Aluminium and its wire applications – a valid alternative for copper

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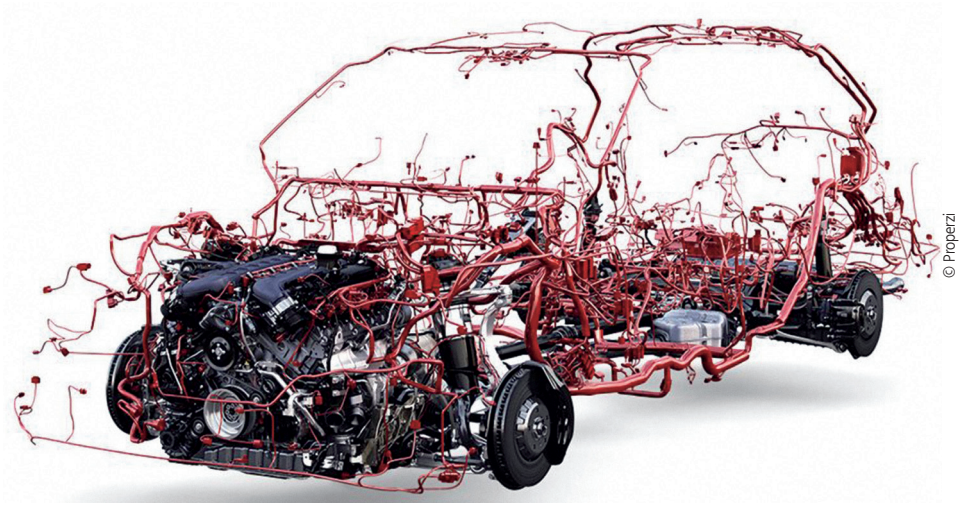
The vast majority of applications for aluminium wire is in the electrical sectors. Choosing conductive metals for different industries and applications can be a challenge. Copper is often used in cables and wires because of its excellent conductivity and malleability. But it is relatively heavy and expensive compared to aluminium. Switching to aluminium, which is lighter and significantly less costly than copper, is a viable option in many cases. Using aluminium successfully is a matter of understanding the capabilities of this conductive metal and how to deal with the challenges it presents.



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Typical example of wiring in automobiles

If aluminium is used as a conductor material, its lower conductivity requires a wire size that is approximately one-third larger than that of a copper wire. In the end, however, the insulating material used with the wire plays a crucial role in performance and an aluminium wire can possess the same current carrying capacity as a copper wire. Aluminium's larger wire size would only be a disadvantage in applications requiring tight spacing, e.g. when installed in densely packed control boxes.

The facts for aluminium speak for themselves when it comes to the issue of weight. As a raw material, aluminium is approx. 70 percent lighter in weight than copper. This can be helpful in the efforts of numerous application fields looking to reduce the weight of all components. Naturally, when used in electrical cables, the lower weight makes them easier to install. High-voltage lines have long been made from aluminium; the lighter weight reduces the tensile force placed on wire and masts significantly. But even industries such as automotive manufacturing and the aeronautical industry are switching to aluminium wires. This is why entire wiring harnesses made of aluminium are already installed in the Airbus A380.

Aluminium wiring in homes has an interesting and controversial history. We've had lots of questions: "Is it safe? Should it be replaced?" The short answer is that it is safe and does not need to be replaced. However, it's good to be aware of some special considerations.

Electrical wiring in homes has traditionally been copper since the introduction of electricity in homes in the late 19th century. Aluminium wiring was introduced to homes in North America in the mid-1960s. The price of copper was very high, and aluminium was a cost-effective alternative.

Not as good as copper

Was aluminium as good as copper? Not quite. It was recognized from the beginning that copper is a better conductor of electricity. The manufacturers and authorities adjusted for that by using slightly larger aluminium wire to perform the same work as copper.

Shortly after aluminium wiring became popular, some problems started to appear. These included flickering lights, warm cover plates on switches and receptacles, and burned insulation on wiring. There was an overheating issue, and overheating can mean fires. They looked into it and found that there were three other differences between copper and aluminium.

- *Softness:* Aluminium is a much softer metal than copper. Electricians who had always worked with copper found that it was very easy to nick, cut or crush the aluminium wiring when removing insulation or making connections. They had to be gentler. Damaged wire creates local hot spots and results in overheating.
- *Creeping:* When electricity flows through wire, the wire heats up. Aluminium wire expands more than copper when it heats up. The repeated expansion and contraction as the wire heated up and cooled down caused the wire to creep out from under the terminal screws that held the wire in place. This wire creeping resulted in loose connections and overheating.
- *Rusting:* When metals rust, they form an oxide on the surface. Rust on steel is red, rust on copper is green, and rust on aluminium is white. It's not a big problem when copper wiring rusts, since the copper oxide that forms is electrically conductive. It does not interfere with the wire's ability to do its job. When aluminium wiring rusts, the white oxide is not a very good electrical conductor. It does interfere with the flow of electricity, and again, can cause overheating.

The problem was at connections, such as receptacles, switches, light fixtures, appliance connections, and at the panel. The solution was special connectors.

In recent years, the automobile market has invested immense resources in order to reduce both the electric cables bill and the production of CO_2 to try to overcome these problems and today wire harnesses have become an important reality in this sector.

Obviously, Pure EC Grade Aluminium (99.7% Al) is not used, but rather wires made of 'patented' alloys in the 1xxx, 6xxx and 8xxx series.

The trend started in Europe 20 years ago and aluminium battery cable is already used in several vehicles by many companies. Some Italian cable battery manufacturers have won this bet and today these cables are mainly

made with Aluflex 131050 alloy and a standard EC Grade 1370 – Conductal 137050. Japanese automakers are close and hope to reduce vehicle weight by up to 20 kg by replacing copper with aluminium in various wiring applications. It is now very close to reaching these values. In the case of hybrid and/or electric cars, these values have even been exceeded.

Where and when it all started

Practically, in the field of electrical applications, aluminium has had an incredible development in the last 100 years. Here is where it all started: the earliest use of recognizable electrical cable was probably the early commercialized Telegraph lines such as the one strung between Washington, D.C., and Baltimore, Maryland in 1844.

These early cables were made of iron and were difficult to produce. In order to improve the production by lubricating the iron surface of the wires, copper sulphate was used to apply a thin copper coating. The superior conductive property of the copper was soon realized and copper eventually replaced these early iron conductors. By 1913 the International Electrotechnical Commission established IACS (International Annealed Copper Standard) as a benchmark for the resistivity of copper as being equal to 100 percent conductivity.

In the 1930s the first trials with PVC insulations were being made in Germany and by the end of the second world war there were significant varieties of synthetic rubbers and polyethylene.

By the 1950s PVC was commercially viable and replaced rubber cables in many areas, particularly in domestic wiring. Aluminium was also starting to be used widely as an alternative conductor. For many years pure aluminium 99,5% (AA1350) was the only aluminium used to produce wire.

A new era began

The first 8000 series electric conductor alloy, still widely used in some applications, was developed and patented in 1972 by Aluminium Company of America (Alcoa). This alloy, along with AA-8030 (patented in 1973) and AA-8176 (patented in 1975) perform mechanically like copper. Hence the new era of aluminium for electrical application began.

In the late 1940s, Continuus-Properzi invented the continuous casting and direct rolling process (CCR lines) for the production of nonferrous wire rod. In the beginning the lines were much simpler as the market required the casting and rolling of pure aluminium.

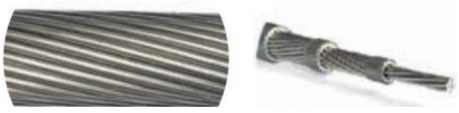
As the aluminium rod market evolved, and many different types of alloys were introduced to meet a wide range of applications, the Properzi CCR lines became more and more sophisticated and included the ability to produce tight coils in order to meet, and exceed, the needs of the rod producer and downstream cable manufacturers.

Here is a summary of the various applications for the electrical alloys that are produced on Properzi lines every day throughout the world.

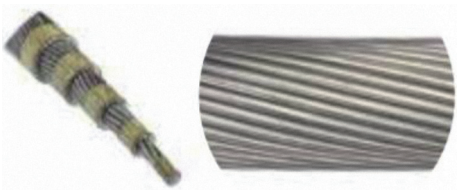
1. AAC (All-Aluminium Conductors)
2. AAAC (All Aluminium Alloy Conductors)
3. ACAR (Aluminium Conductor Alloy Reinforced)
4. ACSR (Aluminium Conductor Steel Reinforced)
5. AACSR (Aluminium Alloy Conductor Steel Reinforced)
6. ACSR/AS (Aluminium Conductor Aluminium Clad Steel Reinforced)
7. ACSR/TW (Shaped Wire Aluminium Conductor, Steel Reinforced)
8. ACSS/AS (Aluminium Conductors– Aluminium Clad Steel supported)
9. ACCC (Aluminium Conductor Composite Core)
10. High Thermal and HTLS Conductors

Explanations:

1) AAC (All Aluminium Conductors) – composed by various aluminium wires stranded in concentric layers having main applications in low voltage lines and substations connections



2) AAAC (All Aluminium Alloy Conductors) – composed by various aluminium alloy wires stranded in concentric layers having main applications in low, medium, high and very high voltage onto overhead lines



3) ACAR – (Aluminium Conductor Alloy Reinforced) is formed by concentrically stranded wires of Aluminium 1350 on a high strength aluminium-magnesium-silicon (AlMgSi) alloy core. The number of wires of Aluminium 1350 and AlMgSi 6xxx alloy depends on the cable design.

4) ACSR – (Aluminium Conductor Steel Reinforced) is concentrically stranded conductor with one or more layers of hard drawn 1350-H19 aluminium wire on galvanized steel wire core. ACSR conductors combine the light weight and good conductivity of aluminium with the high tensile strength and ruggedness of steel.

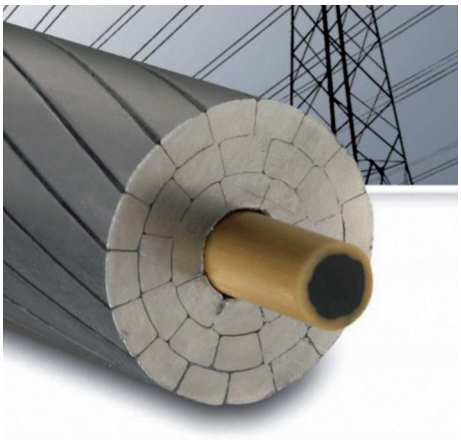
5) AACSR (Aluminium Alloy Conductor Steel Reinforced) – steel core aluminium alloy conductors composed by various aluminium alloy and galvanized steel wires stranded in concentric layers. Main applications include medium, high and very high voltage onto overhead lines.

6) ACSR/AS (Aluminium Conductor Aluminium Clad Steel Reinforced) - the mechanical properties of ACSR/AS conductors are similar to ACSR conductors but offers improved ampacity and resistance to corrosion because of the presence of aluminium clad steel wires in the core. These conductors are better replacements for ACSR conductors where corrosive conditions are severe.

7) ACSR/TW (Shaped Wire Aluminium Conductor, Steel Reinforced) – Shaped Wire Compact Concentric-Lay-Stranded Aluminium Conductor, Steel-Reinforced (ACSR/TW) is a concentrically stranded conductor, made with trapezoidal-shaped 1350-H19 wires over a high strength steel core.

8) ACSS/AS (Aluminium Conductors – Aluminium Clad Steel supported) – Aluminium Conductor Aluminium Clad Steel Supported (ACSS/AS or ACSS/AW) is a composite concentric-lay stranded conductor with one or more layers of hard drawn and annealed 1350-0 aluminium wires on a central core of aluminium clad steel core.

9) ACCC (Aluminium Conductor Composite Core) – the ACCC conductor utilizes a lightweight, high strength carbon and glass fibre core embedded in a high performance thermoset resin matrix, produced using an advanced pultrusion process. The hybrid structural core

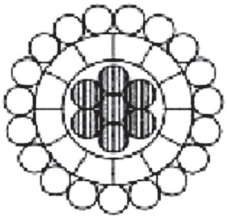


is surrounded by helically wound, fully annealed, trapezoidal shaped, high-efficiency aluminium wires.

10) High Thermal Conductors

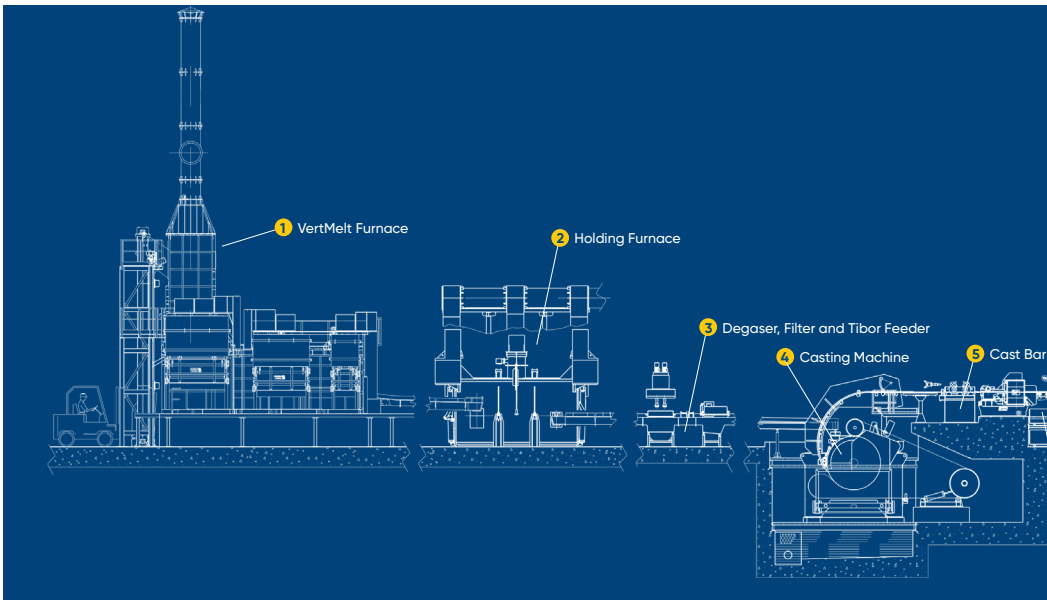
10 a) TACSR (Thermal resistant aluminium alloy conductors steel reinforced)

TACSR conductors are very similar in construction to a conventional ACSR conductor but the EC Grade Aluminium wires are replaced with Hard Drawn Aluminium wires of Heat Resistant Aluminium Alloy (generally known as TAL). TACSR can be safely operated continuously above 150° C allowing to pump more current through the conductor. Where there is a need to transmit higher power but restrictions on getting new power corridors approved, various types of TAL conductors are one of the best creative solution options to utilities. Ability of the zirconium doped aluminium alloy to maintain its electrical and mechanical properties at elevated temperatures makes these conductors a very cost-effective solution in refurbishing the existing lines with enhanced capacity.



10 b) GZTASCR (Thermal resistant aluminium conductors steel reinforced with GAP)

Gap-type ZT-aluminium conductor steel reinforced (GZTACSR) uses heat-resistant aluminium over a steel core. A small annular Gap is maintained between a high-strength steel core and the first layer of aluminium alloy strands. The gap between the first layer of trapezoidal shaped aluminium strands and the steel core is filled with high thermal resistant grease. The principle of the Gap type conductor is that it can be tensioned on the steel core alone during installation. This construction allows for low sag properties. Presence of heat resistant zirconium aluminium alloy makes the conductor suitable for continuous operation at elevated temperature (up to 210° C) without affecting its mechanical and electrical properties.



General layout of a Properzi CCR line

All of the aluminium alloys listed above are produced on a daily basis using Properzi CCR lines that have evolved over time in order to satisfy the progressing market requirements. Here is a short description of the line.

General layout of a Properzi CCR line

(1) VertMelt furnace: it has several operational advantages and it has been designed to minimize fuel consumption, grant constant and homogeneous melting rate and characteristics of the liquid aluminium with a capacity ranging from 1.5 up to 10 t/h.

(2) Holding furnace(s): the capacity is defined in accordance with the melting rate of the VertMelt, the production rate of the casting machine, and the alloy range to be produced in order to have the proper time to homogenize the liquid metal bath.

(3) Degaser, filter and TiBor feeder: these devices are usually required to carry out the liquid metal treatment just prior to casting. The main purpose is to reduce the hydrogen content, capture the solid inclusions and oxides in the metal, and inoculate the grain refiner, if needed.

(4) Casting machine: a wide range of casting machine models, differing mainly in the casting wheel diameter and cross section of the cast bar, can be provided in accordance with the production rate, the alloy range to be produced, and the environmental conditions.

(5) Cast bar straightener: to straighten the cast bar before entering downstream equipment such as the automatic bar shear, the induction bar heater, the cast bar cooling tunnel, and the milling machine.

(6) Automatic bar shear: to cut the bar automatically during the start-up and in the unlucky event of an emergency downstream.

(7) Milling machine: required when producing 5xxx series alloys to remove the upper layer of the cast bar.

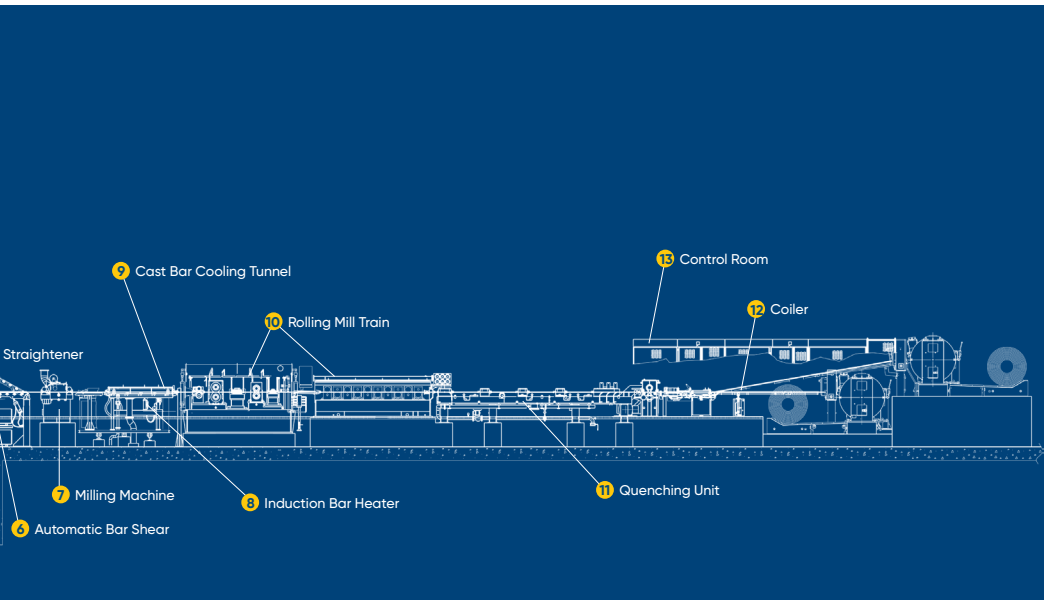
(8) Induction bar heater: when producing some alloys, electrical alloys in particular, it is required to increase the cast bar temperature before entering the rolling mill.

(9) Cast bar cooling tunnel: designed to reduce the cast bar temperature before entering the rolling mill in order to achieve the desired temper grade, particularly with 1xxx series alloys.

(10) Rolling mill: we have twelve rolling mill models, with 2-roll and 3-roll rolling stands, that can be combined in several rolling train combinations defined by considering the cast bar section (linked to the production rate), the alloy range, and the rod diameters to be produced. The Properzi unique combination of a roughing mill with 2-roll rolling stands that provide the necessary high reduction rate and a finishing mill with the legendary 3-roll rolling stands ensures rod diameter tolerance and quality surpassing the applicable specifications.

(11) Quenching unit: in order to cool the rod before being coiled and, in the case of some electrical alloys (particularly with 6xxx series), to achieve the desired temper.

(12) Coiler: the coiler model is defined according to the preferred coil type (loose coils or tight coils), the production rate, and the coil



dimensions / weight (European and/or American standard). The coiler is equipped with strapping and unloading units.
(13) Control room and electrical control cabinets: the widest range of the most common electrical / automation components can be incorporated in our design according to customer requirements / preference; including the latest market developments in automation and compatibility with Industry 4.0.

Regarding the shaped wire aluminium conductor mentioned above, Properzi since few years is capable to supply a CRE (Continuous Rotary Extrusion) called Pro-Form (Properzi Forming Machine) capable to supply:

- Shaped Al wire (trapezoidal)
- Al solidal cables and conductors (sector profile)
- Al profiles / bus bars
- Al tubes
- Cladding of steel wire with aluminium.

Aluminium does not completely replace copper, but, as explained above, allows the adaptation of many tailor-made solutions. Properzi has the perfect solution for all your requirements.

Author

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