ГЕОТЕХНОЛОГИЯ. ГОРНЫЕ МАШИНЫ

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A review of the methods of mine support protection from the effect of different types of corrosion

Aleksandr K. Kirsanov[1]*, Aleksei E. Karvanen[2], Sergei V. Anushenkov[3]
[1] Siberian Federal University, Krasnoyarsk, Russia
[2] OOO Zapoliarnaia construction company, Norilsk, Russia
[3] AO Sibir–Polimetally, Rubtsovsk, Russia
e-mail: akirsanov@sfu-kras.ru

Abstract
Introduction. *Underground mine workings often develop perfect conditions for different types of corrosion. Metal arches, anchors, metal meshes, and other steel support structures installed in underground workings are affected by groundwater and atmosphere, which can gradually cause corrosion, and therefore loss of bearing capacity. Hence, one of the main process tasks mining engineers face today is finding methods of mine support protection from the effect of corrosive environment to increase their lifespan.*
Research objective *is to carry out a review of the existing methods of mine support protection from the effect of different types of corrosion in underground mine workings.*
Results. *A review of the main corrosion types which typically affect metal support structures in underground conditions is presented. Based on the review results, several methods of support protection from corrosion are described, including various protective coatings such as epoxy resins and galvanizing, alternative materials of carbon steel, barrier protection, and a combination of these methods.*
Conclusions. *Each method has its advantages and disadvantages. As early as at the design stage, it is important to assess the specific mine working location conditions in order to assess the degree of risk. It should be done in order to choose the optimal strategy for mine support protection from the effect of different types of corrosion. The paper sets a direction for the search of modern technologies aimed at improving the corrosion resistance of mine support materials.*

Keywords: *mine support; mine support degradation; metal corrosion; water corrosion; mine support protection; stability; mine workings; atmospheric corrosion; protective coating.*

Introduction. Underground mining throughout the world and in the Russian Federation in particular, is growing every year [1, 2]. Metal (metal frame support, rock bolting, reinforcement cages, etc.) is the main material used for different configurations of mine support. The formation of different types of corrosive environment is among its principal negative factors (Figure 1).

Corrosion of steel support structures of mine support systems, pipelines, steel work of shaft, and surface structures is a common problem for mining enterprises developing underground deposits.

Searching for the methods of protecting mine support metal elements from the effect of any corrosion type is therefore an urgent scientific and technical problem.

Methods of research. The present article is a review of several corrosion types common for underground mining. The existing methods of protection against the effect of different types of corrosion are demonstrated. These methods became common both in the domestic and foreign mining practice. The authors obtained information about the methods from relevant scientific and technical literature and directly from specialists working at existing mines.

Review of the main types of corrosion. The occurrence of corrosion mainly depends on the value of environmental variables, namely temperature, humidity, airflow rate, total dissolved solids, water chemistry, etc. The following is a summary of the two main types of corrosion that often occur in the course of underground mining.

Water corrosion. At the stage of issuing exploration license, enterprises are required to provide water quality forecasts throughout the life of mine as of a hazardous production facility. These forecasts include the indicators of water acidity (pH) and metal ions presence.

Mine waters can be conventionally classified into three types [3–5]:

– acidic waters, pH < 6.5, increased mineralization;
– neutral fresh waters, pH = 6.5–8.5, mineralization up to 1 g/l;
– brackish and salt waters, pH = 6.5–8.8, mineralization above 1 g/l.

If steel is exposed to acidic water, the main factors affecting the rate of corrosion are pH and temperature. Low pH and high temperatures result in the highest rate of corrosion.

Corrosion of metal when in contact with neutral pH water is mainly determined by salinity (measured as the total amount of dissolved solids or with the help of electrical conductivity as an indirect measure) and dissolved oxygen. However, the presence of some aggressive ions (for example, chloride, sulfate, iron and copper) can result in rapid and localized pitting corrosion.

Atmospheric corrosion. Metals and concrete are attacked by corrosion in mines not only under the effect of aggressive waters, but also due to metal and concrete structure surfaces contact with the mine air characterized by dust content, high air temperature, humidity and the presence of gaseous corrosion reagents.

According to studies conducted by Canadian scientists [6], the relative humidity and temperature of air have the greatest influence on corrosion propagation. It has been proved that the rate of corrosion doubles for every 10 °C rise in temperature.

Studies have also shown that the rate of corrosion propagation is strongly affected by relative humidity from 60 to 100%. Under the relative humidity below 60%, atmospheric corrosion is scarcely observed.

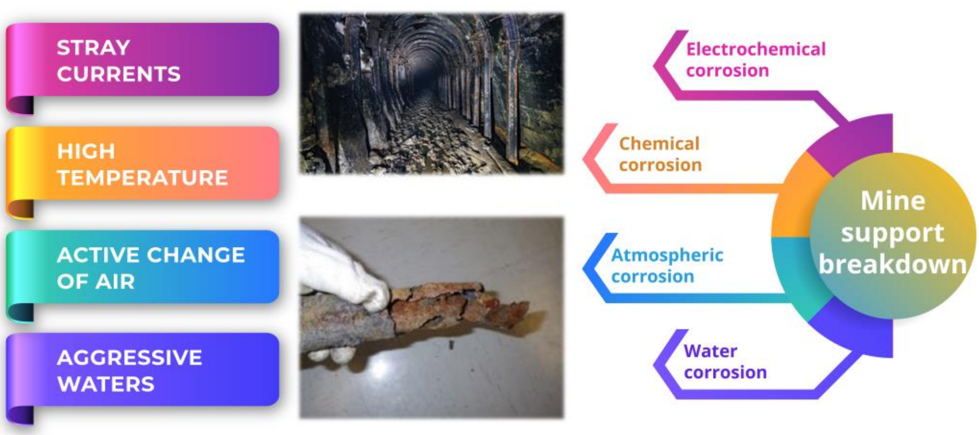

Figure 1. Main types of corrosion effect on mine support
Рисунок 1. Основные виды воздействия коррозии на горную крепь

Figure 2. Corrosion protection methods
Рисунок 2. Способы защиты от воздействия коррозии

The air flow rate and pollutants concentration can be classified into three main types of aggressiveness:

– stagnant air (the highest level of hazard for a mine support);
– waste air – return ventilation air (medium hazard);
– mixed air – standard mine atmosphere (low level of hazard).

Other types of corrosion. In addition to the above types of corrosion, there are also electrochemical and chemical corrosion types, as well as electrocorrosion, biocorrosion and other types that have a material adverse effect on mine support integrity, and therefore its bearing capacity [7–12].

Corrosive environment formation is a potential risk for workers and production due to the reduced lifespan of support elements and their possible collapse. However, the mechanisms that influence the rate of corrosion are relatively well understood, and necessary data is usually collected as early as at the stages of mining enterprise design and operation, which allows to take timely measures.

The main types of corrosion protection. Corrosion protection generally falls into four main categories: protective coatings, carbon steel alternatives, barrier protection, and combinations of these methods (Figure 2) [6, 13–15].

Protective coatings not only protect products from corrosion, but also give some valuable physical and chemical properties to surfaces, such as wear resistance, electrical conductivity, etc. Many coatings (epoxy resins, paints, zinc and aluminum coatings, thermal pastes, etc.) can withstand aggressive environment. The disadvantage of such coatings is their brittleness and cracking under load, which exposes uncovered steel minimizing the effectiveness of coating.

Protective coatings, depending on type, are characterized by a degree of corrosion resistance: from low (zinc) to high (thermoplastic coatings). The same is true of the wear resistance of some protective coating types. In the mining industry, this corrosion protection method can be applied to various types of anchors, reinforcement bars, and metal plates.

Alternative carbon steel support materials are mesh polymers or fiberglass polymers. They represent structural steel that contains fewer impurities. Stainless steel, depending on type, can have high corrosion resistance on retention of the ability to deform. However, high cost limits its use in the mining industry.

Barrier protection and a combination of methods. Due to its chemical composition, cement grouting can provide excellent protection in low load environment, but tends to crack and leak aggressive water under relatively light loads.

Complete sealing of the mine support with cement grouting or resin solution can provide acceptable corrosion protection. Resins are more resistant to deformation and cracking, which also provides better protection.

A combination of coatings (for example, galvanizing or thermal pastes with complete cement grouting to protect the bearing elements) is now widely used in underground mines. In underground mines with acidic groundwater, thermoplastic coatings, and cement grouting are commonly used.

Control proposal for the areas with a corrosive environment. In addition to the above protection methods, mining enterprises should introduce a digital map of potentially corrosive mine sections as an emergency prevention measure.

Such a map can be compiled in the form of thermal sectors: red color indicating high probability of corrosion, orange color indicating environment probability of corrosion, and green color for low probability. This approach will make it possible to assess the potential for corrosion propagation in the territory of a particular section and the entire mine and can be used by other mine services when mapping potentially hazardous zones.

Identification of potentially hazardous zones will allow the enterprise management to organize mine support review boards well in advance and plan repair operations if necessary.

Conclusions. For large underground mines where the working length reaches hundreds of kilometers [16], mine support must ensure the support of the mined-out area for a sufficiently long period of time. Therefore, possible corrosion manifestation and, as a result, mine support bearing capacity violation in some sections must be taken into account at the design stage.

The review of the existing methods of mine support protection from the effect of different types of corrosion presented in the article makes it possible to set the direction of the search for modern technologies aimed at improving the corrosion resistance of materials, ways to reduce the corrosive environment aggressiveness, and the possibility of using certain protective coatings to protect the mine support from the effect of a corrosive environment.

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Information about the authors:

Aleksandr K. Kirsanov – PhD (Engineering), associate professor of the Department of mine and underground construction, Siberian Federal University. E-mail: akirsanov@sfu-kras.ru; https://orcid.org/0000-0001-7977-4954
Aleksei E. Karvanen – deputy chief engineer for mechanization and equipment, OOO Zapoliarnaia construction company. E-mail: lex19-88@mail.ru
Sergei V. Anushenkov – chief engineer, AO Sibir–Polimetally. E-mail: s.anushenkov@mail.ru

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Обзор способов защиты горных крепей от воздействия различных видов коррозии

Кирсанов А. К.[1], Карванен А. Е.[2], Анушенков С. В.[3]
[1] Сибирский федеральный университет, Красноярск, Россия.
[2] ООО «Заполярная строительная компания», Норильск, Россия.
[3] АО «Сибирь–Полиметаллы», Рубцовск, Россия.

Реферат

Введение. *В подземных горных выработках зачастую формируются идеальные условия для возникновения различных видов коррозии. Стальные опорные элементы в виде металлических арок, анкеров, металлических сеток и т. д., установленные в подземных выработках, подвергаются воздействию грунтовых вод и атмосферы, что может вызвать коррозию, и, следовательно, потерю несущей способности с течением времени. В этом контексте одна из главных технологических задач, стоящих сегодня перед горными*

инженерами, – найти способы защиты горных крепей от воздействия агрессивной среды, чтобы продлить срок их эксплуатации.
Цель работы. *Настоящая работа направлена на обзор существующих способов защиты горных крепей в подземных горных выработках от воздействия различных видов коррозии.*
Результаты. *Представлен обзор основных видов коррозии, которые в большинстве случаев поражают элементы металлической крепи в подземных условиях. По результатам проведенного обзора было описано несколько способов защиты металлической крепи от коррозии, включая использование различных защитных покрытий в виде эпоксидных смол и оцинковки, альтернативных материалов из углеродистой стали, барьерной защиты и комбинации данных способов.*
Выводы. *Каждый из представленных способов имеет свои преимущества и недостатки, для выбора оптимальной стратегии защиты горной крепи от воздействия различных видов коррозии еще на этапе проектирования важно оценить конкретные условия расположения выработки для оценки степени риска. В работе задан вектор поиска современных технологий по повышению коррозионной стойкости материалов горных крепей.*

Ключевые слова: *горная крепь; разрушение крепи; коррозия металла; водная коррозия; защита крепи; обеспечение устойчивости; горные выработки; атмосферная коррозия; защитное покрытие.*

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Сведения об авторе:

Кирсанов Александр Константинович – кандидат технических наук, доцент кафедры шахтного и подземного строительства Сибирского федерального университета. E-mail: akirsanov@sfu-kras.ru; https://orcid.org/0000-0001-7977-4954
Карванен Алексей Евгеньевич – заместитель главного инженера по механизации и оборудованию ООО «Заполярная строительная компания». E-mail: lex19-88@mail.ru
Анушенков Сергей Викторович – главный механик АО «Сибирь–Полиметаллы». E-mail: s.anushenkov@mail.ru

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