Examining the Characteristics of Pedrollo_CP130 Centrifugal Pump in Simulated Service Conditions

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Abstract: *In my study I examine the characteristics of a Pedrollo_CP130 centrifugal pump during operation. My choice of topic is justified by the facts that Pedrollo pumps have widely been applied, they are reliable and can be operated highly efficiently. Since their improper usage can cause problems, I decided to study the parameters of Pedrollo_CP130 pumps during operation to be able to avoid these problems. The fundamental characteristics of these pumps are flow rate, elevation head, power demand and efficiency. The monitoring of the pump's characteristics is undertaken in the fluid dynamics laboratory in Széchenyi István University. The measuring device available in the laboratory is suitable for measuring the parameters of pumps. The whole measurement process is traceable on the screen belonging to the measuring device and the measurement parameters can be determined and the results can be recorded by computer software. In my study I describe the measuring device used in the hydrodynamics laboratory at Széchenyi István University. I give a description about the types of measurements available in the laboratory and show the measurement results carried out by a Pedrollo_CP130 pump, the correlations determined from them and the conclusions taken from the measurement. The outcomes of my study can be beneficial when we operate pumps of similar types.*

Keywords: *Elevation head, flow rate, power demand, efficiency, pump*

1. Introduction

Pumps determine all aspects of our lives and influence them directly or indirectly. Some areas, including but not limited to water supply, water-related activities, crisis and disaster management, firefighting, health care, agriculture, industry, producing electricity, household technology and food industry, where pumps play an important role. Pumps are one of the most well-known and widespread type of a machine. Their task is to move fluid from one place to another, generally from a lower place to a higher one in a certain distance. The most important technical parameters of a pump are fluid volume moved per unit time, elevation head, NPSH and efficiency [1]. The operational characteristics of a pump are the data and the correlations which reflect the characteristics of the pump during operation. Pumps always carry various types of fluids integrated with some type of motor, pipes and packers. These are called outer characteristics. The hydraulic system, the construction materials and the structure of the pump belong to its internal characteristics [2].

2. The description of the laboratory of fluid mechanics at Széchenyi István University

2.1 The construction of the measuring device in the Laboratrory of Fluid Mechanics at Széchenyi István University

Certain measurements in a pump start-up required for "The Machinery in Thermotechnics and Fluid Mechanics" are carried out in the laboratory of the Széchenyi István University (Fig. 1). The Pedrollo CP_130 and Nocchi_CB80_38T hydraulic pumps move water from a lower tank into a upper tank through a symmetric pipe system. Due to the design of the pipe system, ball valves allow different ways for water to be moved between the two tanks. This makes it possible to examine their operation in line or in parallel and the parallel operation of the pipes. The elevation head of the pumps can be determined by the manometers installed into the suction and the discharge lines. Primarily the control fittings installed into the section placed after the connection of the two lines control the flow rate of the pumps. The flow meters installed into the discharge pipes are used to measure the flow rate of the water carried by the pumps [3].

From the discharge pipe of the pump a bypass branches and returns to the suction tank which allows to carry out measurements relative to the so-called bypass control. Control fittings and flow rate gauge can be found int the bypass. Both the lower and the upper tank bear hose fittings. Overpressure and vacuum can be created in the tanks with modifying the position of the fitting installed into the pipe for the returning water. By means of the frequency inverter on the pumps' motors, revolution can be controlled within certain limits. Water control is performed with Programmable Logic Controllers placed into the switch cabinet next to the apparatus. Opening the ball valve, water can be returned from the upper tank into the lower tank. Stopping and restarting the pumps, the power absorbed by the engine, the modification of revolution, the modification of mains frequency and its instantaneous value together with recording the pressures and flow rates in the software running in the portable computer can be carried out with connecting the measuring device and the computer with a USB. The measuring device is demonstrated on the graphic user interface, on which the position of the pins and control fittings can be illustrated. The different measured values can be read. The software opens the measured values and the applied settings can be opened with MS Excel program [3].

Fig. 1. Laboratory of Fluid Mechanics at Széchenyi István University [3]

Table 1: Technical Specifications of Measuring Equipment [4]

	Technical Specifications	
Pump Type	Pedrolló CP130	Nocchi CB80/38
Amount of Delivered Water	Q_{max}=100 l/min	Q_{max}=80 l/min
Delivery Height	H_{max} =20 metre (2 bar)	Hmax =30 metre (3 bar)
Number of Impeller Vanes	N=1pc	N=2 pcs
Electric Motor	P=0,37 kW, 3x400 V AC	P=1,1 kW, 3x400 V AC
Speed of Electric Motor	n= 2800 rpm	n= 2800 rpm
Range Regulated by Frequency changer	f=30-60Hz	f=30-60Hz

2.2 The measurements that can be carried out in the Fluid Mechanincs Laboratory at Széchenyi István University

Current measurements related to the subject of "Machinery in Fluid Mechanics and Thermotechnics" are the realization of the Affinity Laws, the Affinity Laws on the Best Efficiency Point of the characteristic curve, joint operation of pipes in parallel, joint operation of pumps in parallel and joint operation of pumps in-line

3. Measurements carried out in the Fluid Mechanics laboratory at Széchenyi István University

3.1 Taking the characteristic curve of the pump

As the first step in my examination, I selected the pipeline track, which can be seen in Fig.2.

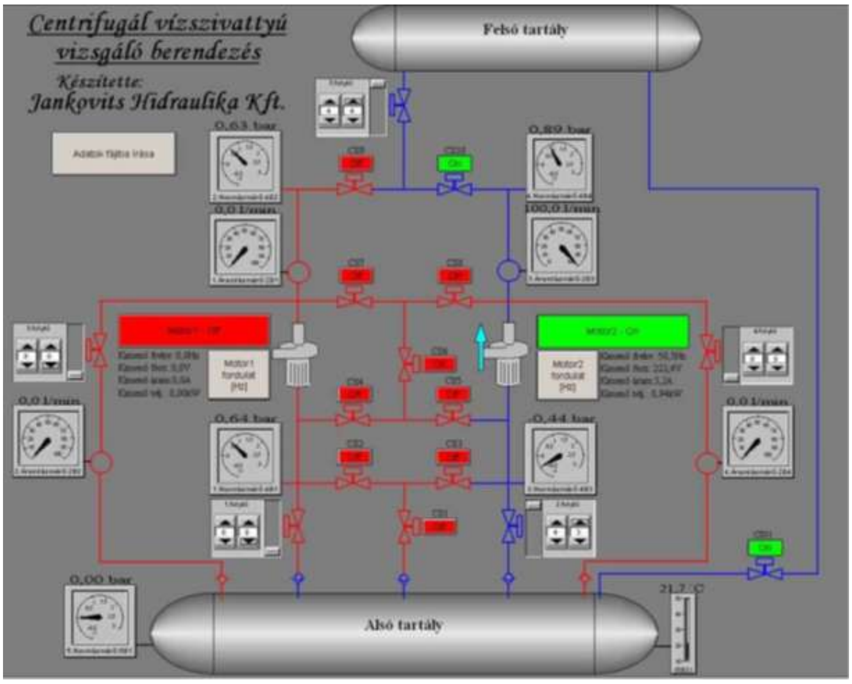

Fig. 2. Graphic User Interface of the software [3]

In Figure 2 fluid can flow in the blue lines. Green fittings are in an open stage, red pipes do not let fluid flow because the red fittings are in closed stage. These settings were carried out on the test bench and digitally on the evaluating software interface as well. The collected data were documented by the software of the computer. At the end of the measurement phase, I saved the data as a csv file and processed them with MS-Excel. The current status of the measured values was monitored on the LCD screen see Figure 1. At the constant speed of the pump (3000 rpm) I increased the flow rate from zero to the maximum possible with gradually opening the control fitting installed into the discharge pipe. At each measuring point, I recorded the values both in front of the inlet and after the outlet of the pump and the power absorbed of the electric motor. To achieve higher accuracy, three measurements were taken with 2-3 seconds difference at each measuring point and their arithmetical mean was used for further calculations. The measured values served as a basis for calculating the elevation head in the following formula (1).

$$H = \frac{(p_2 - p_1) \cdot 10^5}{\rho \cdot g} \qquad (1)$$

Table 2: The measured and calculated data of Pedrollo pump [Author compilation]

Motor frequency [Hz]	Pump revolution [rpm/min]	Motor performance [kW]	Flow rate [l/min]	Pressure [bar]	Elevation head [m]
50	3000	0,21	0,00	2,13	21,71
		0,22	7,00	2,01	20,49
		0,23	16,00	1,93	19,67
		0,25	23,00	1,85	18,86
		0,26	31,00	1,78	18,14
		0,27	40,00	1,67	17,02
		0,28	48,00	1,57	16,00
		0,29	56,00	1,47	14,98
		0,30	64,00	1,33	13,56
		0,31	79,00	1,07	10,91
		0,31	82,00	1,02	10,40

Using the measured values, after carrying out the necessary calculations, I drew a series of points illustrating how the elevation head changes in the function of flow rate.

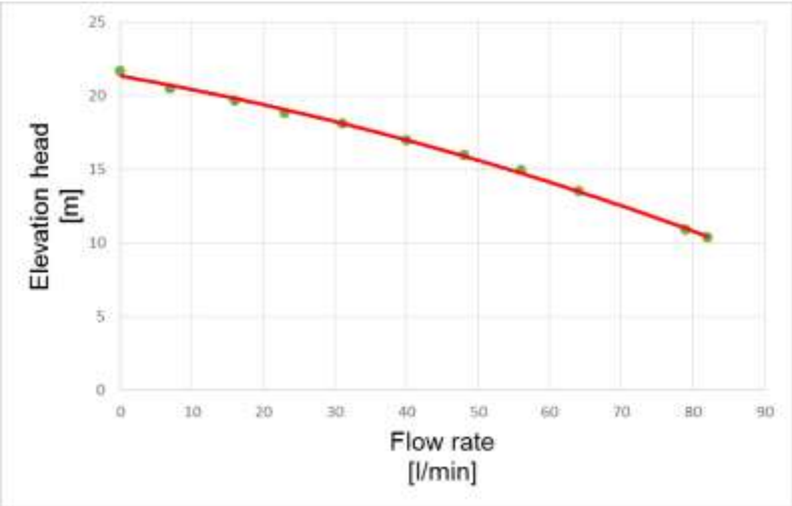

Fig. 3. Characteristic curve of Pedrollo pump [Author compilation]

Table 3 shows the flow rate and the elevation head of the Pedrollo CP_130 pump given by the manufacturer.

Table 3: The measured and calculated data of Pedrollo pump [4]

Motor frequency [Hz]	Flow rate [l/min]	Elevation head [m]
50	0,00	23,00
	10,00	22,00
	20,00	21,00
	30,00	20,00
	40,00	19,00
	50,00	18,00
	60,00	17,00
	70,00	15,50
	80,00	14,00

Figure 4 shows the characteristic curves of various Pedrollo pumps given by the manufacturer. I used the CP_130 type for testing.

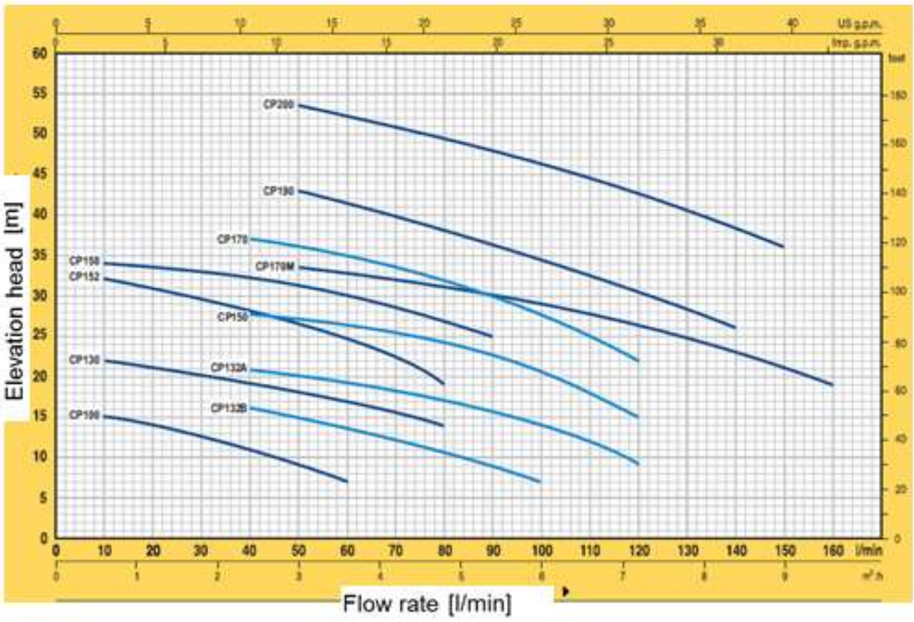

Fig. 4. Characteristic curves of various Pedrollo pumps

From fig. 4 and the data in the instruction manual, it can be concluded that the data I measured and my calculated results show a 5%-difference on average. It can be justified with with the fact that my measurements were carried out under non-standard circumstances. Due to local conditions there can be significant differences as well.

3.2 Defining the flow rate – performance curve of the pump

Table 4 shows the results of my measurements on flow rate-performance.

Table 4: Pedrollo pump flow rate performance [Author compilation]

Motor frequency [Hz]	Pump revolution [rpm/min]	Motor performance [kW]	Flow rate [l/min]
50	3000	0,210	0,00
		0,220	7,00
		0,230	16,00
		0,250	23,00
		0,260	31,00
		0,270	40,00
		0,280	48,00
		0,290	56,00
		0,300	64,00
		0,310	79,00
		0,310	82,00

I designed the flow rate-performance curve on the basis of the measured data.

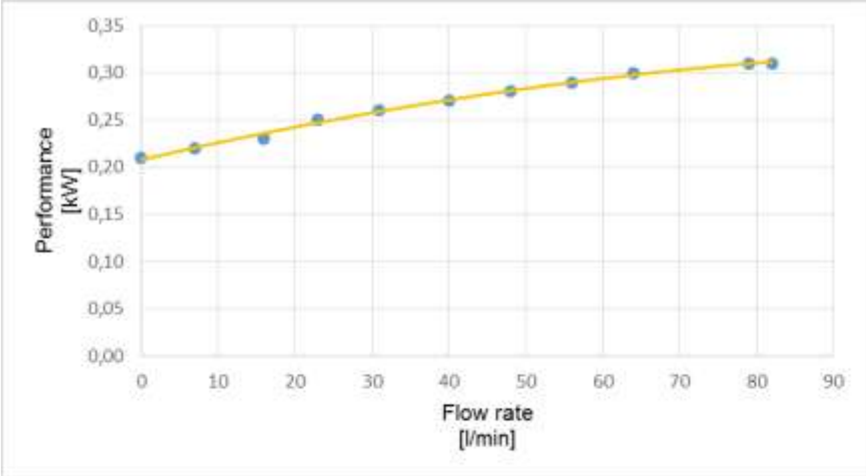

Fig. 5. Pedrollo pumps flow rate – performance curve [Author compilation]

3.3 Examining the Affinity Laws on the Best Efficiency Point of the curve

The purpose of the measurement is to examine the realization of the Affinity Laws on the Best Efficiency Points of the characteristic curves with different revolutions. The Affinity Laws states that the characteristic curves' corresponding points at different revolution values lay on the same central quadratic parabola. It means that the elevation head is proportional to the square of revolution and flow rate is directly proportional to revolution [5].

$$\frac{\dot{V}_1}{\dot{V}_2} = \frac{n_1}{n_2} \tag{2}$$

$$\frac{\mathrm{H}_1}{\mathrm{H}_2} = \left(\frac{\mathrm{n}_1}{\mathrm{n}_2}\right)^2 \tag{3}$$

$$\dot{\mathrm{V}}_2 = \frac{\mathrm{n}_2}{\mathrm{n}_1} \cdot \dot{\mathrm{V}}_1 \tag{4}$$

$$H_2 = \left(\frac{n_2}{n_1}\right)^2 \cdot H_1 \tag{5}$$

$$\left(\frac{\dot{V}_2}{\dot{V}_1}\right)^2 = \left(\frac{H_2}{H_1}\right) \tag{6}$$

$$H_2 = \frac{H_1}{\dot{V}_1{}^2} \cdot \dot{V}_2{}^2 \tag{7}$$

$$H_2 = K \cdot \dot{V}_2{}^2 \tag{8}$$

To examine the Affinity Laws on the Best Point Efficiency it is needed to create the pump's characteristic and flow-efficiency fitting curve taken at various revolution values. Based on the measuring method introduced in 3.1, I drew the pump's characteristic curve on rated speed (at 50 Hz power frequency), a smaller than rated speed (at 30Hz power frequency) and a higher than rated speed (at 60Hz power frequency). Flow rate and the density of the transport medium served as a base for my calculations to determine the theoretically appropriate efficiency and the one on the basis of the motor performance [6].

$$\eta = \frac{H \cdot \rho \cdot g \cdot \dot{V}}{P} \quad (9)$$

Tables 5-6-7 show the measured and calculated values at different revolutions.

Table 5: Measurement results of the motor operated at 30 Hz frequency [Author compilation]

Motor frequency [Hz]	Pump revolution [rpm/min]	Motor performance [kW]	Flow rate [l/min]	Pressure [bar]	Elevation head [m]	Efficiency [%]
30	1800 ford/min	0,07	0,00	0,82	8,36	0,00
		0,07	8,00	0,77	7,85	14,67
		0,08	16,00	0,74	7,54	24,67
		0,08	24,00	0,69	7,03	34,50
		0,09	31,00	0,65	6,63	37,31
		0,10	39,00	0,58	5,91	37,70
		0,10	48,00	0,50	5,10	40,00

Table 6: Measurement results of the motor operated at 50 Hz frequency [Author compilation]

Motor frequency [Hz]	Pump revolution [rpm/min]	Motor performance [kW]	Flow rate [l/min]	Pressure [bar]	Elevation head [m]	Efficiency [%]
50	3000	0,21	0,00	2,13	21,71	0,00
		0,22	7,00	2,01	20,49	10,66
		0,23	16,00	1,93	19,67	22,38
		0,25	23,00	1,85	18,86	28,37
		0,26	31,00	1,78	18,14	35,37
		0,27	40,00	1,67	17,02	41,23
		0,28	48,00	1,57	16,00	44,86
		0,29	56,00	1,47	14,98	47,31
		0,30	64,00	1,33	13,56	47,29
		0,31	79,00	1,07	10,91	45,45
		0,31	82,00	1,02	10,40	44,97

Table 7: Measurement results of the motor operated at 60 Hz frequency [Author compilation]

Motor frequency [Hz]	Pump revolution [rpm/min]	Motor performance [kW]	Flow rate [l/min]	Pressure [bar]	Elevation head [m]	Efficiency [%]
60	3600 ford/min	0,29	0,00	2,70	27,52	0,00
		0,30	7,00	2,53	25,79	9,84
		0,33	16,00	2,35	23,96	18,99
		0,35	23,00	2,26	23,04	24,75
		0,36	31,00	2,14	21,81	30,71
		0,39	39,00	2,01	20,49	33,50
		0,40	48,00	1,86	18,96	37,20
		0,41	55,00	1,71	17,43	38,23
		0,42	63,00	1,56	15,90	39,00
		0,43	71,00	1,40	14,27	38,53
		0,44	80,00	1,22	12,44	36,97
		0,44	85,00	1,09	11,11	35,09

To be able to determine the flow rate at Best Efficiency Point, I illustrated the relevant efficiency curve belonging to each revolution value separately. Then I drew all the curves in one diagram. (Fig. 6) The values are summarised in Table 8.

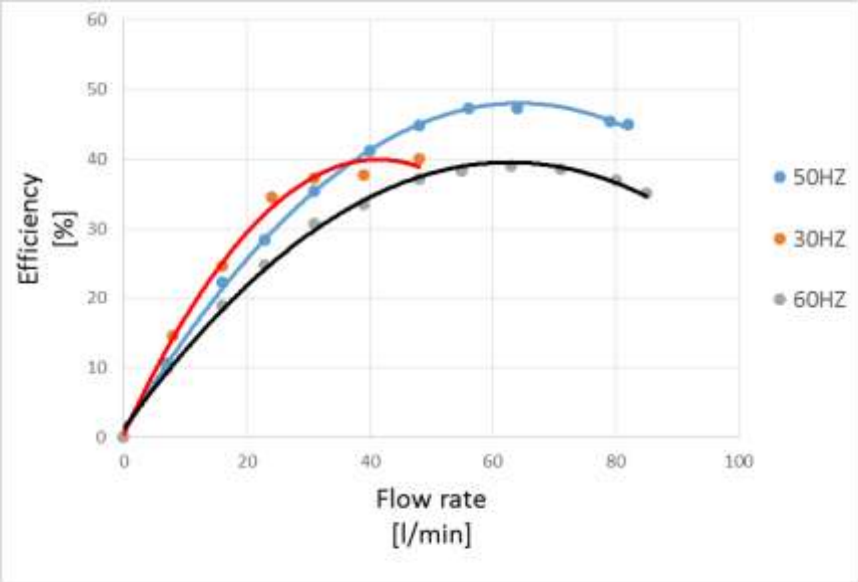

Fig. 6. Efficiency curves of a Pedrollo pump [Author compilation]

Table 8: Measurement results of the motor operated at 60 Hz frequency [Author compilation]

Motor frequency [Hz]	Maximum efficiency/Best Efficiency Point [%]	Flow rate [l/min]
30	40,00	48,00
50	47,31	56,00
60	39,00	63,00

The characteristic curve shown in Figure 7 presents the values recorded as the result of the measurements in one coordinate-system.

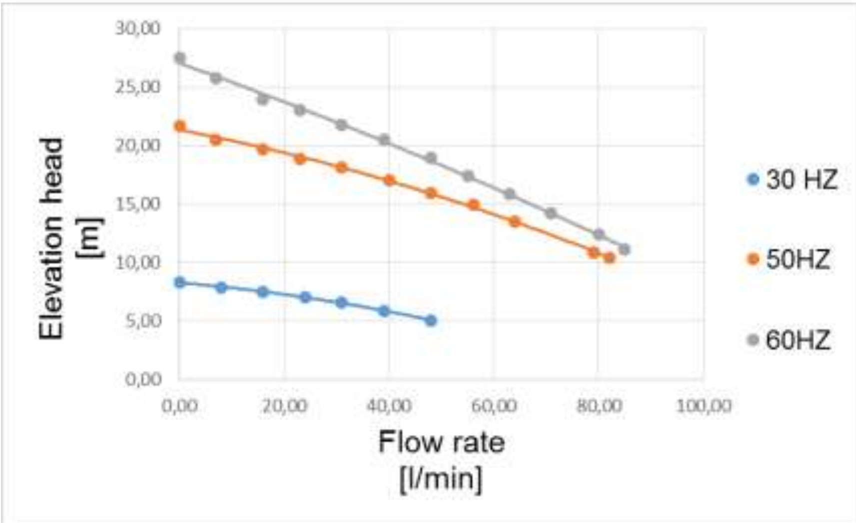

Fig. 7. Characteristic curves of a Pedrollo pump [Author compilation]

In the coordinate-system of the characteristic curves I drew the affinity parabola, which intersects the characteristic curve of rated speed at the Best Efficiency Point (also known as normal operating point of a pump). This is shown in Fig.8.

Table 9: Best efficiency Point at rated speed/revolution [Author compilation]

Motor frequency [Hz]	Maximum efficiency/Best Efficiency Point [%]	Flow rate [l/min]	Elevation head [m]
50	47,31	56,00	14,98

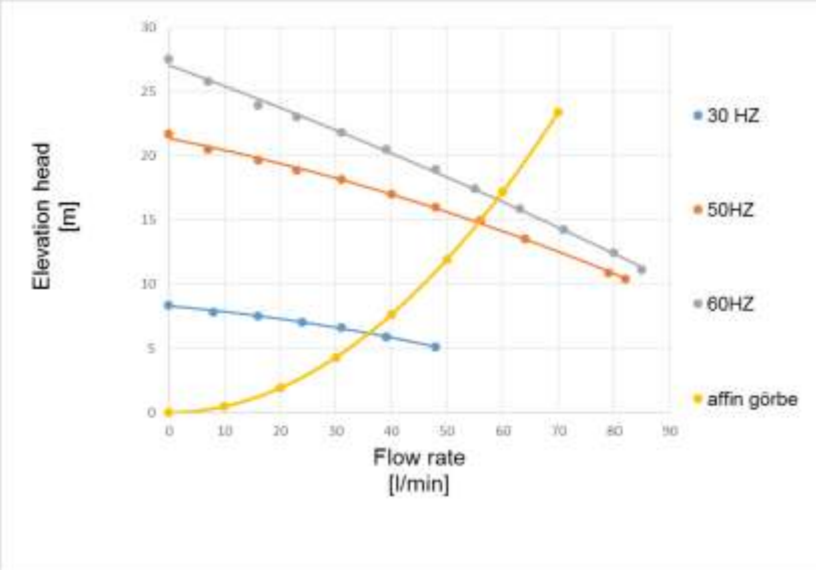

Fig. 8. Characteristic curves of Pedrollo pumps, affinity parabola [Author compilation]

I read the coordinates of the intersection of affinity parabola and the characteristic curve taken at 30 Hz and 60 Hz and summarised them in Table 10.

Table 10: Best efficiency Point at rated speed/revolution [Author compilation]

Revolution [rpm/min]	Flow rate [l/min]	Elevation head [m]
1800	36,00	6,15
3000	56,00	14,98
3600	59,00	16,85

I calculated the Affinity Laws' realization degree:

$$\frac{\dfrac{\left|\dfrac{Q_2}{Q_1}-\dfrac{n_2}{n_1}\right|}{\dfrac{n_2}{n_1}}+\dfrac{\left|\dfrac{Q_2}{Q_3}-\dfrac{n_2}{n_3}\right|}{\dfrac{n_2}{n_3}}}{2} \quad (10)$$

With the first method the Affinity Laws' realization degree is: 10,275 % The Affinity Laws are realized at the Best Efficiency Point in the characteristic curve since it is within 9%. On the basis of the given results it can be stated that the Affinity Laws came to realization. The differences may be caused by the volumetric and hydraulic losses [7]. The accuracy of measurement and evaluation must be added to the consideration of the given results. During the measurement process the set frequency fluctuated influencing the characteristic curve and the values among the measuring points [8].

4. Conclusions

In my study I presented the measuring device in the Fluid Mechanics laboratory at Széchenyi István University. I explained the types of measurements available in the laboratory and described the measurement results carried out by a Nocchi_CB80_38T pump. I stated the relations and made conclusions from the results. It is important to note that measurements during operation are generally carried out under non-standard conditions. Due to the local conditions, usually you must accept the sometimes significant differences as well. The results clearly show that if the revolution decreases, the flow changes and the efficiency is highly reduced. Increasing revolution may cause stiffness related problems on the one hand, or the appearance of cavitation resulting in "broken down" characteristic curves on the other hand. The experience and results recorded in my study are suitable to make the operation of pumps more effective. A more detailed studying of cavitation and processing its measurement results are likely to improve the efficiency and the safety of the system.

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