Tunnelling and Underground Space Technology 75 (2018) 90–99

Contents lists available at ScienceDirect

Tunnelling and Underground Space Technology

journal homepage: www.elsevier.com/locate/tust

Development of an empirical model to estimate disc cutter wear for sedimentary and low to medium grade metamorphic rocks

Jafar Hassanpour

School of Geology, College of Science, University of Tehran, Tehran, Iran

ARTICLE INFO

Keywords:
Disc cutter life
Normal wear
Tunnel boring machine (TBM)
Vickers hardness (VHNR)

ABSTRACT

In hard rock tunneling with TBM, changing worn or damaged disc cutters has a major effect on TBM performance and consequently on constructing time and cost. So, developing reliable methods to estimate disc cutter life in different geological conditions helps to estimate TBM performance and completion time and cost, accurately. In this research, using actual data collected during construction and pre-construction phases of Ghomrood water conveyance tunnel (GWCT) project, an empirical prognosis model is proposed to evaluate cutter wear and life in low to medium grade metamorphic rocks. Data obtained from different stages of this very long tunneling project, including records of TBM performance, operational parameters and cutter wear changes and variations of geological parameters are compiled in a special database and analyzed statistically to obtain reasonable relationships between cutter life or wear and effective geological parameters. Results of statistical analyses showed that correlations between intact rock parameters and cutter wear are reasonable and can be accepted as empirical prediction models for estimating cutter life or wear in similar geological conditions. This proposed model can be applied for limestone and sandstone layers and schistose and foliated rocks including shales, slates, phyllites and green schists with different quartz content and with a UCS range of 30–150 MPa. In this research a comparison was also made between the current model and previous models proposed by the author and his colleagues for different geological conditions. The results show that although these models are similar in shape and inputs, their outputs are different. So, each model must be used according to its application range.

1. Introduction

Although, the cutting tool wear phenomena is a very important parameter in economical application of tunnel boring machines (TBMs), only a very few studies have done by researchers to evaluate influence of rock and soil abrasiveness on tool wear (West, 1989, Deketh et al., 1998, Käsling and Thuro, 2010, Grødal et al., 2012, Jakobsen and Lohne, 2013, Liu et al., 2017) and its consequent effect on TBM performance (Nelson et al., 1994, Gehring, 1995, Rostami, 1997, Bruland, 1998, Bieniawski et al., 2009, Frenzel, 2011, Hassanpour et al., 2014, 2015, Macias, 2016, Wang et al., 2015, 2017). Currently, only a few common cutter wear prediction models are used in practice. The most commonly used ones are the models developed at Colorado School of Mines (CSM model, Rostami, 1997) and Norwegian University of Science and Technology (NTNU model, Bruland, 1998, Macias, 2016). A very brief description of these models have been presented in previous paper by the author and his colleagues (Hassanpour et al., 2014).

In the most recent work done by Hassanpour et al. (2014), a new empirical model was developed empirically to relate disc cutter wear to the ground condition. That model was based on data obtained from a long mechanized tunnel in Iran, recently constructed in pyroclastic and mafic igneous rocks. In this study, in continuation of research being done by the authors, a similar methodology was applied to develop a cutter wear prediction model for foliated and schistose rocks, including shales, slates, phyllites and green schists as well as sandstones and limestones with different quartz content and with a UCS (uniaxial compressive strength) range of 30–150 MPa. Data applied to develop this model were collected during construction of Northern part of Ghomrood tunnel (lots 3 and 4, with length of about 18 km) constructed using a double shield machine in central Iran through Jurassic metamorphic rocks of Sanandaj-Sirjan zone. These data were also applied to develop a more general prediction model published recently by the author and his colleagues (Hassanpour et al., 2015).

2. Project description

The Ghomrood Water Conveyance Tunnel (GWCT) with a total length of about 36 km is the main component of water conveying system to central Iran and has been constructed to transfer 23 m^3/s of

E-mail address: hassanpour@ut.ac.ir.

https://doi.org/10.1016/j.tust.2018.02.009
Received 28 June 2017; Received in revised form 14 January 2018; Accepted 23 February 2018

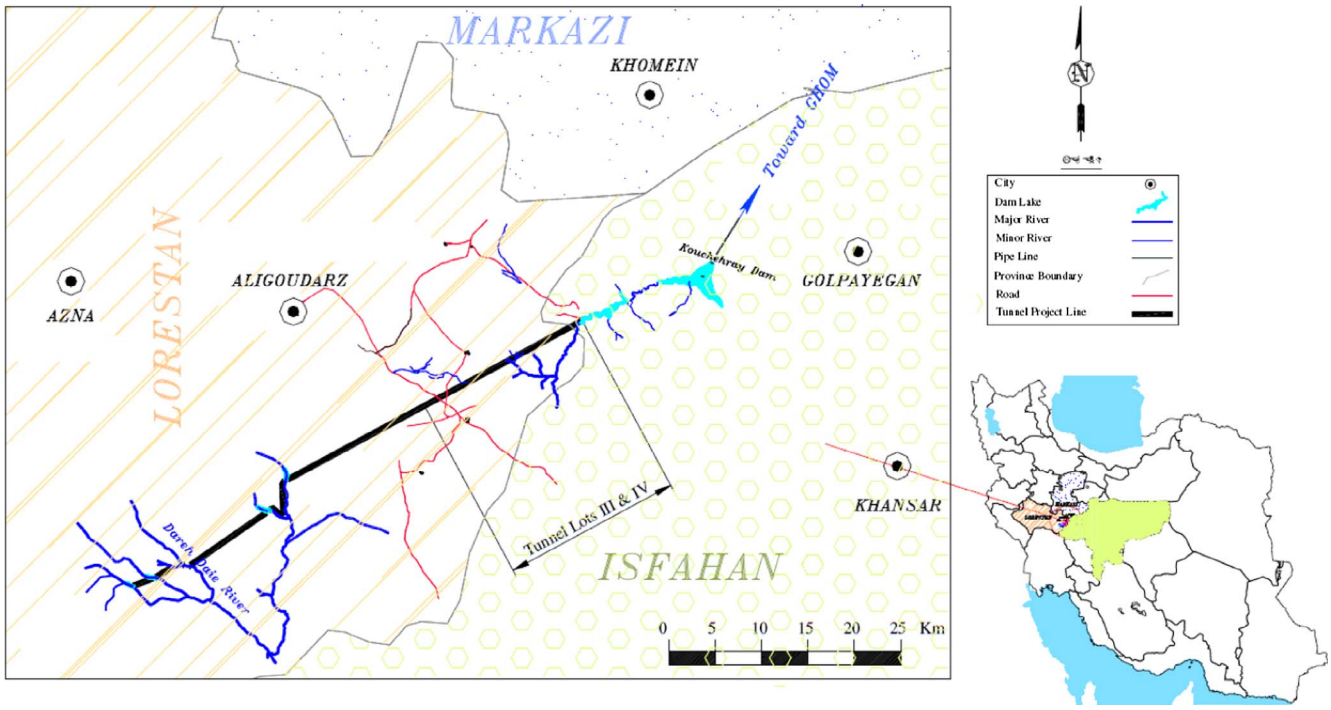

Fig. 1. Geographical situation of the project.

Table 1
Main specifications of TBM.

Parameter	Value
TBM model	TB 453 E/TS
Manufacturer	WIRTH
Machine diameter	4.525 m
Disc cutters diameter	432 mm
Number of disc cutters	35
Number of drive motors	4
Max. operating cutterhead thrust	18,000 kN
Cutterhead power	1120 kW
Cutterhead speed	0 to 12 rpm
Max. cutterhead torque	802 kNm (90% efficiency level) 1600 (Break out mode)
TBM stroke	650 mm
TBM weight (approx.)	250 tons

water from Dez river branches at Lorestan province to Ghomrood basin (Fig. 1). At pre-bid stage, the tunnel had been divided into four sections each 9 km in length (Lots no 1 to 4) and awarded to 3 different contractors. After tendering, a double shield (DS) type TBM was selected to excavate two northern sections (Lots 3 and 4) and two southern sections were supposed to be excavated by drill and blast methods using two inclined access tunnels at middle parts. During construction of southern sections and after encountering several adverse geological and hydrogeological conditions in different parts of main and access tunnels, the construction method was changed by client. Finally, 24.5 km of tunnel (two lots of 3 and 4 and a part of lot 2) was excavated using a DS machine from northern portal and a new EPB hard rock machine was selected to finish the remaining 11 km of the tunnel from southern portal (lot #1 and remaining part of lot 2). One of the access tunnels and a small cavern were applied to disassemble and pull out two machines from the main tunnel.

Tunnel excavation, at the northern portal, was commenced in February 2004. Lots No 3 and 4 with a total length of about 18 km were

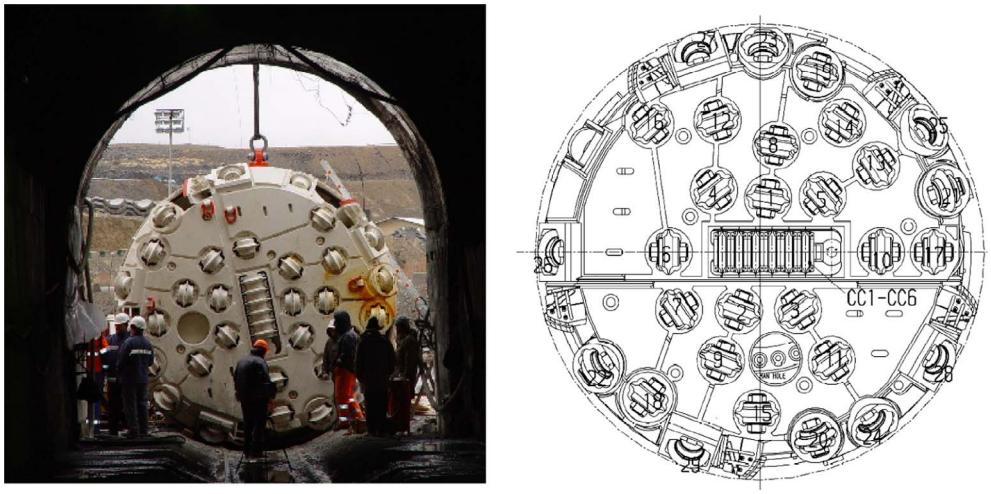

Fig. 2. A View of machine cutterhead and disk cutters arrangement on the cutterhead.