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Relationship of Geosciences and Mechanical Engineering in Increasing the Productivity of Tunnel Boring Machines

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Abstract

In the academic and industrial environments of Iran, there is little understanding of the relationship between geological science and technical branches (mechanics, electronics, etc.). Such concepts are not explained in Iran's higher education curriculum, and almost no source of research has been published in persian. The history of collaborative studies between mechanical engineers and geoscientists can be considered at the onset of the topics of the Terramechanics. But one of the common industrial areas between mechanical engineers and geologists in our country is mechanized tunneling technology. The design and construction of TBMs is based on the geological data of the projects. Many mechanical and electronic technical defects occur on the TBM in the face of unfavorable geological conditions on the excavation path. The performance of the various parts of the machine and even the amount of their consumables (oils, greases, etc.) are directly related to changes in the geological conditions of the forward pathway. Therefore, during excavation, sometimes in the face of certain geological conditions, changes in the mechanical and electronic structure of the machine to cross the problematic zones are inevitable. In this research, by studying the excavation conditions in Bazideraz tunnel, the necessity of initiation of interdisciplinary studies of geology graduates with the mechanical engineers in higher education and industries of the country is discussed. In this paper, with the analysis of the operational parameters of the TBM and the study of geological conditions, discusses how to change the structure of the TBM. The results show that in this project, in order to adapt the structure of the machine to the geological conditions of the route, a series of structural reforms including the removal of 26 thrust jacks, the installation of 9 probe drilling holes in the middle shield, the removal of all passive articulation cylinders (16 jacks), a change in the arrangement of the disc cutters, and the construction of 7 gearbox converters to increase the rotary speed of the cutterhead, inevitable.

Keywords: *TBM, Terramechanics, Mechanics, Gearbox Converters, Passive Articulation Cylinders.*

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Extended Abstract:

1. Introduction

In the academic and industrial environments of Iran, there is little understanding of the relationship between geological science and technical branches (mechanics,electronics, etc.). Such concepts are not explained in Iran's higher education curriculum, and almost no source of research has been published in persian. The history of collaborative studies between mechanical engineers and geoscientists can be considered at the onset of the topics of the Terramechanics. Terramechanics studies in earth sciences have focused more on the field of military geology (the development of the war machine industry based on the recognition of the morphology of earth's effects, as well as the topics of soil and rock mechanics). But one of the common industrial areas between mechanical engineers and geologists in our country is mechanized tunneling technology. The design and construction of TBMs is based on the geological data of the projects. Many mechanical and electronic technical defects occur on the TBM in the face of unfavorable geological conditions on the excavation path. The performance of the various parts of the machine and even the amount of their consumables (oils, greases, etc.) are directly related to changes in the geological conditions of the forward pathway. Therefore, during excavation, sometimes in the face of certain geological conditions, changes in the mechanical and electronic structure of the machine to cross the problematic zones are inevitable.

2. Materials and methods

In this research, by studying the excavation conditions in Bazideraz tunnel, the necessity of initiation of interdisciplinary studies of geology graduates with the mechanical engineers in higher education and industries of the country is discussed. In this paper, with the analysis of the operational parameters of the TBM and the study of geological conditions, discusses how to change the structure of the TBM.

3. Results

The TBM when faced with intact rocks (RQD: 100) and mass rocks (RQD: more than 80) faces numerous challenges. The reduction of penetration rate, increased wear of cutting discs, increasing the consumables of the machine (types of oils, grease and foam) were the main challenges. The results of the analysis of the operational parameters of the TBM (at 750 m of the beginning of tunnel) indicate that the mechanical structure of the machine has caused the cutting mechanism to not be performed properly in the rocks. The results of the analysis of the operating parameters of the TBM indicate that if the gearbox structure of the machine is changed (the rotary speed of the cutterhead increases only up to 4 RPM), a significant increase in the penetration rate and a significant decrease in time excavation will be created (Fig. 1), which in practice will greatly improve the performance of the machine. By reducing the excavation time, the amount of consumables will be reduced and will be normalized. It was therefore decided number of 7 converters should be made for the gearboxes of the machine. Then, by installing the converters between the electromotors and the gearboxes, the rotary speed of the cutterhead was increased from 2 to 5 RPM. To investigate the feasibility of this idea, the design and construction of converters were carried out using the ability of specialists in domestic Industries. The design of the gears inside the converters (Fig. 2) was done in such a way that the speed of the gearbox output rotation at

the point of attachment to the main bearing (Fig. 3) is increased relative to the rotation of the input (from the electromotor's side). After the preparation and installation of the converters (their placement between the electromotors and the gearboxes), the electrical engineers also provided the necessary arrangements (adjusting the PLC of the machine, coordinating the electromotors, etc.) and eventually the electromotors to run the scheme was launched (Fig. 4). Although in this test, the rotary speed of the cutterhead increased for moments, but in less than ten minutes the temperature of the gearbox converters increased to more than 60 degrees. The problem with the sealing system (between the converters and the gearboxes) caused the water and oil to be mixed in gearboxes. In addition to these problems, the end bearing of the two gearboxes in the short test run was subjected to crushing. Finally, by removing the converters, the electromotors were connected to the gearboxes without intermediary, and excavation operations started with the same basic structure of the machine. From other experiences of this project, the TBM has been stopped at two locations in the fault zones. At the stopping position of 4997 km, the shield was completely stuck. The operator to release the machine, increase the thrust force (to about 50,000 kn). But due to this force, 12 of the total of 16 passive articulation cylinders were broken apart successively. As a result, the middle shield and the tail shield about 40 cm separated from each other (Fig. 5). Due to the directness of the excavation path, the removal of passive articulation cylinders did not pose a problem .Therefore, it was decided that the remaining passive articulation cylinders (which were not defective) would also be removed. Finally, it was decided that, in accordance with the technical specifications of the shields of the machine, for the complete connection of the two shields, use of the welding method (on the connecting line of the two shields at 360 degrees). At this stage, after welding the entire shields and connecting them to each other (Fig. 6), the thrust force of the device was increased to 54,000 kn and machine was released. In addition to the this actions in this project a series of changes to the structure of the machine was also carried out in the face of an influx of groundwater (removing Jack 26th thrust, creating 9 holes for probe drilling in the shield: Fig. 7, transferring of the the location of the hydraulic pumps and the main reservoir of the oil from the front shield range to 50 m behind).

4. Conclusion

The results show that in this project, in order to adapt the structure of the machine to the geological conditions of the route (massive rocks with high quality designation, fault zones, water and gas influx), a series of structural reforms including the removal of 26 thrust jacks, the installation of 9 probe drilling holes in the middle shield, the removal of all passive articulation cylinders (16 jacks), a change in the arrangement of the disc cutters, and the construction of 7 gearbox converters to increase the rotary speed of the cutterhead, inevitable.

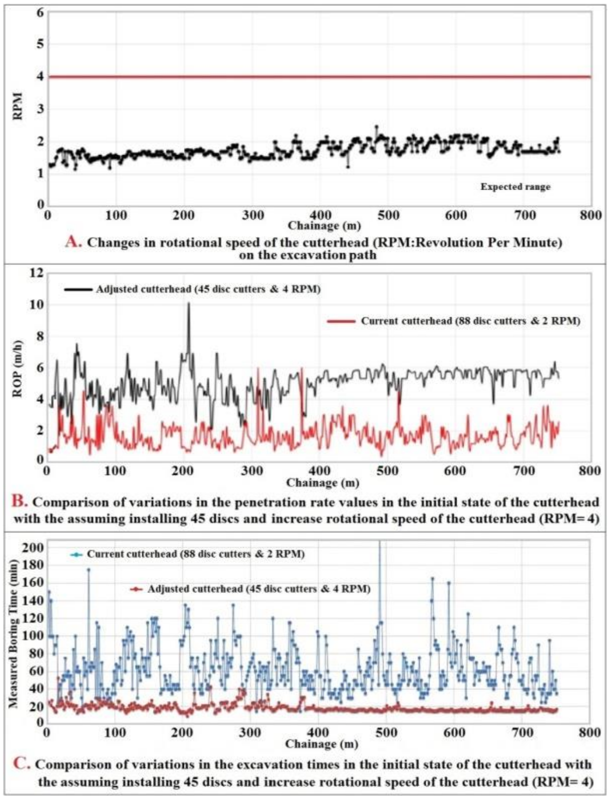

Figure 1. The effect increase rotational speed of the cutterhead on the penetration rate and excavation time.

Figure 2. Gears and components of gearbox converters.

Figure 3. Connecting the gearbox to the main gear.

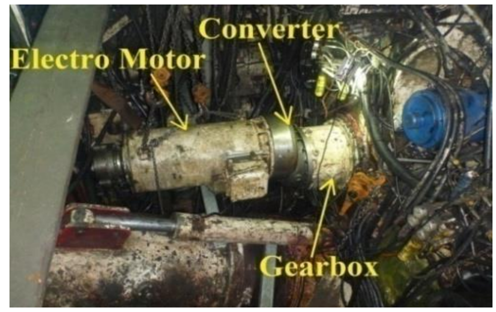

Figure 4. Installing the converter between the electro motor and the gearbox

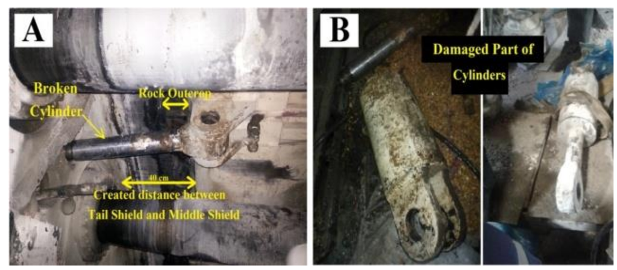

Fig. 5. A- Broken cylinder, created distance between tail shield and middle shield. B- Damaged part of cylinders.

Figure 6. A- Cutting and preparing shields for welding. B- Welding two shields to each other.

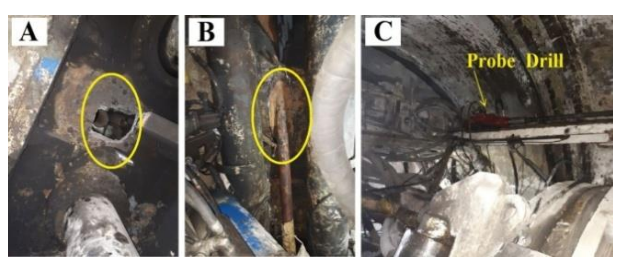

Figure 7. A- Installation of probe drilling holes in the middle shield. B- Conductor pipe is installed on holes. C- Probe drill.

References:

Aghanabati, A. 2004. Geology of Iran, Publication of Geology of Iran, First Edition, 586 pages. (In Persian).

Bacon, S.N., McDonald, E.V., Baker, S.E., Caldwell, T.G. and Stullenbarger, G. 2008. Desert terrain characterization of landforms and surface materials within vehicle test courses at U.S. Army Yuma Proving Ground, USA: Journal of Terramechanics, Vol. 45, pp. 167–183.

Bekker, M.G. 1956. Theory of land locomotion: the mechanics of vehicle mobility. Ann Arbor: The University of Michigan Press.

Bekker, M.G. 1960. Off the road locomotion. Ann Arbor, Michigan: University of Michigan Press.

Bruland, A., 1998. Hard rock tunnel boring, vol.1-10, Ph.D. thesis, Norwegian university of science and technology (NTNU), Trondheim, Norway.

Dasch, J.M. and Gorsich, D.J. 2012. TARDEC story: sixty-five years of innovation, 1946–2010. Defense Department, Army, U.S. Army Tank Automotive Research, Development and Engineering Center (TARDEC); 309 p.

Drescher A. and Hambleton, J.P. 2010. Geotechnics and Terramechanics, 58th Annual Geotechnical Engineering Conference, University of Minnesota, pp. 7-19.

Halvorson, J.J., McCool, D.K., King, L. and Gatto, L. 2001. Soil compaction and over-winter changes to vehicle ruts, Yakima Training Center, Washington:Journal of Terramechanics, Vol. 38, pp. 133–151.

Harmon, R.S. and McDonald, E.V. 2014. Military geoscience in the twenty-first century- A historical perspective and overview,The geological society of america Reviews in Engineering Geology XXII, pp.1-10.

Hassanpour, J., Rostami, J. and Zhao, J. 2011. A new hard rock TBM performance prediction model for project planning, Tunneling and Underground Space Technology, Vol. 26, no. 5: 595–603.

Henderson, J.P. 2014. Dust storms and the 1980 Iran hostage rescue attempt, The geological society of america Reviews in Engineering Geology XXII, pp.49-55.

Joudaki, V., Ajalloeian, R. and Hassanpour, j. 2019. Necessity of Revising the Educational and Research Headings of Geological Colleges for Approaching Technological Applications in Industries (With a Special Focus on Mechanized Tunneling Technology). Iranian Journal of GEOSCIENCES, Vol .28 No.112. (In Persian).

Joudaki, V., Sohrabi-Bidar, A., Ajalloeian, R., Amini, N. and Dickmann, T. 2018. Evaluation of Tunnel Seismic Prediction (TSP) Test Results based on Geological Observations and Analysis of the Parameters of the EPB Hard Rock Machine. Iranian Journal of Engineering Geology, Vol.11, No.2, pp. 15-31. (In Persian).

Macias, F.J., 2016. Hard Rock Tunnel Boring, Performance Predictions and Cutter Life Assessments (Ph.D. thesis). Norwegian University of Science and Technology (NTNU), Trondheim, Norway, p. 203.

Moreland, S.J., Newby, M.A., Stein, N., Steffy, A.C., Zhou, F., Zastrow, A.M., Vasavada, A.R., Fraeman, A.A. and Stilly, E.K. 2017. Relating geologic units and mobility system kinematics contributing to Curiosity wheel damage at Gale Crater, Mars. Journal of Terramechanics, Vol.73, pp. 73–93.

Muro, T. 1988. Drilling rate of rotary percussion Drill bits and rock characteristics, Journal of Terramechanics, Vol. 25, No. 3, pp. 191-199.

SCE (Sahel Consultant Engineers)., 2015. Geological and Engineering Geological Review of Bazideraz Water Conveyance Tunnel. SCE 4120 UNG TUN EG RP 001 D0.

Shoop, S.A. 1993. Thawing soil strength measurements for predicting vehicle performance: Journal of Terramechanics, Vol. 30, pp. 405–418.

Stocklin, J., 1977. Structural correlation of the Alpine range between Iran central Asia. Memoire Hors-Serve No.8 dela Societe Geologique de France, 8: 333-353.

Rostami, J., 1997. Development of a Force Estimation Model for Rock Fragmentation with Disc Cutters Through Theoretical Modeling and Physical Measurement of Crushed Zone Pressure. Ph. D. Thesis, Colorado School of Mines, Golden, Colorado, USA, P. 249.

Thuro, K. and Wilfing, L., 2017. TBM performance prediction in hard rock.12th Iranian and 3rd Regional Tunnel Conference, 27-29 Nov. 2017, Tehran, Iran.

Villeneuve, M.C., 2017. Hard rock tunnel boring machine penetration test as an indicator of chipping process efficiency. Journal of Rock Mechanics and Geotechnical Engineering, Vol. 9, No. 4, pp. 611-622.

Wong, J.Y. 2010. Terramechanics and Off-Road Vehicle Engineering, Elsevier, pp. 1–19.