

13,000 ml SUB Power Number



Power Number test on 13 liter CellVessel performed by Jesper Julian Struve Andersen
Company: CerCell A/S
Date: 2022-OCT

Contents

What is Power Number.....	1
Test setup.....	2
Measured and calculated Power Numbers.....	4
Comments.....	5

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:

$$\text{Watt} = \text{Power Number} \times \text{Density} \times \text{Agitator speed}^3 \times \text{Rotor Diameter}^5$$

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

P = Rotor power, Watt

N_p = Power Number

ρ = Density of liquid, kg/m³

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.

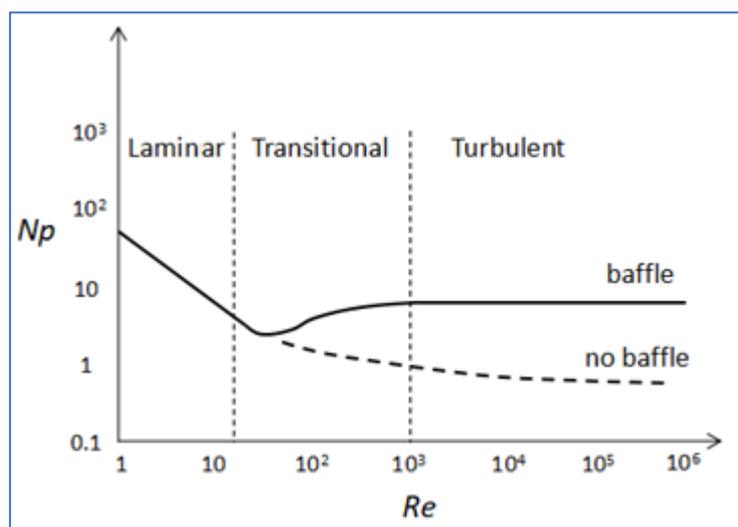


Figure 1: Graph of Power Number change according to Reynolds Number (RPM) increasing.

Test setup

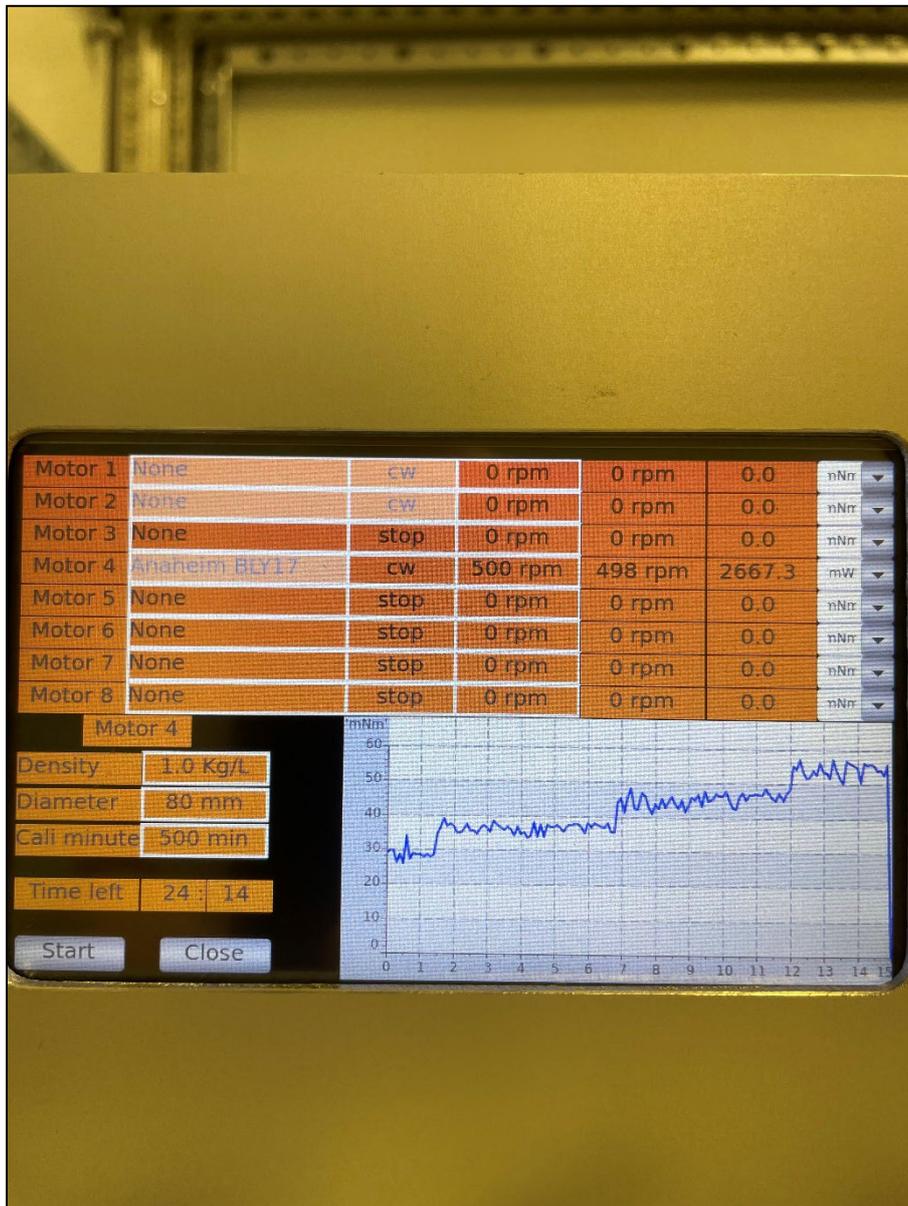
The picture below show the setup with a replica of the 13 L CellVessel SUB with 2 pcs OD 80 mm impeller prepared specifically for this test.

Steps:

1. Run the impeller at the wished tested RPM without water for 20 min (for heating the motor and the head plate drive up, it will have an impact on the efficiency of the power consumed), read out the power (mW) consumed in the total system (motor + drive).
2. Run the impeller at the wished tested RPM with water for 10 min, read out the power (mW) consumed in the total system (motor + drive + water resistance).
3. Subtract the 2 numbers to get the power consumed only by the impeller (water resistance) and calculate the Power Number.



Picture 1: 13 L vessel with the NEMA-17 BLDC motor from a CILIX-19 drive system.



Picture 2: CILIX-19 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)

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

$\rho = 1000 \text{ kg/m}^3$ (demi water is used)

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

$D^5 = 80 \text{ mm}$ impeller is used $0,080^5 = 0,00000328$ Rotor/impeller diameters in meters

RPM	P	N_p	ρ	n^3	D^5
100	0,034	2,24	1000	4,63	0,00000328
150	0,093	1,81	1000	15,63	0,00000328
200	0,168	1,38	1000	37	0,00000328
250	0,336	1,55	1000	72,34	0,00000328
300	0,596	1,45	1000	125	0,00000328
350	0,953	1,47	1000	198,5	0,00000328
400	1,431	1,47	1000	246,3	0,00000328
450	2,026	1,46	1000	421,88	0,00000328
500	2,801	1,47	1000	578,7	0,00000328

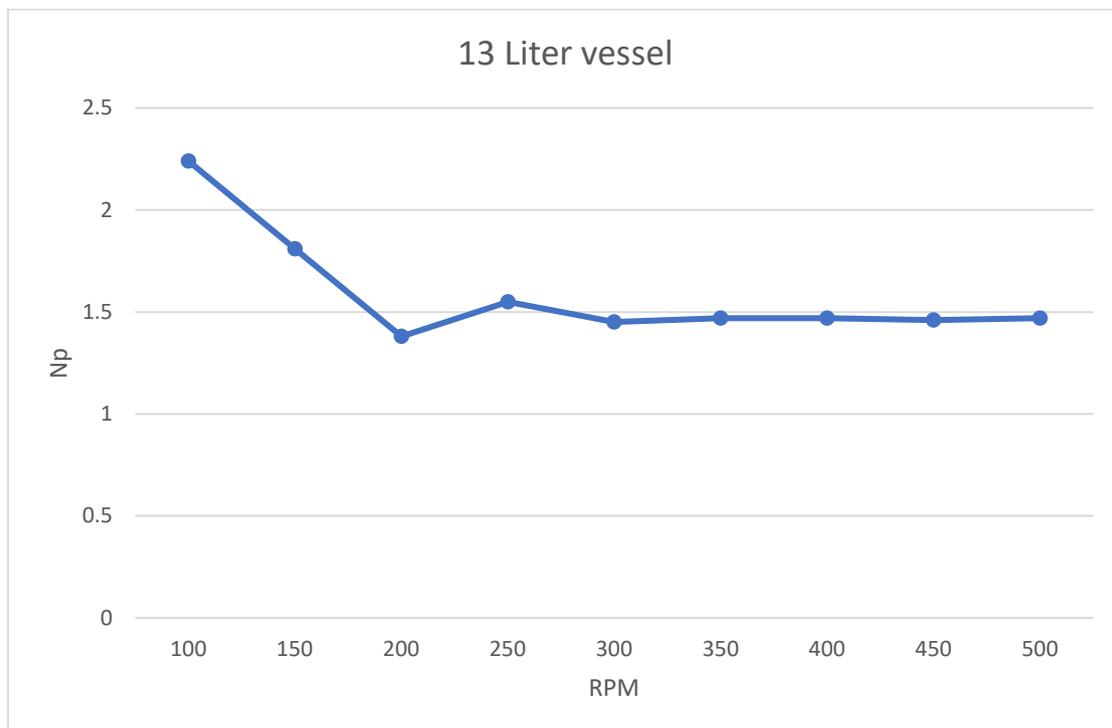


Figure 2: Graph of the test results.

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 100 RPM up to 500 RPM where the Power Number is between 1.38 to 2.24 but around 300 RPM the Power Number stay around 1.46 to 1.47.

An attempt on 50 RPM was also made, but the friction in the drive and motor was too large compared to the power consumed by the impeller at the low RPM, so the result was not valid.

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>