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[1.] Martin ŽARNAY, [2.] Martin SOKOL, [3.] Peter KAMAS

RESEARCH AND OPTIMIZATION OF THE MANIPULATION SYSTEM FOR THE GEOTHERMAL WELLS

[1-3.] Department of Design and Mechanical Elements, Faculty of Mechanical Engineering, University of Žilina in Žilina, SLOVAKIA

Abstract: The current drilling technologies allow better use of natural resources, but they are still limited by appropriate natural conditions, such as the locations of faults and geologically active areas. In these places, the crust is thinner, or near the surface is located magma chamber and thus rocks have a higher temperature near the surface. Therefore, the development of new innovative principles drilling focuses on achieving greater depths, where even without geological anomalies is possible to achieve the desired temperatures. With the development of new innovative principles of drilling geothermal wells and also with the requirements for the development of support systems - subsystems that will enable these new principles in practice are rising. The article deals with a manipulation system for innovative ways of drilling the ultra-deep geothermal wells. It concerns with the definition of the problem of the innovative ways for drilling the geothermal wells, the requirements for designing the manipulation system and its gradual design and the optimization.
Keywords: Geothermal energy, ultra deep well, manipulation system, engineering design, optimization

1. INTRODUCTION

Geothermal energy as heat energy of the Earth, founds its technical applications only in recent decades with the development of drilling technologies.

The current drilling technologies allow better use of natural resources, but they are still limited by appropriate natural conditions, such as the locations of faults and geologically active areas. In these places, the crust is thinner, or near the surface is located magma chamber and thus rocks have a higher temperature near the surface. Therefore, the development of new innovative principles drilling focuses on achieving greater depths, where even without geological anomalies is possible to achieve the desired temperatures. With the development of new innovative principles of drilling geothermal wells and also with the requirements for the development of support systems - subsystems that will enable these new principles in practice are rising.

2. PROBLEM DEFINITION

Accessibility to the hot rocks (300 – 400°C) or hot geothermal water is at present limited to technology opportune naturally - geological conditions, where suitable rock or water is located at depths up to 3 km. Rocks with the sufficient temperature, however, are under the entire surface of the earth, but at greater depth 3 km – 10 km (Figure 1). Today's technology is able to achieve this depth, but due to the mechanical principle of eroding rock, the mechanical connection is necessary to exist, between drilling head and the drive on the surface. Drill head has a relatively small lifetime and must be replaced after a small drilled depth. With the deepening wells the cost is increasing exponentially and time to replace the drill head is extended as it is necessary pull the whole mechanical coupling of the borehole out, from borehole bottom to the surface and after replacement of drilling head subsequently stack back into the borehole.

GA Drilling company is developing a new system of "drilling" - deepening ultra-deep boreholes (Plazmabit) , which according to its principle of continuous deepening removes the exponential increase in price and the time needed to create ultra-deep the borehole (6 – 10 km). This principle is based on rock-melting by plasma and subsequent injection of water into the melt. By rapid heating of water generated steam is spraying melt into the surrounding cooling water, where it solidifies and as a small fraction of melt product is led away with cooling water to the surface.

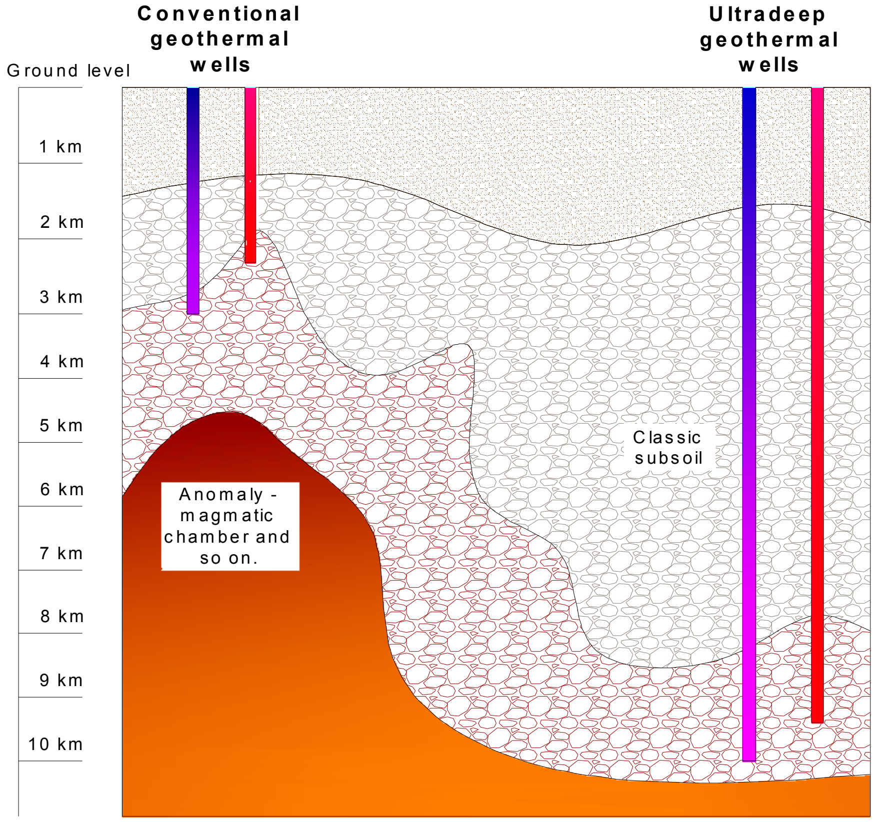

Figure 1. Comparison of traditional and ultra-deep geothermal wells

For proper operation of Plazmabit is necessary to ensure accurate positioning of the plasma ”drill” head just above the bottom of the borehole. Difference in comparison with today's technology is also planned connection of drilling equipment with surface. The connection provides electricity supply, supply of cooling and process water and fibre optic flow of the information. Tow rope in connection provides only emergency extraction of drilling equipment, because, due to the flexibility of the rope and the expected depth of the borehole it would be impossible to ensure accurate positioning of the plasma head. For these reasons, was created requirement for the structural design of the manipulation device for the Plazmabit currently developed system, in which will be included.

3. WORKING CONDITION AND REQUIREMENTS

Manipulation device for the Plazmabit will work in very variable environment. During drilling from the surface to a maximum depth will vary the pressure and temperature. Operating pressures are in the range from the atmospheric pressure (1013 hPa) to about 100 MPa. Borehole wall temperature increases with each kilometre approximately by 30 ° C - 40 ° C. At a depth of 10 km may thus reach the borehole wall temperature to 400 ° C. For those pressures and temperatures water as the environment can change phase from liquid to supercritical or subcritical.

Handling system activity is expected in the borehole with a diameter of 280 mm ± 20 mm with smooth walls with exactly undefined coefficient of the friction, disturbances circularity and cylindricity and unknown surface waviness. The main function of the manipulation system is to perform controlled movements of Plazmabit in the borehole up and down, while allowing the flow of cooling and process water and other energy and information flows through the inner tube and outflow of cooling water around the tube up. Manipulation system must be compact, so that space to store other functional modules such as: control systems, lines, power transformers and other operating systems of Plazmabit will be created. Provisionally assumed that the entire system - the Plazmabit will weigh 4000 kg, and the estimated length of the device is 10 m. However, this is only the agreed baseline. Estimated time of producing well is 3000 hours, i.e. time of unlimited operation and it is based on the required mean time between failures of operating device. Maximum speed of travel is determined from 3.3 m / hour. to 5 m / h., but the device must be able to continuously change the speed from 0 m / hr. to the maximum designed speed. Required is also the ability to control the vertical axis of moving device in the range of ± 1.5 ° and the correct inaccuracies of drilling or create a curved borehole with a radius of 100 meters.

4. SOLUTION

Taskmaster and the initializer of requirement for the structural design of the manipulation device of the Plazmabit is the company GA Drilling. The principal investigator is the Department of Design and Mechanical Elements of the Faculty of Mechanical Engineering, University of Žilina.

Constructional and development process began with analysis of the suprasystem - ambient, defining needs and conditions of solution and analysis of system - the process of drilling and objectives of solution was defined. Considering that nowadays similar device is not developed and it is a unique device preparatory phase of tasks has been more difficult and creation of assignment more important. Because it is a unique device, it is a design task, in which is an enormous amount of information are unknown at the beginning of solution and therefore over time and the design process assignment is still complemented by the new requirements and classifications.

Ideological drafts of device were created and each researcher of the research team of the department created several variants. Consequently, drafts were based on different physical principles with different kinematic, organ and building structures. Together was created more than 30 basic variants, plus their variations and combinations. Due to the large number of variants and width of the problem, was necessary to categorize these variants and evaluate them in groups. And thus accelerate the selection of the final option - the concept for development.

Evaluation and selection started with the calculation of the maximum length of device from need to adjust the direction of drilling with preliminary radius of curvature R = 100 m. That length was calculated and set out to 2.5 m, which is insufficient for all necessary systems of Plazmabit. For this reason, it was necessary to create a modular structure and individual modules flexibly connect. As part of research and development are considered two fundamental types of drives, electro-mechanical system and electro-hydraulic-mechanical system. Because each of these types of drives has its negligible benefits, has not been selected only one type of drive, but simultaneously develop two variants. The proposed variants could be for reasons of principle divided into two groups with continuous and discontinuous movement. The first group provides movement and attachment on borehole wall in a single device and it leads to the use of wheels or continuous track, which must simultaneously provide many tasks and still be extremely space efficient. The second group are variants with discontinuous movement, in which the movement and attachment on walls of well - anchoring is provided by two separate modules. Those variants work with caterpillar-like motion, in which one anchoring module intercepts on borehole wall - anchor itself, movement - translating module moves the second anchoring module, in which at maximum extension anchoring parts anchor itself. Consequently, the first anchoring module is released and shift module is retracted. This cycle is still repeated and according to control choppy movement downward and upward occurs. In order to provide a continuous movement of the drilling head, between the bottom anchoring module and drilling head is inserted compensation shift module which provides continuous movement of the drilling head even if the movement of Plazmabit is choppy. For the next steps were selected variants of the second group, thus anchoring-translational variants, which have the advantage in dividing technical problem into two parts and thus with respect to complexity of assignment is easier to solve. Capturing of the anchoring module on the borehole wall during the intermittent motion we consider to be reliable solution against still moving wheel or track.

Translational module should consist of the one linear drive or more linear drives. For translational modules has been selected one linear actuator positioned in the middle of the module. Translational modules provide also bend between rigid assembly modules. For compensation translational module is selected use of the multiple smaller drives, at least three, that will ensure the control of tilting of drilling head against the borehole axis, possibly parallel displacement.

Variants of the anchoring modules can be divided into 3 groups according to anchoring method to the wall of borehole. Fixing - anchoring can be shaped, but for the surface variability these types of variations are not suitable, even if to anchor is needed a relatively low forces. Force anchoring is essentially independent of the surface profile, using a large contact force and through the friction the position of the anchoring the module is provided. The described variants have the disadvantage of the need for large forces and need for more massive design. For further action were selected variants with a force anchoring mechanism, but over drawing up and modifying contact members (Figure 2) is passed to the combination anchoring, in which initially there is a forcible securing and appropriately shaped contact member is partially pushed into the borehole wall and thus insure the anchoring form fit.

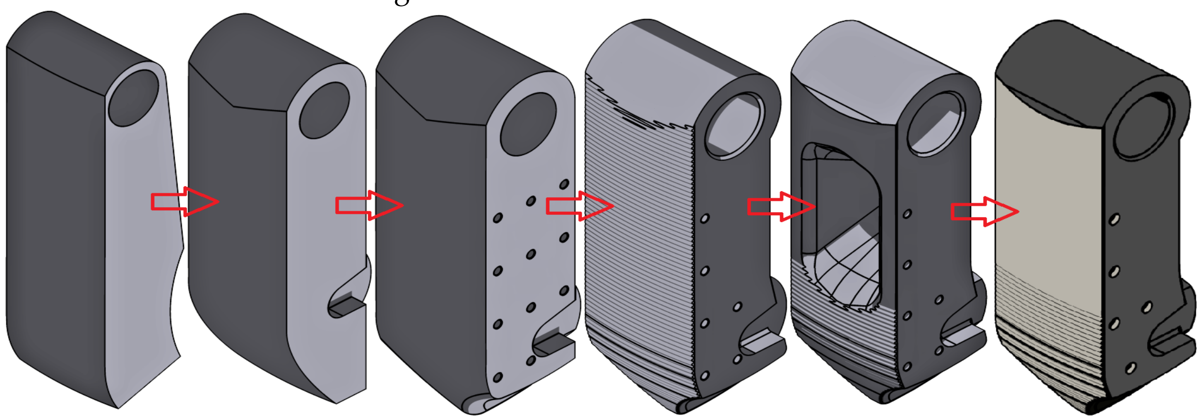

Figure 2. Gradual changes in the design of the rotary contact member and the change of force principle of anchoring to combined by suitable modification of contact surface

Selected concepts were then further elaborated and evaluated. After evaluating has been selected final concept, which was developed in a comprehensive 3D model of a functional model, which is shown in figure 3. The system is used to verify its functionality and reliability, soundness and also verify manufacturability, compound-ability and controllability.

5. OPTIMIZATION

Currently, after the creation and elaboration of the final version of variants, the overall model is continually modifying and optimizing due to the stress analysis of individual component or complete assemblies. As an example can be consider change of the frame of anchoring module to increase its stiffness based on the strength analysis (Figure 5).

Nowadays, the various sites of the constructions are under the optimization to increase the stiffness, remove the stress concentrators, whether in terms of manufacturability and assembly. For example, in figure 4 are shown the sketches of the internal frame of anchoring module, which was modified to create optimum shape. Internal cylindrical shape was changed from cylindrical to polygonal and also subsequently changed the shape of the ribs. With the minimal increase in weight was increased the rigidity and also was acquired the easier manufacturability.

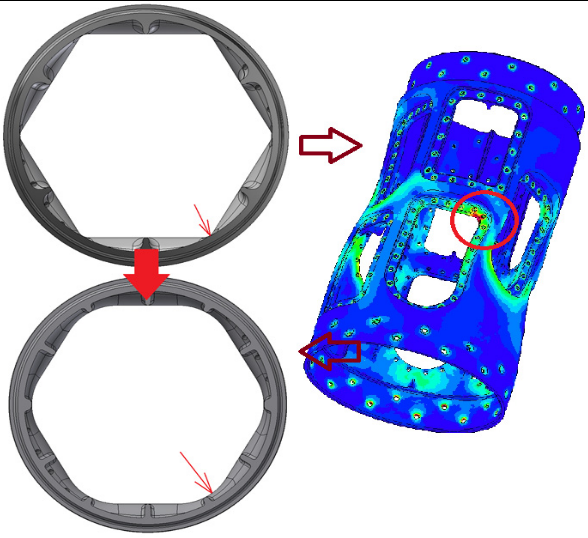

Figure 3. Increased stiffness of the frame of anchoring module due to the strength analysis by reinforcement critical points

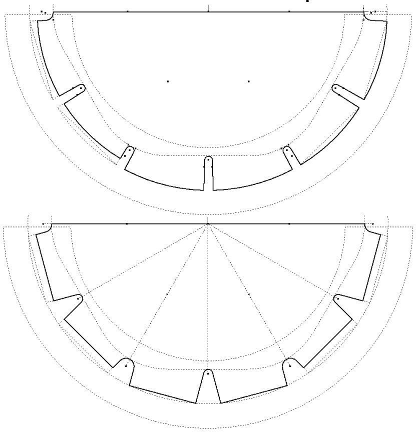

Figure 4. Top: The original design of the milled rib frame of anchoring module
Bottom: Modified design of the milled rib frame of anchoring module

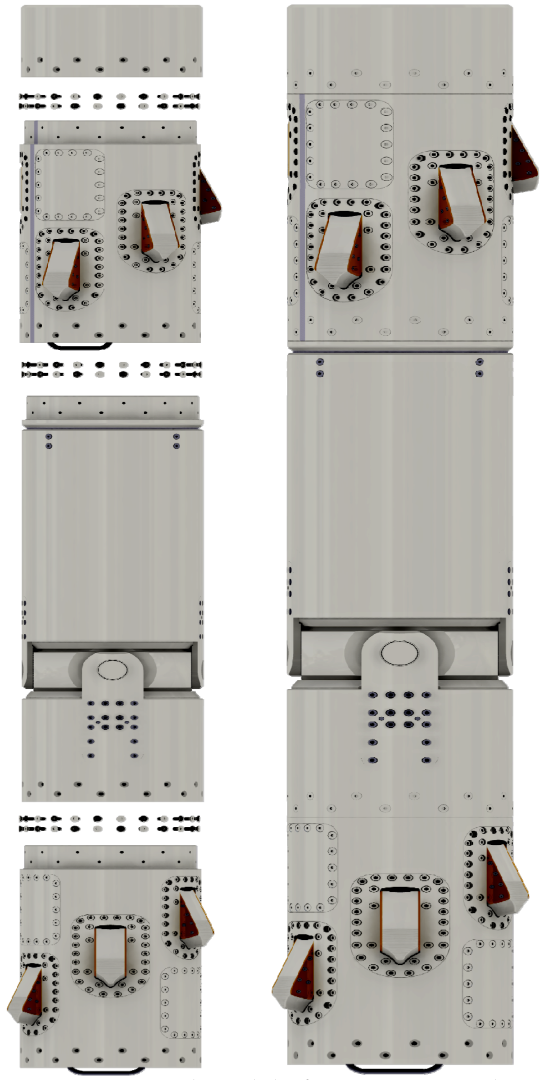

Figure 5. Functional model of movement-anchoring mechanism of Plasmabit, individual modules on the left and assembled on the right side (not in scale)

6. CONCLUSION

The article discusses the solutions of the constructional development task solved at the Department of Design and Machine components in cooperation with the company GA Drilling. This article briefly summarizes the procedure of the development of anchoring-translating mechanism – a system of innovative way of drilling the geothermal wells with plasma.

After editing and optimizing 3D CAD model was created the technical documentation on which base will be created the functional model. The function model of movement – anchoring system will serve for testing the functional structure as well as testing the manufacturability, assembly and other characteristics of the design.

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