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PRELIMINARY STUDY ON URANIUM ORE GRADE CONTROL TECHNIQUES FOR THE HUSAB MINE, NAMIBIA

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The Husab mine is situated within the Namib Desert in the Erongo region of western-central Namibia, only 6km south of the Rossing mine owned by Rio Tinto, approximately 60km east of the coast town of Swakopmund and less than 100km northeast from the Walvis Bay Port, the largest deep water port in the southwestern Africa and thus it has convenient traffic conditions and extremely favorable infrastructure conditions for development. As the most important uranium discovery in the world since 2000, the Husab mine has total uranium resource of nearly 300,000 tons of U3O8 with ore reserves of 300 million tons containing 156,000 tons of U3O8 at average grade of 518ppmU3O8.

The Husab mine is the first ultra large uranium mine under the construction and operation by China General Nuclear Power Corporation (thereinafter "CGN"for short). Since its mine construction and pre-stripping commenced in 2013, its ore mining commenced in May 2015 and the first barrel of uranium oxide was produced on 31th Dec., 2016, indicating that the Husab mine had been constructed and put into production successfully since CGN acquired it in 2012. The Husab mine has a designed annual mining capacity of over 100 million tons, an annual ore processing capacity of 15million tons and an annual output of 6500tons of U3O8 and it will be the largest open-pit uranium mine with the largest mining capacity and ore processing capacity in the world.

Over more than one year's mining production and operation, the production management, equipment maintenance and technical management system have been fully established at the Husab mine and its operation activities such as the operation of process plant and mining production and so on has gradually gone to the right way. However, due to the larger variations in the shapes of ore bodies than expected, the inaccuracy of measurement of uranium grade, large-scale mining fleets and the precision loading errors etc., lots of outstanding issues have been identified in the fields of the consistency between the grade of resource model and that of mined ore and the control on dilution and loss in the course of mining such as high dilution and loss ratios, large variation in the grade in the mining process. These issues will have important bad effect and even impede the stable production of the Husab mine and thus it is urgent to carry out the study on key techniques of uranium ore grade control for the Husab mine to solve these issues from its mining production.

This study focuses on the whole process of mining production and has conducted the following research work including the establishment of geological resource –grade control model system, the optimization on the mining production procedures, the application of controlled blasting technology with a higher precision and its optimization, the application of rapid and accurate grade measurement by down-hole gamma logging. This research work will effectively improve the ore dilution and loss in the course of mining production and further improve the production capacity and its economics of the Husab mine.

ADVANCEMENT ON THE STUDY OF ORE GRADE CONTROL TECHNIQUES FOR THE HUSAB MINE

1) Establishment and improvement of "three stage"resource –grade control model system

At the moment, the "two stage"resource –grade model system has been adopted at the Husab mine, that is, geological resource model (MIK model) based on exploration database and grade control model (GC model) based on down-hole gamma logging data from blasting holes. The annual plan for mining production, blasting block design, mining and stripping production plan and blasting hole design are proposed based on the MIK model and the mining block definition (composite model) and loading plan are proposed based on the GC model. But due to the fact that the drilling exploration grid is mostly 25m×25m to 50m×50m or larger and the fact that the MIK model is not updated using the mining production data, the MIK model has a low accuracy and reliability with respects to the mining production and thus it cannot be used to effectively guide the annual mining production plan, blasting block design, blasting hole design and its optimization. At the same time, however, the unreasonable model parameters reduce the accuracy of GC model and thus it cannot well define the ore-waste boundary so as to meet requirements of loading and ore blending.

On the basis of extensive discussions and sites to other large scale open-pit mines and combined with the actual mining production of the Husab mine, this study proposes the hierarchical, segmental and stable "three stage" resource –grade control model system consisting of resource/reserve model –interim model –grade control model that can be updated dynamically. The grade control model is created based on down-hole gamma logging data from blasting holes by interpolating the ore grade for the block model of a specific blasting block and is used to guide the definition of mining blocks, wire connection for blasting, ore loading and blending. The geological resource model is created by using the geological database incorporating drill-hole data from resource drilling and blasting hole from mining production, it interpolates the ore grade distribution for all the ore bodies within the mining district with an updated within each year or once two years and it is used for the optimization on the ultimate open pit boundary, mid- and long-term mining and stripping plan and annual mining production plan. The interim model proposed in this study is a transitional model between the geological model and grade control model that establish the interconnection of the geological model and grade control model to form an inherent geological model system. This interim model is created by using down-hole gamma logging data from blasting holes drilled for 2~3 benches above the current bench and resources drill-hole data below the current bench, it interpolates the grade distribution for the downward one or two benches from the current bench; it is used for the monthly and weekly mining and stripping plan, blasting block design and blasting hole design and thus improves the blasting and mining efficiency.

2) Optimization and improvement of mining production procedures

Since the pre-stripping commenced in 2013 and the ore mining commenced in 2015, a set of intact mining production procedures have been established and the whole mining capacity also increases gradually. But there is still much uncertainty in the whole mining production without the more accurate resource –grade control models in different scales for guidelines and thus it is difficult to meet requirements on the tonnage and grade of ore to be mined so as to ensure the smoothness of mining production at the Husab mine. Hereby, the geological resource models are re-created and updated for the first stage of mining areas in Pit #1 and #2 based on understanding of the mine geology and combined with the geological information and grade data, further define the spatial distribution of ore bodies and exhibit the grade distribution, which will provide guidelines for preparing the mid- and long-term mining plan and annual mining plan. The interim model proposed in this study provides more accurate ore-waste boundaries within the benches to be mined and thus it lays a better foundation for preparing the monthly and weekly mining plans, blasting block design and blasting hole design. The more scientific and reasonable grade control models and accurate ore-waste boundaries will greatly enhance the blasting efficiency and the output of mined ore and reduce the ore dilution and loss and at the same time, it is also very favorable to ore blending directly within the pit to reduce the ore re-transport.

3) Application of advanced controlled blasting technology and its optimization

Up to present, the mining production still focus on increasing the stripping capacity at the Husab mine and is not completely transited to focus on mining capacity to provide the ore in tonnage and expected grade required by the process plant. Therefore, the relatively simple blasting technology and blasting scheme are adopted currently at the Husab mine. Neither different blast schemes are adopted according to the differences in mechanical properties of rocks within different blasting blocks and nor the advanced blasting technology is adopted to effectively separate the ore and waste. Thus it is required to improve the blasting efficiency. In this study, the quality of rock masses has been assessed on the basis of studying the physical and mechanical properties of main ore and rocks within the mining district and the rock masses are divided into two categories according to their blastability: one is rock masses of easy to blast consisting of near-surface loose and poorly cemented sandstone and calcrete; the other is rock masses of difficult to blast consisting of underground hard and intact granite, marble, gneiss, schist and quartzite. The ore and rocks are classified as the rock types of difficult to blast at the Husab mine.

On the basis of analyzing the blasting parameters currently used at the Husab mine and considering the requirements of ore loading, hauling and primary crushing of ore, it is believed that the current blasting parameters are effective for blasting within the areas of ore and thus relatively reasonable . But it is not reasonable that these parameters are used for blasting within the areas of waste without any modification and they could be improved greatly. Consequently, lots of research work has been conducted to improve blasting parameters used for blasting within the areas of waste, the desktop analyses and digital stimulation are also proceeded and the next step to carry on the field trial on site and then they are applied at the Husab mine.

In addition, it is difficult to control the ore dilution and loss due to the fact that there is no interim model and accurate grade control model to guide the mining production and the special technologies, such as pure blasting, separating blasting and slag-remaining blasting, are not applied at the Husab mine and at the same time, the field trial of blast-induced movement monitoring does not provide a good result. It is proposed in this study to adopt different blasting technology and schemes to control the blasting and successfully separate the ore and waste according to the distribution of ore and waste and their scale within the mining area based on the more accurate interim –grade control models. For the blocks with a large scale and area of ore and waste, it is proposed to individually design blasting holes on the block of ore or waste and then blast to successfully separate the ore and waste when the ore area or waste area meets the requirements of an individual block; when the area or waste area is not large enough to be designed an individual block, it is proposed to modify the blasting parameters such as the blasting hole design, charge structure, blasting delay time and initiation mode to generate physical zones of easy to identify in visibly such as zones with visible difference in sizes within the ore or waste areas and flutes at the boundaries of ore and waste and thus, the ore and waste are finally separated to guide the ore loading and reduce the ore dilution and loss.

4) Application of uranium grade measurement technology by down-hole gamma logging

At the moment, the uranium content of ore is determined dominantly by the chemical method of analysis and assisted by the radiometric measurement at the majority of uranium mines in the world except those in China and in the Commonwealth of Independent States. It not only takes a long time but also expensive to determine uranium by the chemical method of analysis and thus it is difficult to ensure the smooth operation at the Husab mine. A set of intact radiometric measurement technology and method system has been established including the technology, equipment, operation manuals and technical standards etc., through over tens of years'efforts especially the practices in the exploration and production of uranium mines in China. Since early the Husab mine was put into production, the radiometric measurement system and related operation manuals and standards has been established gradually, including key equipment facilities such as down-hole gamma logging system, truck scanner system, belt scanner system at the primary crushing station and corresponding calibration of technical parameters and the construction of standard calibration models on the site. Consequently, it ensures the grade of ore will be determined accurately on time to fully meet the production requirements at the Husab mine.

CONCLUSIONS

A set of intact mining production procedures and technical standards have been established preliminarily since the Husab mine was put into production. The continuous research achievements in this study shows that the effective results have been achieved in the fields of the resource –grade control models, optimization on the mining production procedures, controlled blasting technology and radiometric measurement technology and thus the mining capacity and efficiency has been improved effectively and the ore dilution and loss has been reduced obviously, laying a strong foundation for the ramp-up production of the Husab mine.

Country or International Organization

China

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