Safety In Mines Research Advisory Committee
Project Summary : GEN 810

Project Title:	Development of a smart rockbolt for underground monitoring operations

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Category:	Rockfalls and rockburst	**Applied Research**	

Summary

Rockbolting is a prerequisite for providing roof support in mining operations. The problem of rock pressure becomes worse as mining becomes deeper. Most of the rockbolts designs are made from simple carbon steel. The related problems of uncertainty as to the quality of installation of grouted steel tendons for reinforcement of rock around tunnels and stope gullies, and the effect of corrosion, rock deformation and repeated dynamic loading from seismic events on the integrity of even well installed tendons, have been long recognised both in South Africa and world-wide.

Support, which is adequate on installation, may be insufficient when loading conditions change. A smart rockbolt was therefore proposed that, when stressed underground, undergoes a microstructural transformation, with its properties changing from a non magnetic to magnetic depending on the degree of plastic deformation, thus leading to a change in longitudinal ultrasonic velocity. These properties can be monitored using a portable magnetic and ultrasonic instrument respectively to determine a change in loading conditions, and to warn of a possible overload condition. The smartbolt acts as a sensor for determination of stresses in mine workings. Also, since the smartbolt alloy could be installed in a mine containing aggressive minewater, the opportunity has been taken to study some of its corrosion properties.

This report detail the research work performed at Mintek for SIMRAC into the development of a sensor material (smartbolt alloy) using metastable austenitic stainless steel. This study was split in to two phases. Phase 1 investigated the use of magnetic methods in measuring the stress or microstructural transformation in an individual bolt in both laboratory and underground environment. The corrosion performance of the smartbolt alloy was evaluated in synthetic mine water and compared with that of AISI 304 and 316 as well as mild steel. Phase 2 investigated the use of ultrasonic methods, modelling of the smartbolt alloy and testing underground.

Phase 1: Mintek identified an alloy composition as being suitable for acting as a smartbolt material under the influence of strain. Laboratory work has shown that there is good correlation between ferritescope (magnetic) readings and those from a magnetic balance. Some problems do, however, exist with the ferritescope method of monitoring, in particular the depth of penetration. However, tests were carried out underground.

Phase 2: Characterisation have been performed under laboratory conditions and show that the smartbolt alloy has a good combination of high strength and ductility; this is important in order to resist extreme conditions of high tensile and shear stress, much as a conventional roof bolt. Comparisons have been made with standard grades such as Type 304 stainless steel. Modelling load-strain characteristics of smartbolt alloy including the work-hardening behaviour have been performed.

The corrosion rate of the 12Cr-9Mn-C steel (smartbolt alloy) is more than two orders of magnitude lower than that of mild steel and one order of magnitude higher than that of AISI 316 (Figure 1). The value close to 0.01 mm/y over a large pH range is quite acceptable, but the corrosion rate increases sharply below pH 4.

A portable ultrasonic (USM 25 DAC) monitoring device was used to measure the longitudinal velocity during the calibration trials. The results show a good correlation between the longitudinal ultrasonic velocity and strain (Figure 2). Potential smartbolt warning guidelines were drawn up based on load/ferrite and ultrasonic velocity readings.

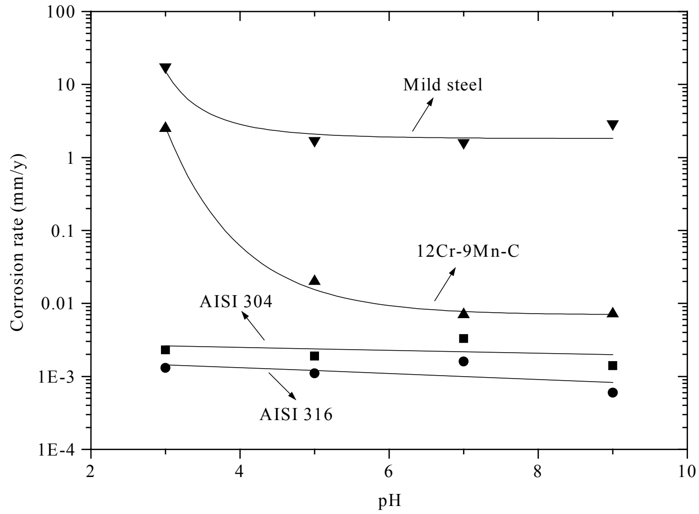

Figure 1. Corrosion rates as a function of pH

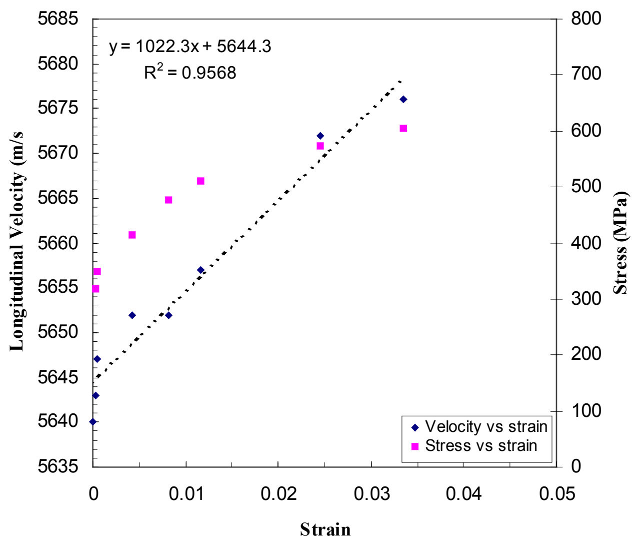

Figure 2. Longitudinal ultrasonic sound velocity versus strain of the smartbolt alloy

Conclusions

- An alloy composition has been identified as being suitable for acting as a smartbolt material under the influence of strain. Some problems do, however, exist with the ferritescope method of monitoring, in particular the depth of penetration.
- The use of the smartbolt concept together with ultrasonic monitoring can be an effective and simple method of monitoring the load in a bolt. The readings are accurate and the technique should help to promote safety in the industry. Information can be gathered and logged quickly to determine whether bolts are bent, broken, or overloaded.
- Ultrasonic methods appear to be a satisfactory method for interrogating smartbolts but the overall hardware package may need to be refined with continuing feedback from mining personnel.
- Smartbolt alloy is particularly suited to application where corrosion is problematic.