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POSSIBLE CORROSION PROBLEMS IN LIGHTNING PROTECTION SYSTEMS

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Abstract

Various materials are available to build lightning protection systems. Selection of materials and cross-sections requires knowledge of the relevant standards and the various corrosion processes. The product standard for materials is contained in standard MSZ1 EN 62561:2012 in Hungary [1]. Most lightning protection systems are installed outdoors. The materials used are exposed to the risk of corrosion outdoors due to environmental influences. This requires the use of corrosion-resistant materials and solutions.

Keywords*: Corrosion, corrosion protection, metals and lightning protection materials.*

Introduction

There are different materials available for building lightning protection systems. Selection of materials and cross-sections requires knowledge of the relevant standards and the various corrosion processes. The installation requirements are set out in MSZ EN 62305-1,3,4:2011 and MSZ EN 62305-2:2012 2nd edition, and the product standard for materials is contained in MSZ EN 62561:2012 [1]. This standard requires not only the materials for lightning protection systems to be used but also the minimum cross-sections to be used.

Types of useable materials

The following materials may be used in lightning protection[2]:

- Steel and stainless steel
- Galvanized steel[3]
- Copper, aluminium and aluminium alloy
- Metal coated materials
- Composite materials (with PVC or high voltage insulation coating)

[1] MSZ = Magyar Szabvány = Hungarian Standard
[2] MSZ EN 62561:2012 obligations
[3] Hot-dip galvanized steel = zinc-coated iron material on its surface

Steels

According to international definition [2], steels are iron (Fe) materials with a carbon (C) content of less than 2% or less and may contain other substances. There are exceptions, such as certain chromium steels with a carbon content greater than 2%. Stainless steels are substances which, due to their chemical composition, are not oxidized, so they are resistant to the harmful chemical processes created by various environmental influences. Hot dip galvanized steel [3]

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means steel which has been zinc coated (Zn) with its protective surface. Zinc plating of different surfaces is also called galvanizing [4], for which there are several methods [3].

Aluminium and Alloys

In addition to steels, aluminium and various aluminium alloys are common materials. In most cases, "pure" aluminium is made of a soft material, with an alloyed version in both soft and semi-hard versions

Metal Coated Materials

Nowdays, some metal coated materials have appeared (figure 1). These are metallic materials that are coated with other metals in micron thickness, such as copper-coated steel (Fe/Cu), copper-coated aluminium (Al/Cu), tin (Sn) coated copper (Cu/gal Sn). These materials have two great advantages. One is that they are cheaper than their "solid" counterparts. For example, copper-plated steel is significantly cheaper than the solid copper version. Another benefit is the visual aspect. The use of copper conductors is aesthetically pleasing for the appearance of a copper-roofed building. The coating is corrosion-resistant until it is damaged, from which point the material begins to deteriorate during the electrochemical corrosion process. Interestingly, the bonding of copper and aluminium metals is extremely electrochemically harmful, but due to the special coating technology, this "pairing" does not cause electrochemical corrosion to occur without external damage.

Fig.1. Zinc (Zn) coated steel, copper (Cu) coated aluminium and tin (Sn) coated copper arrestor [5]

Composite Materials

Composite materials are aliased materials. They are materials that consist of two or more components with different properties (chemical, physical, etc.) that results in the combination of a new substance. Such properties can be e.g. stronger mechanical properties, corrosion resistance, lower weight etc. In lightning protection, the word 'composite' is not used, instead, the word 'insulated conductor' is commonly used to build protection. There are two types, one is PVC coated conductor. Here the function of the insulation is to protect against corrosion. The other is the conductor with high resistance insulation. Here, the purpose of this isolation is to prevent induced high-voltage insulation. By using it, you can avoid discharges to metal elements or to possibly man. Coating with the highest insulating properties is equivalent to 90 cm air insulation. Some types of these can be seen in figure 2.

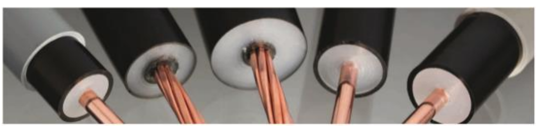

Fig.2. Types of composite materials [6]

Corrosion[4] of Materials

Most lightning protection systems are installed outdoors. The materials used are exposed to the risk of corrosion outdoors due to environmental influences. Due to definition, the corrosion is the failure of materials to lose material due to contact with their environment. One problem that arises is that the electrical conductivity of the various oxide layers is much worse than that of their pure metal counterparts because of their higher resistance, which can result in significant heating at different contacts. This creates a dangerous ignition effect. Another problem is that with such increased resistance the lightning current is looking for another way to the ground. This requires the use of corrosion-resistant materials.

Types of Corrosion

There are several types of corrosion. Types of chemical, electrochemical and physical corrosion. The structural materials of lightning protection are metals due to the need for conducting lightning currents.

[4] Latin corrodo = to erode

Chemical corrosion refers to the failure of metals due to various environmental influences. The metals are then converted to oxides, hydroxides, sulphides and carbonates by substances taken from their environment. In practice, this process is known as rusting.

Electrochemical corrosion occurs when two metals of different electrode potentials are in contact with one another and galvanically interconnected by a conductive medium (electrolyte). Then a galvanic element[5] is formed, whereby one of the parties is transformed into some kind of oxide and loses its pure metal character.

Physical corrosion occurs due to the weakening of the bond between the crystals. The result of this process is, for example, the appearance of cracks. If the structural element is subjected to mechanical stress (e.g. tensile stress), then the corrosion effects on a more aggressive level of the structural element.

Connection options for different metals

Metallic materials should not be galvanically bonded to any metallic material. Different metals can only be "paired" with specific materials. If the wrong combination is chosen, moisture will form a galvanic cell and cause electrochemical corrosion of the materials. The pairing options are listed in table 1.

Table 1. Connecting options of metals [7] (Own edited version)

	Steel	Aluminium	Copper	StSt
Steel (St/tZn)	yes	yes	no	yes
Aluminium	yes	yes	no	yes
Copper	no	no	yes	yes
StSt	yes	yes	yes	yes

Not all metallic materials can be combined with other metallic materials due to mentioned reasons above, so the question then arises as to what needs to be done and what solution exists if we still want to achieve galvanic coupling of such ’non-pairable’ materials? The solution is to use two-metal connecting elements (e.g. types of clamps). The version shown in figure 3, is suitable for forming a copper-aluminium connection. The aluminium-copper connection is very electrochemically dangerous, but the middle plate of said device is made by a special process which does not develop electrochemical corrosion.

[5] Galvanic cell: connecting two materials of different standard potentials with a conductive medium

This solution can securely connect copper and aluminium materials. Such materials are called cupal[6] materials.

Fig.3. Two-metal clamp (cupal[6]) [8]

Protection against corrosion

It is possible to protect against this type of damage. Protection can be achieved by passive, active corrosion protection or also using corrosion resistant materials.

Passive corrosion protection means applying a suitable coating. Then a specific type of corrosion-resistant surface (heat, chemical, etc.) is applied to the surface to be protected.

Active corrosion protection

When you connect an external power source to a metal or alloy, the corrosion rate changes. If the metal is polarized anodically, the corrosion current density will increase and the corrosion rate will increase In contrast, when the metal is cathodically polarized, the corrosion current density is reduced (the external power source is working against local elements), the corrosion rate is reduced. In practice, this is the case, for example, with a high-pressure gas network laid in the ground where 60-70 V DC is connected to the gas pipeline.

The use of corrosion-resistant materials means the use of alloys. There are two types of materials. Different metals combined with other metals (alloys) and weather resistant steels. Metallic alloys are expensive materials.

Corrosion protection aspects of lightning protection

When designing lightning protection, it is important to consider not only the chosen material, but also other considerations.

They are:

- Built-in materials should be accessible
- If enclosed sections are to be installed, they shall be hermetically sealed
- Do not have a discontinuous weld outdoors [9]
- There should be no collection point for dirt

[6] cupal = Word made up of chemical symbols of copper (Cu) and aluminium (Al) and the word ‘to pair’. Not acronym.

Potential for corrosion in lightning protection materials

There are several types of corrosion sources when installing lightning protection systems. It is important to apply appropriate corrosion protection because e.g. for materials located in difficult to access places (height, cultural facilities, etc.), you may incur additional high repair costs.

Chemical corrosion occurs in two cases when lightning protection is installed. One of the cases is the use of outdoor materials by humidity and rain.The other case is the earth-installed drain, which is used in addition to the moisture/water in the ground, even in various acidic environment. Experience has shown that the corrosion effect at crossings is very strong. In practice, this means the passage of materials between air-ground and concrete-air media. It is extremely important to choose the right material, because it is possible to replace the structural elements outdoors, but with some exceptions, it is no longer possible to change the materials placed in the ground, these materials must be functional for as long as practically possible the building will stand. Examples of such materials are alloy aluminium and hot dip galvanized steel like V2A[7] [10]. In practice, the use of these materials is widespread because of their excellent heat load resistance, which is important because lightning current can carry a high degree of heat load [11]. Environmental considerations are also important when selecting materials. Contrary to the urban environment, the humidity near the seashore aggressive due to its salt content and makes the structures more stressful [12], so it should be taken into consideration. In addition to corrosion caused by water, the corrosion resistance to acidic media is an important criterion for materials used in ground. For example the hot dip galvanized steel in soil corrodes before the lifetime of the building (10-30 years). The solution is to use an alloy containing 2% molybdenum (Mo). One type of material is V4A[8] [13], shown in figure 4.

Fig.4. Unalloyed and alloyed version of steel [14]

[7] V2A: international code is 1.4301 [10]
[8] V4A: international code is 1.4401, 1.4404, 1.4571 [13]

Electrochemical corrosion occurs when two metals of different standard potentials come into contact with one another and are galvanically bonded by a damp medium (e.g. rain, mist, water from sprinkling, etc.). In practice, this is case may occur for electrical connections or at the connection of the mechanical supports outdoors where moisture can touch the surfaces.

For electrochemical corrosion or a typical example of its prevention, which affects many buildings, is the use of steel in concrete during grounding. The steel material in the concrete is then contacted with a steel grounding device in the ground. At first thought, one might think that joining the two iron materials would not be a problem, but in reality this should not be done. The steel in the concrete behaves as if it were (wet) copper in the soil, thus creating an electrochemically iron-copper connection which should be avoided (figure 5).

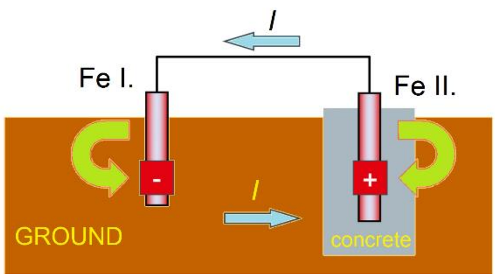

Fig.5. Connected iron in ground and in concrete [15] (Own edited version)

The solution in the ground is the use of stainless steel. It is the grounding's task to inject lightning current coming from the arrester into the ground. This can be achieved if the medium is damp, that is, the earth must be moved / placed in a damp medium. From the design point of view, there are many cases where the building has thermal insulation, waterproofing, stone chips or the concrete foundation itself is made of waterproof concrete. In this case, due to the mentioned insulation solutions, the galvanic connection of the conductor must be driven into a damp medium by a separate solution. This can be done using stainless materials. An important requirement is the outstanding durability, because the grounding structures placed under the building cannot be replaced. It is also important to note the choice of materials for brackets or clamps that may be included in the plaster. Again, no materials should be placed in the plaster except copper and hot dip galvanized steel as the environment of the plaster is alkaline, which permanently damages this structural element and as a result, the aluminium cannot form an oxidation barrier.

Physical corrosion is not common with lightning protection systems. The specific weight of the 50 mm^2 cross-section aluminium wire is only 136 kg/km, so for a 100 m tall building this would only mean a total weight of 13.6 kg which is partially relieved at intervals by the vertical load in the supporting brackets at intervals.

Conclusions

This article describes the materials used in lightning protection systems and their types of corrosion damage. These forms of corrosion can cause very serious damage as the lightning protection system is comparable in life to the life of the building, so it is essential to use corrosion resistant materials. Exterior structural elements can be replaced, but in the ground, especially with respect to the building under the building cannot be replaced, so it is very important to know these materials. In many cases, we do not pay attention to the pairing of materials that I detailed in my article. In conclusion, when selecting lightning protection materials, it is mandatory to comply with the standard MSZ EN 62561:2012 and to take into account the corrosion stresses summarized in this article.

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