Theoretic and experimental research on the possibilities for moderning and reabilitating the extraction installation of the Slănic Prahova salt mine.

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Abstract. The paper deals with the subject of rehabilitation and mechanical modernization of the extraction plant within the mining operation of the salt mine from Slanic Prahova region. The extraction plant serves the 23 August mine shaft of the Unirea mine, and also this mine has been converted into a tourist mine. The rehabilitation of the extraction installation consists in the change of the cutting wheels from the extraction tower due to excessive degradation, requiring the redesign under strict conditions, and also the rehabilitation and extension of the saline water extraction system from the tourist mine. The modernization of the extraction plant consists in the change of the DC hoist engine with an asynchronous engine of the same energy power and research on the possibilities of increasing the cable transport capacity with technical changes made to the extraction tower, mine shaft and the sump. Modernization and rehabilitation carried out on the extraction installation at the Slanic Prahova salt mine, will provide a safety in operation and efficiency to using the necessary electricity for hoist engine operations.

1 Introduction

In the context of the salt mining operation in the town of Slanic in Prahova County, the extraction facility serving the mining enterprise is undergoing major transformations. The first transformation occurred, when the mine and the installation received a new field of activity, i.e. tourism.

The second transformation will take place with the rehabilitation and modernization of various systems such as the cutting wheels in the extraction tower, the hoist engine, the increase in transport capacity, and the new evacuation of groundwater. The rehabilitation of the cutting wheels in the extraction tower is necessary due to excessive damage to the cutting wheel sides, which has caused the extraction installation to become a major failure.

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Modernization of hoist engine by changing the DC hoist engine of Ilgner type, with an asynchronous hoist engine of the same output power. Regardless of the type for hoist engine, increasing cable-carrying capacity becomes a priority for the rational use of resources.

The last general problem of this mining enterprise is the evacuation of salin water from the 23 August sump, which can be solved by upgrading the water drainage and evacuation system. [1]

2 Theoretical and experimental research on the rehabilitation of cutting wheels from the extraction tower

The divert cutting wheels for the extraction machine Phoebus 2500x1000 serving the 23 August sump of Unirea shaft mine, from Slanic Prahova, are necessary for the operation of the extraction installation and the transportation of personnel and tourists in to the mine. The current left-hand cutting wheel, as viewed from the extraction hoist engine, is out of service due to the destruction of the inside wall of the hoisting rope channel (fig.1).

The breaking was caused by the reduction in wall thickness, figure 2, due to the wear of adhesion caused by the contact between the hoisting rope and the channel. This destruction of the side wall of the cable channel has also been determined by the five lateral cuttings required for introducing the lining packages along the channel in the form of a swallow's tail of the cutting wheel.[2] Note that the cutting wheel consists of a cast iron crown in construction, which has ten protrusions with recesses for the placement of spit pairs.[1,3]

Fig.1. Wheel with split flange

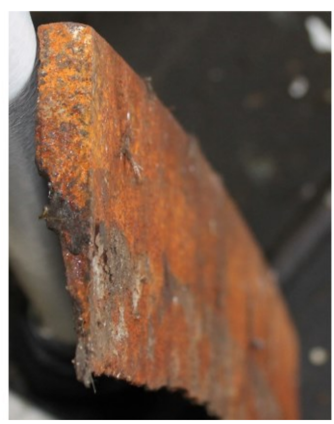

Fig.2. Broken flank

The rehabilitation of the cutting wheel will be done by redesigning a new cutting wheel under the required conditions, using CAD-type software and by virtual simulation of the cutting wheel by applying the forces acting on it. Following redesign of the cutting wheel and simulation with the forces acting on it, the cutting wheel can be produced and fitted instead of the old one. The results of the redesign are shown in Figure 3 and the results of the tests are given in Figure 4 and 5.

The old cutting wheel it is built by casting cast iron, thus making the crown of the cutting wheel, the spokes are riveted on both the crown and the cutting wheel hub. The new cutting wheel will be manufactured by assembling two half-shells attached to each other with bolts, centered on the cutting wheel hub by means of spokes and welded with MIG/MAG type equipment, both the crownwheel spokes and the hub spokes. (fig.5)

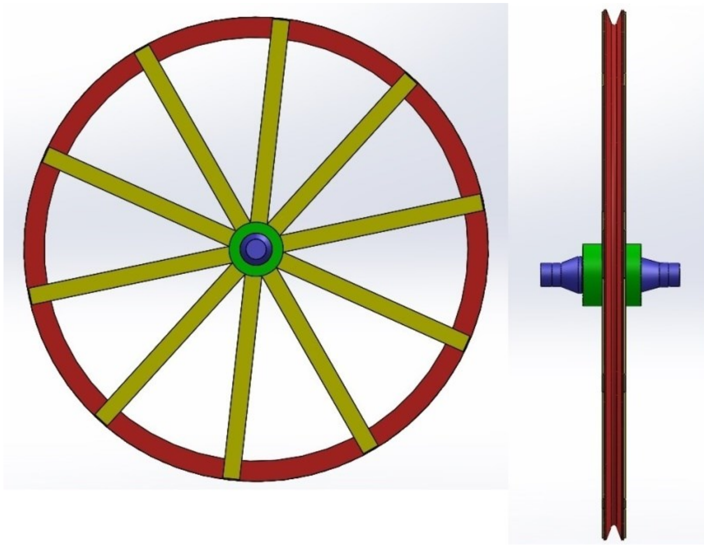

Fig.3. The newly modeled cutting wheel in SolidWorks program.

In simulation using the solid works software, the minimum force (fig.4)[4] to which the tumblewheel is subjected is 28028 N, composed of the weight of the extraction cage, the balancing rope and its bounding device and the extraction cable at the lowerest level. The maximum force (fig.5) where the cutting wheel has to bear during exploitation and it includes the weight of the cage loaded with 6 persons, the bounding device of the cable and the maximal length of the bounding cable of 265 meters.[5,6]

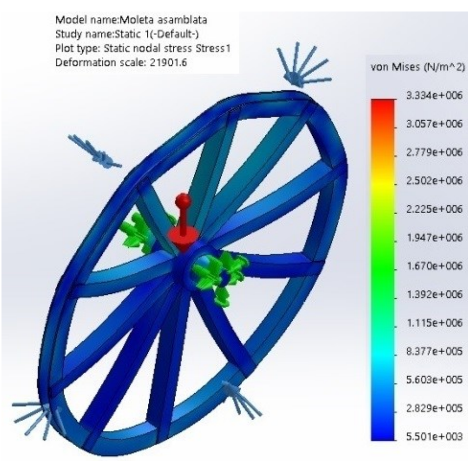

Fig.4. Wheel simulation with minimum force

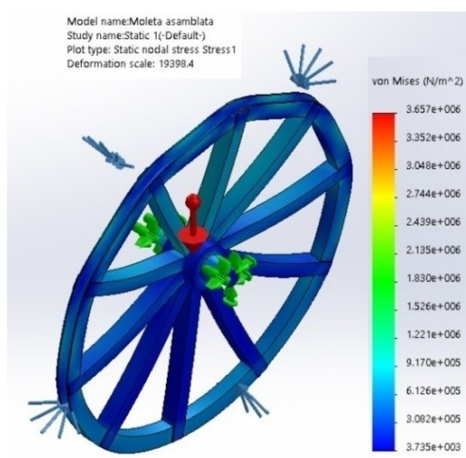

Fig.5. Wheel simulation with maximum force

According to mathematical analysis and simulation by CAD software, the new cutting wheel resists the forces to which it will be subjected and the deformations being minor and forming part of the officials regulations.

3 Theoretical research regarding changing the hoist engine of the extraction installation

The DC hoist engine with which the extraction installation from the 23 August mine shaft is equipped, is an engine produced in 1932 and fitted in place at the hoist engine building, in 1935. The hoist engine is part of the Ilgner electric hoist engine category (Fig. 6), which requires a DC generator to be able to operate (Fig.7).[4,7]

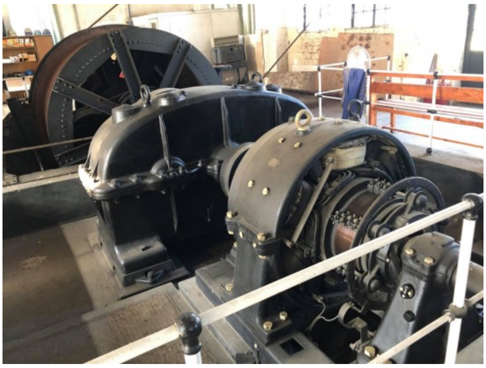

Fig.6. Motorul electric de curent continuu

Fig.7. Generatorul de curent continuu cu volant.

The need to change this electric engine occurs due to the high risk of accident when the electric generator is switched on. The electric generator under the current conditions can only start with manual help from the operator of the extraction installation. Under the given conditions, the operator's safety is endangered by the fact that the moment of rotation it applies to the generator is to spin with a connecting flange using an improvised metal device of a length of 1,20 m. The second problem with the DC generator is that from the time of the first revolution to the moment it reaches the nominal working speed, the time requirement is 23 minutes in the summer and winter can be up to 40 minutes.

Following the two major problems of the DC generator together with the burial wear of the hoist engine and the high power consumption for the start-up, it is proposed to change them. In order to have the necessary results, for the technical solution of changing the hoist engine, and we need to calculate the analytical, kinematic and dynamic, of the extraction installation.

Once these results are known from kinetics and dynamical extraction instalation, a second analytical section can be determined, namely the calculation of safety factors. The last analytical calculation will be the determination of the effective output power of the DC hoist engine and the calculation of the output power of the asynchronous hoist engine as follows.

Calculation of output power at the DC hoist engine and the asynchronous hoist engine is determinate due to the cyclical nature of the extraction process, the electric motor of the extraction machines operates intermittently with variable load. For the purpose of determining the drive power, the actual intermittent mode is equivalent to a continuous operating mode and a constant load to produce the same thermal effect in the engine wires.

Calculation of the effective power, with the speed parameters of the DC hoist engine.

Maximum transport speed for persons:

$$v = 4 \quad [m/s] \tag{1}$$

Maximum throttle for transporting persons:

$$a = 0.7\ [m/s^2] \tag{2}$$

DC hoist engine power:

$$P_m = \frac{\left(a \cdot d_Q \cdot \frac{4}{100} + \frac{d_Q \cdot v}{100}\right)}{0.85} = 118.8\ [kW] \tag{3}$$

Rated speed of the DC hoist engine:

$$n_{nomact} = 580\ [rot/min] \tag{4}$$

The reduction ratio of the reduction gear is: i_{red}

$$i_{red} = 11.5 \tag{5}$$

The power required to maintain the empty cage balance in case of the drums disengaged P_{max}:

$$P_{max} = \frac{(M_{st2} \cdot n_{nomact} \cdot 100)}{0.8 \cdot 950500 \cdot 11.5} = 228.986[\ kW] \tag{6}$$

The power of the DC engine shall be rounded to 229 kW and shall comply with the technical documentation at the salt mine at Slanic Prahova.

Calculation of the power for the asynchronous drive motor with a nominal speed of 4 m/s.

Maximum transport speed for persons:

$$v = 4 \quad [m/s] \tag{7}$$

Maximum throttle for transporting persons:

$$a = 0.7\ [m/s^2] \tag{8}$$

The calculated rated speed of the asynchronous hoist engine: n_{nom}:

$$n_{nom} = \frac{v}{\pi \cdot D_j} \cdot 11.5 \cdot 60 = 351.414\ [1/min] \tag{9}$$

The adjusted rated speed of the asynchronous hoist engine:: n_{nom}:

$$n_{nom} = 345\ [rot/min] \tag{10}$$

Actual speed :

$$v_{real} = n_{nom} \cdot \pi \cdot \frac{D_j}{11.5 \cdot 60} = 3.927\ [m/s] \tag{11}$$

Efficiency of the mechanical installation: η_{mec}:

$$\eta_{mec} = 0.85 \tag{12}$$

Output engine power P_m:

$$P_m = \frac{\left(a \cdot d_Q \cdot \frac{v_{real}}{100} + \frac{d_Q \cdot v_{real}}{100}\right)}{\eta_{mec}} = 116.632\ [kW] \tag{13}$$

An asynchronous electric motor of 132 kW is adopted at a speed of 345 rpm.

Reduction ratio of reduction gear :

$$i_{red} = 11.5 \tag{14}$$

The power required to maintain the empty cage balance in case of the drums disengaged:

$$P_{max\,nou} = \frac{(M_{st2} \cdot n_{nom} \cdot 100)}{\eta_{mec} \cdot 95500 \cdot 11.5} = 128.195\ [kW] \tag{15}$$

The calculations can lead to the determination that the 229 kW DC hoist engine can be replaced by the 129 kW asynchronous hoist engine, which can operate under the same conditions and with the same forces at the extraction installation.

3 Increasing the transport capacity of the extraction installation

Based on the technical documentation, the 3D extraction tower and the drawing for the analysis of the tower located at the 23 August mine shaft at Slanic Prahova saline could be arranged. Figure 8 shows the 3D model of the tower and the drawing, which allowed the calculation model and its demands to be established.

Starting from the construction of the tower and the way to achieve the second boarding ramp, on the eastern side of the tower, at a height of 3560 mm from the current ramp, the cage's constructive solution, which is shown in Figure 9, has resulted. [4]

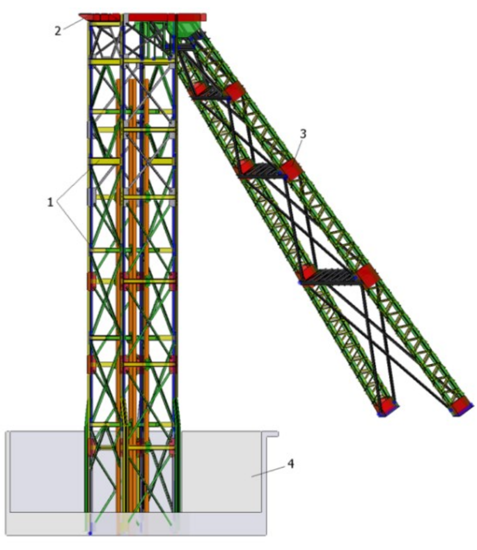

Fig.8. Model of tower.1 — tower with guides; 2 — wheel platform; 3 — countereffort; 4 — shaft ramp.

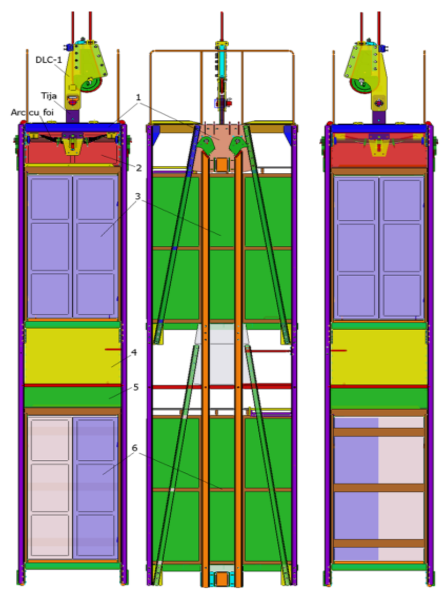

Fig.9. Construction of the two-stage cage. 1 – metal frame; 2 – upper panel; 3 – upper cab; 4 – intermediate panel; 5 – lower panel; 6 – lower cab.

Its drawing also allowed the 3560 mm dimension to be established between the vetches of the two-story cage, which would double the flow of personal transport on the shaft. Following weighing of the empty cages by means of a dynamometer set between a tower mounted metal beam and the DLC-1 rope device of the cage, it has been established that the mass of the new cage must not exceed 2300 kg, which has been used in the calculation bar, and not as much as the southern cage had 2750 kg, weight that come from adding some supplimentar reinforcement.

The calculation brief was performed for a dynamic coefficient of extraction installations of 1,6, and based on the tower's constructive geometry and geometrical characteristics of the component parts sections (tower, platform, counter-effort) the geometric model of the tower calculation was developed. The undetermined tower static system has been resolved by the unit load method - Mohr-Maxwell and the Verestesceaghin process, resulting in inflexi torque, normal and recutter force diagrams, and their values for the three stress cases are given in Figure 10: 1 - both cages are empty; 2 - one cage is loaded with people and one cage is empty; 3 – both cages are loaded with people.

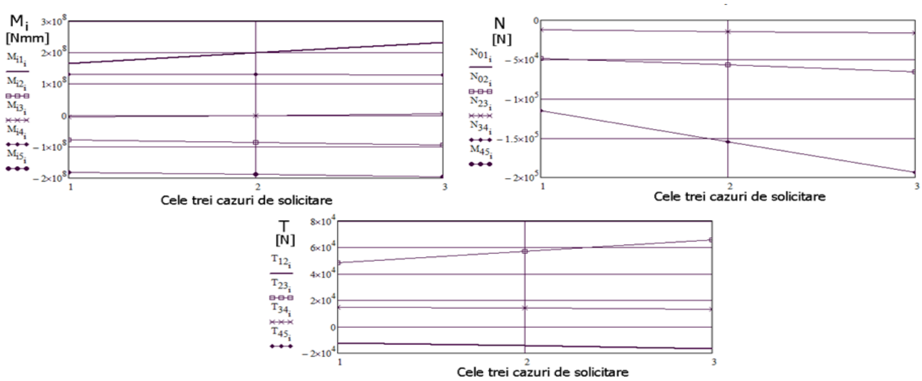

Fig.10. Bending moment, normal and recutter force diagrams.

To increase the carrying capacity of the extraction installation, the cages had to be redesigned, taking into account that the single-floor cage has a weight of 2750 kg with the balancing rope and DLC-1. The weight of the 6 people transported is approximately 480 kg, resulting in a total weight of 3230 kg and the other cage weight 2780 kg.

The cage designed to increase carrying capacity has a weight of 2200 kg on its own with the balancing rope and DLC-1, a capacity of 12 persons, weighing 960 kg, resulting in a total mass of 3160 kg. The difference in weight between the two cages is 70 kg. By replacing new weights in the existing single-deck cage calculation bar, all the forces and moments that result are slightly smaller than the calculated previous ones. In conditions where the decreased forces are very small, we can consider the DC hoist engine or the asynchronous hoist engine, the winding drums, the extraction rope and the braking installation to be in normal working conditions, and do not require further modifications.

4 Modernization of the mine water evacuation system

In order to be used as a saline mine and turist site, water infiltration was drained from two places where two lakes were threatened. Both lakes were originally arranged for the purpose of collecting infiltrations and were subsequently also arranged for the tourist attraction. So the two infitration lakes can take over, drain and retain infiltrations, without them continuing to flood saline mine and endanger tourists. These water inflation retained by Lake 1, 2 and the sump of the 23 August mine shaft, require a new water evacuation system.

The old system was originally designed for a much lower infiltration rate than the current one. This high flow is due to numerous cracks in the salt that increasingly facilitate the infitration of rainwater.

Due to the mine plans and the measurements made, it has been possible to determine the volumes of water that are infused as well as the volumes of water to be discharged.

The maximum water volumes are: Volume of the shaft sump V_j=60 m^3 , volume of the lake 1 V_{L1}=939,3 m^3, volume of the lake 2 V_{L2}=1855,5 m^3, total volume being the relationship:

$$V_t = V_j + V_{L1} + V_{L2} = 2854{,}8 \text{ m}^3 \tag{16}$$

Due to the leisure facilities in Lake 1 and lake 2 these infiltrations cannot be completely discharged and some of the water is required at the artesians in lakes.

Required volumes of discharges are: Volume of the shaft sump $V_{jevac} = 57{,}6 \text{ m}^3$, volum of the lake 1 $V_{L1evac} = 281{,}8 \text{ m}^3$, volume of the lake 2 $V_{L2evac} = 956{,}8 \text{ m}^3$, the total volume of saline water discharged given by the relationship:

$$V_{tevc} = V_{jevac} + V_{L1evac} + V_{L2evac} = 1296{,}2 \text{ m}^3 \tag{17}$$

For the determination of the infiltration rate in each zone, will use the next method, which assumes that water is drained from the maximum level up to a set minimum level and that refills are timed to their maximum level. The experimental pump used has an exhaust flow rate of 10 m^3/h and the quart formula is shown below:

$$Q_i = Q_p \frac{t_2}{t_1+t_2} \quad [\text{m}^3/\text{h}] \tag{18}$$

where: Q_p - pump flow rate used in the experiment; t_1- the time required to fill the place by infiltration after it has been emptied to the minimum level considered; t_2- the time of the discharge of the saline water using an experimental pump.[1]

Using formula (18) for each zone, we can express the following results:the flow rate of condensation at sump $Q_{ij} = 0.33$ m^3/h, the infiltration flow rate for the lake 1 $Q_{iL1} = 1{,}4$ m^3/h, the infiltration flow rate for the lake 2 $Q_{iL2} = 3{,}6$ m^3/h.

From the calculated flow rates and the volumes of water to be discharged, the required discharge flow of the pumps and the hydraulic network can be calculated.

The parameters required to calculate the system of discharge pumps to be met, are the pumping height which is 203 meters, the respective suction height between 3-5 m, the local and linear pressure losses of the hydraulic system.[7]

By referring to the technical offers submitted by an industrial pump manufacturer, the technical offer given in Table 1, parameters required depending on the economic solution is provided by the SADU pump.

Tabel.1. Centrifugal pump types.

Pump type	Q-flow rate m^3/h	Pumping height (h)	Max.Temp. ˚C	Nominal Pressure (Bar)	DN intake (mm)	DN discharge (mm)
NDS	100-2000	25-95 m	105	10	200-400	150-350
SADU	1-80	20-220 m	130	30	50-100	40-80
SD	15-180	20-900 m	130	64-100	65-125	50-100
JIU	20-220	100-300 m	105	25;64	100-150	80-125

The SADU pump can meet the primary need for saline water discharge at a height of 208 meters, gives us the required exhaust flow, centrifugal pumps of this type can be built, and the maximum nominal diameters for connecting the pipes are the same as those in the mine.

Pressure losses are calculated with the relationship:

$$h_{pt} = h_{local} + h_{liniar} = 24{,}07\ [H_2O] \quad (19)$$

$$h_{liniar} = \lambda \frac{L}{D} \cdot \frac{v^2}{2 \cdot g} = 4{,}06\ [H_2O] \quad (20)$$

$$h_{liniar} = \lambda \cdot \frac{L}{D} \cdot \frac{v^2}{2 \cdot g} = 17{,}76\ [H_2O] \quad (21)$$

where: h_{pt} – total pressure loss; h_{local} – local pressure loss; h_{liniar} – pressure losses on pipes, elbows, check valves, sorters, return valves and other hydraulic system components; v^2 - for the discharge pipe, choose between 1.5 - 2.2 m/s^2 (for relation19); λ – Linear loss coefficient depending on flow rate and Raynolds number; D – diameter; L – length; g – gravitational acceleration.

According to the calculation roundup performed for one pump and a two-pump system, the operating point of one pump was determined followed by the operating point of the two parallel-linked centrifugal pumps.

Formula by which parabola h can be determined:

$$h' = aQ^2\ m[H_2O] \quad (22)$$

$$a = 0.08\left(\frac{\lambda L}{D} + \sum \xi_i\right) \cdot D^4 = 24{,}07\ \ m\ [H_2O] \quad (23)$$

The point of operation F of a centrifugal pump will be at the intersection of the characteristic curve of the pump and the characteristic of the piping, drawn on the same scale. The height and flow given by the pump under the actual operating conditions of the hydraulic grid will be Q_f and H_f. Figure 12 shows the operating point graph of the parallel-linked centrifugal pumps for the hydraulic grid.

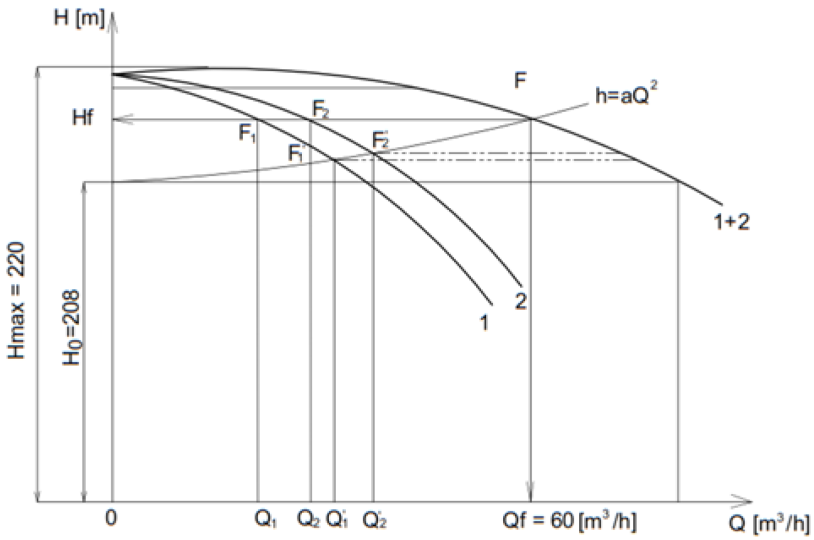

Fig.12. The operating point of centrifugal pumps connected in parallel under concrete conditions of the hydraulic network.

Note from the graph in Figure 12 that the aggregate flow rate is less than the sum of flows at individual operation.

Approximately 22 hours are required to evacuate water to pump system conditions. So the installation will be used once every week to ensure the correct level of the water that is inflating inside the salt mine.

5 Conclusions

The following conclusions can be drawn from the research carried out in the work on the extraction facility at the salt mine in Slanic Prahova:

The necessity to change the disabled extraction instalation, which transports tourists from the mine, is the first and most important step. This can be done by the cutting wheels rehabilitation with the current alienation and simulation solutions. The suggested solution for replacing the cutting wheels is acceptable because it meets the current standards.

The DC hoist engine operating the extraction system requires changing with an asynchronous hoist engine due to its wear, tear and the danger shown by the generator. The power generator can cause serious personal injury by starting with manual help only, which cannot continue. The proposed new engine will be efficient for the extraction facility, accidents will be excluded compared to current one and will be more energy efficient.

The modernization of the cage by redesigning it and increasing its transport capacity from 6 to 12 people will have an impacement for the efficiency of the extraction instalation, the used electrical energy and economic efficiency.

The rehabilitation and upgrading of the underground water disposal facility can give us safety for tourists, dry sump for the extraction installation and stop the flood effect of the salt mine.

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