Consideration of Total Station as Baseline for Tape Measurements Improvement in Holing Prediction at Underground Deep Level Gold Mine

Gloria Khoza [1], Elvis Fosso-Kankeu[2] and Hendrik Grobler[3]

***Abstract*—**Over the last few years, accurate and safe break-through (holing) has been a problem in Underground deep level gold mines because of factors including the inherent inaccuracy of tape measurements.

In this study, data collected from total station measurements and tape measurements in an underground deep level gold mine were compared using statistical analysis, then recommendations were made based on error margin.

Tape surveying methods and recording of distance require human involvement at various stages of the process compared to total station measuring. It is therefore likely that the former method will be more prone to error. The margin between these two methods has never been evaluated in the context of ultra-deep level gold mining activities. The study tested the accuracy of tapes versus the accuracy of Total station using a hypothesis test, F test. It was found that tape measurements are less accurate from Total station measurements when applied for holing prediction in ultra-deep level gold mine. It is recommended that for high accuracy work the Total station should be used to measure underground stopes faces on a deep level gold mine.

***Keywords*—** Total station, Tape measurements, underground deep level gold mines, Error analysis, Holing, Accuracy.

I. Introduction

The purpose of the research is to investigate the accuracy of tape measurements in comparison with total station measurements in a selected deep level gold mine with regards to its impacts on the stope face holing and advance meters measured underground towards providing a scientific basis for future decisions regarding underground survey. Underground mining poses different impacts to the environment such as seismic events, rock structure, rock movement, employee's health and safety. The research attempts to explore new way of taking underground measurements towards reviewing and improving existing safety measures for mine employees [especially mine surveyors] in order for them to do safe survey work underground conditions. Many underground deep level gold mines often experience a situation whereby survey plans suggest that there are some holed stope faces, yet it is not so underground. This causes a false holing and additional costs to production because they have to drill more than what they planned for because they do not reach the holing position**.**

II. Research Problem

In the last few years, there has been a problem of holing accuracy in the underground deep level gold mine because of tape measurements. Particularly, some mines continue to experience false holing between the current working places, the mined-out areas and the workplaces that are advancing towards one another, (Mantey and Aduah, 2021). Also, the underground deep level gold mining industry has been experiencing challenges during mining operations due to geological structures such as faults and dykes, fall of ground, and seismic events that make holing to be the most affected (Brent et al., 2017). Further, the deep level gold mine underground conditions are very harsh, the rock temperature can reach up to 60°C which can lead to heat exhaustion or death (Neingo and Tholana, 2016).

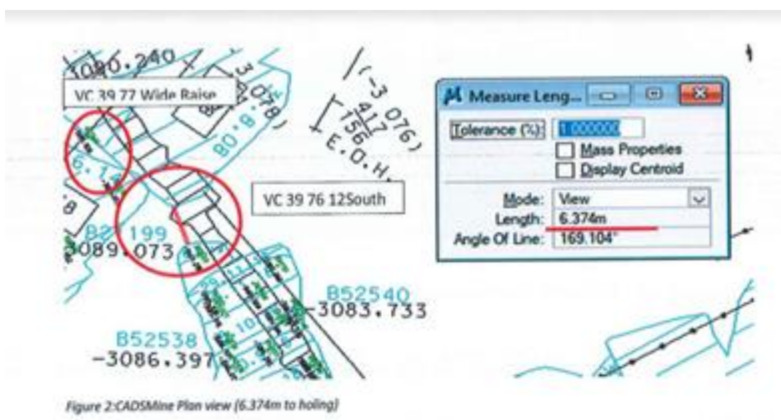

Fig.1 *Diagram showing the work place where planned holing position was missed*.

Gloria Khoza[1] is with the Department of Mining Engineering, University of South Africa, Florida Campus, Private Bag X6, Johannesburg 1710, University of South Africa, (UNISA), South Africa.

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Elvis Fosso-Kankeu[2] is with the University of South Africa .

Hendrik Grobler[3] is with the University of Johannesburg

Despite these challenges and problems, the South African mining industry continues to push the production without adequate safety consideration. For instance, the deep level gold mines in West Wits are well known for their unpleasant underground working environment.

Moreover, there appears to be a lack of research focusing on the surveying, measuring and mapping at the underground deep level gold mining. Also, a deep level gold mine(name withheld) situated within the West Wits region, has on more than one occasion exhibited a number of work places that are not holing to the positions that were expected to hole into.

Fig. 2 underground stope face

III. Materials and Methods

A. The Study Area

This study was conducted at a mine shaft in one of the deep level gold mines within the West Wits region of Johannesburg, South Africa on July 2021.

B. Methods used

The study was conducted in three phases. The first phase was data acquisition process, the second phase was the data collection, the third phase was the data analysis, and the last phase was the accuracy assessment.

1. Data acquisition

The data used for this study included measured working places with tape measurements and with the total station measurements, measurements were taken for different stope faces during the month of July 2021 at a deep level gold mine. This exposure has triggered the interest for a deep understanding into what can be done for all these places that are not holing, holing to wrong position, inaccuracy of measurements and survey closure in the mining industry. Currently, at a major mine shaft (name withheld), there is a problem of stope faces which is believed to have holed according to survey plans. However, it is not the case underground. For instance, in June 2019, working panel VC39 76 12 South was measured and plotted on the survey plan as holed but was later (in July 2019) found to be 6.374 .

2. Reconnaissance

A preliminary reconnaissance of the study area was performed. Part of the reconnaissance included identifying the work places measured with tapes and again with total station, the time spent when measuring with tapes as well as the time spent using total station, the underground conditions like ventilation, temperature and the support of the ground on how easy to access the stope face that is going to be measured.

3. Monitoring Parameters on Total station

A standard procedure was established that includes (but not necessarily limited to):

a. Observation procedures and techniques
b. Instrument settings
c. Corrections to be applied to measurements
d. Data verification and calculation checks
e. Limits of allowable error
f. Processing, presentation and analysis of results
g. Care, maintenance and adjustment of equipment

4. Personal protective equipment

i. The Responsible Surveyor according to Regulation 17(2) (a) of MHSA ensured that:

a. Protective clothing and equipment is available to all survey team members who were required to use such items.

Permission to enter workings –

b. No Surveyor or survey team member may enter any working place without the permission of the ganger or miner responsible for the safety of the working place.

5. Use of Safety Devices

a. The use of Safety flashing lights by all Surveyors underground is mandatory.

6. Hazards and Risks

a. The Responsible Surveyor is to ensure a Hazard and Risk Register is available on demand in the Survey Office.

b. Each member of staff is responsible for reporting of any potential risk related hazards without delay in the Hazard and Risk Register. The Responsible Surveyor and the staff member concerned must sign these entries.

c. The Responsible Surveyor is to ensure the contents of the Risk Register is brought to the attention of the appropriate mine official / manager for action and acknowledgement is to be recorded in the Register.

C. Data Collection

Data was collected at Manyano shaft Sibanye Stllwater Kloof mine on July 2021 and the following equipment's were used;

1. The measurements were taken by Total station, machine setup under a known peg, backsited to a known peg and offset the stope faces, then plotted at surface and got the underground stope faces square meters, underground stope faces lengths and underground face advanced meters.
2. The measurements were taken by tapes to get underground stope faces and underground face lengths, underground face advanced meters

TABLE I:
VALUES OF AREA IN SQUARE METERS, FACE LENGTHS AND FACE ADVANCED METERS

Prod month	Workplace / Section	Tape m2 meas	Total station m2 Meas	FL tapes meas	FL Total station meas	M Adv tapes	M Adv Total station
202107	23924: VC40 76 06AS	48	48	15	15	3,2	3,2
202107	24264: VC40 73 03AN	126	68	23	20	5,5	3,4
202107	24421: VC40 77 11BN	126	136	23	22	5,5	6,3
202107	25926: KL40 78 01S	108	121	27	37	4,0	3,2
202107	26123: VC40 90A 05S	212	120	27	35	7,9	3,5
202107	26191: VC40 73 3BN	160	141	22	24	7,3	5,8
202107	26625: KL40 78 01AS	124	149	24	46	5,2	3,2
202107	26696: VC40 90A 04S	195	150	25	27	7,8	5,7
202107	26699: VC40 90A 02S	167	185	26	25	6,4	7,4
202107	26700: VC40 90A 03S	189	181	26	26	7,3	7,0
202107	26787: KL40 83B 03S	103	122	12	31	8,6	3,9
202107	26882: VC40 68B 02AN	150	174	15	15	10,0	11,8

V. RESULTS

The study tested the accuracy of tapes versus the accuracy of Total station using a hypothesis test, F test. The following calculations of F test were made;

Two variances were compared between the Area measured in square meters and no difference in variances. Therefore, the hypothesis is accepted. F calculated value: 1.213004 and F value from Table 2: 2.98. This is taken as a supposition on the basis of this finding serving as a starting point for further investigation. In addition, Reda and Bedada (2012) conducted similar study on total station accuracy analysis and comparison of manual and automatic target recognition measurement. They reported that the effect of color surfaces on distance measurement was found statistically equal. Also, the error in distance increased as the incident angle in the target increases. Similarly, Coaker (2009) found that tape measurement may produce results that could be said to have high precision but low accuracy. Also, unavoidable random errors are likely to occur with tape measurement.

From the results, it can be concluded that the tape measurements are less accurate compared with Total station measurements. The Figure 3 above showing the blue line of tape measurements indicates that those measurements are not in the position where the face is supposed to be, and the red line which is total station measurement I goes along exactly to the face position.

EXPLANATION OF TABLES

TABLE II
VALUES OF AREA IN M2 MEASURED WITH TAPES AND TOTAL STATION

Workplace / Section	Tape m2 meas	Total station m2 Meas
VC40 76 06AS	48	48
KL40 83B 03S	103	122
KL40 78 01S	108	121
KL40 78 01AS	124	149
VC40 73 03AN	126	68
VC40 77 11BN	126	136
VC40 68B 02AN	150	174
VC40 73 3BN	160	141
VC40 90A 02S	167	185
VC40 90A 03S	189	181
VC40 90A 04S	195	150
VC40 90A 05S	212	120

	Tape	Total station	
MEAN	142	133	
Variance	2116,242	1744,629	
Observation	12	12	
df	11	11	
F	1,213004		
F Critical	2,98		

TABLE III
VALUES OF FACE LENGTH MEASURED WITH TAPES AND TOTAL STATION

Workplace / Section	FL tapes meas	FL Total station meas
KL40 83B 03S	12	31
VC40 76 06AS	15	15
VC40 68B 02AN	15	15
VC40 73 3BN	22	24
VC40 73 03AN	23	20
VC40 77 11BN	23	22
KL40 78 01AS	24	46
VC40 90A 04S	25	27
VC40 90A 02S	26	25
VC40 90A 03S	26	26
KL40 78 01S	27	37
VC40 90A 05S	27	35

	Tape	Total station	
MEAN	22	27	
Variance	26,81061	83,35606	
Observatio	12	12	
df	11	11	
F	0,32164		
F Critical	2,98		

Fig.5 underground stope faces measured by tapes

TABLE IV
VALUES OF METERS ADVANCE MEASURED WITH TAPES AND TOTAL STATION

Workplace / Section	M Adv tapes	M Adv Total station
VC40 76 06AS	3,2	3,2
KL40 78 01S	4,0	3,2
KL40 78 01AS	5,2	3,2
VC40 73 03AN	5,5	3,4
VC40 77 11BN	5,5	6,3
VC40 90A 02S	6,4	7,4
VC40 73 3BN	7,3	5,8
VC40 90A 03S	7,3	7,0
VC40 90A 04S	7,8	5,7
VC40 90A 05S	7,9	3,5
KL40 83B 03S	8,6	3,9
VC40 68B 02AN	10,0	11,8

	Tape	Total station	
MEAN	7	5	
Variance	3,853561	6,631515	
Observatio	12	12	
df	11	11	
F	0,581098		
F Critical	2,98		

Fig. 6 VC40 90A 05S

Fig. 7 KL33 16 08S showing underground face that was measured by tapes and also measured by Total station.

VI. Conclusion

It is therefore recommended that for high accuracy work, the Total station should be used to measure underground stopes faces on a deep level gold mine and the holing will not be a problem as well as the cost in production will be less. More importantly, the safety of the survey team will not be at risk because they will not be holding tape to the stope face that has temporary underground support and high temperature.

VII. Author's Profile

Gloria Hombakazi Khoza from 2007 worked in the mine called Goldfields now it is Sibanyestillwater as a Surveyor until January 2021. She obtained Advanced Valuation at Chamber of mines in 2011 and Advanced Mine Survey at Chamber of mines in 2012. She graduated from the University of Johannesburg (UJ) in 2018 with a BTech: Mineral Resources Management. She joined the University of South Africa (UNISA) in 2021 as a Junior Lecturer. She is currently registered for a Masters of Sustainable Mining at the University of Johannesburg (UJ) where she is working on research project that investigates *Tape measurements when compared to total station measurements in deep level gold mines.* Her field of specialization is Mine Survey. She is a Senior Associate member of The Institute of
Mine Surveyors of South Africa- IMSSA**.**

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