

DESCRIPTION**Title: METHOD FOR MANUFACTURING AN ALUMINUM ALLOY PART****Technical field**

5 The technical field of the invention relates to a method for manufacturing a part made of an aluminum alloy, implementing an additive manufacturing technique.

Prior art

10 Additive manufacturing techniques have been developed since the 80s. These consist in shaping a part by material addition, which is in contrast with machining techniques which aim to remove the material. Formerly restricted to prototyping, additive manufacturing is now operational for manufacturing industrial products in mass production, including metal parts.

15 The term “additive manufacturing” is defined according to the French standard XP E67-001 as a “set of processes allowing manufacturing, layer-by-layer, by material addition, a physical object based on a digital object”. The standard ASTM F2792 (January 2012) also defines additive manufacturing. Different additive manufacturing approaches are also defined and described in the standard ISO/ASTM 17296-1. Resorting to an additive manufacture to make an aluminum part, with low porosity, has been described in the document WO2015/006447. In general, the application of successive layers is carried out by application of a so-called filler material, and then melting or sintering the filler material using an energy source such as a laser beam, an electron beam, a plasma torch or an electric arc. Irrespective of the additive manufacturing approach that is applied, the thickness of each added layer is in the range of a few tens or hundreds of microns.

20 Other additive manufacturing processes can be used. For example, and without limitation, mention may be made of melting or sintering a filler material in the form of a powder, for example laser melting or sintering. The patent application US2017/0016096 describes a method for manufacturing a part by localized melting obtained by exposing a powder to an energy beam of the electron beam or laser beam type, the method also being called Laser Powder Bed Fusion or Electron Beam Melting.

25 A person skilled in the art knows solutions that allow thermal stability of the mechanical properties, but which are not necessarily adapted to high temperatures (cf. for example the patent application WO202/070451, which discloses an alloy comprising from 1 to 10% of Fe, from 1 to 10% of Cr and optionally up to 4% of Zr, Hf, Er, Sc and/or Ti).

The mechanical properties of the aluminum parts obtained by additive manufacturing depend on the alloy forming the filler metal, and more specifically on its composition, as well as on the heat treatments applied following the implementation of the additive manufacturing.

5 The Applicant has determined an alloy composition which, when used in an additive manufacturing process, allows obtaining parts with remarkable mechanical performances, yet without it being necessary to implement heat treatments such as solution heat treatment and quenching.

According to one variant of the present invention, with a wise selection of the additive elements, the Applicant has identified compositions of aluminum alloys intended for additive
10 manufacturing processes allowing obtaining both very good processability of the parts, in particular in processes of the laser powder bed fusion type, and excellent mechanical performances of the parts in service at high temperature, i.e. for temperatures higher than or equal to 200°C. The excellent mechanical performances of the parts in service can be obtained
15 by maximizing the yield strength of the parts at 200°C or at 250°C after a post-manufacturing heat treatment, for example for 1h at 400°C. For illustration, the obtained yield strength $R_{p0.2}$ can be greater than or equal to 165 MPa at 250°C.

Pure aluminum powders may be used as a reducing agent in the solid propellant of aerospace thrusters. Consequently, aluminum powders with more than 97% aluminum are generally considered in some countries as dual-use goods (DUG) requiring export licenses. This
20 classification represents a constraint that might slow down the commercialization of some aluminum powders comprising more than 97% aluminum intended for additive manufacturing methods, for example such as laser powder bed fusion. Thus, it seems to be advantageous that the developed solution has less than 97% of aluminum, i.e. more than 3% added elements in total.

25 According to another variant of the present invention, through a wise selection of the additive elements, the Applicant has identified compositions of aluminum alloys intended for additive manufacturing processes, in particular laser powder bed fusion, these compositions comprising more than 3% additive elements in total and allowing good processability of the parts in the laser powder bed fusion method, while maximizing the mechanical performances of the parts in
30 service.

Disclosure of the invention

A first object of the invention is a method for manufacturing a part comprising forming successive metal layers, superposed on top of one another, each layer being formed by the deposition of a filler metal, the filler metal being subjected to an energy input so as to melt down and form, when solidifying, said layer, the method being characterized in that the filler metal is an aluminum alloy comprising the following alloying elements in weight percents:

- at least one alloying element selected from among: Zr, Hf, Sc and Er, according to a mass fraction of 0.01 to 1.60%, preferably 0.03 to 1.50%, preferably 0.05 to 1.40%, preferably 0.10 to 1.30%, preferably 0.20 to 1.25%, preferably 0.30 to 1.20%, preferably 0.40 to 1.00%, preferably 0.50 to 0.90%, preferably 0.60 to 0.80% each and in total;
- Fe, according to a mass fraction of 0.05 to 3.00%, preferably 0.10 to 3.00%, preferably 0.20 to 3.00%, preferably 0.30 to 3.00%, preferably 0.40 to 3.00%, preferably 0.50 to 2.90%, preferably 0.60 to 2.80%, preferably 0.70 to 2.70%, preferably 0.80 to 2.70%, preferably 0.90 to 2.60%, preferably 0.90 to 2.50%, preferably 0.90 to 2.40%, preferably 0.90 to 2.30%, preferably 0.90 to 2.20%;
- Cr, according to a mass fraction of 0.50 to 4.00%, preferably 0.70% to 4.00%, preferably 1.00 to 4.00%, preferably 1.30 to 3.90%, preferably 1.50 to 3.80%, preferably 1.60 to 3.70%, preferably 1.70 to 3.60%, preferably 1.75 to 3.50%, preferably 1.75 to 3.40%, preferably 1.75 to 3.30%, preferably 1.75 to 3.20%, preferably 1.80 to 3.20%, preferably 1.90 to 3.20%, preferably 1.90 to 3.00%, preferably 1.90 to 2.50%, preferably 1.90 to 2.20%;
- Mg, according to a mass fraction of 0.01 to 3.50%, preferably 0.03 to 3.50%, preferably 0.05 to 3.50%, preferably 0.10 to 3.40%, preferably 0.20 to 2.50%, preferably 0.30 to 2.30%, preferably 0.40 to 2.10%, preferably 0.40 to 1.80%, preferably 0.50 to 1.80%, preferably 0.50 to 1.50%, preferably 0.50 to 1.20%;
- optionally at least one alloying element selected from among: Mn, V and Ti according to a mass fraction greater than or equal to 0.03%, preferably greater than or equal to 0.05%, preferably 0.10 to 3.00%, preferably 0.20 to 2.50%, preferably 0.30 to 2.40%, preferably 0.40 to 2.30%, preferably 0.40 to 2.20%, preferably 0.40 to 2.10%, preferably 0.40 to 2.00%, preferably 0.40 to 1.90%, preferably 0.40 to 1.80%, preferably 0.40 to 1.70%, preferably 0.40 to 1.60%, preferably 0.40 to 1.20%, each and in total;
- optionally Mo, according to a mass fraction greater than or equal to 0.03%, preferably greater than or equal to 0.05%, preferably 0.10 to 3.00%, preferably 0.20 to 2.50%, preferably 0.30 to 2.40%, preferably 0.40 to 2.30%, preferably 0.40 to 2.20%, preferably 0.40 to 2.10%, preferably

- 0.40 to 2.00%, preferably 0.40 to 1.90%, preferably 0.40 to 1.80%, preferably 0.40 to 1.70%, preferably 0.40 to 1.60%, preferably 0.40 to 1.20%;
- optionally Si, according to a mass fraction less than or equal to 3.00%, preferably less than or equal to 2.50%, preferably less than or equal to 2.00%, preferably less than or equal to 1.50%, preferably less than or equal to 1.00%, preferably less than or equal to 0.50%, preferably less than or equal to 0.20%, preferably less than or equal to 0.15%, preferably less than or equal to 0.10%;
 - optionally Ni, according to a mass fraction less than or equal to 3.00%, preferably less than or equal to 2.50%, preferably less than or equal to 2.00%, preferably less than or equal to 1.50%, preferably less than or equal to 1.00%, preferably less than or equal to 0.50%;
 - optionally at least one alloying element selected from among: Cu and Ag, according to a mass fraction of 0.05 to 1.40%, preferably 0.10 to 1.40%, preferably 0.10 to 1.30%, preferably 0.10 to 1.20%, preferably 0.10 to 1.10%, preferably 0.10 to 1.00%, preferably 0.10 to 0.90%, preferably 0.10 to 0.80%, preferably 0.10 to 0.70% for Cu;
 - according to a mass fraction of 0.05 to 3.00%, preferably 0.10 to 2.00%, preferably 0.10 to 1.60%, preferably 0.10 to 1.50%, preferably 0.10 to 1.40%, preferably 0.10 to 1.30%, preferably 0.10 to 1.20%, preferably 0.10 to 1.10%, preferably 0.10 to 1.00%, preferably 0.10 to 0.90%, preferably 0.10 to 0.80%, preferably 0.10 to 0.70% for Ag and in total;
 - optionally at least one alloying element selected from among: Zn and Li, according to a mass fraction of less than 2.00%, preferably less than or equal to 1.50%, preferably less than or equal to 1.00%, preferably less than or equal to 0.50%, more preferably less than or equal to 0.30% each and in total;
 - optionally at least one alloying element selected from among: Co, La, Ce, mischmetal, W, Ta, Nb, Nd, Y, Tm, Lu, Yb, Sr, Ba, Sb, Bi, Ca, P, B, In and Sn, according to a mass fraction less than or equal to 2.00%, preferably less than or equal to 1.50%, preferably less than or equal to 1.00%, preferably less than or equal to 0.50%, more preferably less than or equal to 0.30%, even more preferably less than or equal to 0.10% each, and less than or equal to 2.00%, preferably less than or equal to 1.00%, preferably less than or equal to 0.50%, preferably less than or equal to 0.30% in total;
 - impurities: < 0.05% individually, and preferably < 0.15% in total;
- the remainder being aluminum.

In particular, each layer may describe a pattern defined based on a digital model.

According to one embodiment, the filler metal is in the form of a powder, the exposure of which to a beam of light or of charged particles, results in a local meltdown followed by a solidification,

so as to form a solid layer. According to another embodiment, the filler metal originates from a filler wire, the exposure of which to a heat source, for example an electric arc, results in a local meltdown followed by a solidification, so as to form a solid layer.

A second object of the invention is a metallic part, obtained by a method according to the first
5 object of the invention.

A third object of the invention is a filler material, in particular a filler wire or a powder, intended to be used as a filler material of an additive manufacturing process, characterized in that it consists of an aluminum alloy, comprising the following alloying elements (mass percentages):

- at least one alloying element selected from among: Zr, Hf, Sc and Er, according to a mass
10 fraction of 0.01 to 1.60%, preferably 0.03 to 1.50%, preferably 0.05 to 1.40%, preferably 0.10 to 1.30%, preferably 0.20 to 1.25%, preferably 0.30 to 1.20%, preferably 0.40 to 1.00%, preferably 0.50 to 0.90%, preferably 0.60 to 0.80% each and in total;
- Fe, according to a mass fraction of 0.05 to 3.00%, preferably 0.10 to 3.00%, preferably 0.20 to 3.00%, preferably 0.30 to 3.00%, preferably 0.40 to 3.00%, preferably 0.50 to 2.90%,
15 preferably 0.60 to 2.80%, preferably 0.70 to 2.70%, preferably 0.80 to 2.70%, preferably 0.90 to 2.60%, preferably 0.90 to 2.50%, preferably 0.90 to 2.40%, preferably 0.90 to 2.30%, preferably 0.90 to 2.20%;
- Cr, according to a mass fraction of 0.50 to 4.00%, preferably 0.70% to 4.00%, preferably 1.00 to 4.00%, preferably 1.30 to 3.90%, preferably 1.50 to 3.80%, preferably 1.60 to 3.70%,
20 preferably 1.70 to 3.60%, preferably 1.75 to 3.50%, preferably 1.75 to 3.40%, preferably 1.75 to 3.30%, preferably 1.75 to 3.20%, preferably 1.80 to 3.20%, preferably 1.90 to 3.20%, preferably 1.90 to 3.00%, preferably 1.90 to 2.50%, preferably 1.90 to 2.20%;
- Mg, according to a mass fraction of 0.01 to 3.50%, preferably 0.03 to 3.50%, preferably 0.05 to 3.50%, preferably 0.10 to 3.40%, preferably 0.20 to 2.50%, preferably 0.30 to 2.30%,
25 preferably 0.40 to 2.10%, preferably 0.40 to 1.80%, preferably 0.50 to 1.80%, preferably 0.50 to 1.50%, preferably 0.50 to 1.20%;
- optionally at least one alloying element selected from among: Mn, V and Ti according to a mass fraction greater than or equal to 0.03%, preferably greater than or equal to 0.05%, preferably 0.10 to 3.00%, preferably 0.20 to 2.50%, preferably 0.30 to 2.40%, preferably 0.40 to
30 2.30%, preferably 0.40 to 2.20%, preferably 0.40 to 2.10%, preferably 0.40 to 2.00%, preferably 0.40 to 1.90%, preferably 0.40 to 1.80%, preferably 0.40 to 1.70%, preferably 0.40 to 1.60%, preferably 0.40 to 1.20%, each and in total;
- optionally Mo, according to a mass fraction greater than or equal to 0.03%, preferably greater than or equal to 0.05%, preferably 0.10 to 3.00%, preferably 0.20 to 2.50%, preferably 0.30 to

2.40%, preferably 0.40 to 2.30%, preferably 0.40 to 2.20%, preferably 0.40 to 2.10%, preferably 0.40 to 2.00%, preferably 0.40 to 1.90%, preferably 0.40 to 1.80%, preferably 0.40 to 1.70%, preferably 0.40 to 1.60%, preferably 0.40 to 1.20%;

- optionally Si, according to a mass fraction less than or equal to 3.00%, preferably less than or equal to 2.50%, preferably less than or equal to 2.00%, preferably less than or equal to 1.50%, preferably less than or equal to 1.00%, preferably less than or equal to 0.50%, preferably less than or equal to 0.20%, preferably less than or equal to 0.15%, preferably less than or equal to 0.10%;

- optionally Ni, according to a mass fraction less than or equal to 3.00%, preferably less than or equal to 2.50%, preferably less than or equal to 2.00%, preferably less than or equal to 1.50%, preferably less than or equal to 1.00%, preferably less than or equal to 0.50%;

- optionally at least one alloying element selected from among: Cu and Ag, according to a mass fraction of 0.05 to 1.40%, preferably 0.10 to 1.40%, preferably 0.10 to 1.30%, preferably 0.10 to 1.20%, preferably 0.10 to 1.10%, preferably 0.10 to 1.00%, preferably 0.10 to 0.90%, preferably 0.10 to 0.80%, preferably 0.10 to 0.70% for Cu;

according to a mass fraction of 0.05 to 3.00%, preferably 0.10 to 2.00%, preferably 0.10 to 1.60%, preferably 0.10 to 1.50%, preferably 0.10 to 1.40%, preferably 0.10 to 1.30%, preferably 0.10 to 1.20%, preferably 0.10 to 1.10%, preferably 0.10 to 1.00%, preferably 0.10 to 0.90%, preferably 0.10 to 0.80%, preferably 0.10 to 0.70% for Ag and in total;

- optionally at least one alloying element selected from among: Zn and Li, according to a mass fraction less than 2.00%, preferably less than or equal to 1.50%, preferably less than or equal to 1.00%, preferably less than or equal to 0.50%, more preferably less than or equal to 0.30% each and in total;

- optionally at least one alloying element selected from among: Co, La, Ce, mischmetal, W, Ta, Nb, Nd, Y, Tm, Lu, Yb, Sr, Ba, Sb, Bi, Ca, P, B, In and Sn, according to a mass fraction less than or equal to 2.00%, preferably less than or equal to 1.50%, preferably less than or equal to 1.00%, preferably less than or equal to 0.50%, more preferably less than or equal to 0.30%, even more preferably less than or equal to 0.10% each, and less than or equal to 2.00%, preferably less than or equal to 1.00%, preferably less than or equal to 0.50%, preferably less than or equal to 0.30% in total;

- impurities: < 0.05% each, and < 0.15% in total;

the remainder being aluminum.

The aluminum alloy forming the filler material may have the features described in connection with the first object of the invention.

The filler material may be in the form of a powder. The powder may be such that at least 80% of the particles composing the powder have an average size in the following range: 5 to 200 μm , preferably from 5 to 150 μm , preferably from 5 to 25 μm , or from 20 to 60 μm or from 20 to 80 μm or from 20 to 90 μm or from 20 to 100 μm or from 20 to 110 μm or from 20 to 120 μm .

- 5 In the case where the filler material is in the form of a wire, the diameter of the wire may in particular be comprised between 0.5 mm and 3 mm, and preferably comprised between 0.5 mm and 2 mm, and more preferably comprised between 1 mm and 2 mm.

A fourth object of the invention is the use of a powder or of a filler wire as described above and in the rest of the description in a manufacturing process selected from among: laser powder bed
10 fusion, electron beam melting, cold spray, laser metal deposition, additive friction stir, spark plasma sintering or inertia rotary friction welding, preferably laser powder bed fusion.

Other advantages and features will appear more clearly from the following description of particular embodiments of the invention, provided as non-limiting examples, and shown in the figures listed hereinbelow.

15 **Figures**

Figure 1 is a diagram illustrating an additive manufacturing process of the laser powder bed fusion type.

Figure 2 is a diagram illustrating an additive manufacturing process of the wire arc additive manufacturing type.

- 20 Figure 3 is a diagram of the test piece used according to the examples.

Disclosure of specific embodiments

Unless stated otherwise, in the description:

- the designation of the aluminum alloys is in compliance with the nomenclature of The Aluminum Association;
- 25 - the contents of chemical elements are reported in % and represent mass fractions. The notation $x\% - y\%$ means higher than or equal to $x\%$ and lower than or equal to $y\%$.

By impurities, it should be understood chemical elements unintentionally present in the alloy, preferably according to a mass fraction of less than 0.05%.

According to the present invention, the expression "*at least one alloying element selected from among: X, Y (...) and Z*" means that each of the mentioned elements can be present, alone or in
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combination with any of the other element(s), according to the specified mass fractions. Hence, this expression covers each of the mentioned elements and all possible combinations thereof.

According to the present invention, the optional elements are:

- either absent, i.e. considered to be an unintentional impurity according to a mass fraction of less than 0.05%,
- or present according to the specified mass fractions.

Figure 1 schematizes the operation of an additive manufacturing process of the laser powder bed fusion type. The filler metal 15 is in the form of a powder disposed over a support 10. An energy source, in this case a laser source 11, emits a laser beam 12. The laser source is coupled to the filler material by an optical system 13, whose movement is determined according to a digital model *M*. The laser beam 12 propagates according to an axis of propagation *Z*, and follows a movement according to a plane *XY*, describing a pattern dependent on the digital model *M*. For example, the plane is perpendicular to the axis of propagation *Z*. The interaction of the laser beam 12 with the powder 15 causes a selective fusion of the latter, followed by a solidification, resulting in the formation of a layer 20₁...20_n. When a layer has been formed, it is covered with powder 15 of the filler metal and another layer is formed, superposed with the layer made before. For example, the thickness of a layer may be comprised from 10 à 250 µm, for example 30 µm, or 60 µm, or 80 µm, or 90 µm, or 100 µm, or 110 µm, or 120 µm, or 130 µm, or 140 µm, or 150 µm, or 160 µm, or 170 µm, or 180 µm, or 190 µm, or 200 µm.

An increase in the layer thickness could be beneficial for increasing productivity during the printing and for limiting the susceptibility to thermal cracking related to the residual stresses during the manufacturing of the part and/or during a post-manufacturing heat treatment. An increase in the layer thickness can be accompanied by an adaptation of the power of the laser and of the hatch spacing (distance between two successive laser passes) and of the scanning speed of the laser in order to ensure a complete melting of each layer of powder under optimal conditions. For example, the layer thickness may be comprised between 60 and 250 µm, preferably 80 to 200 µm, preferably 90 to 180 µm, preferably 100 to 180 µm, preferably 110 to 170 µm, preferably 120 to 160 µm.

For aluminum alloys, the support 10 or platform may be heated to a preheating temperature *T* of up to 500°C. The machines currently available on the market generally offer heating of the platform up to 200°C. For example, the heating temperature of the platform (= preheating temperature *T*) may be approximately 50°C, or 100°C, or 150°C, or 200°C, or 250°C, or 300°C, or 350°C, or 400°C, or 450°C, or 500°C. The heating of the platform generally allows reducing the

humidity in the powder bed and also reducing the residual stresses on the parts being manufactured. The humidity level at the level of the powder bed seems to have a direct effect on the porosity of the final part. Indeed, it seems that the higher the humidity of the powder, the higher the porosity of the final part will be. It should be noted that heating the platform is one of the existing possibilities for carrying out hot additive manufacturing. However, the present invention could not be limited to the use of this heating means alone. All of the other heating means, allowing carrying out this preheating step, can be used in the context of the present invention to heat and control the temperature, for example an infrared lamp. Thus, the method according to the present invention can be carried out at a preheating temperature T of up to 500°C. In the previous and next paragraphs, the preheating temperature T can relate to the platform, the powder bed or the manufacturing chamber.

For some compositions, the Inventors have noticed that when the preheating temperature T, for example of the powder bed, is lower than or equal to 160°C and higher than or equal to 25°C, the parts have better resistance to the thermal cracking related to the residual stresses. Preferably, the preheating of the powder bed may be performed at a preheating temperature T lower than or equal to 140°C or, better still, lower than or equal to 130°C. The preheating temperature T is higher than room temperature. The preferred preheating temperature ranges T of the powder bed are: $25^{\circ}\text{C} \leq T \leq 160^{\circ}\text{C}$, preferably $30^{\circ}\text{C} \leq T \leq 150^{\circ}\text{C}$, preferably $50^{\circ}\text{C} \leq T \leq 150^{\circ}\text{C}$, preferably $50^{\circ}\text{C} \leq T \leq 140^{\circ}\text{C}$, preferably $60^{\circ}\text{C} \leq T \leq 140^{\circ}\text{C}$, preferably $70^{\circ}\text{C} \leq T \leq 135^{\circ}\text{C}$, preferably $80^{\circ}\text{C} \leq T \leq 130^{\circ}\text{C}$.

According to one alternative, the preheating temperature T corresponds to the conditions under which an effective expansion could be obtained. The preheating temperature range T may then be comprised between 300°C and 500°C, preferably from 300 to 400°C, preferably from 300 to 350°C. It is considered that, at this preheating temperature range T, the manufacturing conditions of the part generate less residual stresses. According to this alternative, an expansion post-manufacturing heat treatment, as described below in the present description, is also relevant.

The powder according to the present invention may have at least one of the following features:

- Average particle size from 5 µm to 200 µm, preferably from 5 to 150 µm, preferably from 5 to 25 µm, or from 20 to 60 µm, or from 20 to 80 µm, or from 20 to 90 µm, or from 20 to 100 µm, or from 20 to 110 µm, or from 20 to 120 µm. The given values mean that at least 80% of the particles have an average size within the specified range.
- Spherical shape. For example, the sphericity of a powder may be determined using a morphogranulometer.

- Good castability. For example, the castability of a powder may be determined according to the standard ASTM B213 or the standard ISO 4490:2018. According to the standard ISO 4490:2018, the flow time is preferably shorter than 50.
- Low porosity, preferably from 0 to 5%, more preferably from 0 to 2%, even more preferably from 0 to 1% by volume. In particular, the porosity may be determined by analysis of images from optical micrographs or by helium pycnometry (cf. the standard ASTM B923).
- Absence or small quantity (less than 10%, preferably less than 5% by volume) of small particles (1 to 20% of the average size of the powder), called satellites, which stick to the larger particles.

10 The implementation of such a method allows manufacturing parts at a high yield, which could reach and even exceed 200 cm³/h by laser.

Moreover, the Applicant has observed that the application of post-manufacturing heat treatments such as quenching could induce a distortion of the part, because of the brutal temperature variation. In general, the distortion of the part is even more significant as its dimensions are large. Yet, the advantage of an additive manufacturing process is specifically to obtain a part whose shape, after manufacture, is permanent, or quasi-permanent. The occurrence of a significant deformation resulting from a post-manufacturing heat treatment should therefore be avoided. By quasi-permanent, it should be understood that a finish machining could be performed on the part after manufacture thereof: the part manufactured by additive manufacturing extends according to its final shape, within the finish machining margins.

Having noticed the foregoing, the Applicant has sought an alloy composition, forming the filler material, allowing obtaining mechanical and electrical or thermal conductivity properties that are acceptable, without the need for the application of heat treatments, following the formation of the layers, i.e. following the formation of the final part, which might induce a distortion. In particular, the aim is to avoid heat treatments involving an abrupt variation in the temperature. Thus, the invention allows obtaining, by additive manufacturing, a part whose mechanical properties, in particular in terms of yield strength, and electrical or thermal conductivity, are satisfactory. Depending on the selected type of additive manufacturing process, the filler material may be in the form of a wire or a powder.

The following elements may be used in the aluminum alloy.

Zr, Hf, Sc and/or Er:

According to the present invention, at least one alloying element selected from among: Zr, Hf, Sc and Er is present in the aluminum alloy according to a mass fraction of 0.01 to 1.60%, preferably 0.03 to 1.50%, preferably 0.05 to 1.40%, preferably 0.10 to 1.30%, preferably 0.20 to 1.25%, preferably 0.30 to 1.20%, preferably 0.40 to 1.00%, preferably 0.50 to 0.90%, preferably 0.60 to 0.80% each and in total. In one embodiment, the mass fraction of at least one alloying element selected from among: Zr, Hf, Sc and Er is greater than or equal to 0.01%, or 0.02%, or 0.04%, or 0.06%, or 0.08%, or 0.10%, or 0.12%, or 0.14%, or 0.16%, or 0.18%, or 0.20%, or 0.22%, or 0.24%, or 0.26%, or 0.28%, or 0.30%, or 0.32%, or 0.34%, or 0.36%, or 0.38%, or 0.40%, or 0.42%, or 0.44%, or 0.46%, or 0.48%, or 0.50%, or 0.52%, or 0.54%, or 0.56%, or 0.58%, or 0.60% each and in total. In one embodiment, the mass fraction of at least one alloying element selected from among: Zr, Hf, Sc and Er is less than or equal to 1.60%, or 1.55%, or 1.50%, or 1.45%, or 1.40%, or 1.35%, or 1.30%, or 1.25%, or 1.20%, or 1.15%, or 1.10%, or 1.05%, or 1.00%, or 0.95%, or 0.90%, or 0.85%, or 0.80% each and in total.

According to one variant of the present invention, at least one alloying element selected from among: Zr, Hf, Sc and Er is present in the aluminum alloy according to a mass fraction less than or equal to 0.65%, preferably 0.01 to 0.60%, preferably 0.05 to 0.50%, preferably 0.10 to 0.45%, preferably 0.15 to 0.40% each and in total.

According to another variant of the present invention, at least one alloying element selected from among: Zr, Hf, Sc and Er is present in the aluminum alloy according to a mass fraction of 0.40% to 1.60%, preferably 0.50% to 1.50%, preferably 0.55% to 1.40%, preferably 0.60 to 1.30%, preferably 0.60 to 1.25%, preferably 0.60 to 1.20%, preferably 0.60 to 1.00%, preferably 0.60 to 0.95%, preferably 0.65 to 0.90% each and in total.

These elements have a high solubility in the as-manufactured state. Thus, the addition thereof can significantly lower the conductivity in the as-manufactured state. However, the addition of a post-manufacturing heat treatment, for example at a temperature between 300 and 450°C, for durations of 0.5 to 10 hours, can allow significantly lowering their concentrations in solid solution by the formation of hardening dispersoids of the Al₃X type (X = Zr or Hf or Sc or Er). The formation of these dispersoids during the heat treatment can allow simultaneously increasing the hardness and the electrical conductivity compared to the as-manufactured state.

These elements could also allow controlling the granular structure during laser melting by promoting the apparition of equiaxed grains.

Moreover, the presence of at least one alloying element selected from among: Zr, Hf, Sc and Er in the alloy can confer a good processability on the alloy, the term processability referring to the ability of an alloy to be shaped by an additive manufacturing process. This can manifest itself, in a part manufactured by additive manufacturing, as a quasi-absence of defects, of the solidification cracking type, and a low porosity.

Fe:

According to the present invention, the element Fe is present in the aluminum alloy according to a mass fraction of 0.05 to 3.00%, preferably 0.10 to 3.00%, preferably 0.20 to 3.00%, preferably 0.30 to 3.00%, preferably 0.40 to 3.00%, preferably 0.50 to 2.90%, preferably 0.60 to 2.80%, preferably 0.70 to 2.70%, preferably 0.80 to 2.70%, preferably 0.90 to 2.60%, preferably 0.90 to 2.50%, preferably 0.90 to 2.40%, preferably 0.90 to 2.30%, preferably 0.90 to 2.20%. In one embodiment, the mass fraction of Fe is greater than or equal to 0.05%, or 0.10%, or 0.15%, or 0.20%, or 0.25%, or 0.30%, or 0.35%, or 0.40%, or 0.45%, or 0.50%, or 0.55%, or 0.60%, or 0.65 %, or 0.70%, or 0.75%, or 0.80%, or 0.85%, or 0.90%. In one embodiment, the mass fraction of Fe is less than or equal to 3.00%, or 2.95%, or 2.90%, or 2.85%, or 2.80%, or 2.75%, or 2.70%, or 2.65%, or 2.60%, or 2.55%, or 2.50%, or 2.45%, or 2.40%, or 2.35%, or 2.30%, or 2.25%, or 2.20%.

This element can allow increasing the mechanical strength of the alloy by solid solution and/or by dispersoids which could form during the manufacturing of the part or during post-manufacturing heat treatments. This element has a low solubility in aluminum. The addition of this element allows increasing the yield strength, but an excessive addition of Fe, i.e. at contents greater than or equal to 3.00%, can lead to an increase in the cracking susceptibility and lower the elongation at rupture.

Cr:

According to the present invention, the element Cr is present in the aluminum alloy according to a mass fraction of 0.50 to 4.00%, preferably 0.70% to 4.00%, preferably 1.00% to 4.00%, preferably 1.30 to 3.90%, preferably 1.50 to 3.80%, preferably 1.60 to 3.70%, preferably 1.70 to 3.60%, preferably 1.75 to 3.50%, preferably 1.75 to 3.40%, preferably 1.75 to 3.30%, preferably 1.75 to 3.20%, preferably 1.80 to 3.20%, preferably 1.90 to 3.20%, preferably 1.90 to 3.00%, preferably 1.90 to 2.50%, preferably 1.90 to 2.20%. In one embodiment, the mass fraction of Cr is greater than or equal to 0.50%, or 0.55%, or 0.60%, or 0.65%, or 0.70%, or 0.75%, or 0.80%, or 0.85%, or 0.90%, or 0.95%, 1.00%, or 1.05%, or 1.10%, or 1.15%, or 1.20%, or 1.25%, or 1.30%, or 1.35%, or 1.40%, or 1.45%, or 1.50%, or 1.55%, or 1.60%, or 1.65%, or 1.70%, or 1.75%, or

1.80%, or 1.85%, or 1.90%. In one embodiment, the mass fraction of Cr is less than or equal to 4.00%, or 3.95%, or 3.90%, or 3.85%, or 3.80%, or 3.75%, or 3.70%, or 3.65%, or 3.60%, or 3.55%, or 3.50%, or 3.45%, or 3.40%, or 3.35%, or 3.30%, or 3.25%, or 3.20%, or 3.15%, or 3.10%, or 3.05%, or 3.00%, or 2.95%, or 2.90%, or 2.85%, or 2.80%, or 2.75%, or 2.70%, or 2.65%, or 2.60%,
 5 or 2.55%, or 2.50%, or 2.45%, or 2.40%, or 2.35%, or 2.30%, or 2.25%, or 2.20%.

This element can allow increasing the mechanical strength of the alloy by solid solution and/or by dispersoids which could form during the manufacturing of the part or during post-manufacturing heat treatments. The addition of this element can allow increasing the yield strength at room temperature and at high temperature, this effect being accentuated by the
 10 presence of Fe in the alloy. Thus, a simultaneous addition of Cr and Fe can be advantageous for increasing the mechanical strength at room temperature and at high temperature (temperature higher than or equal to 200°C).

An excessive addition of Cr, i.e. according to mass fractions greater than or equal to 4.00%, or even 3.20%, or even 2.20%, could lead to an increase in the cracking susceptibility and lower the
 15 elongation at rupture.

Cr has a low diffusion coefficient in aluminum, which can allow conferring a high thermal stability on the alloy.

Cr has high solubility in aluminum and has a negative effect on the conductivity. The use of this element is of interest for the alloys aimed at some uses not requiring particular performances
 20 in terms of electrical or thermal conductivity but which require a high mechanical strength, like structural parts, hydraulic blocks, etc.

Mg:

According to the present invention, the element Mg is present in the aluminum alloy according to a mass fraction of 0.01 to 3.50%, preferably 0.03 to 3.50%, preferably 0.05 to 3.50%,
 25 preferably 0.10 to 3.40%, preferably 0.20 to 2.50%, preferably 0.30 to 2.30%, preferably 0.40 to 2.10%, preferably 0.40 to 1.80%, preferably 0.50 to 1.80%, preferably 0.50 to 1.50%, preferably 0.50 to 1.20%. In one embodiment, the mass fraction of Mg is greater than or equal to 0.01%, or 0.02%, or 0.03%, or 0.04%, or 0.06%, or 0.08%, or 0.10%, or 0.12%, or 0.14%, or 0.16%, or 0.18%, or 0.20%, or 0.22%, or 0.24%, or 0.26%, or 0.28%, or 0.30%, or 0.32%, or 0.34%, or 0.36%,
 30 or 0.38%, or 0.40%, or 0.42%, or 0.44%, or 0.46%, or 0.48%, or 0.50%. In one embodiment, the mass fraction of Mg is less than or equal to 3.50%, or 3.45%, or 3.40%, or 3.35%, or 3.30%, or 3.25%, or 3.20%, or 3.15%, or 3.10%, or 3.05%, or 3.00%, or 2.95%, or 2.90%, or 2.85%, or 2.80%, or 2.75, or 2.70%, or 2.65%, or 2.60%, or 2.55%, or 2.50%, or 2.45%, or 2.40%, or 2.35%, or

2.30%, or 2.25%, or 2.20%, or 2.15%, or 2.10%, or 2.05%, or 2.00%, or 1.95%, or 1.90%, or 1.85%, or 1.80%, or 1.75%, or 1.70%, or 1.65, or 1.60%, or 1.55%, or 1.50%, or 1.40%, or 1.30%, or 1.20%.

This element can allow increasing the mechanical strength of the alloy by solid solution. In a counter-intuitive way, it can also allow improving the resistance to cracking. The excessive addition of this element, for example at contents greater than or equal to 3.5%, could degrade the resistance to intergranular corrosion, via the formation of the anodic phase β (Mg_5Al_8) at the grain boundaries. The formation of this phase can occur at room temperature and its formation can be accelerated for temperatures higher than or equal to 60°C.

In a counter-intuitive manner, Mg can also allow increasing the mechanical properties, in particular the yield strength ($R_{p0.2}$) and the ultimate tensile strength (R_m) when hot, for example at 200°C or 250°C. The addition of Mg at well-controlled contents can also allow increasing the elongation at rupture when hot, for example at 200°C or 250°C.

This positive impact of the addition of Mg on the elongation at rupture seems all the more pronounced when:

- The equiaxed grains do not form an interconnected three-dimensional network;
- The surface fraction of equiaxed grains is less than 30%, preferably less than 20%, preferably less than 10%, preferably less than 5%;
- The equiaxed grains have an average diameter larger than or equal to 0.5 μm , preferably larger than or equal to 1 μm , preferably larger than or equal to 2 μm , preferably larger than or equal to 3 μm , preferably larger than or equal to 4 μm , preferably larger than or equal to 5 μm .

This element is susceptible to evaporation during the laser melting, which could lead to the formation of fumes and instabilities of the molten baths. This evaporation should be taken into account to adjust the concentration of Mg in the powder according to the target Mg content for the part.

Mn, V and/or Ti:

According to the present invention, at least one alloying element selected from among: Mn, V and Ti can be present in the aluminum alloy according to a mass fraction greater than or equal to 0.03%, preferably greater than or equal to 0.05%, preferably 0.10 to 3.00%, preferably 0.20 to 2.50%, preferably 0.30 to 2.40%, preferably 0.40 to 2.30%, preferably 0.40 to 2.20%, preferably 0.40 to 2.10%, preferably 0.40 to 2.00%, preferably 0.40 to 1.90%, preferably 0.40 to 1.80%, preferably 0.40 to 1.70%, preferably 0.40 to 1.60%, preferably 0.40 to 1.20%, each and in total. In one embodiment, the mass fraction of at least one alloying element selected from

among Mn, V and Ti is greater than or equal to 0.03%, or 0.05%, or 0.10%, or 0.15%, or 0.20%, or 0.25%, or 0.30%, or 0.35%, or 0.40%, each and in total. In one embodiment, the mass fraction of at least one alloying element selected from among: Mn, V and Ti is less than or equal to 3.00%, or 2.90%, or 2.80%, or 2.70%, or 2.60%, or 2.50%, or 2.40%, or 2.30%, or 2.20%, or 2.10%, or 2.00%, or 1.90%, or 1.80%, or 1.70%, or 1.60%, or 1.50%, or 1.40%, or 1.30%, or 1.20%, each and in total.

These elements can allow increasing the mechanical strength of the alloy at room temperature and at high temperature by solid solution and/or by dispersoids which could form during the manufacturing of the part or during post-manufacturing heat treatments. These elements have a low diffusion coefficient in aluminum, which allows conferring a high thermal stability on the alloy.

These elements have a high solubility in aluminum and have a negative effect on the conductivity. The addition of these elements is of interest for the alloys intended for some uses requiring no particular performances in terms of electrical or thermal conductivity but which require a high mechanical strength, like structural parts, hydraulic blocks, etc.

The excessive addition of these elements can increase the cracking susceptibility of the alloy, thus according to one variant the content of these elements is kept below 3.00% each and in total.

Preferably, the aluminum alloy necessarily comprises at least one alloying element selected from among: Mn, V and Ti, under the conditions as defined above, and in particular according to the mass fractions as described above.

According to one variant, the aluminum alloy comprises, preferably consists of: 0.50 to 0.90% of at least one alloying element selected from among Zr, Hf, Sc and Er, preferably Zr, each and in total; 0.90 to 2.20% of Fe; 0.90 to 3.20%, preferably 0.90 to 2.20% of Cr; 0.40 to 1.90%, preferably 0.40 to 1.80%, preferably 0.40 to 1.50% of Mg; 0.40 to 1.60% of at least one alloying element selected from among Mn, V and Ti, preferably Mn and V, each and in total; optionally up to 0.20%, preferably up to 0.15%, preferably up to 0.10% of Si; preferably the remainder being aluminum and impurities.

According to one variant, Ti can be absent from the aluminum alloy, i.e. optionally present only as an impurity, according to a mass fraction of less than 0.05%, preferably less than 0.03%.

Mo:

According to the present invention, the element Mo can be present in the aluminum alloy according to a mass fraction greater than or equal to 0.03%, preferably greater than or equal to 0.05%, preferably 0.10 to 3.00%, preferably 0.20 to 2.50%, preferably 0.30 to 2.40%, preferably 0.40 to 2.30%, preferably 0.40 to 2.20%, preferably 0.40 to 2.10%, preferably 0.40 to 2.00%, preferably 0.40 to 1.90%, preferably 0.40 to 1.80%, preferably 0.40 to 1.70%, preferably 0.40 to 1.60%, preferably 0.40 to 1.20%. In one embodiment, the mass fraction of Mo is greater than or equal to 0.03%, or 0.05%, or 0.10%, or 0.15%, or 0.20%, or 0.25%, or 0.30%, or 0.35%, or 0.40%. In one embodiment, the mass fraction of Mo is less than or equal to 3.00%, or 2.90%, or 2.80%, or 2.70%, or 2.60%, or 2.50%, or 2.40%, or 2.30%, or 2.20%, or 2.10%, or 2.00%, or 1.90%, or 1.80%, or 1.70%, or 1.60%, or 1.50%, or 1.40%, or 1.30%, or 1.20%.

This element can allow increasing the mechanical strength of the alloy by solid solution and/or by dispersoids which could form during the manufacturing of the part or during post-manufacturing heat treatments. This element has a low solubility in aluminum. The addition of this element allows increasing the yield strength, but an excessive addition of Mo i.e. at contents greater than or equal to 3.00% could lead to an increase in the cracking susceptibility and lower the elongation at rupture.

Si:

According to the present invention, the element Si can be present in the aluminum alloy according to a mass fraction less than or equal to 3.00%, preferably less than or equal to 2.50%, preferably less than or equal to 2.00%, preferably less than or equal to 1.50%, preferably less than or equal to 1.00%, preferably less than or equal to 0.50%; in one embodiment, the Si content is less than or equal to 0.30%, preferably less than or equal to 0.20%, preferably less than or equal to 0.15%, preferably less than or equal to 0.10%. According to one variant, the element Si can be present in the aluminum alloy according to a mass fraction greater than or equal to 500 ppm, or greater than or equal to 0.10%, or greater than or equal to 0.15%.

In one embodiment, the mass fraction of Si is less than or equal to 3.00%, or 2.90%, or 2.80%, or 2.70%, or 2.60%, or 2.50%, or 2.40%, or 2.30%, or 2.20%, or 2.10%, or 2.00%, or 1.90%, or 1.80%, or 1.70%, or 1.60%, or 1.50%, or 1.40%, or 1.30%, or 1.20%, or 1.10%, or 1.00%, or 0.90%, or 0.80%, or 0.70%, or 0.60%, or 0.50%, or 0.45%, or 0.40%, or 0.35%, or 0.30%, or 0.25%, or 0.20%, or 0.15%, or 0.10%.

This element can allow increasing the mechanical strength of the alloy by solid solution and/or by precipitates or dispersoids which could form during the manufacturing of the part or during

post-manufacturing heat treatments. This element could have a beneficial effect by reducing the susceptibility to cracking.

The addition of Si in the presence of Zr could lead to the formation of AlZrSi coarse phases which would limit the hardening power of Zr after heat treatment.

5 **Ni:**

According to the present invention, the element Ni can be present in the aluminum alloy according to a mass fraction less than or equal to 3.00%, preferably less than or equal to 2.50%, preferably less than or equal to 2.00%, preferably less than or equal to 1.50%, preferably less than or equal to 1.00%, preferably less than or equal to 0.50%. According to one variant, the
10 element Ni can be present in the aluminum alloy according to a mass fraction greater than or equal to 500 ppm, or greater than or equal to 0.10%, or greater than or equal to 0.15%, or greater than or equal to 0.20%, or greater than or equal to 0.30%, or greater than or equal to 0.40%.

In one embodiment, the mass fraction of Ni is less than or equal to 3.00%, or 2.90%, or 2.80%,
15 or 2.70%, or 2.60%, or 2.50%, or 2.40%, or 2.30%, or 2.20%, or 2.10%, or 2.00%, or 1.90%, or 1.80%, or 1.70%, or 1.60%, or 1.50%, or 1.40%, or 1.30%, or 1.20%, or 1.10%, or 1.00%, or 0.90%, or 0.80%, or 0.70%, or 0.60%, or 0.50%.

This element can allow increasing the mechanical strength of the alloy by solid solution and/or by dispersoids which could form during the manufacturing of the part or during post-
20 manufacturing heat treatments. This element has a low solubility in aluminum. The addition of this element could allow hardening the alloy without having a significant impact on conductivity.

Cu and/or Ag:

According to the present invention, at least one alloying element selected from among: Cu and Ag can be present in the aluminum alloy
25 according to a mass fraction of 0.05 to 1.40%, preferably 0.10 to 1.40%, preferably 0.10 to 1.30%, preferably 0.10 to 1.20%, preferably 0.10 to 1.10%, preferably 0.10 to 1.00%, preferably 0.10 to 0.90%, preferably 0.10 to 0.80%, preferably 0.10 to 0.70% for Cu;
according to a mass fraction of 0.05 to 3.00%, preferably 0.10 to 2.00%, preferably 0.10 to 1.60%, preferably 0.10 to 1.50%, preferably 0.10 to 1.40%, preferably 0.10 to 1.30%, preferably 0.10 to
30 1.20%, preferably 0.10 to 1.10%, preferably 0.10 to 1.00%, preferably 0.10 to 0.90%, preferably 0.10 to 0.80%, preferably 0.10 to 0.70% for Ag and in total.

In one embodiment, the mass fraction of at least one alloying element selected from among: Cu and Ag is greater than or equal to 0.05%, or 0.06%, or 0.07%, or 0.08%, or 0.09%, or 0.10% each and in total. In one embodiment, the mass fraction of at least one alloying element selected from among: Cu and Ag is

5 less than or equal to 1.40%, or 1.30%, or 1.20%, or 1.10%, or 1.00%, or 0.90%, or 0.80%, or 0.70% for Cu;

less than or equal to 3.00%, or 2.90%, or 2.80%, or 2.70%, or 2.60%, or 2.50%, or 2.40%, or 2.30%, or 2.20%, or 2.10%, or 2.00%, or 1.90%, or 1.80%, or 1.70%, or 1.60%, or 1.50%, or 1.40%, or 1.30%, or 1.20%, or 1.10%, or 1.00%, or 0.90%, or 0.80%, or 0.70% for Ag and in total.

10 These elements can allow increasing the mechanical strength of the alloy by solid solution and/or by hardening precipitates which could form during the manufacturing of the part or during post-manufacturing heat treatments.

According to one variant, Cu can be absent from the aluminum alloy, i.e. optionally present only as an impurity, according to a mass fraction of less than 0.05%, preferably less than 0.03%.

15 **Zn and/or Li:**

According to the present invention, at least one alloying element selected from among: Zn and Li can be present in the aluminum alloy according to a mass fraction less than or equal to 2.00%, preferably less than or equal to 1.50%, preferably less than or equal to 1.00%, preferably less than or equal to 0.50%, more preferably less than or equal to 0.30% each and in total. According to one variant, at least one alloying element selected from among: Zn and Li can be present in the aluminum alloy according to a mass fraction greater than or equal to 500 ppm, or greater than or equal to 0.10%, or greater than or equal to 0.20% each and in total.

In one embodiment, the mass fraction of at least one alloying element selected from among: Zn and Li is less than 2.00%, or less than or equal to 1.90%, or 1.80%, or 1.70%, or 1.60%, or 1.50%, or 1.40%, or 1.30%, or 1.20%, or 1.10%, or 1.00%, or 0.90%, or 0.80%, or 0.70%, or 0.60%, or 0.50%, or 0.40%, or 0.30% each and in total. In one embodiment, the mass fraction of at least one alloying element selected from among: Zn and Li is greater than or equal to 500 ppm, or 0.06%, or 0.07%, or 0.08%, or 0.09%, or 0.10%, or 0.11%, or 0.12%, or 0.13%, or 0.14%, or 0.15%, or 0.16%, or 0.17%, or 0.18%, or 0.19%, or 0.20% each and in total.

30 These elements could allow increasing the mechanical strength of the alloy by solid solution. However, these elements are sensitive to evaporation during the laser melting, which could lead to the formation of fumes and instabilities of the melt baths. The excessive addition of these

elements could significantly lower the electrical conductivity. Thus, according to one embodiment, the addition of these elements should preferably be avoided.

According to one variant, Zn can be absent from the aluminum alloy, i.e. optionally present only as an impurity, according to a mass fraction of less than 0.05%, preferably less than 0.03%.

5 **Co, La, Ce, mischmetal, W, Ta, Nb, Nd, Y, Tm, Lu, Yb, Sr, Ba, Sb, Bi, Ca, P, B, In and/or Sn:**

According to the present invention, at least one alloying element selected from among: Co, La, Ce, mischmetal, W, Ta, Nb, Nd, Y, Tm, Lu, Yb, Sr, Ba, Sb, Bi, Ca, P, B, In and Sn can be present in the aluminum alloy according to a mass fraction less than or equal to 2.00%, preferably less than or equal to 1.50%, preferably less than or equal to 1.00%, preferably less than or equal to 0.50%,
10 more preferably less than or equal to 0.30%, even more preferably less than or equal to 0.10% each, and less than or equal to 2.00%, preferably less than or equal to 1.00%, preferably less than or equal to 0.50%, preferably less than or equal to 0.30% in total. According to one variant, at least one alloying element selected from among: Co, La, Ce, mischmetal, W, Ta, Nb, Nd, Y, Tm, Lu, Yb, Sr, Ba, Sb, Bi, Ca, P, B, In and Sn can be present in the aluminum alloy according to a
15 mass fraction greater than 100 ppm, or greater than 300 ppm, or greater than 500 ppm each and in total.

In one embodiment, the mass fraction of at least one alloying element selected from among: Co, La, Ce, mischmetal, W, Ta, Nb, Nd, Y, Tm, Lu, Yb, Sr, Ba, Sb, Bi, Ca, P, B, In and Sn is less than or equal to 2.00%, or 1.90%, or 1.80%, or 1.70%, or 1.60%, or 1.50%, or 1.40%, or 1.30%, or
20 1.20%, or 1.10%, or 1.00%, or 0.90%, or 0.80%, or 0.70%, or 0.60%, or 0.50%, or 0.40%, or 0.30% each and in total, or less than or equal to 0.20% or 0.10% each. In one embodiment, the mass fraction of at least one alloying element selected from among: Co, La, Ce, mischmetal, W, Ta, Nb, Nd, Y, Tm, Lu, Yb, Sr, Ba, Sb, Bi, Ca, P, B, In and Sn is greater than or equal to 100 ppm, or 200 ppm or 300 ppm or 400 ppm or 500 ppm each and in total.

25 These elements can allow increasing the mechanical strength of the alloy by solid solution and/or by dispersoids or precipitates which could form during the manufacturing of the part or during post-manufacturing heat treatments.

The addition of Ca can be of interest, particularly to limit the evaporation of the Mg and limit oxidation thereof at the surface of the liquid bath during the atomization step and during the
30 laser powder bed fusion step.

According to one variant, B can be absent from the aluminum alloy, i.e. optionally present only as an impurity, according to a mass fraction of less than 0.05%, preferably less than 0.03%, preferably less than 0.01%, preferably less than 0.005%. The method may comprise, following

the formation of the layers, i.e. following the formation of the final part, applying at least one heat treatment. This treatment is also called post-manufacturing or post-treatment heat treatment. The post-manufacturing heat treatment can be or comprise aging or annealing. It may also comprise a solution treatment and a quenching, even though these should be avoided.

5 It may also comprise a hot isostatic pressing.

According to a first variant, in order to favor the mechanical properties, the post-manufacturing heat treatment can be performed:

- at a temperature T' higher than 400°C , in which case the duration of the post-manufacturing heat treatment is from 0.1h to 50h, preferably from 0.1h to 10h;
- 10 - or at a temperature T' from 300°C to 400°C , in which case the duration of the post-manufacturing heat treatment is from 0.1h and 200h.

According to a second variant, in order to favor the thermal or electrical conduction properties, the post-manufacturing heat treatment can be performed at a temperature T' higher than or equal to 350°C or 400°C for a duration of 0.1h to 200h, so as to obtain an optimal thermal or electrical conductivity.

According to another variant, two-step post-manufacturing heat treatments can allow maximizing the electrical conductivity. These treatments firstly consist of a first step at a temperature $T'1$ higher than 450°C for a duration of 0.1h to 100h, followed by a second step at a temperature $T'2$ comprised between 300°C and 450°C for a duration of 0.1h to 200h.

20 According to another variant, two-step post-manufacturing heat treatments can allow maximizing the electrical conductivity and/or the hardness. These treatments firstly consist of a first step at a temperature $T'1$ lower than 380°C for a duration of 0.1h to 200h, followed by a second step at a temperature $T'2$ comprised between 380°C and 450°C for a duration of 0.1h to 200h.

25 According to another variant, three-step post-manufacturing heat treatments can allow maximizing the electrical conductivity and/or the hardness. These treatments firstly consist of a first step at a temperature $T'1$ comprised between 250°C and 450°C for a duration of 0.1h to 200h, followed by a second step at a temperature $T'2$ higher than 450°C for a duration of 0.1h to 100h, followed by a third step at a temperature $T'3$ comprised between 250°C and 450°C for a duration of 0.1h to 200h.

30 Multi-step treatments with a number of steps greater than 3 may also be considered.

According to one embodiment, the method may comprise a hot isostatic pressing (HIP). In particular, the HIP treatment may allow improving the elongation properties and the fatigue

properties. The hot isostatic pressing may be carried out before, after or instead of the post-manufacturing heat treatment. Advantageously, the hot isostatic pressing is carried out at a temperature of 250°C to 500°C and preferably from 300°C to 450°C, at a pressure of 500 to 3,000 bar and for a duration of 0.5 to 100 hours.

5 For some compositions and for some types of parts, cracks of the delamination type could appear in the zones of the part with a high concentration of stresses during the post-manufacturing heat treatment of the parts, when the latter is performed in a standard furnace. The use of HIP treatment can allow preventing the apparition of these cracks.

10 Once the parts have been loaded into an HIP furnace, applying the pressure before starting the heating of the furnace can be advantageous to avoid cracking of the delamination type. For example, the pressure can be increased to a value of 1,500 to 3,000 bar before the heating is started.

15 According to an advantageous embodiment, the method does not comprise any quenching following the formation of the layers, i.e. following the formation of the final part, or following the post-manufacturing heat treatment. Thus, preferably, the method comprises no steps of solution treatment followed by quenching.

20 Resorting to a post-manufacturing heat treatment, the manufacturing being carried out by an additive manufacturing process, can allow creating expansion conditions allowing eliminating the residual stresses as well as a precipitation of hardening phases. We also talk about thermal expansion. The Inventors have observed that it was preferable for the setpoint temperature T' of the post-manufacturing heat treatment to be between 300°C and 500°C.

25 The optional heat treatment and/or the hot isostatic pressing can allow in particular increasing the hardness or the yield strength and the electrical conductivity of the obtained product. However, it should be noted that, in general, the higher the temperature, the more the conductivity (electrical or thermal) is favored to the detriment of the mechanical strengths.

30 According to one embodiment, besides the temperature T' of the post-manufacturing heat treatment, the rise in temperature, initiating the post-manufacturing heat treatment, is preferably as fast as possible. For example, during the rise in temperature, the temperature T' rise rate Δ (usually referred to by a person skilled in the art as "*heating rate*" in °C per minute or in °C per second) is preferably greater than 5°C per minute or greater than 10°C per minute, or preferably greater than 20°C per minute and more advantageously greater than 40°C per minute, and more advantageously greater than 100°C per minute. By "rise in temperature", it should be understood the rise in temperature to which the part is subjected during the post-

manufacturing heat treatment. It seems to be optimal for the rise in temperature to be instantaneous, i.e. that the manufactured part is subjected, as soon as the post-manufacturing heat treatment starts, to the setpoint temperature T' of the post-manufacturing heat treatment. An instantaneous rise in temperature may be obtained by placing the manufactured part in a hot furnace, already brought to the setpoint temperature T' , or by a rapid heating means of the fluidized bed or molten salt bath type. The rise in temperature may also be ensured by induction heating.

For the same rise in temperature outside the part, the variation of temperature inside the part depends in particular on the heating medium (liquid or air or inert gas) as well as on the shape of the part. In particular, the temperature across the thickness or at the surface of the part may be different. This is the reason why the aforementioned rise in temperature corresponds to the temperature outside the part. The combination of a preheating temperature T , a post-manufacturing heat treatment temperature T' and a temperature T' rise rate Δ , during the rise in temperature of the post-manufacturing heat treatment, in the aforementioned ranges of values, allows obtaining parts having a good resistance to thermal cracking.

According to another embodiment, suited for structural hardening alloys, it is possible to carry out a solution treatment followed by quenching and aging of the formed part and/or a hot isostatic pressing. In this case, hot isostatic pressing can advantageously replace the solution treatment.

However, the method according to the invention is advantageous because it preferably does not require a treatment consisting in a solution treatment followed by quenching. The solution treatment could have a detrimental effect on the mechanical strength in some cases by contributing to a magnification of the dispersoids or of the fine intermetallic phases. Preferably, the method according to the present invention comprises no solution treatment and/or quenching following the formation of the layers, i.e. following the formation of the final part, or following the post-manufacturing heat treatment.

According to one embodiment, optionally, the method according to the present invention further comprises a machining treatment, and/or a chemical, electrochemical or mechanical surface treatment, and/or a vibratory finishing. In particular, these treatments may be carried out to reduce the roughness and/or to improve the corrosion resistance and/or to improve the resistance to the initiation of fatigue cracks.

Optionally, it is possible to carry out a mechanical deformation of the part, for example after the additive manufacturing and/or before the heat treatment.

Although described in connection to an additive manufacturing process of the laser powder bed fusion type, the method can be applied to other additive manufacturing processes of the wire plus arc additive manufacturing type, mentioned in connection to the prior art. Figure 2 shows such an alternative. An energy source 31, in this case a torch, forms an electric arc 32. In this device, the torch 31 is held by a welding robot 33. The part 20 to be manufactured is disposed on a support 10. In this example, the manufactured part is a wall extending according to a transverse axis Z perpendicular to a plane XY defined by the support 10. Under the effect of the electric arc 32, the filler wire 35 melts so as to form a welding bead. The welding robot is controlled by a digital model *M*. It is moved so as to form different layers $20_1...20_n$, stacked on top of one another, forming the wall 20, each layer corresponding to a welding bead. Each layer $20_1...20_n$ extends in the plane XY, according to a pattern defined by the digital model *M*.

Preferably, the diameter of the filler wire is smaller than 3 mm. It may be comprised between 0.5 mm and 3 mm and is preferably comprised between 0.5 mm and 2 mm, or from 1 mm to 2 mm. For example, it amounts to 1.2 mm.

Moreover, processes other than laser powder bed fusion are possible, for example, and in a non-limiting manner:

- Selective Laser Sintering;
- Direct Metal Laser Sintering;
- Selective Heat Sintering;
- Electron Beam Melting;
- Laser Melting Deposition;
- Direct Energy Deposition;
- Direct Metal Deposition;
- Direct Laser Deposition;
- Laser Deposition Technology;
- Laser Engineering Net Shaping;
- Laser Cladding Technology;
- Laser Freeform Manufacturing Technology;
- Laser Metal Deposition;
- Cold Spray Consolidation;
- Additive Friction Stir;
- Field Assisted Sintering Technology or spark plasma sintering; or
- Inertia Rotary Friction Welding.

Preferably, the part according to the present invention has a grain structure such that the surface fraction of the columnar grains is greater than 60%, preferably greater than 70%, preferably greater than 80%, preferably greater than 90%, preferably greater than 95%.

Preferably, the part according to the present invention has at least one of the following features:

- 5 - A value of $R_{p0.2}$ at 250°C for a strain rate of $5 \times 10^{-3} \text{ min}^{-1}$ greater than or equal to 165 MPa, preferably greater than or equal to 170 MPa, preferably greater than or equal to 175 MPa, preferably greater than or equal to 180 MPa, preferably greater than or equal to 185 MPa, preferably greater than or equal to 190 MPa;
- 10 - A value of $R_{p0.2}$ at 250°C for a strain rate of 10^{-5} s^{-1} greater than or equal to 160 MPa, preferably greater than or equal to 165 MPa, preferably greater than or equal to 170 MPa, preferably greater than or equal to 175 MPa, preferably greater than or equal to 180 MPa.

The solutions according to the present invention are particularly suitable for applications in the electric, electronic and heat exchanger industries.

15 The invention will be exposed in detail in the examples hereinafter, which are given for non-limiting illustrative purposes.

Experimental examples

Example 1

20 A study was conducted on six alloys (A, B, C, D, E, F), the compositions of which, determined by ICP (Inductively Coupled Plasma) in mass percentages, are shown in Table 1 below. These six alloys were obtained in powder form using gas jet atomization (N₂). The size of the particles of the different powders was substantially from 3 µm to 120 µm, the D10 was from 26 to 33 µm, the D50 was from 47 to 58 µm and the D90 was from 81 to 93 µm.

[Table 1]

Alloy	%Fe	%Zr	%Cr	%Mg	%Mn
A	1.90	0.71	2.90	-	-
B	1.90	0.72	2.90	0.85	-
C	1.90	0.74	1.90	-	-
D	1.95	0.74	1.95	0.90	-
E	1.90	0.74	1.90	-	1.00
F	1.95	0.74	1.95	0.90	1.00

25 Using a laser powder bed fusion machine of the EOSM290 type (supplier EOS), cylindrical samples vertical relative to the building direction (direction Z) were produced with the goal of determining the mechanical characteristics of the alloys. These samples had a diameter of 11

mm and a height of 46 mm. During the printing of these samples, the main laser parameters used were the following: laser power of 370 W; scanning speed of 1,300 mm/s; hatch spacing of 0.14 mm; layer thickness of 60 μm . The heating temperature of the manufacturing platform was 100°C. All of the samples underwent a post-manufacturing heat treatment for 1 hour at 400°C with placement in the furnace directly at 400°C.

The cylindrical samples were machined to obtain tensile test pieces with the following characteristics, as described in Table 2 below and Figure 3.

[Table 2]

Test piece type	$\varnothing$ (mm)	M (mm)	LT (mm)	R (mm)	Lc (mm)	F (mm)
TOR 4	4	8	45	3	22	8.7

In Table 2 above and Figure 3, $\varnothing$ represents the diameter of the central part of the test piece; M the width of the two ends of the test piece; LT the total length of the test piece; R the radius of curvature between the central parts and the ends of the test piece; Lc the length of the central part of the test piece and F the length of the two ends of the test piece.

All the test pieces were hot tensile tested at 250°C. One part of the test pieces were tested according to the standard NF EN ISO 6892–2 (2018), with a strain rate of $5 \times 10^{-3} \text{ min}^{-1}$ up to 1% plastic deformation, then $5 \times 10^{-2} \text{ min}^{-1}$ up to the rupture of the test piece (this test condition is called “fast rate” in the rest of the description). The other part of the test pieces was tested with a constant strain rate of 10^{-5} s^{-1} until the rupture of the test piece (this test condition is called “slow rate” in the rest of the description). The main results obtained are presented in Table 3 below.

[Table 3]

Alloy	Strain rate	Rp0.2 (MPa)	Rm (MPa)	Elongation at rupture (%)
A	Fast rate	185.52	212.72	5.23
B		210.47	235.62	7.91
C		169.79	196.35	9.13
D		193.57	214.20	11.50
E		189.61	224.38	7.52
F		205.07	236.85	11.79
A	Slow rate	179.65	194.00	2.78
B		197.46	206.68	4.90
C		164.80	180.82	4.37
D		181.65	190.05	6.03
E		181.20	201.20	3.06
F		189.04	199.44	6.13

Table 4 below allows highlighting the positive effect of the addition of Mg on the tensile performances at 250°C. Each alloy in the first column of Table 4 is compared in the second column to a reference having the same composition but which does not contain Mg. The results of Table 4 show that for all the compositions tested and irrespective of the selected strain rate (fast rate or slow rate), the addition of an Mg content between 0.80 and 1.00% allowed simultaneously increasing the values of Rp0.2 (yield strength), Rm (ultimate tensile strength) and A% (elongation at rupture). This result is counterintuitive since an increase in the yield strength or in the ultimate tensile strength of a material is generally accompanied, according to the knowledge of a person skilled in the art, by a decrease in the elongation at rupture. Thus, the simultaneous increase in the yield strength, the ultimate tensile strength and the elongation at rupture at 250°C obtained by the addition of an Mg content between 0.80 and 1.00% appears to be very advantageous and surprising. In addition, the positive effect of the addition of Mg to the aluminum alloys on the mechanical performances at temperatures higher than or equal to 200°C, as is the case in the present invention, is not known.

[Table 4]

Alloy	Reference for comparison	Addition of Mg (%)	Strain rate	Increase		
				Rp0.2 (MPa)	Rm (MPa)	Elongation at rupture (%)
B	A	+0.85	Fast rate	25	22.9	2.7
D	C	+0.90		21.7	17.6	2.1
F	E	+0.90		16.6	11.3	3.6
B	A	+0.85	Slow rate	17.8	12.7	2.1
D	C	+0.90		16.9	9.2	1.6
F	E	+0.90		7.8	1.8	3.0

Example 2

A study similar to that of Example 1 was carried out on two alloys (G and H). The compositions, determined by ICP (Inductively Coupled Plasma) in mass percentages, are indicated in Table 5 below. These two alloys were obtained in powder form using gas jet atomization (N2). The size of the particles of the different powders was substantially from 3 µm to 120 µm, the D10 was from 26 to 33 µm, the D50 was from 47 to 58 µm and the D90 was from 81 to 93 µm.

[Table 5]

Alloy	%Fe	%Zr	%Cr	%Mg
G	1.90	0.72	2.90	1.70
H	2.00	0.74	2.00	1.80

From alloys G and H, test pieces were manufactured and tensile tested at 250°C under the same conditions as those described in Example 1.

The main results that have been obtained are presented in Table 6 below.

[Table 6]

Alloy	Strain rate	Rp0.2 (MPa)	Rm (MPa)	Elongation at rupture (%)
G	Fast rate	199.78	218.72	8.57
H		206.79	227.34	10.34
G	Slow rate	183.39	190.33	4.62
H		184.91	188.03	4.87

5

Table 7 below allows highlighting the effect on the tensile performances at 250°C of the additional addition of an Mg content of 0.80 to 1.00% compared to a reference that already contains between 0.80 and 1.00% of Mg.

The comparison of alloy H to alloy D shows that for a tensile test at 250°C:

10

- At fast rate, the addition of 0.90% Mg to an alloy already containing 0.90% Mg had a positive effect on Rp0.2 and Rm, but slightly degraded the elongation at rupture.
- At slow rate, the addition of 0.90% Mg to an alloy already containing 0.90% Mg had a very low effect on Rp0.2 (+3.2 MPa) and Rm (-2 MPa) and lowered the elongation at rupture (-1.1%).

The comparison of alloy G to alloy B shows that for a tensile test at 250°C:

15

- At fast rate, the addition of 0.85% Mg to an alloy already containing 0.85% Mg had a negative effect on Rp0.2 and Rm, but improved the elongation at rupture.
- At slow rate, the addition of 0.85% Mg to an alloy already containing 0.85% Mg had a negative effect on Rp0.2 and Rm and had a slight effect on the elongation at rupture (-0.3%).

20

These results showed that an excessive increase in the Mg content to contents greater than or equal to 2.50%, and preferably greater than or equal to 2.00%, does not appear to be beneficial for the yield strength (Rp0.2)/elongation at rupture (A%) compromise at 250°C. The negative effect was more marked when the Cr content of the alloy was 2.90% (comparison between alloys G and B) than when the Cr content of the alloy was 2.00% (comparison between alloys H and D).

[Table 7]

Alloy	Reference for comparison	Addition of Mg (%)	Strain rate	Increase		
				Rp0.2 (MPa)	Rm (MPa)	Elongation at rupture (%)
G	B	+0.85	Fast rate	-10.3	-19.8	+2.9
H	D	+0.90		15.6	11.5	-1.5
G	B	+0.85	Slow rate	-14.1	-16.4	-0.3
H	D	+0.90		3.2	-2	-1.1

Example 3

Test pieces similar to those described in Examples 1 and 2 were manufactured from alloys D, E, F and H.

These test pieces were hot tensile tested at 200°C according to the standard NF EN ISO 6892–2 (2018), with a deformation rate of $5 \times 10^{-3} \text{ min}^{-1}$ up to 1% plastic deformation, then $5 \times 10^{-2} \text{ min}^{-1}$ up to rupture of the test piece (called “fast rate” in the rest of the disclosure). The main results that have been obtained are presented in Table 8 below.

10 [Table 8]

Alloy	Strain rate	Rp0.2 (MPa)	Rm (MPa)	Elongation at rupture (%)
D	Fast rate	221.09	252.43	11.78
E		205.28	257.11	11.44
F		238.59	282.92	14.18
H		246.82	277.7	13.23

Table 9 below allows highlighting the positive effect of the addition of Mg on the tensile performances at 200°C.

The comparison of alloy F to alloy E showed that, at fast rate, the addition of an Mg content of 0.90% allowed simultaneously increasing the values of Rp0.2 (yield strength), Rm (ultimate tensile strength) and A% (elongation at rupture). This result is counterintuitive and confirms the result previously observed for a tensile temperature of 250°C. It should be noted that, at 200°C, the addition of 0.90% Mg led to a greater increase in Rp0.2 (yield strength) and Rm (ultimate tensile strength) than that which was observed in example 1, when comparing the tensile performances of the two same alloys at 250°C.

The comparison between alloys H and D showed that the additional addition of 0.90% Mg to a reference already containing 0.90% Mg allowed simultaneously increasing the values of Rp0.2 (yield strength), Rm (ultimate tensile strength) and A% (elongation at rupture) at 250°C. It should

be noted that at 200°C, the addition of 0.90% Mg led to a greater increase in Rp0.2 (yield strength) and Rm (ultimate tensile strength) than that which was observed at 250°C in example 2, when comparing the tensile performances of the same two alloys.

[Table 9]

Alloy	Reference for comparison	Addition of Mg (%)	Strain rate	Increase		
				Rp0.2 (MPa)	Rm (MPa)	Elongation at rupture (%)
F	E	+0.90	Fast rate	33.3	25.8	2.8
H	D	+0.90		25.3	20.2	1.4

5

Example 4

Test pieces similar to those of Example 1 were manufactured from the 5 alloys (F, H, I, J and K). The compositions, determined by ICP (Inductively Coupled Plasma) in mass percentages, are indicated in Table 10 below. These five alloys were obtained in powder form using gas jet atomization (N₂). The size of the particles was substantially from 3 µm to 120 µm, the D10 was from 26 to 33 µm, the D50 was from 47 to 58 µm and the D90 was from 81 to 93 µm.

10

[Table 10]

Alloy	%Fe	%Zr	%Cr	%Mg	%Mn	%V
F	1.95	0.74	1.95	0.90	1.00	
H	2.00	0.74	2.00	1.80		
I	2.00	0.76	2.00	0.90		1.00
J	2.00	0.78	2.00			2.00
K	1.90	0.73	1.90		2.00	

Characterizations of the granular structure were carried out on one sample per alloy by EBSD ("Electron Back Scattered Diffraction") using an EDAX camera and the software OIM ("Orientation Imaging Microscopy"). These characterizations were carried out using an MEB-FEG of the ZEISS Ultra 55 type with an energy of 15 keV, a working distance of 14 mm and a magnification (x175), with a pitch of 0.5 µm and an analysis surface of 0.293 mm² (0.6125 mm x 0.4785 mm) parallel to the manufacturing direction Z of the sample. The grain boundaries were defined with a disorientation angle greater than or equal to 15°.

15

20

Prior to the characterization by EBSD, all the samples underwent conventional mechanical polishing (abrasive paper with water lubrication then polishing cloths with diamond suspension) up to 1 µm, followed by vibration polishing with an amplitude of 30% for 6 hours, using a 50% dilution of SPM (colloidal silica gel) in water as lubricant.

Alloys K and J had a completely columnar structure. Alloys F and H had a bimodal granular structure with presence of equiaxed grains at the bottom of the molten baths and a columnar structure in the center of the molten baths. This result showed, in a counter-intuitive manner, that the partial replacement of 1% Mn by 1% Mg (comparison between alloys K and F) or the
 5 total replacement of 2% Mn by 1.8% Mg (comparison between alloys K and H) led to a significant change in the grain structure.

Alloy I had a completely columnar structure. This result showed that the replacement of 1% Mn by 1% V (comparison between alloys I and F) allowed, despite the presence of 0.9% Mg in the alloy, maintaining a completely columnar granular structure. This counter-intuitive result
 10 showed that in the presence of 0.9% Mg in the alloy, the addition of 1% V allowed counteracting the refining effect of Mg.

For all 5 alloys (F, H, I, J and K), the number of grains per mm^2 was calculated.

The same analysis surface as that described above was used. The grains touching the edge of the analysis surface were counted. The results are summarized in Table 11 below.

15 The comparison between alloys F and I showed that in the presence of an Mg content of 0.9% in the alloy, the replacement of 1% Mn with 1% V allowed significantly reducing the number of grains per mm^2 , which went from 30,881 to 3,271, respectively.

The comparison between F and H alloys showed that the replacement of 1% Mn with 0.9% Mg allowed increasing the number of grains per mm^2 , which went from 30,881 to 36,693,
 20 respectively.

Alloys I, J and K had a low number of grains per mm^2 (between 3,000 and 4,500). Among these alloys, there were alloys containing no Mg (J and K) and alloy I which contained a combination of addition of 0.9% Mg and 1% V.

Alloys F and H had a large number of grains per mm^2 (between 30,000 and 37,000). These two
 25 alloys had an addition of Mg not combined with an addition of V.

[Table 11]

Alloy	I	J	K	F	H
Number of grains per mm^2	3257	3758	4304	30881	36963

The above-described results showed that controlling the contents of Mg and V in the alloy allowed, for a given concentration of Zr in the alloy, controlling the granular structure and thus
 30 allow optimizing the granular structure according to the targeted final use. For a use requiring increased creep resistance, completely columnar structures would be preferred. However, for

other uses, for example the uses requiring a good compromise between the mechanical properties at room temperature and at high temperature, a bimodal structure could be sought.

For a given manufacturing parameter and platform temperature, the judicious selection of the contents of Zr, Mg and V in the alloy allowed controlling the granular structure of parts printed

5 by additive manufacturing.

CLAIMS

1. Method for manufacturing a part (20) comprising forming successive metal layers (20₁...20_n), superimposed on each other, each layer being formed by the deposition of a filler metal (15, 35), the filler metal being subjected to an energy input so as to melt and form, when solidifying, said layer, the method being characterized in that the filler metal (15, 35) is an aluminum alloy comprising the following alloying elements (mass percentages):
 - at least one alloying element selected from among: Zr, Hf, Sc and Er, according to a mass fraction of 0.01 to 1.60%, preferably 0.03 to 1.50%, preferably 0.05 to 1.40%, preferably 0.10 to 1.30%, preferably 0.20 to 1.25%, preferably 0.30 to 1.20%, preferably 0.40 to 1.00%, preferably 0.50 to 0.90%, preferably 0.60 to 0.80% each and in total;
 - Fe, according to a mass fraction of 0.05 to 3.00%, preferably 0.10 to 3.00%, preferably 0.20 to 3.00%, preferably 0.30 to 3.00%, preferably 0.40 to 3.00%, preferably 0.50 to 2.90%, preferably 0.60 to 2.80%, preferably 0.70 to 2.70%, preferably 0.80 to 2.70%, preferably 0.90 to 2.60%, preferably 0.90 to 2.50%, preferably 0.90 to 2.40%, preferably 0.90 to 2.30%, preferably 0.90 to 2.20%;
 - Cr, according to a mass fraction of 0.50 to 4.00%, preferably 0.70% to 4.00%, preferably 1.00 to 4.00%, preferably 1.30% to 3.90%, preferably 1.50 to 3.80%, preferably 1.60 to 3.70%, preferably 1.70 to 3.60%, preferably 1.75 to 3.50%, preferably 1.75 to 3.40%, preferably 1.75 to 3.30%, preferably 1.75 to 3.20%, preferably 1.80 to 3.20%, preferably 1.90 to 3.20%, preferably 1.90 to 3.00%, preferably 1.90% to 2.50%, preferably 1.90 to 2.20%;
 - Mg, according to a mass fraction of 0.01 to 3.50%, preferably 0.03 to 3.50%, preferably 0.05 to 3.50%, preferably 0.10 to 3.40%, preferably 0.20 to 2.50%, preferably 0.30 to 2.30%, preferably 0.40 to 2.10%, preferably 0.40 to 1.80%, preferably 0.50 to 1.80%, preferably 0.50 to 1.50%, preferably 0.50 to 1.20%;
 - optionally at least one alloying element selected from among: Mn, V and Ti according to a mass fraction greater than or equal to 0.03%, preferably greater than or equal to 0.05%, preferably 0.10 to 3.00%, preferably 0.20 to 2.50%, preferably 0.30 to 2.40%, preferably 0.40 to 2.30%, preferably 0.40 to 2.20%, preferably 0.40 to 2.10%, preferably 0.40 to 2.00%, preferably 0.40 to 1.90%, preferably 0.40 to 1.80%, preferably 0.40 to 1.70%, preferably 0.40 to 1.60%, preferably 0.40 to 1.20%, each and in total;
 - optionally Mo, according to a mass fraction greater than or equal to 0.03%, preferably greater than or equal to 0.05%, preferably 0.10 to 3.00%, preferably 0.20 to 2.50%,

preferably 0.30 to 2.40%, preferably 0.40 to 2.30%, preferably 0.40 to 2.20%, preferably 0.40 to 2.10%, preferably 0.40 to 2.00%, preferably 0.40 to 1.90%, preferably 0.40 to 1.80%, preferably 0.40 to 1.70%, preferably 0.40 to 1.60%, preferably 0.40 to 1.20%;

- optionally Si, according to a mass fraction less than or equal to 3.00%, preferably less than or equal to 2.50%, preferably less than or equal to 2.00%, preferably less than or equal to 1.50%, preferably less than or equal to 1.00%, preferably less than or equal to 0.50%, preferably less than or equal to 0.20%, preferably less than or equal to 0.15%, preferably less than or equal to 0.10%;

- optionally Ni, according to a mass fraction less than or equal to 3.00%, preferably less than or equal to 2.50%, preferably less than or equal to 2.00%, preferably less than or equal to 1.50%, preferably less than or equal to 1.00%, preferably less than or equal to 0.50%;

- optionally at least one alloying element selected from among: Cu and Ag, according to a mass fraction of 0.05 to 1.40%, preferably 0.10 to 1.40%, preferably 0.10 to 1.30%, preferably 0.10 to 1.20%, preferably 0.10 to 1.10%, preferably 0.10 to 1.00%, preferably 0.10 to 0.90%, preferably 0.10 to 0.80%, preferably 0.10 to 0.70% for Cu;

according to a mass fraction of 0.05 to 3.00%, preferably 0.10 to 2.00%, preferably 0.10 to 1.60%, preferably 0.10 to 1.50%, preferably 0.10 to 1.40%, preferably 0.10 to 1.30%, preferably 0.10 to 1.20%, preferably 0.10 to 1.10%, preferably 0.10 to 1.00%, preferably 0.10 to 0.90%, preferably 0.10 to 0.80%, preferably 0.10 to 0.70% for Ag and in total;

- optionally at least one alloying element selected from among: Zn and Li, according to a mass fraction of less than 2.00%, preferably less than or equal to 1.50%, preferably less than or equal to 1.00%, preferably less than or equal to 0.50%, more preferably less than or equal to 0.30% each and in total;

- optionally at least one alloying element selected from among: Co, La, Ce, mischmetal, W, Ta, Nb, Nd, Y, Tm, Lu, Yb, Sr, Ba, Sb, Bi, Ca, P, B, In and Sn, according to a mass fraction less than or equal to 2.00%, preferably less than or equal to 1.50%, preferably less than or equal to 1.00%, preferably less than or equal to 0.50%, more preferably less than or equal to 0.30%, even more preferably less than or equal to 0.10% each, and less than or equal to 2.00%, preferably less than or equal to 1.00%, preferably less than or equal to 0.50%, preferably less than or equal to 0.30% in total;

- impurities: < 0.05% individually, and preferably < 0.15% in total; the remainder being aluminum.

2. Method according to claim 1, characterized in that the aluminum alloy necessarily comprises at least one alloying element selected from among: Mn, V and Ti according to the described mass fractions.
3. Method according to claim 1 or 2, wherein the aluminum alloy comprises, preferably consists of: 0.50 to 0.90% of at least one alloying element selected from among Zr, Hf, Sc and Er, preferably Zr, each and in total; 0.90 to 2.20% of Fe; 0.90 to 3.20%, preferably 0.90 to 2.20% of Cr; 0.40 to 1.90%, preferably 0.40 to 1.80%, preferably 0.40 to 1.50% of Mg; 0.40 to 1.60% of at least one alloying element selected from among Mn, V and Ti, preferably Mn and V, each and in total; optionally up to 0.20%, preferably up to 0.15%, preferably up to 0.10% of Si; preferably the rest aluminum and impurities.
4. Method according to any one of the preceding claims, wherein the part has at least one of the following features:
 - A value of $R_{p0.2}$ at 250°C for a strain rate of $5 \times 10^{-3} \text{ min}^{-1}$ greater than or equal to 165 MPa, preferably greater than or equal to 170 MPa, preferably greater than or equal to 175 MPa, preferably greater than or equal to 180 MPa, preferably greater than or equal to 185 MPa, preferably greater than or equal to 190 MPa;
 - A value of $R_{p0.2}$ at 250°C for a strain rate of 10^{-5} s^{-1} greater than or equal to 160 MPa, preferably greater than or equal to 165 MPa, preferably greater than or equal to 170 MPa, preferably greater than or equal to 175 MPa, preferably greater than or equal to 180 MPa.
5. Method according to any one of the preceding claims, wherein the mass fraction of aluminum is lower than 97%.
6. Method according to any one of the preceding claims, comprising, following the formation of the layers ($20_1 \dots 20_n$), i.e. following the formation of the final part, applying a post-manufacturing heat treatment, preferably an aging or an annealing.
7. Method according to any one of the preceding claims, comprising no solution treatment and/or quenching following the formation of the layers, i.e. following the formation of the final part, or following the post-manufacturing heat treatment.
8. Method according to any one of the preceding claims, characterized in that it is carried out at a preheating temperature T of up to 500°C.

9. Method according to any one of the preceding claims, wherein the filler metal is in the form of a powder (15), the exposure of which to a beam of light (12) or of charged particles results in a local melting followed by a solidification, so as to form a solid layer (20₁...20_n).
10. Method according to any one of claims 1 to 8, wherein the filler metal comes from a filler wire (35), the exposure of which to a heat source (32) results in a local melting followed by a solidification, so as to form a solid layer (20₁...20_n).
11. Metal part obtained by a method forming the object of any one of the preceding claims.
12. Powder, intended to be used as a filler material of an additive manufacturing process, characterized in that it is formed by an aluminum alloy, comprising the following alloying elements (mass percentages):
 - at least one alloying element selected from among: Zr, Hf, Sc and Er, according to a mass fraction of 0.01 to 1.60%, preferably 0.03 to 1.50%, preferably 0.05 to 1.40%, preferably 0.10 to 1.30%, preferably 0.20 to 1.25%, preferably 0.30 to 1.20%, preferably 0.40 to 1.00%, preferably 0.50 to 0.90%, preferably 0.60 to 0.80% each and in total;
 - Fe, according to a mass fraction of 0.05 to 3.00%, preferably 0.10 to 3.00%, preferably 0.20 to 3.00%, preferably 0.30 to 3.00%, preferably 0.40 to 3.00%, preferably 0.50 to 2.90%, preferably 0.60 to 2.80%, preferably 0.70 to 2.70%, preferably 0.80 to 2.70%, preferably 0.90 to 2.60%, preferably 0.90 to 2.50%, preferably 0.90 to 2.40%, preferably 0.90 to 2.30%, preferably 0.90 to 2.20%;
 - Cr, according to a mass fraction of 0.50 to 4.00%, preferably 0.70% to 4.00%, preferably 1.00 to 4.00%, preferably 1.30 to 3.90%, preferably 1.50 to 3.80%, preferably 1.60 to 3.70%, preferably 1.70 to 3.60%, preferably 1.75 to 3.50%, preferably 1.75 to 3.40%, preferably 1.75 to 3.30%, preferably 1.75 to 3.20%, preferably 1.80 to 3.20%, preferably 1.90 to 3.20%, preferably 1.90 to 3.00%, preferably 1.90 to 2.50%, preferably 1.90 to 2.20%;
 - Mg, according to a mass fraction of 0.01 to 3.50%, preferably 0.03 to 3.50%, preferably 0.05 to 3.50%, preferably 0.10 to 3.40%, preferably 0.20 to 2.50%, preferably 0.30 to 2.30%, preferably 0.40 to 2.10%, preferably 0.40 to 1.80%, preferably 0.50 to 1.80%, preferably 0.50 to 1.50%, preferably 0.50 to 1.20%;
 - optionally at least one alloying element selected from among: Mn, V and Ti according to a mass fraction greater than or equal to 0.03%, preferably greater than or equal to 0.05%, preferably 0.10 to 3.00%, preferably 0.20 to 2.50%, preferably 0.30 to 2.40%, preferably 0.40 to 2.30%, preferably 0.40 to 2.20%, preferably 0.40 to 2.10%, preferably 0.40 to 2.00%,

preferably 0.40 to 1.90%, preferably 0.40 to 1.80%, preferably 0.40 to 1.70%, preferably 0.40 to 1.60%, preferably 0.40 to 1.20%, each and in total;

- optionally Mo, according to a mass fraction greater than or equal to 0.03%, preferably greater than or equal to 0.05%, preferably 0.10 to 3.00%, preferably 0.20 to 2.50%,
5 preferably 0.30 to 2.40%, preferably 0.40 to 2.30%, preferably 0.40 to 2.20%, preferably 0.40 to 2.10%, preferably 0.40 to 2.00%, preferably 0.40 to 1.90%, preferably 0.40 to 1.80%, preferably 0.40 to 1.70%, preferably 0.40 to 1.60%, preferably 0.40 to 1.20%;

- optionally Si, according to a mass fraction less than or equal to 3.00%, preferably less than or equal to 2.50%, preferably less than or equal to 2.00%, preferably less than or equal to 1.50%, preferably less than or equal to 1.00%, preferably less than or equal to 0.50%,
10 preferably less than or equal to 0.20%, preferably less than or equal to 0.15%, preferably less than or equal to 0.10%;

- optionally Ni, according to a mass fraction less than or equal to 3.00%, preferably less than or equal to 2.50%, preferably less than or equal to 2.00%, preferably less than or equal to 1.50%, preferably less than or equal to 1.00%, preferably less than or equal to 0.50%;

- optionally at least one alloying element selected from among: Cu and Ag, according to a mass fraction of 0.05 to 1.40%, preferably 0.10 to 1.40%, preferably 0.10 to 1.30%, preferably 0.10 to 1.20%, preferably 0.10 to 1.10%, preferably 0.10 to 1.00%, preferably 0.10 to 0.90%, preferably 0.10 to 0.80%, preferably 0.10 to 0.70% for Cu;

20 according to a mass fraction of 0.05 to 3.00%, preferably 0.10 to 2.00%, preferably 0.10 to 1.60%, preferably 0.10 to 1.50%, preferably 0.10 to 1.40%, preferably 0.10 to 1.30%, preferably 0.10 to 1.20%, preferably 0.10 to 1.10%, preferably 0.10 to 1.00%, preferably 0.10 to 0.90%, preferably 0.10 to 0.80%, preferably 0.10 to 0.70% for Ag and in total;

- optionally at least one alloying element selected from among: Zn and Li, according to a mass fraction of less than 2.00%, preferably less than or equal to 1.50%, preferably less than or equal to 1.00%, preferably less than or equal to 0.50%, more preferably less than or equal to 0.30% each and in total;

- optionally at least one alloying element selected from among: Co, La, Ce, mischmetal, W, Ta, Nb, Nd, Y, Tm, Lu, Yb, Sr, Ba, Sb, Bi, Ca, P, B, In and Sn, according to a mass fraction
30 less than or equal to 2.00%, preferably less than or equal to 1.50%, preferably less than or equal to 1.00%, preferably less than or equal to 0.50%, more preferably less than or equal to 0.30%, even more preferably less than or equal to 0.10% each, and less than or equal to 2.00%, preferably less than or equal to 1.00%, preferably less than or equal to 0.50%, preferably less than or equal to 0.30% in total;

35 - impurities: < 0.05% individually, and preferably < 0.15% in total;

the remainder being aluminum.

13. Use of a powder according to claim 12, in an additive manufacturing process selected from among: laser powder bed fusion, electron beam melting, cold spray, laser metal deposition, additive friction stir, spark plasma sintering and inertia rotary friction welding, preferably laser powder bed fusion.