A method for making parts (6) having a complex geometrical shape, the geometrical shape including e.g. various bends, branching, deflectors, sections or thickness, that includes the steps of: forming a core part (1) having a geometry substantially similar to that of the target shape, except for the outer thickness, using a three-dimensional creation method; wrapping at least a portion of the core part with fibres previously or subsequently impregnated with resin until the final dimensions of the target shape are reached; and curing the resin.
METHOD FOR MAKING COMPOSITE PARTS HAVING COMPLEX SHAPES

[0001] The present invention relates to the field of composite parts. It relates more specifically to methods for making parts having a complex shape. Even more specifically, the application envisaged notably concerns the realization of tubular parts such as aeronautical pipes designed for the air circuit.

[0002] In the aeronautics field, composite materials are increasingly widely used for realizing parts, especially structural parts. ‘Structural parts’ mean parts forming part of the aircraft’s primary structure, which withstands the mechanical forces created by the engines, wings and landing gear in particular.

[0003] However, an increasing number of non-structural parts are now also realized from composite materials.

[0004] The materials in question typically consist of tapes of fibers, possibly crossed, embedded in a thermosetting resin.

[0005] With regard to these parts, many studies have been conducted into the production methods commonly used in order to:

- reduce the production cost of the parts (including in particular the cost of tools, production time, assembly if these parts are made from several pieces designed to be assembled),

- incorporate more functions (which translates into an increased geometric complexity and thus the parts are increasingly complex to realize),

- identify materials allowing a better response to safety requirements (especially with regard to fire, smoke and toxicity standards).

[0009] This is especially the case for non-structural parts such as the pipes of aeronautical ducts for the air circuit, which are realized in pieces and then assembled. These parts are often very complex. Their external shape may also comprise branches, bends and it often has a variable cross-section. Moreover, the interior of these pipes may have a deflector or separation.

[0010] Thus, these geometric constraints mean that many costly tools are required to realize these parts. Alternatively, they are realized in many segments that are subsequently assembled. In addition, these parts are subject to material constraints, since they must be made with materials complying with fire, smoke, toxicity, etc. standards.

[0011] The objective of this invention is therefore to propose a method for manufacturing composite aeronautical parts having complex shapes, allowing:

- tools to be reduced and simplified (target: reducing one-off costs),

- manufacturing and assembling parts to be simplified (target: reducing recurrent costs),

- very complex shapes to be created that cannot be realized by conventional methods,

- materials to be used that are best suited to compliance with the fire, smoke, toxicity standards.

[0016] To this end, the method for realizing parts having a complex geometry, said geometric shape comprising e.g. bends, branches, deflectors, variable cross-sections or thicknesses, comprises steps for:

- creating a core part having a geometry substantially similar to the desired shape, except for the outer thickness, by a three-dimensional creation method,

- wrapping at least one of this core part with fibers previously or subsequently impregnated with resin, in order to obtain the final dimensions of the desired shape after the resin has hardened,

- and hardening of the resin.

It is understood that this is a method for producing a part with a complex geometric shape made of composite material having a structure reinforced by fibers.

[0021] The method possibly also comprises a step of assembling the core part with complementary parts, before wrapping at least one portion of the assembly with fibers previously or subsequently impregnated with resin.

[0022] This arrangement concerns the case of final parts in several portions, an element of which has a very complex shape, for example tubular elements having a simple shape, the whole having at the same time to be wrapped with fibers impregnated with resin for mechanical or other reasons.

[0023] Preferably, the three-dimensional creation method is a laser fusion method (SLS).

[0024] In the preferred embodiment, the thermoplastic resin used is a very high temperature thermoplastic resin.

[0025] More specifically, it is a PEEK (poly-ether-ether-ketone) type of very high temperature thermoplastic resin.

[0026] It is understood that the invention combines known methods for realizing composite parts used in aeronautics and a laser fusion method, apparently not used in the aeronautics field since it produces parts unable to meet the constraints of use in an aeronautical environment with strict safety standards.

[0027] In the field of manufacturing complex-shaped parts, the use of laser fusion methods (laser sintering in English) is known, typically in the medical field; these are usually used to realize prototype metal parts without tools, from powders.

[0028] In a simplified way, an SLS (Selective Laser Sintering) type of laser fusion method, also sometimes called direct metal 3D printing, is a technique for selective laser sintering (heating and melting) without a liquid phase.

[0029] In this way objects are created with a three-dimensional geometry as complex as desired, layer by layer, formed as required on the lower layer, by using the energy of a laser to cause the local fusion of a powder (metal, nylon, polystyrene, etc.) at the selected location, corresponding to a future solid portion of the part desired.

[0030] The method is akin to rapid prototyping with the use of powders. As has been seen, the part is made from a powder bed by consolidating successive sections in an industrial machine.

[0031] The laser consolidates the section at the surface of the preheated powder bed, the machine base penetrates to a predefined distance, a distribution system (usually a roller) deposits a new layer of powder, a new section is consolidated by laser etc.

[0032] The final part obtained can have a very complex shape. No tooling (molding, machining etc.) is necessary to realize the part obtained by this laser fusion method.

[0033] The time to realize parts depends on the desired dimensions and quality of the part. It can take a relatively long time. However, several parts can be made at the same time, which makes the method interesting from a business point of view.
These methods are beginning to be used with composite powders. The laser fusion method is, for example, relatively well developed for polyamide (PA) types of powder.

The parts made of polyamide are usually intended to be rapid prototyping types of demonstration parts. Their lifespan is relatively short because of their limited mechanical performance.

Parts made of PEEK types of resin have also been realized by this method, and are intended in particular for made-to-measure parts for medical applications (e.g. cervical prostheses).

However, for reasons of material behavior and utilization temperatures, the PEEK resin (very high temperature thermoplastic powder) is more difficult to utilize than the polyamide resin.

It is noted that the thermoplastic resin known under the name PEEK (poly-ether-ether-ketone polymer) is a highly plastic resin, used for example as a coating for non-lubricated mechanical parts.

Its melting temperature is 350° C., hence it is called a high temperature resin. This characteristic means it can be used in aeronautical applications. It can thus be used as a thermoplastic resin (already polymerized, unlike thermosetting resins, which are polymerized in a curing phase for the semi-finished item) for impregnating fibers in the context of realizing parts made of composite materials.

Thermoplastic resins also have the advantages of good resistance to impacts, fire, and humidity.

In contrast, because of their method of realization, the parts obtained by a laser fusion method are generally not reinforced by fibers. Thus, in theory they have weak mechanical characteristics and, as a result, these parts are not naturally intended for the aeronautics market. It most often concerns prototype parts, not parts intended for actual use or mass production.

In addition various methods are known in the aeronautics field for realizing parts made of composite materials.

Among these methods can be cited, in particular:

- the layup method of long fiber fabrics or tapes pre-impregnated with a thermosetting or thermoplastic resin,
- the "RTM" (Resin Transfer Molding) method: realizing a fibrous preform impregnated with thermosetting resin in a second step,
- These methods require a polymerization (thermosetting resin) or consolidation (thermoplastic resin) operation under temperature, in a vacuum, and usually under pressure.

These methods are used to realize structural or non-structural parts.

The invention thus combines a method from the medical field, choosing in addition a work material adapted to the constraints of the aeronautics field, with methods known in aeronautics, so that the result obtained is a part with a shape as complex as desired but compatible with an aeronautical use, in a manner consistent with the objectives of the invention.

According to a first embodiment, the core part is wrapped using a layup method for the core part using fabrics or tapes pre-impregnated with resin.

Alternatively, the core part is wrapped using a resin transfer molding method.

For preference, in the step of creating the core part, at least one portion of the surface of said core part intended to receive the fibers is roughened to boost mechanical binding with the fibers' impregnation resin.

This is especially advantageous in the case of a thermosetting resin.

The description that will follow, given solely as an example of an embodiment of the invention, is made with reference to the figures included in an appendix, in which:

FIG. 1 illustrates a core part intended for an air duct, realized in PEEK by laser fusion.

FIG. 2 shows the integration of this core part in a larger part comprising tubular elements made of aluminum.

FIG. 3 illustrates the layup forming the complete part.

FIG. 4 illustrates the complete part in its final state.

The method according to the invention consists of using a core part realized in PEEK by a laser fusion method; this PEEK part is used as a base during the realization of a composite part by methods known per se of pre-impregnation or resin transfer molding (RTM).

In more detail, the method is implemented on the basis of specifications for a complete part to be realized. These specifications are obtained by conventional design methods, for example by using CAD software.

The method thus comprises a first step of realizing a core part using a laser fusion method (SLS), working on a very high temperature resin type of material, here a poly-ether-ether-ketone polymer (PEEK for short).

The design data for the core part 1 to be realized are obtained from the design data for the complete part, taking into account the future thickness of fibers impregnated with resin on a portion of the part's surface (and their possible variation during a curing phase). These data relative to the core part 1 to be realized are then integrated into software controlling the laser fusion device used.

The laser fusion method is assumed to be known per se and is therefore not described further herein. The dimensions of the core part to be realized are only limited by the characteristics of the laser fusion device.

Similarly, the PEEK material and its conditions of implementation are assumed to be known per se.

FIG. 1 shows the core part 1 once realized by a laser fusion method. This core part 1 here comprises a bent branch including three deflectors inside. It is clearly difficult to realize by conventional methods. It may in fact comprise multiple branches, internal separations into different ducts, variations in cross-section or thickness, without modifications to this step of the method.

The core part 1 is thus realized with internal dimensions according to the specifications of the final part to be realized, and external dimensions adapted by taking into account the future thickness of the impregnated fibers.

The surface of the PEEK core part is roughened, by known methods, to boost mechanical binding with the resin of the fabrics (especially in the case of thermosetting resins).

In a second step of the method (FIG. 2), the core part 1 is assembled with tools 2, 3, 4, here of tubular type made of aluminum. These tools, which have a simple geometric shape, are realized by methods known per se. Their end cross-sections are naturally designed for correct assembly with the core part's end cross-sections. They also have external dimensions adapted to their future coating in impregnated fibers. The surface of these tools 2, 3, 4 is possibly treated with a view to being coating by impregnated fibers and then extracted.
In a next step 110 (FIG. 3), the assembled intermediary part obtained at the end of the previous step is wrapped with fabrics or tapes 5 of fibers pre-impregnated with resin (thermosetting in this example), here by rolling around different segments of the part. It is noted that the layup concerns the core part and the tools 2, 3, 4. The layup is realized by a technique known per se.

The thermosetting resin may be epoxy, phenolic or other resins that comply with fire, smoke, toxicity standards and have a polymerization temperature not exceeding 200° C. to avoid approaching the PEEK resin’s melting temperature.

It is noted that the walls of the PEEK part must be sealed to allow the layup of the fabrics or tapes.

In a variant, the layup method is replaced by an RTM, resin transfer molding method. This involves realizing a dry fiber preform on the core part 1 made of very high temperature PEEK, and then impregnating it with resin in a sealed environment or tool provided for this purpose.

The resin transfer molding method (RTM, a method known per se) is characterized by the fact that layers of pre-cut dry fibers are placed in a mold, which is sealed, into which is injected a resin that will impregnate the fibers. In the case of fibers impregnated with thermosetting resin, the resin is then polymerized.

In both cases, in a next step 120, the complete part is finished by polymerization or consolidation of the resin, then the tools 2, 3, 4 are extracted, here by pulling along their axes.

FIG. 4 then shows the final state of the complete part 6.

The method is particularly suitable for closed or revolving parts (e.g. tubular parts). In this case the fabrics or tapes are laid up around the PEEK part. This application example does not limit the scope of the method.

The advantage of combining the two methods makes it possible to benefit from the advantages of each method and minimize the inconveniences:

1/the PEEK part is realized without tools.

2/the PEEK part can have a complex shape with functions integrated, with a negligible impact on the production cost.

3/laying up the fabrics is carried out on the PEEK part, which requires few or no tools. When tools are used, these are much simpler tools than those which would be needed to realize parts having complex shapes by the traditional techniques.

4/the fabrics or tapes provide the reinforcement needed to obtain sufficient mechanical properties for the final part. The mechanical performance of the PEEK part must therefore solely permit the layup and/or impregnation operation, and then polymerization. This allows the design and realization of the PEEK part to be simplified. The polymerization temperature of the resins used does not exceed 200° C. This temperature level allows the PEEK part’s geometry to be unchanged.

The PEEK resin complies very well with fire, smoke, toxicity standards.

The scope of this invention is not limited to the details of the forms of embodiment considered above as an example, but on the contrary extends to modifications in the reach of the expert.

1. Method for making composite tubular parts (6) having complex shapes, characterized in that it comprises steps of:

100—creating a core part (1) having a geometry substantially similar to the desired shape, except for the outer thickness, by a three-dimensional creation method, said geometric shape comprising in particular at least one of the following elements: on the outside of the tube: bend, branch, variable cross-section; or inside the tube: deflector, separation.

105—assembling the core part (1) with at least one tool (2, 3, 4), installed at one of the end cross-sections of said core part.

110—wrapping at least one portion of said core part (1) with fibers (5) previously or subsequently impregnated with resin, until the final dimensions of the desired shape are obtained.

120—hardening the resin, and extracting said tools from the complete part (6).

2. Method according to claim 1, characterized in that the three-dimensional creation method is a laser fusion method (LSF).

3. Method according to claim 1, characterized in that the core part (1) is realized in a very high temperature thermoplastic resin.

4. Method according to claim 3, characterized in that the very high temperature thermoplastic resin is a PEEK (polyether-etherketone) type.

5. Method according to claim 1, characterized in that hardening of the resin is obtained by a phase of polymerization or consolidation of said resin.

6. Method according to claim 1, characterized in that the core part (1) is wrapped using a layup method for the core part (1) using fabric or tapes pre-impregnated with resin.

7. Method according to claim 1, characterized in that the core part (1) is wrapped using a resin transfer molding method.

8. Method according to claim 1, characterized in that in step 100 of creating the core part (1), at least one portion of the surface of said core part (1) intended to receive the fibers (5) is roughened to boost mechanical binding with the fibers’ impregnation resin.