MINISTRY OF EDUCATION

UNIVERSITY OF PETROŞANI

DOCTORAL SCHOOL

DOCTORAL THESIS

THEORETICAL AND EXPERIMENTAL RESEARCH ON THE REABILITY AND MODERNIZATION OF HIGH COMPLEXITY INDUSTRIAL SYSTEMS

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PETROŞANI, 2023

Keywords: Modernization, rehabilitation, industrial installations, mining installations.

The paper addresses the issue of rehabilitation and modernization of industrial systems in general, with reference to the industrial systems of the mining units. The guiding thread of the works is the methodologies used in scientific research considered as a privileged place for intellectual work, completed by the conception, design and implementation of solutions that ensure functionality, additional duration of operation, work safety and economic efficiency.

Since the notion of installation is unanimously accepted in the specialized literature and in the industrial custom in the mining field, during the development of the work, the notion of industrial system was particularized through this notion.

The doctoral thesis "**Theoretical and experimental research on the rehabilitation and modernization of highly complex industrial systems**" was structured in 6 chapters.

In the first chapter of the paper, aspects related to the scientific research of the directions of the mining field are presented, making a comparison at the world level as well as at the national level.

The research studies the possibility of proposing new solutions for the continuous development of the extractive industry, the exploitation of new deposits of various useful mineral substances, the increase of production capacities, the increase of labor productivity in the mining field, all of which are closely related to the development of mechanical mining installations, respectively of drainage, fans, production and distribution of compressed air and surface and underground installations.

In the national salt mines, the method of exploitation has been changed from the method with bell chambers to the one with small chambers and square pillars, which ensure the stability of the land on the surface. In the salt mines of Romania, for the moment when it is decided to close the operation, it does not remain abandoned but is set up for tourism, balneo-climatic treatment bases and places of worship.

The Slănic Prahova salt pan is a national pride of the Romanian people, given the fact that it ranks 3rd in the world and 1st in Europe in terms of its size. In the Slănic Prahova salt pan, a project was implemented through which a radiation monitoring laboratory was created. Also here, a project of the Romanian Academy of Technical Sciences is being developed, through which a Foucault Pendulum, Gravitational Clock with Interactive Kinematics (PF-OGCI) will be placed".

Internationally, the mode of operation is the same as in Romania, namely small rooms and square pillars and the transformation of old horizons into tourist areas. The mining methods were changed from the method with large bell-type chambers to the one with small chambers and square pillars.

After the exploitation of the salt, balneo-climatic treatment bases and places of worship are set up in the remaining spaces. Internationally, the exploitation method is the same as in Romania, namely chambers with pillars and the transformation of old salt mines into tourist destinations.

The world's largest salt mine located in Ontario Canada can be an example to follow in light of the pilot project it has in progress, given that we are going through a period in which we are restoring energy efficiency standards.

Chapter II presents the study on the stability of the Slănic Prahova salt pan in comparison with other salt pans in Romania. The study of the stability of the salt massif begins with the analysis of the stratigraphy, the hydrogeology of the deposit and the calculation of the stability indices.

From a stratigraphic perspective, the salt deposit is concentrated in the post-tectonic blanket deposits of the Tarcău sheet and the pericarpatic area, which have a molasses character; in age, these deposits include the Paleogene interval.

Looking at the hydrogeology of the deposit, salt, which is essentially a rock that has low porosity and permeability. Salt is virtually impermeable and has a significant impact on hydrogeology.

Hydrogeological problems cause the overlying geological formations to have the properties of aquifers, allowing water to seep in and flood the salt pan.

The stability of the salt massif was determined by testing the salt samples in the mineral study laboratory of the University of Petroșani. The salt samples come from 3 salt pans, and the results of the stability criteria highlight the specific density of the salt from Slănic Prahova salt pan having a variation between 2.165 and 2.275·104 N/m^3, with an average of 2.174·104 N/m^3.

The porosity of the salt from Slănic Prahova salt pan is between 2,75 and 5,12% and the humidity of the salt is between 2,95 and 4,15%, with an average value of 3,58%.

The breaking strength in monoaxial compression has values between 27,13 and 32,71 MPa, with an average value of 28,248 MPa. After the breaking strength in monoaxial compression, the salt from Slănic Prahova is the most resistant and the stability of the salt massif is good.

Chapter III presents research on the evaluation of the technical condition of the extraction plant within the Slănic Prahova salt pan, highlighting the need to go through some rehabilitation and modernization processes whose objectives are the redesign and manufacture of the cutting wheel in a state of damage, the increase of the transport capacity through modernization of the extraction vessel (from a one-story cage to a two-story cage), modernization of the extraction engine, modernization of the electrical installation, conception and design of a new underground water drainage facility.

Research on theoretical aspects related to the kinematics and dynamics of extraction installations, usable in the rehabilitation and modernization processes, was applied to the case of the extraction machine from Salina Slănic Prahova.

Following the analysis of the obtained results, directions of action were released in the field of rehabilitation and modernization of the extraction facility, in general and on component subassemblies in particular. It is found that there are consistent reserves in increasing the operating performance and increasing the life of this installation.

Research on the rehabilitation and modernization of the extraction plant cutting wheel was constituted in a case study for the Slănic Prahova salt pan.

The major defect comes from the left cutting wheel, as seen from the extraction machine, which was put out of action due to the destruction of the inner wall of the cable channel. The break occurred due to the reduction of the wall thickness, due to the adhesion wear produced by the contact between the cable and the channel wall.

The hoist engine is old with high electricity consumption. The wear and tear on this engine is high, the engine being manufactured in 1932 and mounted in the extraction machine house in 1935.

The generator is inefficient in terms of energy, it is composed of 3 electric engine with a consumption of 6,000 kW, and the start-up is slow due to decades of operation and wear.

The braking system is functional, but it is technologically and morally outdated. The brake system is in good condition as it was rarely used. Braking of the extraction plant was done by dynamic braking of the direct current engine.

The underground water drainage system must be modernized, by collecting and draining saline water from a basin located next to the extraction well, using a new pump system.

Chapter IV presents the current extraction facility from the Slănic Prahova salt pan, it is operated by means of a generator-motor system called Ilgner (with flywheel).

The direct current generator has in its composition 3 electric engine of approximately the same power, which increase investment, maintenance and high electricity consumption expenses.

In order to adopt a constructive solution and efficiency from the energy point of view, it is necessary to go through the mathematical stages through which we checked the kinematics and dynamics of extraction machines in the current conditions.

Analyzing the way extraction engine are operated, it was found that there are significant break periods in the operating cycle in which, for functional and security reasons, the generator-engine group is permanently in operation.

The research carried out in this chapter becomes the stable basis for the following proposals for the rehabilitation and modernization of the extraction plant, namely the increase of the vertical transport capacity and the change of the electric engine for the energy efficiency of the exploitation of the plant.

Chapter V I determined the technical condition of the cutting wheel that temporarily put the extraction facility of the salt well at Slănic Prahova out of use. The break of the knurled flank was favored by the five lateral cutouts for the insertion of the bandage molds on the dovetail channel in conjunction with the twisting of the extraction tower.

In this sense, for the rehabilitation and modernization of the cutting wheel, their dimensional and constructive surveying was initially carried out, together with the spindle of the cutting wheel and the sliding bearings, elaborating a complete calculation breviary for dimensioning and verification for all the mentioned.

Based on the execution documentation for the 2,500 mm diameter cutting wheel, the old version from the Slănic Prahova mine shaft and the current technology of the cutting wheel manufacturing, the manufacturing documentation for the assembly of the new cutting wheel with a diameter of 2,500 mm in the new version was drawn up.

Similarly, the new solution was developed at the level of the manufacturing project for the metal structure of the cutting wheel, respectively the cutting wheel shaft and the rolling bearings. For this variant, a complete calculation breviary for dimensioning and verification has been elaborated, which highlights, on the one hand, the fact that the constructive solutions adopted ensure the taking over of the demand states and the functionality of the new assembly.

Fundamental elements regarding the execution technology have been developed, considering the fact that the new knurled solution is in the welded version compared to the old manufacturing solution, i.e. in the cast version.

For the finite element analysis of the stress state of the metal structure, the new cutting wheel as an assembly was modeled in 3D in the Solid Edge utility. The designed model was loaded with the forces resulting from the initially developed calculation brief and we simulated the state of tension in the entire structure.

We note that the stress values resulting from the simulation do not exceed the allowed values, respectively the values calculated in the breviary. This fact confirms the correctness of the designed, designed solution and the dimensioning and verification calculations presented in the calculation breviary.

Chapter VI studies the possibility of increasing the vertical transport capacity, the modernization of the drive engine and water infiltration in the tourist mine.

Increasing the transportation capacity of an operating extraction plant is an important and complex issue, if it is necessary and possible to achieve. To achieve this goal, there are several possibilities, among which we mention: modification of the drive system; changing the capacity of the extraction vessel; modification of operating parameters; And so on.

In the case of the present work, the first two possibilities determined by the need to modernize the drive of the extraction plant and by conceiving and designing a two-story extraction cage are considered. Concept and design elements were developed, down to the level of detail, and dimensioning and verification calculations were performed.

In order to fit the cage's current mass of 2,300 kg, it was necessary to make the cage from a metal frame, which gives the cage's resistance structure, and two cabins made of pressed wood and polycarbonate plates for transporting people. The DLC-1 rope, the 160x52 mm rod and the 12-leaf spring parachute from the current cage have been retained, which allows for the quick and economical construction of new two-story cages;

The construction of the metal frame is easy to make, mounted in the shaft ramp and to maintain during operation, due to the possibility of mounting/dismounting the passenger cage and their removal in the shaft ramps.

Following the verification calculations of the parachute mechanism of the old cage, it is demonstrated that the constructive solution for the new cage does not influence by imposing a new parachute assembly.

The need to implement a new saline water drainage system results from the fact that infiltrations are constant and in certain periods of the year more abundant.

The water evacuation system will not work constantly, but can be used under supervision as long as necessary, to maintain the correct water levels in lake 1 and lake 2. The bottom of the salt well from Slănic Prahova will have to be evacuated in proportion to 90

% for optimal safety and maintainability of the well ramp.

The metal and wooden materials located in the area of the ramp and the sump suffer a marked degradation, and can endanger the lives of the tourists transported with the extraction facility as well as the lives of the workers who carry out periodic checks.

The effective discharge time of the brine accumulated in the bottom of the well, Lake 1 and Lake 2, by the designed facility, is approximately 22 hours at current infiltration rates. Climatic changes cause a variation in the infiltrated volumes, which in turn causes the plant to start at shorter time intervals, depending on the needs.

The electric motors of the water evacuation pumps have a wide variety of connections to the mine's electrical installation, which facilitates easy installation without any other necessary modifications from the point of view of the electrical power network.

Original contributions.

Following the elaboration of this paper, a series of original personal contributions have emerged, which will be presented below.

1. Study of the technical conditions and of the defective parameters on the basis of which the constructive assembly composed of the wheel, shaft and sliding bearings has reached the defective stage, followed by the decommissioning of the extraction machines. Under the conditions given based on the study, the design of a new solution of the assembly, for the re-commissioning of the extraction plant, was approached by redesign and verification calculations, followed by 3D modeling and simulation with Solid Edge and Solid Works utility.

2. The study of the kinematics and dynamics of the extraction installation which results in the establishment of tachograms for moving the cage, in order to study the possibilities of changing and modernizing the electric drive, in order to make the extraction installation more energy efficient. The tachogram differs from the current operation of the direct current motor with the proposed variant, respectively asynchronous motor, these being found in the specialized literature.

3. The study of the possibilities to increase the transport capacity of the extraction installation, supposes the analysis of the current one-storey cage, respectively the establishment of its mass, so that the proposed constructive solution falls within the constructive parameters and the norms regarding the safety in operation. a minimum of additional technical changes. The analysis of calculation briefs, the redesign and verification of new cages with two floors, results in a decrease in its mass of 70 kg. The decrease in mass

facilitates the safety cage system of the old cage to be reused in the new construction solution, and is doubled by the calculation brief for checking the construction elements of the safety cage, as well as the final verification of the assembly.

4. Verification of the resistance structure of the tower based on the established loads and the characteristics of the critical sections obtained after modeling the tower using the Solid Edge utility, which involves determining the voltages in the tower, together with the related safety coefficients.

5. Verification of the strength of the constructive solutions by the finite element method, using the program, Solid Works, for the load forces resulting from the calculation patents.

6. The modernization of the groundwater drainage system, consisted in the design of a system of pumps connected in parallel for the evacuation of the new accumulated water flows, and at the same time preventing the mine from reaching the point of being flooded.

7. The use of the Mathcad calculation program for performing the calculations of the constructive solutions for modernization and rehabilitation of the installations, which allowed the easy and precise modeling of the different variants of technical solutions studied.

8. Using the Excel and MathCad utility for calculating the kinematic and dynamic parameters of the extraction installation, including for plotting the variation diagrams of these parameters and tachograms.

9. Use of the Solid Edge computer-aided design system for 3D modeling of construction solutions, wheels, shafts, sliding and rolling bearings, extraction tower, cages and safety catches for cage.