Potential Distribution of Cathodic Protection using Mg as a Sacrificial Anode

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Abstract:

Cathodic protection in the sacrificial system is essentially a controlled electrochemical cell; corrosion on the protected structure is shifted to the anode. When the anode material is coupled to steel, they behave anodically and discharge current.In this work, magnesium used as sacrificial anode for the protection of carbon steel rod that buried in soil with resistance of 1000, 1400, 1800, and 2200Ω/cm that simulate wide range of resistance of Iraqi soil.Potential distribution in different positions between sacrificial anode and the protected structure was measured with respect to copper - copper sulfate electrode, showing that the conditions for the sacrificial anode for the protection of carbon steel rod and simulate with contours.The result show that the increasing of soil resistivity is reduces anode life and impairs its performance. In addition, the changing of sacrificial anode is important because it consumed therefore, it is important to optimize the distance of sacrificial anode from protected structure according to soil resistivity so that avoiding the polarization that causes high consumption rate of anode.

Keyword:cathodic protection, sacrificial anode, potential distribution.

Introduction

Cathodic protection essentially means the reduction or elimination of corrosion on a metal surface by forcing the metal to become a cathode and it is mainly used on many types of structures, such as pipelines, underground storage tank and ship hulls.The two general types of cathodic protection systems are sacrificial and impressed current. Both types of systems can effectively transfer the corrosion reaction (oxidation) from the metal surface to an external anode. If all exposed parts of a structure become cathodic with respect to the electrolyte, corrosion of the structure is eliminated [1].The use of sacrificial anode technologies is a rapidly growing branch of electrochemical treatment for corrosion-damaged structures. The original technologies are general less powerful than impressed current cathodic protection but they are less complex to apply. The technology requires no installed power supply and the installation of electrical cables is mainly limited to non-critical monitoring

[2]. Galvanic cathodic protection systems consist of sacrificial anode fixed to the structure during manufacturing, and provide specified wiring for an inspection station installed near the surface of the ground. Sacrificial anode systems use a material that will develop a more negative voltage when coupled with structure. Typically, sacrificial anode materials include aluminum, magnesium, and zinc.

Galvanic systems have limited life spans during which the sacrificial anode will continue to degrade and protect the structure (tank or piping). When the sacrificial anodes are longer capable of protecting the structure, they lose their protection and being to corrode [2, 3].

Cathodic protection in the sacrificial system is essentially a controlled electrochemical cell. Corrosion on the protected structure is shifted to the anode. When the anode material is coupled to steel, they behave anodically and discharge current, which is picked up by the structure, arresting the corrosion process on the structure [4], and have the advantages of being [5]:

1. Simple to install.
2. Independent of any source of electric power (self-powered).
3. Low maintenance requirement.
4. Less likely to cause stray current interference problem on neighboring structures.
5. When the current requirement is small, a galvanic system is more economical than impressed current system.

Disadvantages are [6, 5]: results and discussion

1. Low driving voltage.
2. Limited to use in low resistivity soils.
3. Not an economical source of large amounts of cathodic protection current.

Current distribution in cathodic protection system is dependent on several factors, the most important of which are driving potential, anode and cathode geometry, spacing between cathode and anode and the conductivity of the aqueous environment which is favorable toward good distribution of current [7].

Magnesium is the most commonly used sacrificial anode material for the protection of buried structures. Magnesium anodes are also used for the protection of the interiors of water tanks and heaters, heat exchanger, condensers, and waterfront structures. And because of their large driving voltage are principally used in soils, water tank, and similar high resistance media. In high conductivity, environments such as seawater magnesium anodes are generally not recommended because of risk of overprotection and high consumption rate [8].

Magnesium has an equilibrium potential of $-2.61V$ vs. SCE and therefore theoretically can provide a very large driving voltage. However,

practical measurements indicate relatively more noble corrosion potential probably due to the electrochemical inefficiency of the metal as a sacrificial anode. The low efficiency (50-60%) has

been attributed to hydrogen evolution at local cathodes and complex surface chemistry at the anode surface. The theoretical current capacity for a magnesium anode is approximately 2200 Ah kg^{-1} whereas actual measured values are in the range of 1200 Ah kg^{-1}[9].
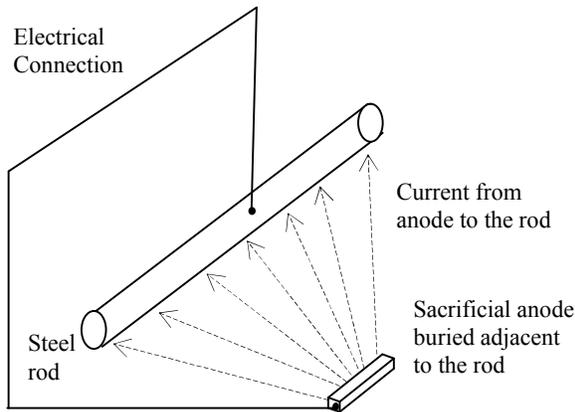

Figure (1) Application of cathodic protection by sacrificial anode

Results And Discussion

Figure (2) shows the potential respect to cu/cu sulfate electrode for soil resistivity of 1000 ohm/cm, It is obvious that the potential is high and the anode could be consumed with short time because of Mg will be polarized at potential higher than 0.9 volt, however the potential required for cathodic protection of steel structure is 850 mV with respect to copper electrode [12] that showed in the figure as dotedline.
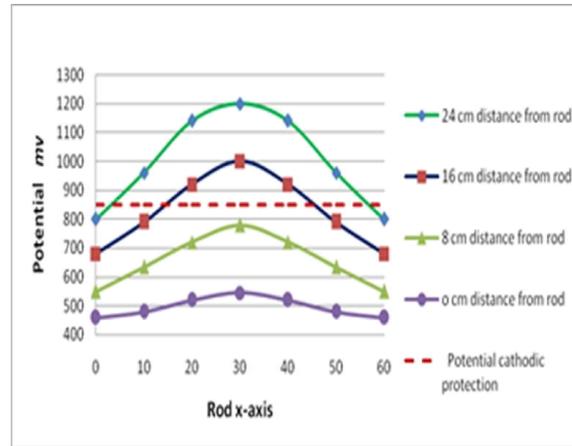

Figure (2)Potential Distribution for Soil Resistance 1000 ohm-cm

Figures (2 – 5) present that the effect of various soil resistivity on potential distribution for Mg (sacrificial anode) on the tube, **figures (3 – 4)** show that the potentials for cathodic protection are slightly acceptable. In addition, from **figure (5)** it can be noted that the potential covered a small region of pipe (in the middle) with protection (high soil resistivity will impede current flow from the anode) [13]

All the results indicate that the ends of the pipe (at x=0, x=60 cm) without protection (the potential decrease down 850 mV mean that the anode (Mg) used as sacrificial is not covering all pipe length with enough protection. For this reason, we can either use another anode (increase the number of anode) or use a large anode instead of this anode until the pipe is becomes fully protected.

It is possible to consider that the optimum soil resistivity 1400 ohm/cm as shown in **figure (6).**
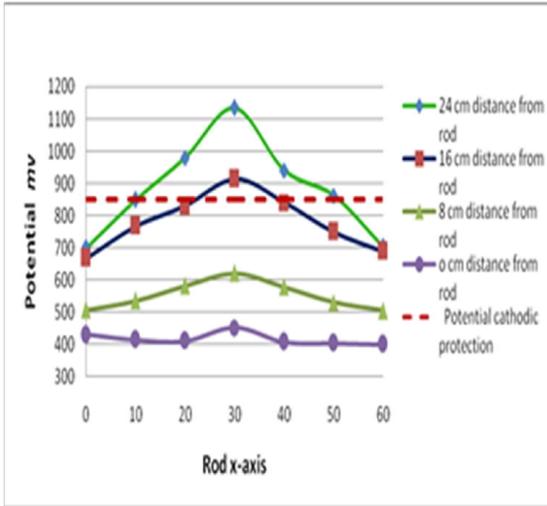
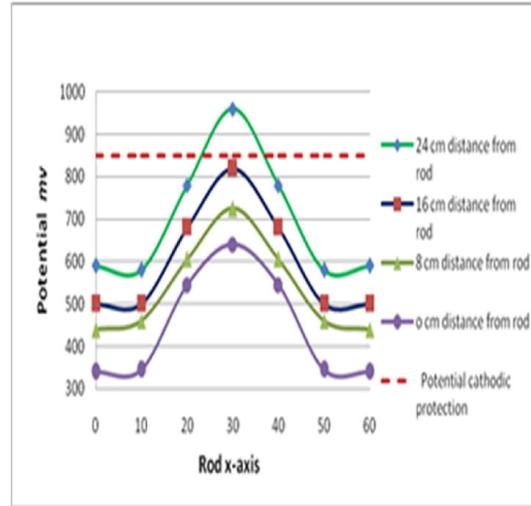**Figure (3)Potential Distribution for Soil Resistivity 1400 ohm-cm**

Figure (5)Potential Distribution for Soil Resistance 2200 ohm-cm
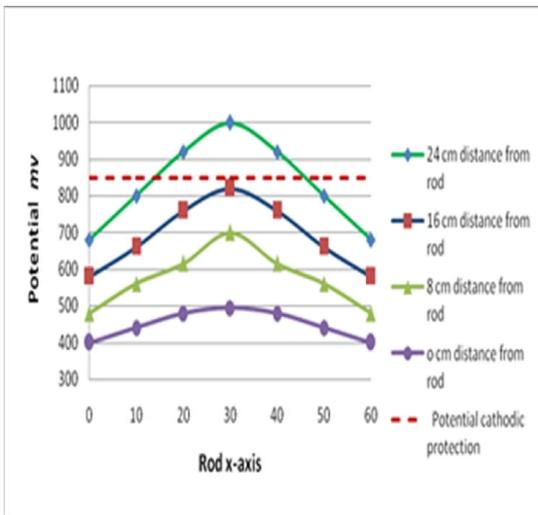

Figure (4)Potential Distribution for Soil Resistance 1800 ohm-cm
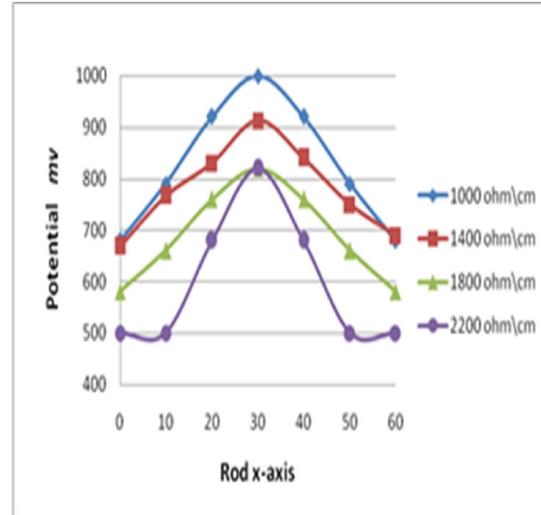

Figure (6) The Effect of Soil Resistance on Potential Distribution in 16 cm distance from rod

On the other hand figure (7) illustrate that the yellow color means the pipe with enough protection; the green color clears the pipe without protection, and the red color for polarization anode.

It is obvious from above that the pipe in the yellow region will be protected.

Calculation:-

$$V_T = V1 + V2 + V3 + V4$$

Kirchhoff's low (Potential voltage at distance (0, 8, 16, 24) cm

$$V_T = IR_1 + IR_2 + IR_3 + IR_4 \quad \text{Ohm's low}$$
$$\text{(I constant)}$$

$$Ri = xi\delta$$
$$V_T = I\delta(x_1 + x_2 + x_3 + x_4) \quad (\delta \quad \text{Soil}$$
$$\text{resistance)}$$

Using above equation to draw the contours for the potential from the sacrificial anode to the rode.

IV. Conclusion

For the same distance and different soil resistivity it was found that, the soil with low resistivity required the minimum number of anodes that used for protection, which means:-

1. The number of anodes increase with increasing of soil resistivity (reduce anode life).
2. Changing the sacrificial anode because it consumed therefore, it is important to optimize the distance of sacrificial anode from protected structure according to soil resistivity so that avoiding the polarization that causes high consumption rate of anode.

From above figures we can calculate the number of anodes needed for protection based on soil resistivity, it can be compute the number and distance of anodes, for example (soil resistivity 1000Ω\cm and 16 cm distance from the rod needed anode with same dimension every 30 cm) and (soil resistivity 1400Ω\cm and 16 cm distance from the rod needed anode with same dimension every 20 cm).

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توزيع جهود الحماية الكاثودية باستخدام المغنيسيوم كأنود مضحي

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الخلاصة:

الحماية الكاثودية بالانود المضحي هو خلية سيطرة كهروكيمياوية,حيث ان التآكل على التركيب المحمي يحوّل إلى القطب الموجب(الانود). عنداقتران القطب الموجب بحديد الفولاذ.

في هذا العمل، إستعمل المغنيسيوم كأنود مضحي لحماية قضيب من الحديد الفولاذي الذي دفن في التربة ذات مقاومة 1000, 1400, 1800، و2200 اوم / سنتيمتر والذي تغطي معدل مقاومة التربة في العراق.

توزيع الجهود في مواقع مختلفة بين الانود المضحي والتركيب المحمي قيس تبعا لـ القطب الكهربائي نحاس ـ نحاس ، حيث ان التوزيع يبين شروط الانود المضحي لحماية قضيب من الحديد الفولاذي ووضح بالمخططات. اوضحت النتائج ان زيادة مقاومة التربة النوعية تقصر عمر الانود وتضعف أداءه. بالإضافة الى اهمية تحسين مسافة الانود من التركيب المحمي تبعا لمقاومة التربة النوعية لكي يتفادى الإستقطاب الذي يسبّب نسبة الإستهلاك العالية للانود.