Conducting Composites as Cable Anodes in Cathodic Protection

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ABSTRACT:

In this paper the principles, as well as the basic parameters, have been described that characterize the anode system with the use of cable anodes in cathodic protection systems of underground structures. In this protection method a conducting composite is used, the mechanical properties of which allow construction of an anode in the form of a cable running along the route of underground structure. It has been shown that graphite in a composite electrode allows appropriate conduction of the electrode. Improvement of the electrochemical properties can be attained by modification of the conducting component with active oxides from the group of platinum metals.

Keywords: cathodic protection, cable anodes, composite materials

1 INTRODUCTION

Anticorrosion protection of underground structures is realised by use of protective coatings and cathodic protection. Cathodic protection together with coating protection is applied especially in the case of gas pipelines. Protection is based on polarising the structure in the cathodic direction to values at which corrosion processes are hindered. Introduction of a protective current is realised by anodes, which are usually made of insoluble materials such as: high-silicon cast iron, graphite and platinised titanium. In the case of cathodic protection of underground structures anodic systems are usually placed in points at given intervals along the route of the structure /1/. Moreover, the anode system is placed at some distance from the protected structure, and the anodes are buried at relatively large depths /1/. This type of solution aims at improvement of the effectiveness of the protective current distribution to the protected structure and a decrease of the structure potential variations.

In spite of many facilities classic solutions are characterised by many disadvantages. The most important problem is occurrence of insufficiently protected areas in places between anode systems and overprotected places in places of installation of anodes. In insufficiently protected places an increase of the corrosion rate can occur, while in overprotected places damage to the protective insulation can be the result or a possibility of occurrence of hydrogen embrittlement as the result of hydrogen liberation /2/. A danger exists of flow of protective current to other structures near the protected object as the result of placing the anode system at some distance from the protected structure. This has a significant effect on operating costs of a cathodic protection system and the possibility of occurrence of underprotected areas.

There is also the possibility of interference of the protective current if other cathodically protected structures are located in the neighbourhood /3/. This causes significant problems connected with the design of a cathodic protection system, especially with the prognosis of the area of protective current distribution.

Typical graphite and high-silicon cast iron anodes are characterised by poor mechanical properties, as a result of which they frequently crack during installation. Graphite anodes are damaged during operation as the result of formed gas, which gathers inside pores causing mechanical and chemical destruction of the anode structure /4/. The electric cable joint is the most sensitive place of the graphite anode during operation /1/. Application of anodes of much better properties such as platinised titanium anodes or titanium anodes covered with platinum metal group active oxides allows elimination of the problems connected with mechanical properties of anodes and allows application of much greater protective currents. Unfortunately, their relatively high price limits wide application of this type of anodes /5/.

A new solution for anode systems, free from many disadvantages, is an anodic system based on the so called cable anode. This solution is one of the most modern and is based on application of electric current conducting composites.

The aim of this paper is characterisation of cable anodes made of composite materials applied in cathodic protection. A method different from the classical one of anode installation has been characterised, as well as the structure of cable anodes and examples of practical applications.

2 CHARACTERISTIC FEATURES OF ANODE COMPOSITES

The introduction of polymeric materials as anodes for cathodic protection has led to completely new possibilities of anode system construction. The basic feature of the polymeric material is its considerable elasticity, as opposed to the brittleness of graphite and ferrosilicon anodes. Cable anodes are made of a copper conductor surrounded by a conducting polymeric material /6,7/. The construction of a cable anode has been presented in Fig 1.

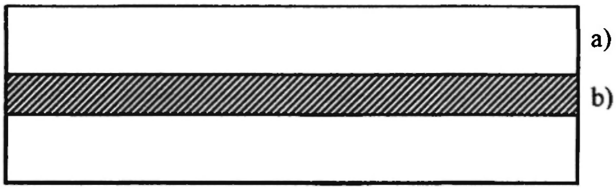

Fig 1: Construction of cable anode
a) conducting composite material
b) copper conductor

Electrical conductance of a composite material is obtained by introduction of a material exhibiting high stability in acidic and highly oxidising environments, i.e., fine graphite or carbon black.

These different construction features of a composite anode in relation to classical solutions became a challenge for laboratory and operating investigations of the so-called cable anodes. The main construction difference between a cathodic protection system based on cable anodes and classical anode systems is that in the former a polymeric material conducting anode is applied running along the route of the structure at a small distance from it. /8,9/. In Fig. 2. a schematic

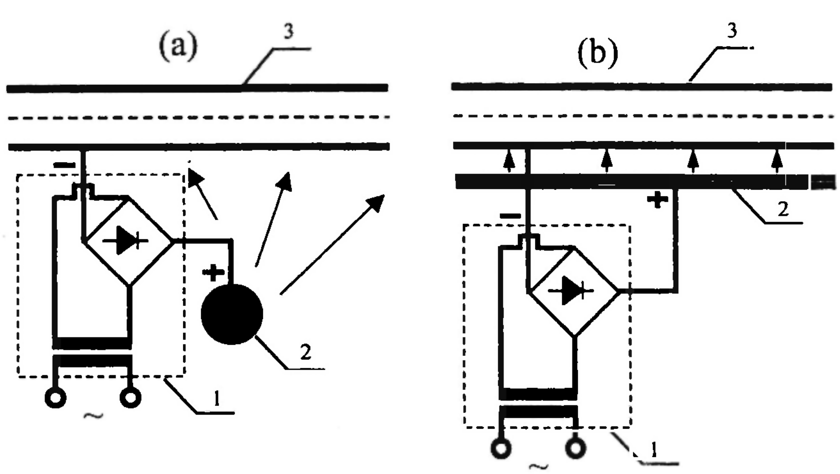

Fig. 2. Cathodic protection installation with the use of
a) classical anodes,
b) cable anodes.
1 - cathodic protection station , 2 - anode system, 3 - pipeline

diagram has been presented of a cathodic protection installation with the use of classical and cable anodes.

The location of anodes along the pipeline route as distinct from point anode systems causes a significant decrease of the protective current and eliminates local overpolarisation of the protected object threatening damage to the insulation. Additionally, by placing the anode much nearer to the protected structure, the risk is decreased of protective current interference on neighbouring structures /10,11/. This feature favours application of cable anodes in the vicinity of towns and industrial plants /12/. Protection is possible with cable anodes of several pipelines running next to each other. In such a case the anode can be placed in between the protected pipelines /13/. In Fig. 3 an analysis has been presented of the protection potential for a classical anode system and a cathodic protection system based on a cable anode.

Cable anodes, like conventional ones, should be placed in a conducting backfill, the main aim of which is extension of the operating time of anodes /14/.

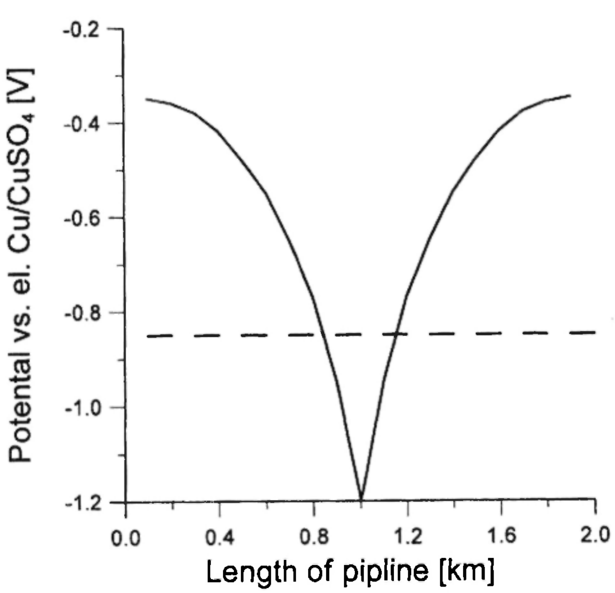

Fig. 3: Schematic diagram of protection potential changes for a classical anode system and a system with application of a cable anode (- - -) cable anode, (—) classical anode

3 MATERIALS FORMING CABLE ANODES

The main component of cable anodes is without doubt the polymeric material. Different types of polymers can be applied for production of composite anodes. As a rule these are materials of high resistance to acids, aggressive aqueous environments and gas chlorine. Three groups of materials can be defined:

- Polyethylene - crosslinked polyethylene, chloropolyethylene, chlorosulphonated polyethylene
- rubber - chloroprene rubber, fluorinated elastomer, rubber modified with chlorine and bromine,
- ethylene-propylene terpolymer.

The ethylene-propylene terpolymer (EPDM) is characterised by the highest chemical resistance, and at the same time by the highest price /15/. Hence, this material finds its widest application during production of composite anodes.

Active fillers are the second main component of cable anodes, the aim of which to ensure electric conductance of the composite material. In the case of composites applied as anodes in cathodic protection usually active carbon black or graphite are used. The general classification of the types of carbon black is as follows /16/:

channel carbon black,
medium conducting - Intermediate Super Abrasion Furnace Black
conducting furnace carbon black,
furnace carbon black of the highest conductance.

Weakly dispersing carbon black is characterised by small particle diameters and high specific surfaces /17/. Highly and very highly conducting furnace or channel carbon black belong to the group of highly dispersing carbon black. This type of carbon black reduces the technological properties of the polymeric mixture due to increase of the hardness and brittleness. An advantage of this type of carbon black is high electric conductance improving electric and electrochemical properties of the whole product. Well dispersing carbon black, i.e., with large particles and a small specific surface (acetylene carbon black), increases the elasticity of the polymeric material, being characterised, however, by significantly lower electric conductance. Composites contain, apart from carbon materials, vulcanising substances, plasticisers, anti-ageing substances and vulcanisation accelerators.

Production of composite anodes in principle does not differ from the process of production of rubber materials. Component mixing operations are performed on a mixing mill, while the final production stage is vulcanisation.

4 APPLICATION OF COMPOSITE ANODES IN CATHODIC PROTECTION

Cable anodes were used for the first time in cathodic protection in the early eighties for protection of reinforced concrete elements /6,7/. The advantageous properties of cable anodes also have been used for construction of cathodic protection systems of underground pipelines /14/. Composite anodes are characterised by a relatively low current-carrying capacity (0.5 A/m^2) hence construction of anode systems of large areas is beneficial. Exceeding the limiting polarising current densities can lead to rapid destruction of the electrode. Composite anodes are characterised by losses equal to 500g/A·per year, this value being comparable to parameters of graphite and ferrosilicon anodes. Gibson and Pikas /18/ evaluated the operating costs of pipelines protected by cable anodes, comparing them with costs of repair of damaged insulation without application of cathodic protection. This analysis showed that application of cable anodes is much more beneficial, and especially that during correct operation the life-time of such a system is very long /18/. The paper of Smith, Salim and Salikin /19/ also confirms that cable anodes can be applied for protection not only of underground pipelines, but also of large fuel tanks with a chain of cable anodes. The conducting polymer material also works remarkably well as an anode of cathodic protection systems of piles submerged in sea water /20-22/.

An interesting application of cable anodes can be found in papers of Jensen and Tems /23, 24/. In this case composite anodes are used for cathodic protection of internal surfaces of steel pipelines covered from the inside with concrete. The composite anode placed inside concrete gives much better current distribution parameters than in the case of application of a conventional cathodic protection system. More advantages in application of composite anodes were noticed with development of composite anode production technology. Kim, Park, Jung and Kim /25/ stated that anodes based on EPDM (ethylene-dien terpolymer) when submerged and in wet sea water environments can exhibit better operating properties than platinum anodes. In most cases graphite or conducting carbon black are the main conducting components in a composite anode. Admixing is also possible of the polymeric mass with powdered metals such as: copper, silver and gold. However, they do have some disadvantages, namely: they require the choice of sulphur-free vulcanising agents; they make it difficult to obtain a good dispersion of mixture components, deteriorating processing properties of the mixture and properties of the rubber. Investigations of Kovatch /26/ prove, however, that good operating results are obtained by joining the polymeric mixture with active metal oxides.

5 NEW TRENDS IN IMPROVEMENT OF COMPOSITE ANODE PROPERTIES

Good operating results are obtained by a combination of the polymeric mixture with active metal oxides /26/. The presence in the polymeric composite of an oxide characterised by high electrocatalytic activity improves its polarisation characteristics, decreases the value and improves potential stability during long-term operation, and also decreases the anode consumption. Also, the addition of modified carbon material allows optimal electrochemical and electric parameters to be attained at significantly lower filler contents. Application seems justified of modified carbon materials when formulating the composition of composite electrodes as anodes in cathodic protection. Their presence may affect the increase of current-carrying capacity of cable anodes /27/.

Anodes based on carbon fibres are a more modern family of anodes belonging to this group /28/. The idea of using this material was formed due to very good results of application of carbon fibres in difficult operating conditions in aviation and the army. Further investigations of composites based on carbon fibres were performed by analysing the relation of the orientation of fibres in the composite mass by electrochemical measurements /29/. Laboratory investigations of carbon fibre anode operation in sea water have proved that in environments of large conductance (sea water), relatively high polymer losses are possible, especially during anodic polarisation at a relatively low current equal to approx. 1 $\mu A/cm^2$ /30/. The cause of this problem is probably connected with the process of anodic reactions of oxygen evolution. The process of oxygen evolution is a multistep reaction characterized by formation of anion-radicals at transition stages, for instance $O_2^{\cdot}$ or other unstable anions like HO_2^-. Due to high reactivity of these products some undesired reactions with anode material occur, leading to a significant mass loss of the anode.

Anodes based on carbon fibre materials have not yet been implemented. However, in the very near future we may expect literature communications concerning results of practical application of these type of anodes in cathodic protection.

6 SUMMARY

The information presented in this paper describes basic features characterising cable anodes. A different method of anode installation allows elimination of problems connected with potential variations of the protected structure and interference of protective current on other structures. This in turn decreases operating costs. Very good mechanical properties of the composite material allow the avoidance of problems connected with damage of anodes during installation. Placement of anodes very near the protected structure significantly simplifies installation of the anode system during construction of, for example, a pipeline and limits the current load flowing through the composite material.

The literature presented in the references point to notable interest in this problem and the obtained technological and economical effects are significant. One may expect that these types of solutions will be applied much more frequently in the near future.

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