

Development of High Strength Aluminum Wires for Low-Voltage Automotive Wiring Harnesses

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ABSTRACT

The weight of wire harnesses increases with the growing number of systems used in the vehicle in recent years. For the purpose of reducing the weight of wire harnesses, aluminum instead of the conventional copper is getting popular as a wire conductor. The conventional Al wire, however, is not able to be used for small gauge wires such as the sizes of 0.35mm² and 0.5mm² and wires used in the engine compartment due to its insufficient conductor strength. For this reason, we tried to develop a stronger aluminum alloy that has conductor strength equivalent to or stronger than that of copper. For the first time in the industry, we have successfully developed a high-strength aluminum alloy wire. Starting with the application of 0.35mm² wire for engine wire harnesses, we began mass production in April 2015.

This paper reports the development of high-strength aluminum alloy that can be used for small gauge wires and wires used in the engine compartment. The target property of aluminum alloy to be developed was specified as 220MPa tensile strength and 50%IACS conductivity. Based on the age-precipitated 6000 series aluminum alloy, additive elements and their content were specified and the alloy composition was determined. The aging conditions were determined by examining the precipitation status of Mg₂Si intermetallic compounds. With this approach, we achieved 250MPa tensile strength and 52%IACS conductivity, both of which are better than the target. We have developed a 0.35mm² wire that is 53% lighter than the same size copper wire.

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BODY OF THE PAPER

1. Introduction

Vehicle weight reduction has been required in recent years to improve fuel economy due to possible environmental impact of exhaust gas as well as concern over diminishing fossil fuel supply.

With the growing number of on-board systems used for better safety and comfort, the number of circuits used in wire harnesses increases. With increasing circuit counts, increased vehicle weight is an issue of concern.

For the purpose of wire harness weight reduction, aluminum conductors are becoming popular alternatives to the conventional copper wire conductors.

Furthermore, aluminum wires provide reduced costs, when compared with copper wires, because of the recently escalating cost of copper. Weight reduction and low cost have triggered increased popularity of aluminum wire for future harness applications.

The conventional aluminum wire is not yet able to be used for small gauge wires such as the sizes of 0.35mm² and 0.5mm² for wires used in the vibration-influenced engine compartment due to its insufficient conductor strength. This limits the weight reduction possibility of wire harnesses.

For this reason, we have developed a high strength aluminum alloy that is as strong as or stronger than copper. This alloy enabled us to produce a 0.35mm² aluminum alloy wire usable in the engine compartment.

For the first time in the industry we successfully used aluminum wires for engine wire harnesses. The high strength 0.35mm² wire Production was started in April 2015.

This paper reports the development of high strength aluminum alloy that can be used specifically for small gauge wires and in the engine compartment.

2. Development of High Strength Aluminum Alloy

2-1. Development Target

In this alloy development, the target was to create an aluminum wire in the cross-sectional area range of 0.35mm² which is the smallest applicable size of conventional copper wire.

Both strength (tensile strength) and electrical conduction characteristics (electrical conductivity) must satisfy the respective criteria to use aluminum wires as automotive wires.

220MPa tensile strength and 50% IACS conductivity were set as target conductor characteristics. The target of tensile strength was set in order to secure the equivalent anti-vibration characteristics to the conventional copper conductor and based on the past strength data of terminal crimping. The conductivity target was set so as to use the same fuse used with the copper conductor when the aluminum conductor is one size bigger than the copper conductor according to the wire size lineup of the ISO standards.

Other detailed material properties are required to satisfy the ISO and other public standards.

2-2. Alloy Design

The conductivity of the typical pure aluminum for industrial use (1060: 99.6% purity) is as high as 62%IACS, but the tensile strength of it is as low as 70MPa^[1]. Higher strength is required to use aluminum for automotive wires.

The aluminum material used for the conventional aluminum wire is alloyed with strengthening elements. Nevertheless its strength is about 120MPa, equal to half of that of copper material, and the aluminum material is only used for small gauge wires down to 0.75mm² ²⁾

In this development, Mg and Si, namely the 6000 series alloy were selected as elements added to aluminum due to the 6000 series owning the most similar properties to the target properties according to the properties of respective aluminum alloys (Figure 1).

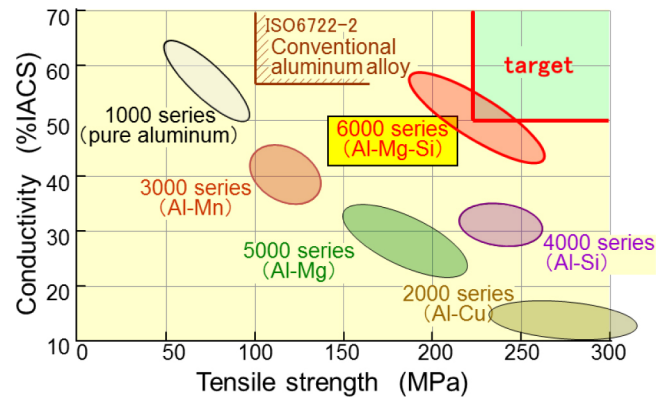


Figure 1. Properties of Respective Aluminum Alloys

With an early sample made by casting the alloy materials, the additive amounts of Mg and Si were determined based on alloy strength, conductivity, wire drawing performance, and elongation characteristic that influences handling.

As a result, we determined the suitable range as shown in Figure 2 and specified the respective additive amounts that satisfy 220MPa tensile strength and 50%IACS conductivity.

Within the suitable range, we determined the optimum range that facilitates manufacturing control, including a consideration of the later described study results of thermal refining method, and selected Al-0.6mass%Mg-0.5mass%Si as the value to design alloy.

In the constituent range selected this time 250MPa tensile strength and 52%IACS conductivity were achieved, resulting in better characteristics than the target values.

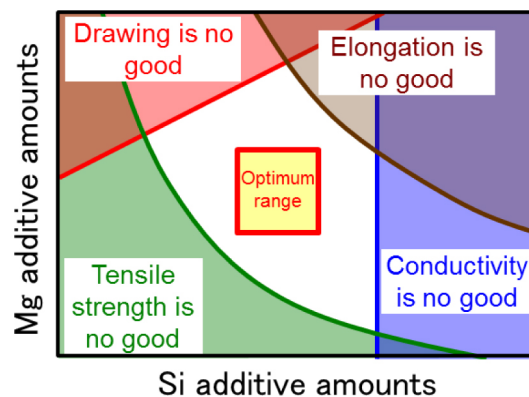


Figure 2. Results of Mg/Si Additives Study

2-3. Development of Refining Method

The 6000 series aluminum alloy selected in this development is heat treatable. Solution heat treatment that makes Mg and Si additive elements are dissolved into aluminum. Aging heat treatment that makes the chemical compound Mg₂Si precipitates in aluminum are used to develop a hard alloy.