Development of Electrical Wire Rod with Recycled Content at TRIMET France

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Abstract

Growth in the European electrical wire market is estimated at 4–5 % per year over the next 10 years, due to a peak in the renewal of overhead lines and the need to extend the network (interconnection, wind turbines, battery recharging stations, etc.). At the same time, there is a threat of a shortage of available metal (supply-demand balance, geopolitical issues, etc.). Finally, cable suppliers are committed to reducing the carbon footprint of their conductors. Recycling aluminium cables seems to be the right solution to these various challenges. Until now, there has been no truly organised closed-loop supply chain for recycling dismantled overhead lines, and no experience of recycling the contents of power rods. This paper explains the challenges involved in developing the production of recycled electric rods from dismantled overhead lines, based on trials carried out at the Saint-Jean-de-Maurienne plant.

Keywords: Electrical wire rod, Recycling, Circularity, Overhead lines cable.

1. Introduction

1.1 French Electricity Network

In the first part of the 20th century, the first electricity networks were built to supply the regions from hydroelectric power. Overhead cable technology was initially pure copper. Aluminium Conductor Steel Reinforced (ACSR) cable then became the standard overhead cable when the technical and economic advantages of aluminium over copper were proven [1]. This overhead line conductor is made of aluminium and steel. Another advantage was that it increased the length of spans (the distance between two electricity pylons), thereby reducing the cost of building an overhead line. Between 1945 and 1975, the electrification of France accelerated with the deployment of the first major transmission network (225 kV) to interconnect regions using aluminium and steel cables. Between 1975 and 2000, a new 400 kV voltage network was created as part of the development of nuclear power plants. The introduction of Almelec cables (aluminium silicon magnesium alloy) offered a better technical and economic optimum thanks to their lightness and mechanical strength, which improved electrical performance and reduced mechanical stress on the pylons. Since 2000, the development of the electricity network has slowed down. Today, the need to renew France's overhead lines is becoming more pressing every year. The average age of overhead lines is around 85 years. This age may vary from one line to another, depending on the location and use of the overhead line. From 2030 onwards, and structurally for the following decades, the renewal effort will reach a level unprecedented in the history of the French electricity network, since the network was built after 1945.

RTE (Réseau de Transport d'Electricité) estimates that it will need to lay tens of thousands of kilometres of new overhead cables between now and 2040 [2]. This will involve both renewing and expanding the network. In order of magnitude, one kilometre of overhead line represents one tonne of aluminium. For RTE, this represents around 2 000 tonnes per year of lines to be recycled.

1.2 Reasons for Developing Recycling

Aluminium wire production began 70 years ago at the Saint-Jean-de-Maurienne plant. Today, TRIMET produces around 90 000 tonnes of wire rod a year for electrical applications ranging from low voltage to high voltage. The carbon footprint of the wire produced at Saint-Jean is one of the best in the world [3] thanks to its cutting-edge electrolysis technology and the origin of its electricity based mainly on nuclear and hydro power. TRIMET France is committed to a CSR approach that resulted in ASI certification [4] in 2022.

Two key points have prompted RTE to take the lead in developing cable recycling:

- Aluminium has been added to the European Commission's list of critical materials,
- The RTE network is going to expand significantly in the coming years/decades, depending on the energy transition scenarios, and will need aluminium to do so.

Recycling dismantled overhead lines not only secures part of the supply of materials, but also reduces the carbon footprint of the new lines installed.

Overhead lines have an estimated lifespan of 85 years, and the investment required is very high. Any change in the production process must be clearly assessed and validated throughout the chain (from the rod producer to the wire manufacturer and the overhead line owner).

2. Experimental Testing of Remelting End-of-life Cables

2.1 Trial Description

End-of-life cables remelting trials were carried out in November 2022 at the TRIMET plant in Saint-Jean-de-Maurienne. The aim was to produce Almelec 610166 wire rod from recycled cables in granulated form.

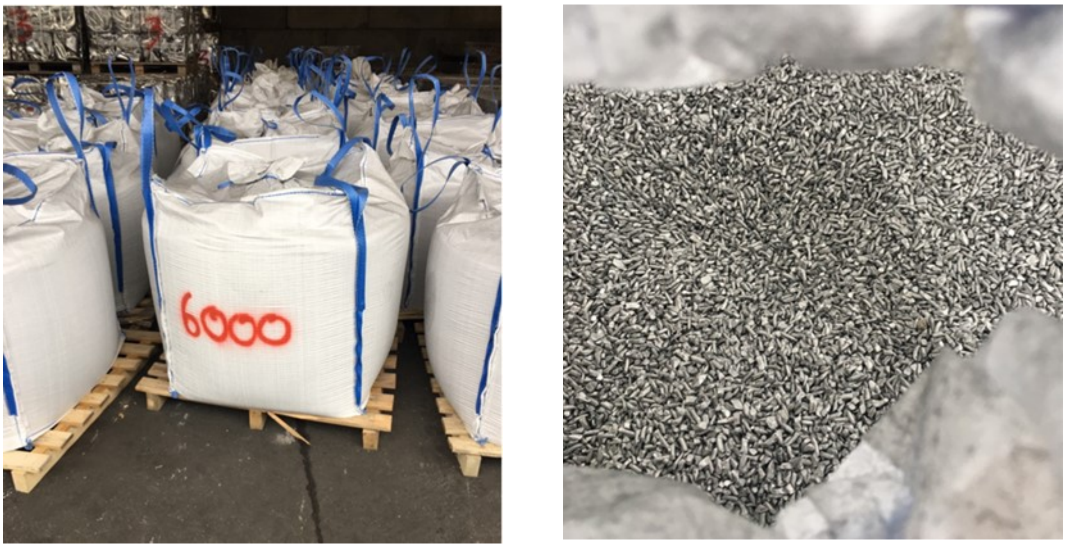

Figure 1. Aluminium granules from end-of-life electrical cables.

For the experimental tests, ten kilometres of overhead lines were dismantled in the Maurienne valley from an old RTE overhead line representing around ten tonnes of Almelec 610166 in granulated form. To obtain these granules (Figure 1), the first step was to sort the Almelec and the steel. Then the Almelec material was washed and crushed.

The tests were carried out on a 32-tonne capacity furnace that feeds the rod machine. The tests involved varying the amount of remelt introduced into the furnace as shown in Table 1. For different trials, the furnace was filled with between 15 to 25 tonnes of liquid metal from the electrolysis sector.

Table 1. Description of the trials.

	Addition of recycled cable	Time for furnace preparation (h)	Metal loss (%)
Trial 1	Low	6	2.58
Trial 2	Middle	7	1.69
Trial 3	High	10.5	2.04

The loading phase posed no particular problems. A pusher system was used to spread out the pellets to facilitate the introduction of the big bags and accelerate melting. The metal loss rates of the furnaces were estimated between 1.7 to 2.6 % during the trials which gives at that stage only an order of magnitude because of the difficulty to have an accurate value for one furnace.

In the case of trial 3, the furnace preparation time was too long to continue casting. In our current configuration, this represents a bottleneck.

2.2 Description of the Carried-out Measurements

2.2.1 On the Product

The following analyses were carried out to characterise the quality of the liquid aluminium at the metal degasser outlet:

- Alscan analyses to measure the hydrogen content;
- Limca analysis to measure the inclusion quality;
- PoDFa analysis to identify the type of inclusions contained in the metal;
- Metal density analysis to check the absence of porosity in the metal.

Figure 2a. Quality measurement equipment. Left: Alscan, Right: density index.

Figure 2b. Quality measurement equipment: Podfa (left), Limca (right).

2.2.2 On the Environment

Emissions sampling pumps have been installed above the furnace to measure emissions during two phases: melting and chemical elaboration of the furnace.

Figure 3. Equipment installed on top of the furnace to measure atmospheric emissions.

2.3 Results

2.3.1 On the Product

The characteristics of the wire rod produced during the various tests were compared with the reference values in Table 2.

Table 2. Mechanical strength and electrical resistivity for the tests.

	Mechanical resistance (MPa)*	Resistivity (µΩ·m)**
Trial 1	191	0.03451
Trial 2	192	0.03486
Trial 3	197	0.03473

*Reference value: 189 MPa (Square deviation: 5.5 MPa)
**Reference value: 0.03444 µΩ·m (Square deviation: 0.0005 µΩ·m).

Metallurgical analyses (Figure 3) were carried out after the T4 heat treatment (quenching). They confirm that the grain structures are completely recrystallized and that the Mg_2Si precipitate sizes are very small, as are the iron phases, which are less than 10 µm.

The hydrogen content (Alscan) were typically around 0.17 mL/100 g.

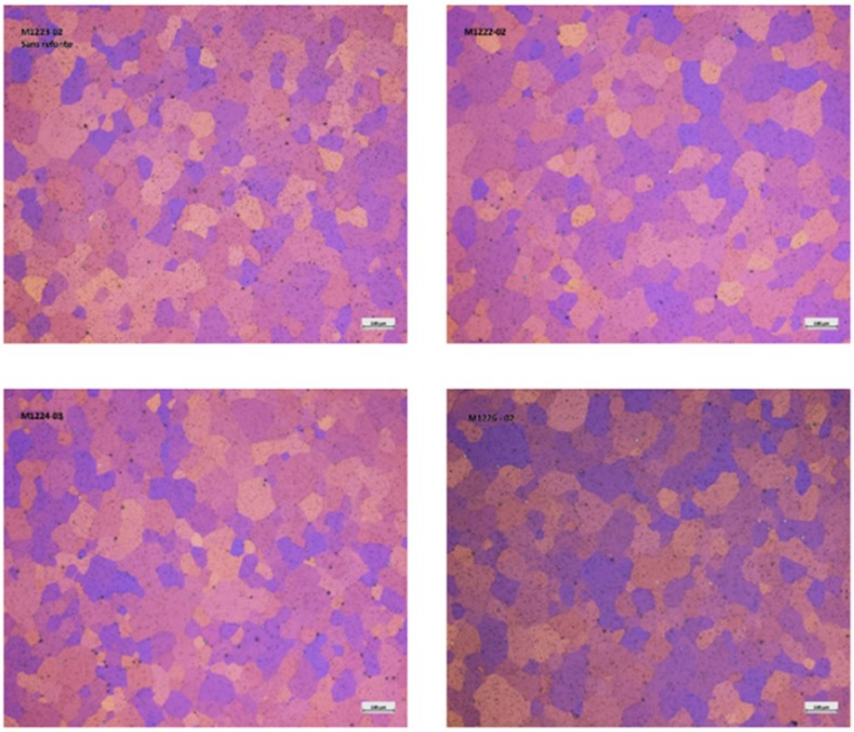

Figure 3. Metallurgical analysis.

The performed analysis concluded that increasing the cable recycling content in the wire rod has no negative impact on the rod's electrical and mechanical characteristics nor on its metallurgical structure.

2.3.2 Environmental Results

No major impact was detected during any of the tests. Only the volatile organic compound (VOC) content appeared to increase slightly. These observations need to be confirmed by further tests. It could come either from oily substances on the surface of the recycling rods, or directly from the plastic of the big bags that were introduced and burnt in the furnace.

3. Next Steps

Since these trials, which validated the technical feasibility, wire rod with recycled content has become part of TRIMET Saint-Jean-de-Maurienne's product portfolio.

The challenge now is to move from a small scale to a full industrial scale with large re-melting volumes. To achieve this, the challenges will be to:

- Structure the upstream supply chain of recycled cables granulates so that it can be reliable in terms of quality, quantity and availability, while managing the risks of explosion associated with any type of external scraps;
- Ensure that the process is economically viable all along the value-chain;
- Adapt production facilities to potentially increase the proportion of recycled cables in rod production up to 50 %.

4. Conclusions

Rising demand for electricity combined with increased renewal of the electricity network and the commitment of all players in the sector to reducing their carbon footprint are creating a huge opportunity to develop recycling in the production of electrical wire rod and cables.

Thanks to tests carried out in partnership between TRIMET France and RTE, it has been validated that recycling end-of-life overhead lines to produce new wire rod up to a significant recycled content has no impact on the quality of the final product.

The organisation of the entire supply chain remains a key point for the future development of cable recycling in order to produce large volumes.

5. References

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