METHOD FOR MANUFACTURING A FLOW BODY WITH A DESIRED SURFACE TEXTURIZATION AND LASER MATERIAL REMOVING DEVICE

Abstract: A method for manufacturing a flow body with a desired surface texturization in order to optimize its resistance, with the following steps: - Applying a coat of clear varnish on at least the primary surface areas of the flow body, and hardening the coat of clear varnish by exposing it to infrared radiation. - Determining the coordinates for the coated flow body surface in the form of real flow body data (130). - Determining a real flow body model (140) for the outer shape of the flow body with the desired surface texturization to be created. - Using a material removing laser (150) to mill the desired surface texturization out of the clear varnish coating, along with a laser material removing device (100) for creating a desired surface texturization on a coated flow body.
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Method for Manufacturing a Flow Body with a Desired Surface Texturization and Laser Material Removing Device

This application claims the benefit of the filing date of German Patent Application No. DE 10 201 1 009 998.0 filed 01.02.201 1 and of United States Provisional Patent Application No. US 61/438,318 filed 01.02.201 1, the disclosures of which applications are hereby incorporated herein by reference.

The invention relates to a method for manufacturing a flow body with a desired surface texturization and a laser material removing device.

DE 10 2006 004644 B4 describes a method for manufacturing flow bodies with texturized flow surfaces. In this case, a surface texture is embossed on a semi-finished product by pressing on a molding tool, wherein the shape of the embossed surface texture corresponds to the texturized flow surface to be fabricated. The semi-finished product with the embossed surface texture is adhesively bonded to a flow body in its unfinished state in order to create the texturized flow surface of the flow body.

The object of the invention is to provide a method for manufacturing a flow body with a desired surface texturization and a laser material removing device with which a desired surface texturization can be created on a flow body in an efficient and sufficiently precise manner.

This object is achieved with the features in the independent claims. Additional embodiments are indicated in the subclaims referring back to the latter.

One aspect of the invention provides a method for manufacturing a flow body with a desired surface texturization in order to optimize its resistance. According to the invention, the flow body can be a watercraft, such as a ship, a surface vehicle, an aircraft or a constituent of such a vehicle with a flow surface provided for exposure to an incoming flow.
In particular, the method for manufacturing a flow body with a desired surface texturization exhibits the following steps to optimize its resistance:

- applying a coat of clear varnish on at least the primary surface area of the flow body, in particular after applying and in particular spraying a color varnish to color the outside of the flow body surface at least on the primary surface area of the flow body,
- hardening the coat of clear varnish by exposing it to infrared radiation,
- determining the coordinates for the coated flow body surface in the form of real flow body data,
- determining a real flow body model for the outer shape of the flow body with the desired surface texturization to be created from the determined real flow body data for the coated flow body surface and from a nominal flow body model for the outer shape of the flow body, to include in particular the desired surface texturization,
- using a material removing laser to mill the desired surface texturization out of the clear varnish coating, wherein commands for activating the material removing laser for creating the desired surface texturization are based on the real flow body model.

The flow body to be provided with a desired surface texturization can here in particular be a watercraft like a ship, a surface vehicle, an aircraft or a constituent of such a vehicle with a flow surface provided for exposure to an incoming flow.

One embodiment of the method according to the invention can provide that

- color varnish and clear varnish be applied over the entire surface of the flow body, including the windows, optionally recessed access openings, and recesses for accommodating parts, components and/or sensors on the outside of the flow body, and that
- clear varnish applied to the windows while milling the desired surface
texturization out of the clear varnish coating be milled off in such a way as to
completely mill off color varnish and clear varnish present on the windows.

It can here be provided in particular that a two-component varnish be used for the clear
varnish coating.

An embodiment of the method according to the invention can provide that commands
for the adjustment motions of the material removing laser are issued based on the real
flow body model by virtue of the fact that, for purposes of material removal, a desired
path for the adjustment motions of the material removing laser is determined based on
a prescribed distance between the desired path and points on the outer surface of the
real flow body model, and the material removing laser is commanded in such a way
that the latter moves along the desired path.

An embodiment of the method according to the invention can provide that commands
for the adjustment motions of the material removing laser are issued based on position
points of the clear varnish-coated outer surface of the flow body to be texturized,
wherein an ultrasound rangefinder is used in an ultrasound removal measurement to
determine the position points as points having a predetermined position for the outer
surface of the clear varnish coating, and a desired path for the adjustment motions of
the material removing laser is determined from these position points, and commands
are issued to the material removing laser so as to move it along the desired path.

An embodiment of the method according to the invention can provide that

- the ultrasound rangefinder traverse desired paths along the surface of the flow
  body to be texturized, and that, at positions of the ultrasound rangefinder, the
  respective position and the distance of the ultrasound rangefinder or a reference
  point of the latter from the outer surface of the flow body to be texturized be
determined, and that the respective position and the respective distance be used
to ascertain a desired position and desired distance for the adjustment motion of
the material removing laser, and that
commands be issued to the adjustment device of the material removing laser in such a way that, while executing the adjustment motion of the material removing laser, the desired distances be corrected based on a laser distance measurement to adjustment positions with a respectively predetermined distance that is predetermined for executing the material removing process.

Another aspect of the invention provides a method with the following steps:

- applying a color varnish to color the outside of the flow body surface, at least on the primary surface areas of the flow body, and applying a coat of clear varnish on at least the primary surface areas of the flow body, wherein the color varnish and clear varnish are applied over the entire surface of the flow body, including the windows, optionally recessed access openings and recesses for accommodating parts, components and/or sensors on the outside of the flow body,

- hardening the coating of clear varnish by exposing it to infrared radiation,

- milling the desired surface texturization out of the clear varnish coating of the clear varnish applied to windows in such a way as to completely mill off color varnish and clear varnish present on the windows.

In particular, it can here be provided in particular that the flow body to be provided with a desired surface texturization be a watercraft, such as a ship, a surface vehicle, an aircraft or a constituent of such a vehicle with a flow surface provided for exposure to an incoming flow.

Another aspect of the invention provides a laser material removing device for creating a desired surface texturization on a coated flow body in order to optimize its resistance, with the laser material removing device exhibiting:

- a nominal flow body model module for storing prescribed nominal flow body model data, which describe the outer shape of the flow body, including the desired surface texturization,
- a laser rangefinder for determining real surface points of the real flow body,
- a flow body data correction module functionally connected with the laser rangefinder, with a function for correcting the prescribed nominal flow body model data to real flow body data for the outer shape of the real flow body with the desired surface texturization to be created,
- a material removing laser for generating the desired surface texturization on the flow body,
- a desired path determining function to determine a desired path as a setting for the adjustment motion of the material removing laser along the flow body in order to generate the desired surface texturization, wherein the desired path determining function ascertains the desired path based on the real flow body data,
- a command output device for issuing commands to the material removing laser, which, based on the real flow body data for the outer shape of the real flow body, generates command signals for moving the material removing laser along the desired path, via which the material removing laser is moved in a predetermined way over the flow surface to mill the desired surface texturization out of the clear varnish coating.

The flow body according to the invention can generally be a watercraft, such as a ship, a surface vehicle, an aircraft or a constituent of such a vehicle with a flow surface provided for exposure to an incoming flow.

In an embodiment of the laser material removing device, the latter can exhibit a texture forming command output device, with which the laser beam is adjusted with respect to direction and intensity as the material removing laser is guided along the desired trajectory, so as to create the desired surface texturization.

In an embodiment of the laser material removing device according to the invention, the latter can exhibit a safety shutdown function with an image recognition module, which performs a function to determine the approach by the laser material remover to a
primer coat located under the clear varnish through a color comparison or radiance factor comparison of the color or radiance factor currently arising at the laser beam interface of the varnish coating to the color or radiance factor of the primer coat, wherein the safety shutdown function generates a shutdown signal, and relays it to the controller to reduce the laser beam intensity or shut down the laser material remover once the color or radiance factor arising at the laser beam interface has dropped below a predetermined difference in color value relative to the color of the primer coat.

Exemplary embodiments of the invention will be described below using the attached Fig. 1, which presents a diagrammatic view of the functions of the laser material removing device according to the invention.

The laser material removing device according to the invention provided with reference number 100 on Fig. 1 is used to fabricate a flow body with a desired surface texturization in order to optimize its resistance. In this conjunction, "desired surface texturization" is understood as a prescribed texturization of a flow surface, and in particular one that was defined in a separate development process. The texturization of a surface to lessen its resistance involves a topological texture or structure of the flow body surface, which imparts a shape to the flow body that reduces or optimizes the resistance of the flow surface due to the texturization when a fluid flows around the latter as intended. The texturization is optimized with respect to lowering resistance to the individual case at hand, in particular to the respective area of the flow surface to be provided with the latter.

Examples for the surface texturization to be created with the solution according to the invention include a rib structure, scaly structure, or golf ball structure.

In particular, the flow body can be an aircraft, a hull, or an automobile, or parts thereof exposed to the flow.

The laser material removing device 100 according to the invention exhibits a material removing laser 150 for milling the desired surface texturization out of a flow body intermediate product, and a controller 110 with a command output module 113 for generating command signals to actuate the material removing laser 150. In particular,
the flow body intermediate product can be a raw product of the flow body, which is coated with a material out of which a suitable structure for the outside of the flow body, i.e., a desired surface texture, can be formed, in particular milled, burned, melted or even cut.

In particular, the material removing laser 150 can be a Picolaser.

According to the invention, the laser material removing device 100 exhibits a nominal flow body model module 120, which stores data that describe the nominal flow body, preferably in a discrete manner. In particular, the data can have the coordinates of points of the nominal flow body model. The points can be stored at a very miniscule distance from each other, preferably a distance of less than 1 mm and i.e., at a respective distance of 0.1 mm between the respectively adjacent points of the point pattern or grid pattern, which defines the respective nominal flow body model.

The outer dimensions of the flow body are stored along with the nominal flow body model or nominal flow body model as a grid pattern in the controller 110 at a predetermined level of accuracy. In particular, the latter can be stored as a pattern or collection of point coordinates. The points can be defined in particular relative to the coordinate system of the flow body itself.

The nominal structural condition of the flow body is determined by the dimensions of the outer structure for the latter, based on the prescribed, and hence ideal, shape of the flow body in its unstressed state. In particular, this ideal shape of the flow body can be the definition or shape of the flow body that was developed based on the layout and testing of the flow body, and is incorporated into the construction documents for manufacturing the latter. As a consequence, the nominal flow body model reflects the ideal flow body in its predetermined form, which has not been deformed through exposure to bearing forces and/or weight forces. In particular, points on the outer structure of the flow body are defined with the nominal flow body model.

In an embodiment, the nominal flow body model can be defined in such a way that the points on the outer structure of the flow body defined with the latter are the points on the outer structure of the flow body in its raw state. In this conjunction, "raw state" is
understood as the outer structure of the flow body after bringing the latter into its final shape using semi-finished products, without having applied a protective or color layer. In aircraft components or aircraft, the surface points will be provided with an additionally applied protective layer by adding an optional location or area-dependent thickness for the protective layer or first layer on the uncoated flow body.

In another embodiment of the invention, the nominal aircraft model is derived from the outer surface points of the nominal flow body model coated with a primer coat as well as other layers to be applied, such as in particular a color layer and/or a clear varnish coating in order to texturize or structure the outer surface of the flow body. Therefore, assumptions can here be made for the thickness of the protective varnish and/or color varnish, so that surface points of the flow body in its raw state plus the thickness of the primer coat and/or color varnish are stored as the nominal flow body model in this case.

In this way, the respectively stored points of the nominal flow body model can be stored with an accuracy of at least 0.1 mm.

By contrast, the real flow body yet to be provided with a surface texture using the method according to the invention has dimensions that deviate from the nominal flow body model, so that deviations exist between the respective point on this real flow body and the respectively corresponding point on the nominal flow body model. These deviations or differences are caused among other things by the mentioned outside forces that act on the flow body to be provided with a surface texture, or also by the dimensional inaccuracies within the framework of the prescribed production tolerances.

According to the invention, the flow body can be in particular an aircraft part or an aircraft, and a method is provided in particular for manufacturing an aircraft part or an aircraft with a desired surface texturization in order to optimize the resistance of the aircraft part or aircraft. Similarly to the above statements, the laser material removing device 100 exhibits a controller 110 and a nominal aircraft model module 120, which stores data that describe the nominal aircraft module, preferably in a discrete manner. In particular, the data can have the coordinates of points on the outer contour of the nominal aircraft module. The points can be stored at a very miniscule distance from
each other, e.g., at a respective distance of 0.1 mm between respectively adjacent points of the point pattern or grid pattern.

The precise outer dimensions of the aircraft are stored with the nominal aircraft model or nominal aircraft model as a grid pattern in the controller 110. Nominal aircraft model is here also understood as a nominal aircraft part model. In particular, the latter can be stored as a pattern or collection of point coordinates. The points can be defined in relation to the coordinate system KS-F of the aircraft itself with the normally used X, Y and Z axes. As already described in general for the flow body, the nominal structural condition of the aircraft part or aircraft is derived from the respective dimensions for the outer structure of the latter, based on the prescribed, and hence ideal, shape of the aircraft part or aircraft in its unstressed state. In particular, this ideal shape of the aircraft part or aircraft can be the definition or shape of the aircraft part or aircraft that was developed based on the layout and testing of the aircraft part or aircraft, and is incorporated into the construction documents for manufacturing the latter. As a consequence, the nominal aircraft model reflects the ideal aircraft part or aircraft in terms of flow in its predetermined form, which has not been deformed through exposure to bearing forces and/or weight forces. In particular, points on the outer structure of the aircraft part or aircraft are defined with the nominal aircraft model.

In particular, the nominal aircraft model can be defined in such a way that the points on the outer structure of the aircraft part or aircraft defined with the latter are the points on the outer structure of the aircraft part or aircraft in its raw states. As described above, it may be assumed in an embodiment of the used nominal aircraft model that a primer, meaning a primer coat, is applied to the surface of the aircraft part or aircraft as the protective layer and the first layer on which a layer is to be applied for painting the flow body. In an alternative embodiment of the used nominal aircraft model, the latter can be defined based on the assumption that a primer, meaning a primer coat, is applied to the outer surface of the aircraft part or aircraft as the protective layer and the first layer on which a layer is yet to be applied for painting the aircraft part or aircraft in a subsequent manufacturing step. In order to determine these points on the coated flow body outer surface, it can here be provided that the coordinates for the points on the outer surface of the aircraft part or aircraft are used or determined from point
coordinates for the completely uncoated aircraft part or aircraft, and obtained by adding an optional location or area-dependent thickness of the protective layer or first layer.

In another embodiment of the invention, the nominal flow body model is derived from the outer surface points of the uncoated nominal flow body model based on the flow body in its raw state and the added layer thicknesses corresponding thereto for the primer coat as well as other layers to be applied, such as in particular a color layer and/or a clear varnish coating in order to texturize or structure the outer surface of the flow body. Therefore, assumptions can here be made for the thickness of the protective varnish and/or color varnish, so that surface points of the flow body in its raw state plus the thickness of the primer coat and/or color varnish are stored as the nominal flow body model in this case.

In this way, the respectively stored points of the nominal flow body model can be stored with an accuracy of at least 0.1 mm.

By contrast, the real flow body yet to be provided with a surface texture using a method according to the invention has dimensions that deviate from the nominal flow body model, so that deviations exist between a respective point on this real flow body and the respectively corresponding point on the nominal flow body model. These deviations or differences are caused among other things by the mentioned outside forces that act on the flow body aircraft to be provided with a surface texture, or also by the dimensional inaccuracies within the framework of the prescribed production tolerances.

According to the invention, the flow body can be in particular an aircraft part or an aircraft, and a method is provided in particular for manufacturing an aircraft part or an aircraft with a desired surface texturization in order to optimize the resistance of the aircraft part or aircraft. Similarly to the above statements, the laser material removing device 100 exhibits a controller 110 and a nominal aircraft model module 120, which stores data that describe the nominal aircraft module, preferably in a discrete manner.

In particular, the data can have the coordinates for points of the nominal aircraft module. The points can be stored at a very miniscule distance from each other, e.g., at a respective distance of 0.1 mm between respectively adjacent points of the point pattern or grid pattern.
The precise outer dimensions of the aircraft are stored with the nominal aircraft model or nominal aircraft model as a grid pattern. In particular, the latter can be stored as a pattern or collection of point coordinates. The points can be defined in relation to the coordinate system KS-F of the aircraft itself with axes X, Y and Z.

The nominal structural condition reflects the dimensions of the outer structure, which are given for the aircraft in the nominal state, meaning in the unstressed state. In the unstressed state, the aircraft structure is not exposed to any outside forces. The nominal structural condition can also be defined in such a way that the aircraft model is not deformed through exposure to the bearing forces and weight forces. Bearing forces are the forces introduced into the overall structure or a bearing in a real aircraft, for example by the landing gear. In the nominal aircraft model relating to the nominal structural condition, the latter can be defined and stored in a first version, in which the surfaces of the nominal aircraft are defined without texturization. The surfaces can here be indicated and defined without a protective layer or primer, or alternatively with such a protective layer. In particular values verified through testing can be used for the thickness of the primer or protective layer to be applied to an aircraft, so that the surfaces with a primer can be derived from the surface data for the nominal aircraft model without the primer coat. According to the invention, a second version of the nominal aircraft model can additionally be used for the method according to the invention as an option, in which the surface areas of the aircraft to be provided with a desired texturization are defined with the outer contour surfaces of this desired texturization. The outer contour surface of the surface texture with the desired texturization in the areas of the aircraft where the desired texturization is to be applied can be defined in particular by a plurality of points on the outer contour surface or by predetermined spatial elements, which are added to the layer to be defined, e.g., to the outer contour data belonging to the raw state of the aircraft.

In these cases, for example, it can be provided for the method according to the invention that the respectively stored points for defining outer contour surfaces of the nominal aircraft model are stored spaced apart from each other by an average distance of at least 0.1 mm within an accuracy of 0.001 mm.
In comparison to the nominal aircraft model of the real aircraft to be provided with a surface texture, the real aircraft to be provided with a desired texturization or surface texture using the method according to the invention has deviating dimensions, and hence deviations of a respective point on this specific aircraft from the respective point on the nominal aircraft model. In order to determine these deviations, the method according to the invention can be used in particular to compare coordinates or data for the outer contour of the real aircraft having a primer or protective layer with coordinates or data for the outer contour of the nominal aircraft model, also having a primer. However, it can also be provided in this comparison that the real aircraft or nominal aircraft model or neither the real aircraft nor the nominal aircraft model [have] outer contour coordinates, in which a protective layer or primer is present or assumed to be present. Among other things, these differences are caused by the mentioned forces acting on the real aircraft to be provided with a surface texture, or also by the dimensional inaccuracies within the framework of the prescribed production tolerances. For this reason, the deviations can result in particular from at least sectional deformations of the real aircraft relative to the nominal aircraft model.

The laser material removing device 100 according to the invention thus exhibits a nominal flow body model module or nominal aircraft model module 120 for storing prescribed nominal flow body model data that describe the outer shape of the flow body or aircraft, including the desired surface texturization. In addition, the laser material removing device 100 according to the invention exhibits a laser rangefinder 160 for determining real surface points on the real flow body or aircraft.

Real surface points on the real flow body or aircraft or comparison points are here determined in such a way that these data along with the nominal flow body model or nominal aircraft model 120 can be used to ascertain real flow body data for the outer shape of the real flow body or aircraft with the desired surface texturization to be created, and in particular a real flow body model or real aircraft model 140. In particular, it can here be provided that the position coordinates for predetermined points on the outer contour surface of the real aircraft be ascertained in a spatially fixed coordinate system, e.g., one related to bearing locations or reference points in the space where the aircraft is located, or with which the origin of such a spatially fixed
coordinate system along with the axial directions of the latter are defined. It can also be provided that the position coordinates be determined using a spatially fixed coordinate system that is identical to the fixed-aircraft XYZ coordinate system. The predetermined points for the outer contour surface of the real aircraft can [be] marked locations of the latter and, for example, the foremost position of the aircraft tip, the rearmost position of the aircraft, as well as points at regular intervals along defined profile lines of the fuselage and/or airfoils. In this case, use can be made in a predetermined manner of points that are defined and, for example, spaced apart from each other at regular intervals on the profile lines of the fuselage lying symmetrically to the XZ plane of the aircraft as well as the profile lines of the fuselage lying in the XZ plane and in particular spaced apart at regular intervals along the Y direction. Alternatively or additionally, the distance measurement can be used to determine the outer contour surface points of the entire real aircraft, which are ascertained at prescribed lattice points of a spatially fixed coordinate system that coincides with the XYZ coordinate system of the plane or is offset in a predetermined manner relative thereto, wherein lattice points of a prescribed lattice of a plane lying parallel to the XY and/or XZ plane or a plane identical with the latter are used as reference points for the distance measurement, for example, and the rangefinder can be used to define the points at which the lines running perpendicular to the respective plane and passing through a respective one of the lattice points intersect with the outer contour surface of the real aircraft as outer contour surface points for which the spatial positions and spatial coordinates are determined.

The invention can provide that the laser rangefinder 160 be moved by a rangefinder adjusting device along a desired path at predetermined points on such a desired path or predetermined points on the outer surface of the real flow body or aircraft, and at these points perform a corresponding distance measurement to determine with a sufficient accuracy the real flow body coordinates or data for the outer shape or contour surface of the real flow body as reference points. According to the invention, the desired path can be prescribed, or can be determined based on the ascertained reference points for the outer contour surface points. In order to determine a real flow body model based on these data and the nominal flow body model, the distance measurement must be performed within a sufficient accuracy. This is why a PicoLaser is preferably used to perform the distance measurements, since the latter can be used
to ascertain the coordinates for the points of the outer surface of the real flow body or aircraft within an accuracy lying in the \( \mu m \) range, and this level of precision makes it possible to determine real flow body data or a real flow body model for the additional procedural steps according to the invention from the nominal flow body model data present at least in the same range of accuracy.

In order to determine real flow body data or a real flow body model, the laser material removing device 100 can exhibit a flow body data correction module 125 that is functionally connected with the laser rangefinder 160, and exhibits a function for correcting the prescribed nominal flow body model data into real flow body data for the outer shape of the real flow body or a real flow body model with the desired surface texturization to be created. It can here be provided that the coordinate system of the nominal flow body model be identical to the coordinate system for the real aircraft.

In particular, the correction function can be designed in such a way that the surface point coordinates for the real flow body or aircraft ascertained via the distance measurement can be compared with the corresponding coordinates of the nominal flow body model without desired texturization, and a deviation or distance lying between the respective points can be determined. In this regard, the surface point coordinates can have a distance of more than 0,01 m and in particular more than 0,1 m from each other. If the surface points of the real flow body have been suitably selected, and in particular are suitably distributed over the entire outer surface, the nominal aircraft model without desired texturization can be used to ascertain the surface points lying between the latter. Connecting lines between the determined outer contour points of the real aircraft can here be used as reference lines, which are established as new outer contour lines of the nominal flow body model. The additional points on the non-deformed or initial nominal flow body model are determined subject to prescribed boundary conditions, and while ascertaining curves through the determined contour surface points, e.g., by projecting the points of the nominal flow body model onto the ascertained curves, so that the latter then become points on a real flow body model or real flow body points. For example, the intermediate points lying between the reference points of the nominal flow body model corresponding to the reference points of the real flow body model can be projected onto the respective reference line by adjusting the
projection direction to the projection direction of the reference points continuously over
the progression of the reference line in a manner corresponding to the distances away
from the respective reference points.

Use can here be made of a version of the nominal flow body model whose contour
surface points are points on the unprimed or primed contour surface of the nominal
flow body. If the coordinates for the contour surface points of the real flow body are
determined in a distance measurement using a flow body having a primer with a layer
thickness, a nominal flow body model can be utilized to generate the real flow body
model or real flow body points, which also exhibits outer contour points corresponding
to outer contour points of a primer with the same layer thickness.

In order to produce data or coordinates for a real flow body model or ascertained real
flow body points with the desired texturization from outer contour surface points of the
real flow body model initially determined without consideration of the desired
texturization or ascertained real flow body points, the desired texturization of the
nominal aircraft model is in a next step added to this real flow body model determined
without consideration of the desired texturization or the ascertained real flow body
points. It can here be provided that the change in distances for reference points and/or
reference lines from the nominal aircraft model to the real aircraft model be considered
accordingly, e.g., as when coating the real aircraft body model with the desired
texturization present from the corresponding nominal aircraft model, which can be done
by proportionately adjusting intermediate points subject to the boundary condition of
retaining the overall volume between the desired texturization and the surface of the
primer for the respective flow body model.

The laser material removing device 100 further exhibits a command output device 113
for issuing commands to the material removing laser 150, which generates command
signals based on the data for the real flow body model 140 for moving the material
removing laser 150 along the desired path. The command signals for moving the
material removing laser 150 causes the material removing laser 150 to traverse the
flow surface in a predetermined manner in order to mill the desired surface texturization
out of the clear varnish coating according to the desired surface texturization generated for the real aircraft model.

In particular, the method according to the invention for manufacturing a flow body with a desired surface texturization for purposes of optimizing its resistance involves the following steps:

- applying and in particular spraying on a coat of color varnish to color the outside of the flow body surface at least on the primary surface areas of the flow body,
- applying a coat of clear varnish on at least the primary surface area of the flow body,
- hardening the coat of clear varnish by exposing it to infrared radiation,
- determining the coordinates for the coated flow body surface in the form of real flow body data 130,
- determining a real flow body model 140 for the outer shape of the flow body with the desired surface texturization to be created from the determined real flow body data 130 for the coated flow body surface and from a nominal flow body model 120 for the outer shape of the flow body, to include in particular the desired surface texturization,
- using a material removing laser 150 to mill the desired surface texturization out of the clear varnish coating, wherein commands for activating the material removing laser 150 for creating the desired surface texturization are based on the real flow body model 140.

The invention can further provide that

- color varnish and clear varnish be applied over the entire surface of the flow body, including the windows, optionally recessed access openings, and recesses for accommodating parts, components and/or sensors on the outside of the flow body, and that
• clear varnish applied to the windows while milling the desired surface
texturization out of the clear varnish coating be milled off in such a way as to
completely mill off color varnish and clear varnish present on the windows.

The clear varnish coating can be applied with a ceramic glass material. The coat of
clear varnish an also be a plasma coating. Alternatively or additionally, a two-
component varnish can be used for the clear varnish coating.

Commands for the adjustment motions of the material removing laser 150 can be
issued based on the real flow body model 140 by virtue of the fact that, for purposes of
material removal, a desired path for the adjustment motions of the material removing
laser 150 is determined based on a prescribed distance between the desired path and
points on the outer surface of the real flow body model 140, and the material removing
laser 150 is commanded in such a way that the latter moves along the desired path.

Commands for the adjustment motions of the material removing laser 150 can be
issued based on position points of the clear varnish-coated outer surface of the flow
body to be texturized, wherein an ultrasound rangefinder 170 is used in an ultrasound
removal measurement to determine the position points as points having a
predetermined position for the outer surface of the clear varnish coating, and a desired
path for the adjustment motions of the material removing laser 150 is determined from
these position points, and commands are issued to the material removing laser 150 so
as to move it along the desired path. An embodiment of the method according to the
invention can provide that the ultrasound rangefinder 170 traverses desired paths
along the surface of the flow body to be texturized, and that, at positions of the
ultrasound rangefinder 170, the respective position and the distance of the ultrasound
rangefinder 170 or a reference point of the latter from the outer surface of the flow body
to be texturized be determined, and that the respective position and the respective
distance be used to ascertain a desired position and desired distance for the
adjustment motion of the material removing laser 150. Commands are here issued to
the adjustment device of the material removing laser 150 in such a way that, while
executing the adjustment motion of the material removing laser 150, the desired
distances are corrected based on a laser distance measurement to adjustment.
positions with a respectively predetermined distance that is predetermined for executing the material removing process.
Claims

1. A method for manufacturing a flow body with a desired surface texturization in order to optimize its resistance, comprising the following steps:
   - applying a coat of color varnish to color the outside of the flow body surface at least on the primary surface areas of the flow body,
   - applying a coat of clear varnish on at least the primary surface area of the flow body,
   - hardening the coat of clear varnish by exposing it to infrared radiation,
   - determining the coordinates for the coated flow body surface in the form of real flow body data (130),
   - determining a real flow body model (140) for the outer shape of the flow body with the desired surface texturization to be created from the determined real flow body data (130) for the coated flow body surface and from a nominal flow body model (120) for the outer shape of the flow body, to include in particular the desired surface texturization,
   - using a material removing laser (150) to mill the desired surface texturization out of the clear varnish coating, wherein commands for activating the material removing laser (150) for creating the desired surface texturization are based on the real flow body model (140).

2. The method according to claim 1, characterized in that the flow body to be provided with a desired surface texturization is an aircraft.

3. The method according to claim 1 or 2, characterized
in that color varnish and clear varnish is applied over the entire surface of the flow body, including the windows, optionally recessed access openings, and recesses for accommodating parts, components and/or sensors on the outside of the flow body, and

in that clear varnish applied to the windows while milling the desired surface texturization out of the clear varnish coating is milled off in such a way as to completely mill off color varnish and clear varnish present on the windows.

4. The method according to one of the preceding claims, characterized in that a two-component varnish is used for the clear varnish coating.

5. The method according to one of the preceding claims, characterized in that commands for the adjustment motions of the material removing laser (150) are issued based on the real flow body model (140) by virtue of the fact that, for purposes of material removal, a desired path for the adjustment motions of the material removing laser (150) is determined based on a prescribed distance between the desired path and points on the outer surface of the real flow body model (140), and the material removing laser (150) is commanded in such a way that the latter moves along the desired path.

6. The method according to one of claims 1 to 3, characterized in that commands for the adjustment motions of the material removing laser (150) are issued based on position points of the clear varnish-coated outer surface of the flow body to be texturized, wherein an ultrasound rangefinder (170) is used in an ultrasound removal measurement to determine the position points as points having a predetermined position for the outer surface of the clear varnish coating, and a desired path for the adjustment motions of the material removing laser (150) is determined from these
position points, and commands are issued to the material removing laser (150) so as to move it along the desired path.

7. The method according to claim 6, characterized in that

- the ultrasound rangefinder (170) traverses desired paths along the surface of the flow body to be texturized, and that, at positions of the ultrasound rangefinder (170), the respective position and the distance of the ultrasound rangefinder (170) or a reference point of the latter from the outer surface of the flow body to be texturized is determined, and that the respective position and the respective distance are used to ascertain a desired position and desired distance for the adjustment motion of the material removing laser (150), and that

- commands are issued to the adjustment device of the material removing laser (150) in such a way that, while executing the adjustment motion of the material removing laser (150), the desired distances are corrected based on a laser distance measurement to adjustment positions with a respectively predetermined distance that is predetermined for executing the material removing process.

8. A method for manufacturing a flow body with a desired surface texturization in order to optimize its resistance, involving the following steps:

- applying a color varnish to color the outside of the flow body surface, at least on the primary surface areas of the flow body, and applying a coat of clear varnish on at least the primary surface areas of the flow body, wherein the color varnish and clear varnish are applied over the entire surface of the flow body, including the windows, optionally recessed access openings and recesses for accommodating parts, components and/or sensors on the outside of the flow body,

- hardening the coating of clear varnish by exposing it to infrared radiation,
- milling the desired surface texturization out of the clear varnish coating of the clear varnish applied to windows in such a way as to completely mill off color varnish and clear varnish present on the windows.

9. The method according to claim 8, characterized in that the flow body to be provided with a desired surface texturization is a watercraft, such as a ship, a surface vehicle, an aircraft or a constituent of such a vehicle with a flow surface provided for exposure to an incoming flow.

10. A laser material removing device (100) for creating a desired surface texturization on a coated flow body in order to optimize its resistance, with the laser material removing device (100) exhibiting:

- an nominal flow body model module (120) for storing prescribed nominal flow body model data, which describe the outer shape of the flow body, including the desired surface texturization,

- a laser rangefinder (160) for determining real surface points of the real flow body,

- a flow body data correction module (125) functionally connected with the laser rangefinder (160), with a function for correcting the prescribed nominal flow body model data to real flow body data for the outer shape of the real flow body with the desired surface texturization to be created,

- a material removing laser (150) for generating the desired surface texturization on the flow body,

- a desired path determining function (115) to determine a desired path as a setting for the adjustment motion of the material removing laser (150) along the flow body in order to generate the desired surface texturization, wherein the desired path determining function (115) ascertains the desired path based on the real flow body data,
a command output device (113) for issuing commands to the material removing laser (150), which, based on the real flow body data for the outer shape of the real flow body, generates command signals for moving the material removing laser (150) along the desired path, via which the material removing laser (150) is moved in a predetermined way over the flow surface to mill the desired surface texturization out of the clear varnish coating.

11. The laser material removing device (100) according to claim 10, characterized in that the flow body is a watercraft, such as a ship, a surface vehicle, an aircraft or a constituent of such a vehicle with a flow surface provided for exposure to an incoming flow.

12. The laser material removing device (100) according to claim 10 or 11, characterized in that the laser material removing device (100) exhibits a texture forming command output device, with which the laser beam is adjusted with respect to direction and intensity as the material removing laser (150) is guided along the desired trajectory, so as to create the desired surface texturization.

13. The laser material removing device (100) according to one of claims 10 to 12, characterized in that the laser material removing device (100) exhibits a safety shutdown function with an image recognition module, which performs a function to determine the approach by the laser material remover to a primer coat located under the clear varnish through a color comparison of the color currently arising at the laser beam interface of the varnish coating to the color of the primer coat, wherein the safety shutdown function generates a shutdown signal, and relays it to the controller to reduce the laser beam intensity or shut down the laser material remover once the color arising at the laser beam interface has dropped below a predetermined difference in color value relative to the color of the primer coat.
**INTERNATIONAL SEARCH REPORT**

**International application No**

PCT/EP2012/000447

**A. CLASSIFICATION OF SUBJECT MATTER**

INV. B64C21/10 F15D1/12 B23K26/40

ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)

F15D B64C B23K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal , WPI Data

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

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<td>US 4 907 765 A (Hirschel Ernst H [DE] ET AL) 13 March 1990 (1990-03-13) col umn 1, line 10 - line 66 col umn 2, line 17 - line 36 col umn 3, line 3 - line 17 col umn 8, line 1 - col umn 10, line 7 figures</td>
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Further documents are listed in the continuation of Box C.

Special categories of cited documents:

* "A" document defining the general state of the art which is not considered to be of particular relevance
* "E" earlier application or patent but published on or after the international filing date
* "L" document with which may throw doubts on priority claim(s) on which the claim to establish the publication date of another citation or other special reason (as specified)
* "O" document referring to an oral disclosure, use, exhibition or other means
* "P" document published prior to the international filing date but later than the priority date claimed

Later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

Document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

Document of particular relevance: the claimed invention cannot be considered further document

Member of the same patent family

Date of the actual completion of the international search

26 April 2012

Date of mailing of the international search report

04/07/2012

Name and mailing address of the ISA

European Patent Office, P.B. 5818 Patentlaan 2 NL-2280 HV Rijswijk

Tel. (+31-70) 340-2040, Fax. (+31-70) 340-3016

Authorized officer

Fageot, Philippe
### DOCUMENTS CONSIDERED TO BE RELEVANT

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<td>A</td>
<td>US 5 281 798 A (HAMM RICHARD R [US] ET AL) 25 January 1994 (1994-01-25) column 1, line 6 - line 13 column 3, line 3 - column 5, line 11 column 7, line 26 - column 11, line 64 figures 1, 2</td>
<td>10-13</td>
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This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
   because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
   because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
   because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ✗ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:
   1-7, 10-13

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☐ No protest accompanied the payment of additional search fees.
This international Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 1-7, 10-13

   a method for manufacturing a flow body with a desired surface texture in order to optimize its resistance, comprising the following steps:
   - applying a coat of color varnish to color the outside of the flow body surface at least on the primary surface areas of the flow body,
   - applying a coat of clear varnish on at least the primary surface area of the flow body,
   - hardening the coat of clear varnish by exposing it to infrared radiation,
   - determining the coordinates for the coated flow body surface in the form of real flow body data,
   - determining a real flow body model for the outer shape of the flow body with the desired surface texture in order to be created from the determined real flow body data for the coated flow body surface and from a nominal flow body model for the outer shape of the flow body, to include in particular the desired surface texture on,
   - using a material removing laser to mill the desired surface texture on out of the clear varnish coating, where the commands for activating the material removing laser for creating the desired surface texture on are based on the real flow body model and a laser material removing device for creating a desired surface texture on on a coated flow body in order to optimize its resistance.

   ---

2. claims: 8, 9

   a method for manufacturing a flow body with a desired surface texture in order to optimize its resistance, involving the following steps:
   - applying a coat of color varnish to color the outside of the flow body surface, at least on the primary surface areas of the flow body, and applying a coat of clear varnish on at least the primary surface areas of the flow body, wherein the color varnish and clear varnish are applied over the entire surface of the flow body, including the windows, optionally recessed access openings and recesses for accommodating parts, components and/or sensors on the outside of the flow body,
   - hardening the coating of clear varnish by exposing it to infrared radiation,
   - milling the desired surface texture on out of the clear varnish coating of the clear varnish applied to windows in such a way as to completely mill off color varnish and clear varnish present on the windows.

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