ENERGY ANALYSIS AND ENERGY BALANCE CALCULATION FOR WARMAN 12-10 GAH PUMP BASED ON IN SITU MEASUREMENTS IN A MINING OPERATION

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Abstract: The paper aligns current global concerns regarding energy sustainability, focusing on issues of operational sustainability of water pumping system.

WARMAN 12-10 GAH pump used in mining groundwater pumping, identification and analysis of the major components, energy flows and performance of this system is the core of the article.

Keywords: energy balance, liquid carrier pumps, energy losses.

1. INTRODUCTION

In order to show the energy performance of the pump at actual operating conditions, energy balances were drawn up on the basis of experimental determinations and analytical calculations; the values obtained were centralised in summary tables and visualised using Sankey diagram [7].

WARMAN 12-10 GAH pump energy balances provide information - in tabels form and graphically - on useful and wasted energies, allowing energy managers at the companies concerned to plan the necessary measures to assess energy consumption and prepare annual reports to the National Energy Regulatory Authority (ANRE) [6].

2. MEASURING APPARATUS USED IN EXPERIMENTAL DETERMINATIONS

The measuring instruments used in the experimental determinations are in the laboratories of the University of Petroșani. For flow measurement, the ultrasonic flow meter FLUXUS - ADM 6725 was used, it uses ultrasonic signals, which vary in time.

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The ultrasonic signals are emitted by a transducer installed on one side of a pipe and reflected to the second transducer. These signals are emitted alternately in the direction of flow and vice versa. The transit time of the ultrasonic signals in the flow direction is shorter than against the flow direction [1], [4].

Fig. 1. FLUXUS ultrasonic flow meter - ADM 6725

The transit time difference Δt is measured and allows the determination of the average flow velocity along the propagation path of the ultrasonic signals. Correction of the flow profile is performed to obtain the average flow velocity which is proportional to the flow rate.

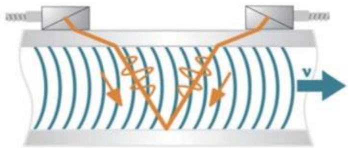

Fig. 2. Ultrasonic signal path

The calculation of the volume flow is performed using the equation:

$$Q = k_{\mathrm{Re}} \cdot A \cdot k_{\alpha} \cdot \Delta t / (2 \cdot t_t) \qquad (1)$$

The received ultrasonic signals will be checked for their usefulness as well as for the measurement and plausibility of the measured values which will be immediately evaluated. The complete measurement cycle is controlled by integrated microprocessors. Disturbances will be removed by statistical signal processing [2].

In the pictures below you can see the location of the ultrasonic flowmeter and see the different water flow values.

Fig. 3. Ultrasonic flowmeter recording a flow rate of 1449,90 m^3/h

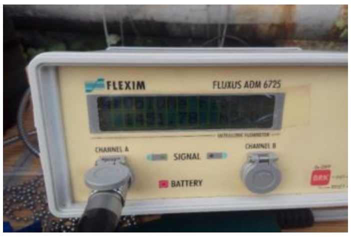

Fig. 4. Ultrasonic flowmeter recording a flow rate of 1451,78 m^3/h.

Fig. 5. Ultrasonic flowmeter recording a flow rate of 1457,33 m^3/h.

3. WATER FLOW VARIATION DIAGRAM

Following the measurements carried out on site, using the ultrasonic flow meter and recording the data in the measurement sheet, I was able to produce the water flow variation diagram where the flow rate can be observed over a period of 10 seconds, Figure 6 [4].

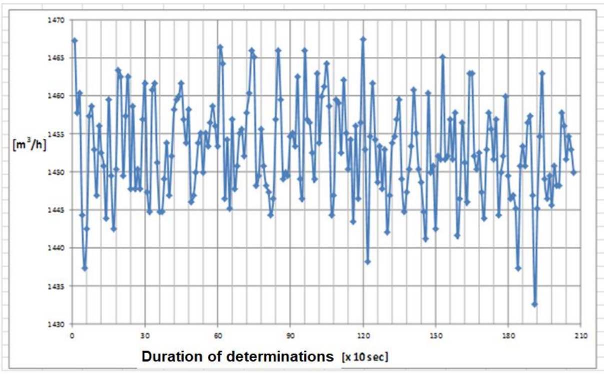

Fig. 6. Water flow variation diagram

4. ENERGY BALANCE FOR WARMAN PUMP 12-10 GAH AT DIFFERENT LOADS

The elements of the actual hourly energy balance for the WARMAN 12-10 GAH pump at nominal load and part load have been highlighted.

a) Elements of the actual hourly energy balance for the WARMAN 12-10 GAH pump at nominal load with nominal parameters according to the characteristic curves in the brochure [4]:

- Q_{max} = 1800 m^3/h; H_{max} = 78 m; P_{mot} = 382 kW;
- Pump shaft power P_p = 450 kW;
- Total pump efficiency η_p = 84,87 %;
- Mechanical efficiency η_m =96,20 %;
- Hydraulic efficiency η_h = 89,84 %;
- Efficiency volumetric η_v = 98,20 %;
- Nominal specific energy consumption $C_{nom.\ sp.en.}$ = 0.278 kWh/m^3.

Table 1. ***The actual hourly balance for WARMAN 12-10 GAH pump - nominal load***

Energy input in contour			**Energy output in contour**		
Name	**[kWh]**	**[%]**	**Name**	**[kWh]**	**[%]**
Energy at the pump shaft	450,00	100,00	Useful energy		
			Water flow energy	381,91	84.87
			Lost energy		
			Mechanical losses in the pump	18,45	4,10
			Hydraulic losses in the pump	41,13	9,14
			Volume losses in the pump	8,51	1,89
			Total losses	68,09	15,13
TOTAL	450,00	100,00	TOTAL	450,00	100,00

b) Elements of the actual hourly energy balance for the WARMAN 12-10 GAH pump at part load with measured and calculated parameters [4]:

- Q_{max} = 1453 m^3/h; H_{max} = 70 m; P_{mot} = 277 kW;
- Pump shaft power P_p = 384,72 kW;
- Total pump efficiency η_p = 72,00 %;
- Mechanical efficiency η_m =92,00 %;
- Hydraulic efficiency η_h = 83,20 %;
- Efficiency volumetric η_v = 94,10 %;
- Specific energy consumption $C_{sp.en.}$ = 0.294 kWh/m^3.

Table 2. ***The actual hourly balance for WARMAN 12-10 GAH pump - part load***

Energy input in contour			**Energy output in contour**		
Name	**[kWh]**	**[%]**	**Name**	**[kWh]**	**[%]**
Energy at the pump shaft	384,72	100,00	Useful energy		
			Water flow energy	277,00	72,00
			Lost energy		
			Mechanical losses in the pump	29,20	7,59
			Hydraulic losses in the pump	65,06	16,91
			Volume losses in the pump	13,46	3,50
			Total pierderi	107,72	28,00
TOTAL	384,72	100,00	TOTAL	384,72	100,00

The energy balance based on experimental determinations and analytical calculations is shown in Figure 7.

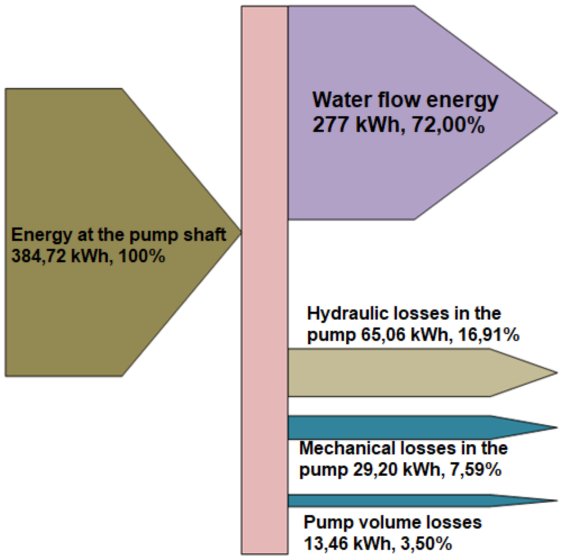

Fig. 7. Sankey diagram for energies in and out of the WARMAN 12-10 GAH pump contour

In order to determine the average energy used daily (24 hours) by a pump, on the basis of existing statistical data from the beneficiary, correlated with the literature, the values (at the level of energy used per hour from the grid of 500 kWh, related to the nominal regime) specified in Table 3 and shown in Figure 8 were calculated [3],[5].

Table 3. ***Average daily energy use***

Load regime/consumption characteristics		**Energy consumption/day**
Load factor	**Duration**	**[kWh]**
[%]	**[hours/day]**	25
10	0,5	50
20	0,5	75
30	0,5	200
40	1	250
50	1	1470
60	4,9	2100
70	6	2080
80	5,2	1800
90	4	200
100	0,4	8250
TOTAL	24	16500

The variation of the energy used by the pump during a day, as a function of the load factor and the duration of the load related to the load factor.

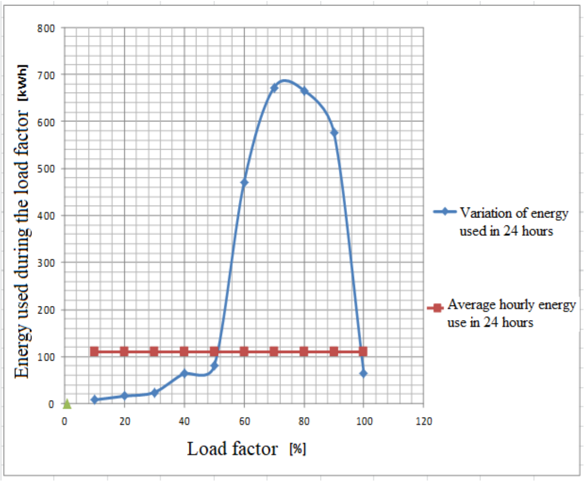

Fig. 8. Energy used during the load factor [kWh]

Dividing the total daily consumption (8250 kWh) by 24 hours results in a daily average hourly consumption of 343.75 kWh, which corresponds to a useful power of the water current of 222,5 kW.

5. CONCLUSIONS

From the curve of variation of the energy used in 24 hours, it appears that the major consumption values fall in the range of 60-90% of the nominal load. Such a load corresponds to the rational area (from the pump characteristic) of operation. In this zone the pump has major efficiencies and shows hydrodynamic stability.

One (costly, energy-efficient) measure to be taken by the technical staff, which will make a significant contribution to increasing energy efficiency and reducing energy consumption, is to introduce flow regulation through speed regulation.

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