Use of aluminum conductors in submarine power cables

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ABSTRACT

This paper identifies aspects to be considered when selecting aluminum as conductor material in submarine power cables, as an alternative to copper. After a basic introduction into the role of aluminum alloy and temper for the strength and electric conductivity of aluminum the results of tensile tests on welded aluminum conductors are reported. It is demonstrated that aluminum conductors are strong enough for most submarine applications. A comparison of aluminum and copper cables of equal transmission capacity is made showing that both alternatives are very similar with respect to size, weight and sea bottom stability. The economic advantages of aluminum cables lay in the largely reduced conductor material cost and, in many cases, reduced installation cost due to fewer installation campaigns and submarine cable joints.

KEYWORDS

Aluminum conductor, corrosion, cable weight, tensile strength, seabed stability, vortex-induced-vibration.

INTRODUCTION

Aluminum, with a density of 2,7 kg/dm^3, is the lightest of the most common used metals and the term “light alloys” was used for a long time as an umbrella term for the different type of aluminum alloys available. The low weight is maybe aluminum’s strongest characteristic but aluminum and its alloys have many more strong and positive characteristics which make them very suitable to use in several different applications.

Beside copper, aluminum is the only material used for power cable conductors in an industrial scale. Its low weight and advantageous price has made it the conductor material of choice for underground cables in many countries, e.g. Denmark and UK. However, the use of aluminum for submarine cables is less common. Some utilities see the economic opportunities of using aluminum while others exclude aluminum conductors already in the project specifications.

Mechanical strength and corrosion issues are the mostly heard arguments against the use of aluminum in submarine power cables. Also seabed stability is sometimes questioned for submarine cables that are not buried.

ALLOYS AND TEMPER STATE

Aluminum is available in many different alloys and temper states. The mechanical and electric properties vary largely across this spectrum. Aluminum alloys are grouped in number series 1XXX, 2XXX etc. related to their main alloy constituents.

Pure aluminum from the 1XXX series is usually chosen for insulated high-voltage cables, eg aluminum 1350 (Al min. 99,5 %) because of its high electric conductivity. Prior to 1975, aluminum 1350 was designated as EC, or Electrical Conductor, aluminum. Alloys with higher tensile strength but lower electrical conductivity than 1XXX are used for overhead line conductors, e.g. 6201. Table 1 shows the principal aluminum alloy series and in brief properties and applications.

Table 1. Aluminum alloys and their applications

Alloy series	Alloy elements	Properties	Applications
1XXX	None (>99% Al)	Good weldability, good corrosion resistance	Conductors, food industry, deep drawing
2XXX	Copper	High strength, poor weldability, good machinability	Air frames-Aircraft parts, rivets, machinery components
3XXX	Manganese	Good weldability, good corrosion resistance	Marine structures, building industry, radiators, tubes/pipes, soft drink cans
4XXX	Silicon		Welding material
5XXX	Magnesium	Good weldability, Good corrosion resistance	Chemical plants, marine structures, shipbuilding
6XXX	Magnesium Silicon	Good weldability, good corrosion resistance	Extruded profiles, window frames, sailing boat masts, diversified constructions
7XXX	Zinc	High strength	Bridges, beer barrels, aircraft, space industry, ski poles

Beside the chemical composition, as expressed in the alloy designation, the temper state of the material is decisive for the mechanical properties. The temper state of a particular aluminum grade changes with the degree of cold working or degree of age hardening. The different temper states available for aluminum and its alloys are described thoroughly in other articles. The temper state expressions are explained in the European standard EN 515 [1]. The basic tempers are F (as manufactured), O (annealed), H (work hardened) and T (age hardened). The letters are followed by 1 to 5 digits to explain the complete temper state of the material.