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TOMASZ SIOSTRZONEK
PIOTR TRÓJCA
JAKUB WÓJCIK

Winding machine additional overload state indication as supporting solution for mine shaft hoist operators

Dangerous events that take place in the mining plant always give us a chance to rethink whether the design of a faulty device could have been improved enough to prevent such a situation. The same scenario takes place with mining shaft hoist. Without a doubt, a starting point for discussions about additional mining shaft hoist security measures is the last dangerous situation that took place in a Silesian mine in 2017. This article is an analysis of the probable causes and conclusions that can be drawn from that incident.

Key words: *mining shaft hoist, logger, winding machine control system*

1. MINING SHAFT HOIST GENERAL CHARACTERISTICS

The mining fall in which the incident took place is a 7.5-m-radius double-compartment shaft with a depth of 710.5 m. In Compartment A, the mining level is at –650 m, whereas Compartment B's mining level is –500 m. The arrangement of the individual vessels in the shaft shield is shown in Figure 1.

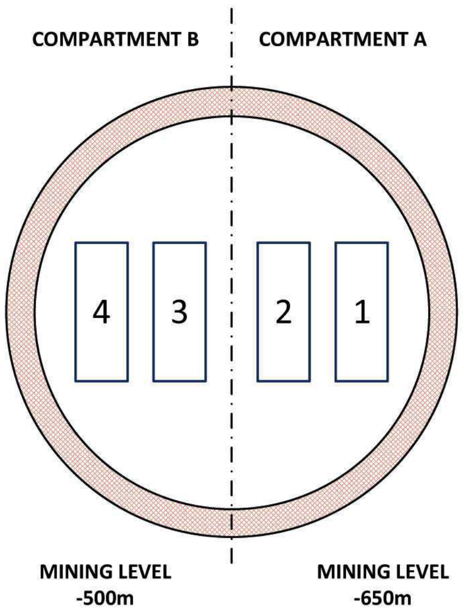

Fig. 1. Shaft disc vessel arrangement

The incident took place in Compartment A equipped with a Koepe wheel-type 4L5500/2×3600 winding machine [1] approved in accordance with [2]. The Koepe pulley is 5.5 m in diameter and supplied with two PW motors (3.6 MW each) working on a common shaft. The motors are powered by a static thyristor converter. The motor excitation systems are powered by bidirectional converters. The direction of the rotation is changed by changing the direction of the current flow through the excitation circuits. The mine shaft hoist is equipped with disc brakes. Four pairs of spring-hydraulic actuators are mounted on each of the four brake stands.

The control system of the winding machine enables mining in manual or automatic modes. The AR-3c recorder was used to record the operating parameters of the hoist.

The hoisting machine is a two-vessel machine with a total coal transport mass of 30 Mg and a vessel linear velocity of 16 m/s in the shaft. The locations of the individual levels are shown in Figure 2.

The shaft is equipped with a rigid vessel mounting. The shaft-guiding lines with dimensions of 160 × 220 × 9000 mm are fixed to 150 × 200 girders placed on the shaft lining 4.5 m apart.

To guide the vessels in the guidelines, sets of rolling guides are used that are mounted on the head and lower arm of each vessel.

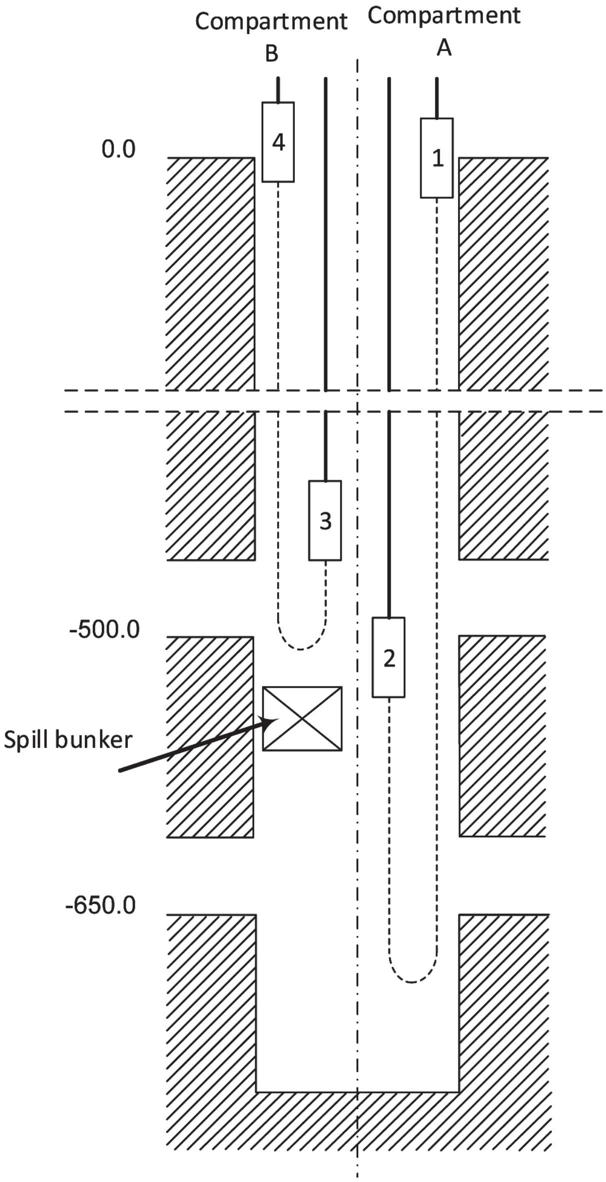

Fig. 2. Cross-section of shaft with location of levels

2. EVENT DESCRIPTION

The unfortunate event took place during working hours in Compartments A and B. As a result of a coal overload, Skip No. 2 hit Compartments B's spill bunker's steel parts that were sticking out beyond the safe zone. While descending, Skip No. 2 was suddenly stopped by the protruding elements of the tank and then suddenly released. The cause was probably the displacement of these parts. Description and reasons of this accident are described in [3]. As a result, the following components were damaged:

- shaft guiding rails,
- shaft buntons installed on the south side,
- wiremash partings,
- balance rope turning station,
- skip,
- skip load suspension,
- 4 head ropes,
- steel-rubber tailrope rubber coating.

The following question arises: were there no symptoms before then that could have indicated that something disturbing was happening in the mining shaft?

For this purpose, records from the logger installed in accordance with [2] were used. The results of the analysis are presented in a later part of this article.

3. AR-3c LOGGER DATA

An AR-3c logger is built in Compartment A. It is setup to log all control and diagnostic signals required to analyze any incorrect behavior of the mining shaft elements [4].

In a separately excited DC machine, the torque generated on the machine shaft is directly proportional to the current of the main circuit (armature circuit).

In the case of stopping Vessel No. 2 by the construction of the spill bunker, the load torque suddenly decreased.

Fig. 3. AR-3c logger

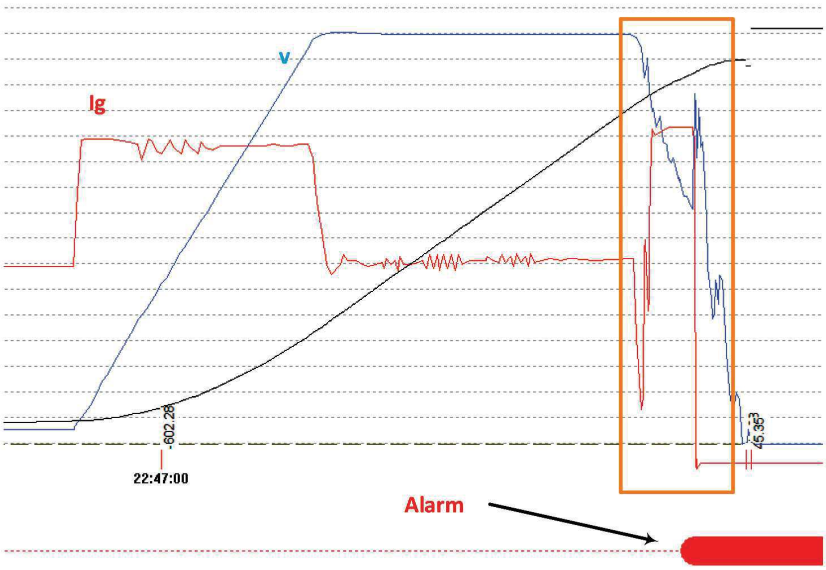

Fig. 4. Logger data during incident

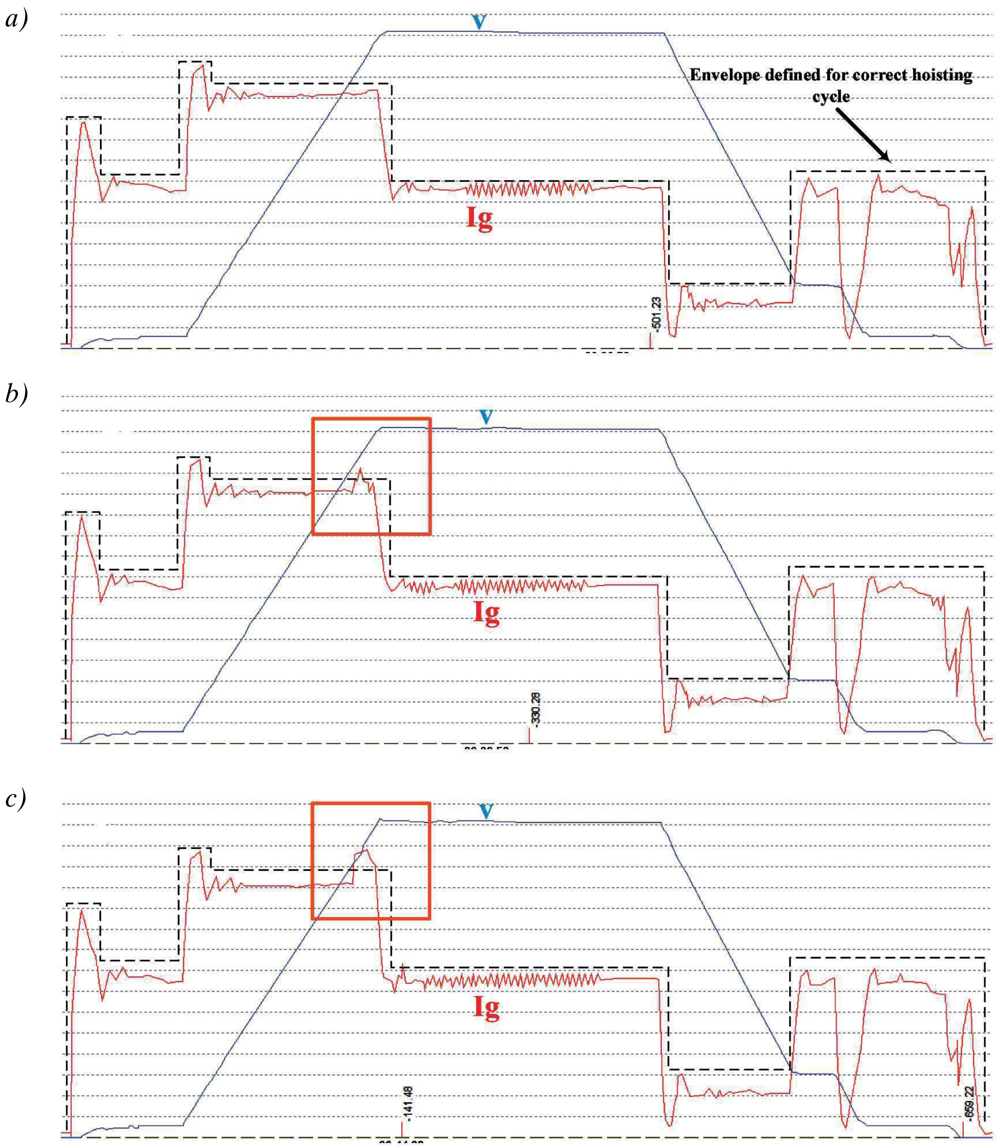

Fig. 5. Main circuit current Ig and vessel speed v waveforms – data acquired from AR-3c logger: a) no disturbances visible (correct waveforms); b) three cycles before incident; c) cycle directly before incident

The regulation system behaved properly. The current value dropped down to rise to its maximum value limited by regulator settings. At this point, the machine became a single-end machine. After this, the second vessel release skip went into a freefall. This caused its speed to rise above the permissible value and the machine to be switched off due to exceeding the maximum limit.

4. DESCRIPTION OF CONDITIONS ON BASIS OF LOGGER DATA

An analysis of the winding machine logger records was carried out in a wider range than solely at the time of the event.

The ten cycles preceding the incident were analyzed. Further than three cycles before the event, no disturbing changes in either the current or speed can be observed (Fig. 5a). For each form of the current waveforms in Figure 5, the envelope was applied on the basis of the normal course, which is information regarding whether there was an anomaly in the system. Three cycles before the occurrence of the event, an increase of approx. 500A in the main circuit current is visible above the value set for this fragment of the hoisting cycle. The full Vessel 2 was ascending during this time. It can be concluded that the vessel was already in contact with a deviated design of the adjacent compartment tank. The operation of the shaft station devices suggested that disturbing noises were heard in the mining shaft. In the cycle preceding the event, the increase in current when passing the vessel in the vicinity of the tank was already at 900 A and lasted much longer (Fig. 5c).

5. CONCLUSIONS

On the basis of the analysis of the winding machine logger data, it can be stated that it was possible to detect the symptoms of an impending threat earlier. For several cycles before the incident, it was possible to observe anomalies in the course of the main circuit current. The current changes were caused by a variable load torque resulting from the appearance of an additional obstacle to Vessel 2.

It is not possible to detect this type of anomaly only by observing the current waveforms on the driver's desk or in the logger. To properly respond to such irregularities, it would be necessary to place an additional indicator of such a state on the driver's desk as well as appropriate changes in the regulations [5].

In the form of a visual signal (a glowing lamp) placed on the driver's desk, this indicator would be activated when the permissible value of the current is exceeded by the assumed value for a given fragment of the driving diagram. If established in double-compartment shafts with different levels of extraction, it would require the service staff to take control actions in case of its activation.

This would be an element that should draw the attention of the staff, especially the supervision workers. If there is an overload of the machine in the form of an increase in current, this is due to the operation of an additional load moment, which can have various causes. For the people controlling the technical condition of shaft reinforcement and the auxiliary equipment of the shaft, it is necessary to assess whether vessels on their ways encounter obstacles that may cause dangerous consequences. The implementation of this type of indication device is easy from the technical point of view, as a current measurement is already carried out in each machine.

References

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TOMASZ SIOSTRZONEK, Ph.D., Eng.
JAKUB WÓJCIK, M.Sc., Eng.
Department of Power Electronics and Energy Control Systems
Faculty of Electrical Engineering, Automatics, Computer Science, and Biomedical Engineering
AGH University of Science and Technology
al. A. Mickiewicza 30, 30-059 Krakow, Poland
{tsios, jakubwojcik}@agh.edu.pl

Piotr TRÓJCA, M.Sc., Eng.
State Mining Authority
Specialized Mining Office
ul. Obroki 87, 40-833 Katowice, Poland
sug@wug.gov.pl