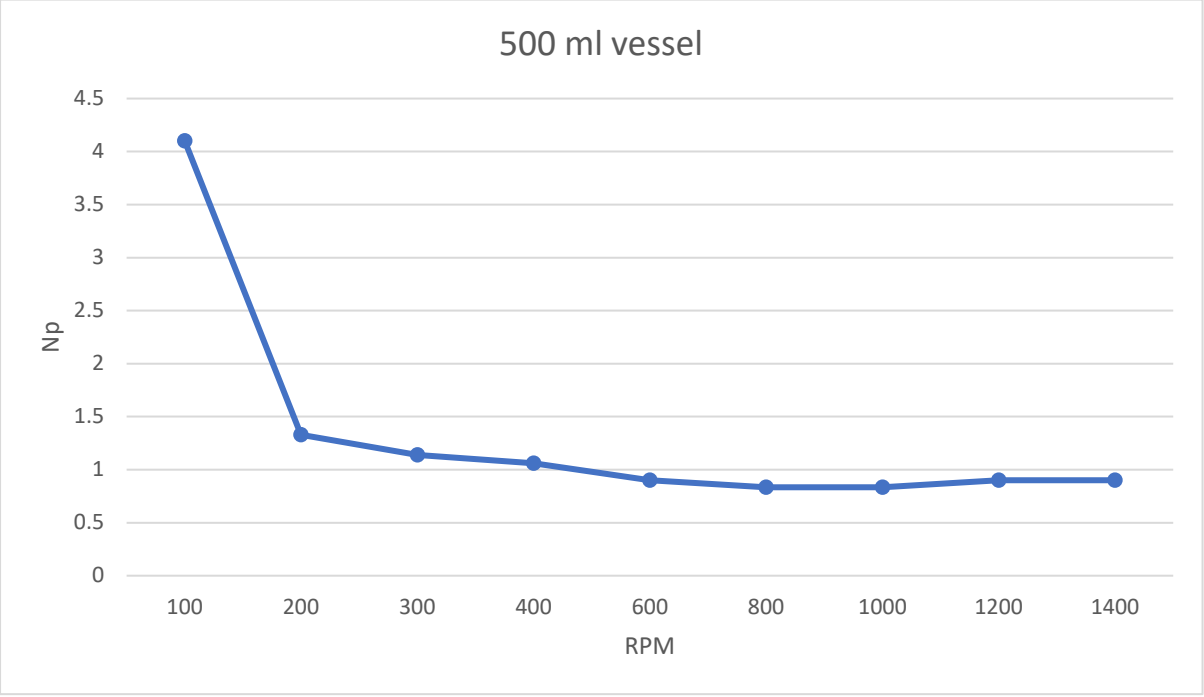


Figure 2: Graph of the test results.

Comments

This test was performed with multi channel Cilix-19 and a NEMA-17 servo motor.

We can conclude that the setup can give valid data from 200 RPM up to 1,400 RPM where the Power Number range between 0.834 to 1.33.

At 100 RPM and water in the vessel, the power consumed is 1 mW which is only 6,25 % of the total power consumed (16 mW total). Using the smaller NEMA-13 motor the consumed power will increase and hereby accuracy will increase – future plan.

Next step to repeat the test and measure lower than 100 RPM will be with dual channel Cilix and NEMA-13 (available from FEB 2023) that consumes less power and hereby increase the precision on Power Number calculation.

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https://cronus-pcs.com/products/themis-motor-drive