Measurement of water turbine characteristics

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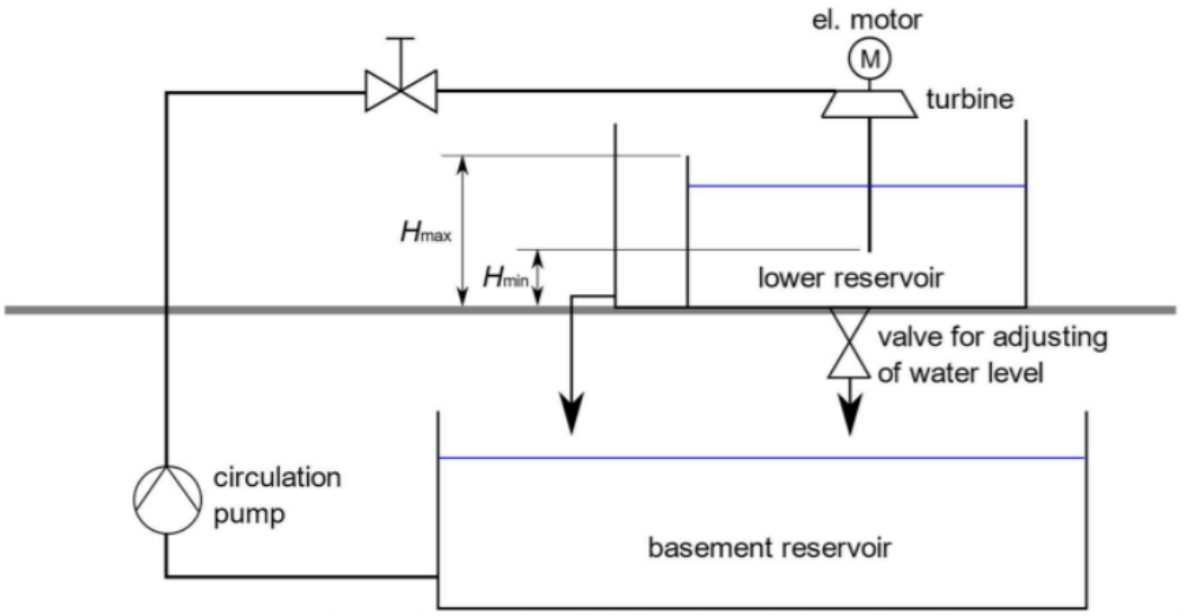
Laboratory setup



Schematic of the measurement setup

To carry out these measurements, water is pumped from a tank and fed under the control of a valve directly to the turbine. The water then falls into the lower reservoir and is returned via an adjustable valve to the basement reservoir. If the lower reservoir water level hits H_{max} there is a safety escape route to make the water flow back into the basement reservoir.

Methodology

What we called the characteristic of the turbine is in fact it's operational points, the points of Q, ΔP where its efficiency η is maximum. The method to calculate this operational point is to compare the hydraulic power created by the turbine to the mechanical power captured by the linked engine.

$$P_{hydro} = Q.\Delta P$$
$$P_{meca} = C.\omega = r.F.\omega$$
$$\eta = \frac{P_{meca}}{P_{hydro}}$$

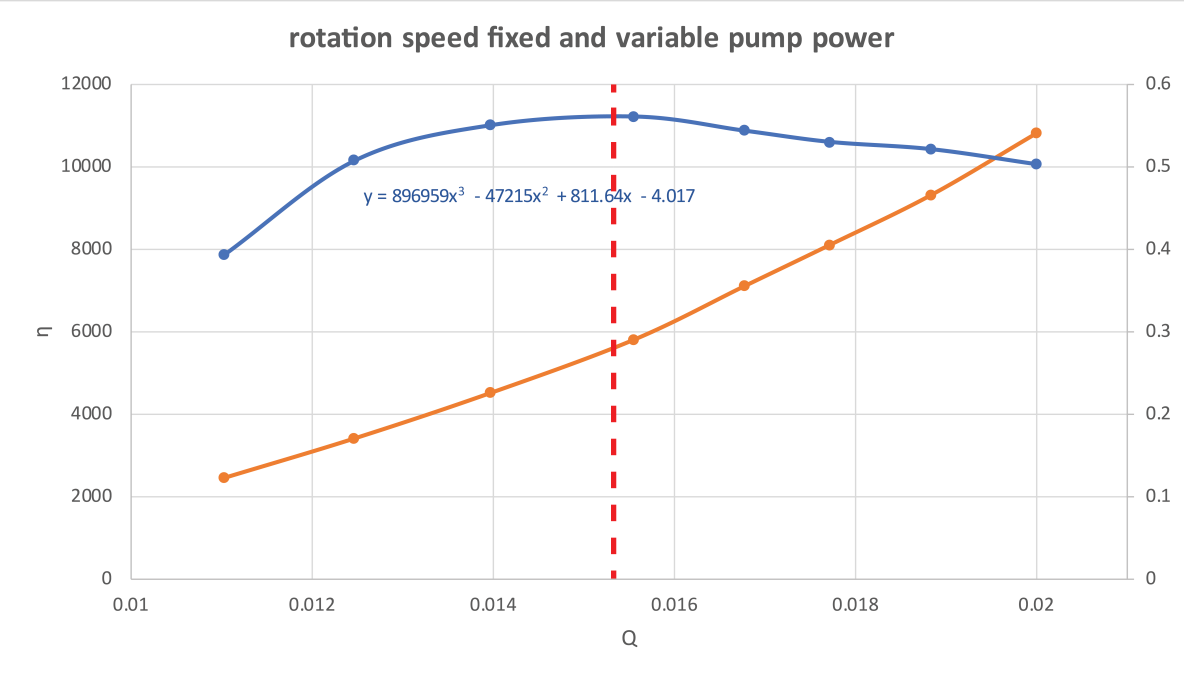
Where :

- Q is the flow rate measured by an electromagnetic flow meter
- ΔP is the pressure difference measured by a differential pressure transducer
- $C = r.F$ the torque applied to the motor shaft by the turbine
- $r = 7,5$ cm the action turbine radius
- F is the acting force,
- ω is the speed of rotation of the turbine

Measurement

First calculation, rotation speed fixed and variable pump power

F	ω	Q	ΔP	C	Pmeca	Phydro	η
[N]	*[rad/s]*	*[m3/s]*	*[Pa]*	*[N.m]*	*[W]*	*[W]*	*/*
3	47.12389	0.011028	2450	0.225	10.60288	27.01806	0.392437
6.1	47.12389	0.012472	3410	0.4575	21.55918	42.53028	0.506914
9.8	47.12389	0.013972	4510	0.735	34.63606	63.01472	0.54965
14.3	47.12389	0.015556	5800	1.0725	50.54037	90.22222	0.560177
18.3	47.12389	0.016778	7100	1.3725	64.67754	119.1222	0.542951
21.5	47.12389	0.017722	8100	1.6125	75.98727	143.55	0.529344
25.8	47.12389	0.018833	9300	1.935	91.18473	175.15	0.520609
30.7	47.12389	0.02	10800	2.3025	108.5028	216	0.502328



We have : $\eta = 896959Q^3 - 47215Q^2 + 811.64Q - 4.017$

We can therefore calculate the maximum of this function and deduce from it the operational points.

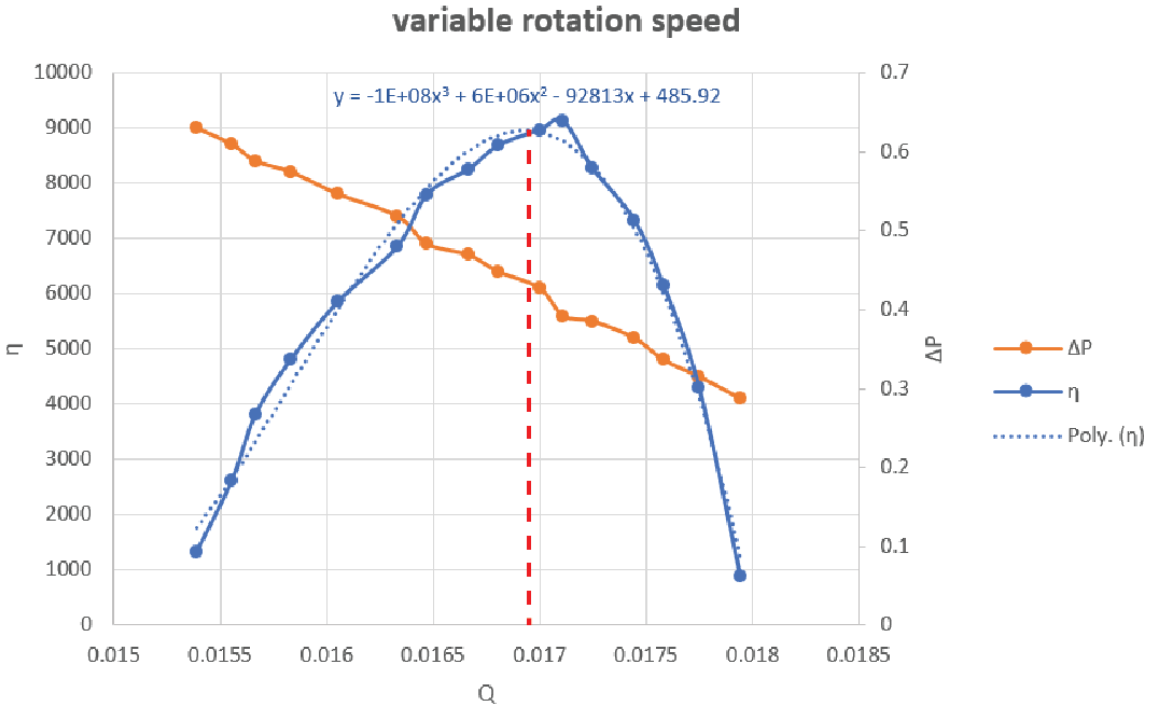
$Q_{ope} = 0,015$ m^3/s

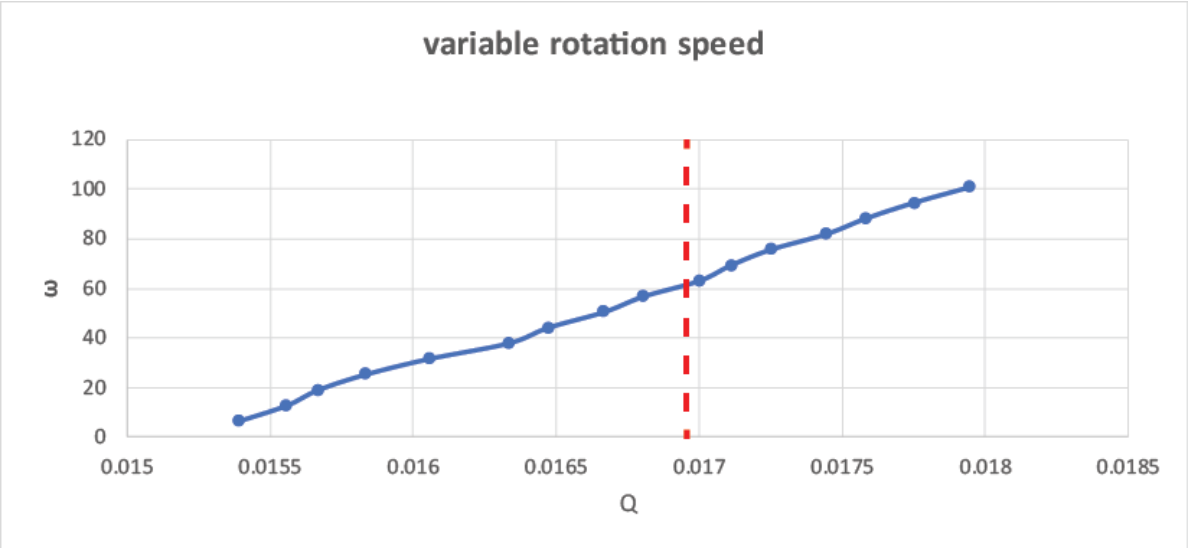
$\Delta P_{ope} = 5,4$ kPa

$\eta_{ope} = 0,56$

Second calculation, variable rotation speed

F	ω	Q	ΔP	C	Pmeca	Phydro	η
[N]	*[rad/s]*	*[m3/s]*	*[Pa]*	*[N.m]*	*[W]*	*[W]*	*/*
27.3	6.283185	0.015389	9000	2.0475	12.86482	138.5	0.092887
26.4	12.56637	0.015556	8700	1.98	24.88141	135.3333	0.183853
24.9	18.84956	0.015667	8400	1.8675	35.20155	131.6	0.267489
23.2	25.13274	0.015833	8200	1.74	43.73097	129.8333	0.336824
21.8	31.41593	0.016056	7800	1.635	51.36504	125.2333	0.410155
20.5	37.69911	0.016333	7400	1.5375	57.96238	120.8667	0.479556
18.8	43.9823	0.016472	6900	1.41	62.01504	113.6583	0.545627
17.1	50.26548	0.016667	6700	1.2825	64.46548	111.6667	0.577303
15.4	56.54867	0.016806	6400	1.155	65.31371	107.5556	0.607256
13.8	62.83185	0.017	6100	1.035	65.03097	103.7	0.627107
11.8	69.11504	0.017111	5600	0.885	61.16681	95.82222	0.638336
9.7	75.39822	0.01725	5500	0.7275	54.85221	94.875	0.578152
7.6	81.68141	0.017444	5200	0.57	46.5584	90.71111	0.51326
5.5	87.96459	0.017583	4800	0.4125	36.2854	84.4	0.429922
3.4	94.24778	0.01775	4500	0.255	24.03318	79.875	0.300885
0.6	100.531	0.017944	4100	0.045	4.523893	73.57222	0.061489





We have : $\eta = -1.10^8 Q^3 + 6.10^6 Q^2 - 92813Q + 485.92$

We can therefore calculate the maximum of this function and deduce from it the operational points.

$\omega_{ope} = 60$ rad/s

$Q_{ope} = 0,0169$ m^3/s

$\Delta P_{ope} = 6,15$ kPa

$\eta_{ope} = 0,63$