using suitable measures. Owing to the shapes of the cracks and damage, which are all different, this often proves difficult.

The established repair methods have a process chain which is executed almost completely manually and is characterised by a long and unstable processing time and a low reproducibility of the results of the repair. Both process stability and process quality are highly dependent on the expertise and the years of experience of the person responsible.

The quality of the known repair methods is therefore strongly influenced by the human factor. On the whole, these are also very complex methods, in particular because it must be ensured and documented that the high aviation requirements are met.

Some of the problems are, for example, the inaccuracies which occur when adjusting the components and the complicated and complex patch repairs, in which a damaged region is completely replaced, and this is also associated with high heat input during a weld repair. The high heat input may cause hot crack formation and also results in a high level of finishing complexity owing to the high weld allowance. Furthermore, high heat input leads to distortion, which can only be reduced or corrected by complex clamping devices and also subsequent adjustment processes.

The problem addressed by the invention is therefore that of providing an improved method and a corresponding device for repairing an aircraft and/or gas turbine component.

The invention solves this problem using the features of the independent claims. Further preferred embodiments of the invention are found in the drawings, the dependent claims and the associated description.

In order to solve the problem, according to the invention a method for repairing an aircraft and/or gas turbine component is proposed, wherein the method comprises the automated steps of:

a) checking the component for cracks using an optical measurement method, wherein gathered geometric and/or damage data are stored in a component-specific manner,
b) generating an adaptive processing strategy on the basis of the gathered geometric and/or damage data in a data processing unit,
c) machining the component,

d) gathering the altered geometric data of the component,
e) carrying out repair welding,
f) checking the component for cracks using an optical measurement method.

The method according to the invention can fully automatically adaptively select and/or define a strategy for repairing the component on the basis of detected damage information which is generated during the automatic inspection or check for cracks, and can then automatically carry out said strategy. For this purpose, a database which is linked to the data processing unit contains predefined cases of damage and shapes which are compared with the damage which is currently present in each case. The various cases of damage and/or shapes may in turn each be linked to specific nominal repair programs.

The correct repair measure is then selected. In addition to predefined damage geometries, certain repair logics, the position of the damage on the component, the context of an individual point of damage in a damage cluster, technological information, for example available milling cutter sizes and repair strategies which have been defined in the past, are involved in defining the processing strategy. Preferably, data is continuously transferred between automatic inspection and automatic processing.

The method according to the invention also makes it possible to document, in a component-specific manner over the entire service life of the component, all damage and the repair measures which are carried out. For this purpose, a computer program is preferably provided which automatically stores all the results and component-, repair- and technological information in a database. As a result, damage can be tracked over the service life of the component in order to draw conclusions on the significance or necessity of a repair measure.

Using the method according to the invention, the process times can be reduced and the productivity, reproducibility and process stability and quality can be significantly increased.

For example, the size of the heat-affected zone during welding can be decreased or highly reduced by the automated repair welding, and this has a positive effect on the material properties.

The automated repair welding is therefore preferably automatically scheduled by the data processing unit on the basis of the altered geometric data of the component. The cracks and/or other damage which have been prepared in this way are then preferably closed by a robot unit using a laser powder build-up welding method.

In a further preferred embodiment, the altered geometric data are gathered by automatically scanning the component and are preferably taken into account in the respective processing programs. In this case, the milling path is optically detected and the geometric information is passed to the next process step, for example to the path planning for the welding process.

Preferably, after the automated repair welding, the need for finishing work is automatically calculated. More preferably, the weld volume geometry is calculated in an intermediate step and the need for finishing work is automatically determined on the basis of the weld volume geometry.

Similarly to the welding program, this can take place automatically on the basis of the available data and nominal programs without the component actually having to be re-measured. Nominal programs are general processing strategies for components as they would be if the component were in a new condition and had the related geometry. Adaptive programs include adaptations to the actual available component, for example certain path parameters for equalising particular geometries, whereas component-independent parameters, such as the cutting speed, remain the same. In the previously-described preferred embodiment, an adapted processing program is automatically produced for finishing milling work.

In another preferred embodiment, the actual weld volume geometry is determined by measuring, for example automatically scanning, the weld seams, and can therefore be taken into account in an adapted finishing program.

Since comparatively little distortion occurs owing to the automated welding, the finishing work can also be reduced or even omitted. Welding without allowance may also be made possible.

The welding process preferably has separate online process monitoring. This is capable of identifying errors or variations in the process on the basis of certain information, for example

The method according to the invention is well suited to those aircraft or gas turbine components which are used as combustion chamber components of an aircraft engine. Combustion chamber components are subjected to high stress and checking for cracks and repair is usually associated with high complexity, which can be significantly reduced by the method according to the invention. In this case, the gas turbine component may for example have a nickel or cobalt base material.

Preferably, the component is a gas turbine component made of a superalloy. Repairing components made of superalloys is generally complex owing to the particular material properties combined with the aviation requirements for repairs. The method according to the invention makes it possible to repair such highly stressed and expensive components in an automated manner.

In order to solve the problem, according to the invention a device is proposed for repairing an aircraft or gas turbine component, wherein the device comprises at least one rotary table for receiving the component, for example an aircraft or gas turbine component, and/or a workpiece carrier, and is set up to carry out the above-described method.

The rotary table may preferably be rotated about its own axis, whereby the component placed thereon can be well processed, for example by a robot unit.

Preferably, the device comprises an automated storage rack, one or more rotary tables and one or more robot units. Different components are stored in the storage rack and are transported via a transport system to the respective processing stations on which the robot units are arranged.

The invention is explained in the following on the basis of preferred embodiments with reference to the accompanying drawings, in which:

Fig. 1 is a view of a device according to the invention comprising a plurality of robot units; and

Fig. 2 shows another embodiment of a device according to the invention.

Claims

1. Method for repairing an aircraft and/or gas turbine component (31), characterised in that the method comprises the automated steps of:

a) checking the component (31) for cracks using an optical measurement method, wherein gathered geometric and/or damage data are stored in a component-specific manner,

b) generating an adaptive processing strategy on the basis of the gathered geometric and/or damage data in a data processing unit (1),

c) machining the component (31),

d) gathering the altered geometric data of the component (31),

e) carrying out repair welding,

f) checking the component (31) for cracks using an optical measurement method.

2. Repair method according to claim 1, characterised in that milling paths and/or a milling strategy are automatically generated in step b) by the data processing unit (1).

3. Repair method according to any of the preceding claims, characterised in that the component (31) is automatically adjusted before step a) and/or f).

4. Repair method according to any of the preceding claims, characterised in that, while checking for cracks, current is individually regulated in each individual pixel.

5. Repair method according to any of the preceding claims, characterised in that, in order to gather the geometric and/or damage data within the context of checking for cracks, the detected individual images are put together by transformation and registration processes to form a full image of the component (31).

6. Repair method according to claim 5, characterised in that, in order to analyse the total point cloud of the component (31), it is broken up into portions which are individually checked for damage, and structural features and damage being determined, and differentiated on the basis of model parameters.

7. Repair method according to claims 5 and 6, characterised in that damage detected in portions which reaches to the edge of the portion is marked and is taken into account for analysing the adjacent portion.

8. Repair method according to any of the preceding claims, characterised in that a data processing unit (1) automatically defines a repair strategy using the geometric and/or damage data gathered in step a) and predefined technological parameters, and produces a global repair program for the component (31).

9. Repair method according to any of the preceding claims, characterised in that the automated repair welding is automatically scheduled by the data processing unit (1) on the basis of the altered geometric data of the component (31).

10. Repair method according to any of the preceding claims, characterised in that the altered geometric data are gathered by automatically scanning the component (31).

11. Repair method according to any of the preceding claims, characterised in that the method steps a) to f) are carried out multiple times in succession on the same component (31).

12. Repair method according to any of the preceding claims, characterised in that the component (31) is a gas turbine component made of a superalloy.

13. Device for repairing an aircraft or gas turbine component (31), characterised in that the device comprises at least one rotary table for receiving the component (31) and/or a workpiece carrier (32) and is set up to carry out the method according to any of claims 1 to 12.

14. Device according to claim 13, characterised in that the device comprises an automated storage rack (21), one or more rotary tables and one or more robot units (52, 62, 72, 82).

using suitable measures. Owing to the shapes of the cracks and damage, which are all different, this often proves difficult.

The established repair methods have a process chain which is executed almost completely manually and is characterised by a long and unstable processing time and a low reproducibility of the results of the repair. Both process stability and process quality are highly dependent on the expertise and the years of experience of the person responsible.

The quality of the known repair methods is therefore strongly influenced by the human factor. On the whole, these are also very complex methods, in particular because it must be ensured and documented that the high aviation requirements are met.

Some of the problems are, for example, the inaccuracies which occur when adjusting the components and the complicated and complex patch repairs, in which a damaged region is completely replaced, and this is also associated with high heat input during a weld repair. The high heat input may cause hot crack formation and also results in a high level of finishing complexity owing to the high weld allowance. Furthermore, high heat input leads to distortion, which can only be reduced or corrected by complex clamping devices and also subsequent adjustment processes.

From EP 2 286 956 A1 a method for automatically repairing of machine parts is known, where first of all a damaged first geometry of the machine part is digitally captured. Subsequently material is removed at the damaged position, and the second geometry newly created by the material removal is again digitally captured. In a final procedural step material is deposited, where the digitized data of the second geometry are used to control the material deposit procedure.

In WO 2009/105221 A2 a method is suggested where a contour of the part to be repaired is recorded photo-topographically by using optical reference objects which are arranged at the part, such that the damaged area can be digitally imaged. On the basis of the digital damage image obtained in this manner, a repair of the part is subsequently carried out.

Further a method for repairing a strongly damaged part from the hot gas area of a gas turbine is known from EP 2 484 481 A1. Here the damaged area of the part is removed firstly, such that a recess is formed. Subsequently a measurement of the part with the recess

is carried out, such that forming a replacement piece to be inserted in said recess is possible on the basis of the obtained measurement data. In a final procedural step the replacement piece is permanently connected to the part.

Also it is known from “Investigation of a 3D non-contact measurement based blade repair integration system” (Gao Jian et al., Aircraft Engineering and Aerospace Technology, 2005, vol. 77., No. 1, p. 34-41) to repair a gas turbine part by digitally capturing the damaged geometry of the part at first, and afterwards developing a repair strategy on the basis of the obtained data. During the repair process the gas turbine blade is for example arranged on a manipulator with two degrees of freedom.

Finally, “An integrated adaptive repair solution for complex aerospace components through geometry reconstruction“ (Gao Jian et. al, The International Journal of Advanced Manufacturing Technology, 2008, vol. 36, No. 11-12, p. 1170-1179) discloses a similar apparatus through which a complete three-dimensional digital image of a gas turbine blade can be obtained for a later repair.

The problem addressed by the invention is therefore that of providing an improved method and a corresponding device for repairing an aircraft and/or gas turbine component.

The invention solves this problem using the features of the independent claims. Further preferred embodiments of the invention are found in the drawings, the dependent claims and the associated description.

In order to solve the problem, according to the invention a method for repairing an aircraft and/or gas turbine component is proposed, wherein the method comprises the automated steps of claim 1.

The method according to the invention can fully automatically adaptively select and/or define a strategy for repairing the component on the basis of detected damage information which is generated during the automatic inspection or check for cracks, and can then automatically carry out said strategy. For this purpose, according to the invention, a database which is linked to the data processing unit contains predefined cases of damage and shapes which are compared with the damage which is currently present in each case. The various cases of damage and/or shapes may in turn each be linked to specific nominal repair programs.

The correct repair measure is then selected. In addition to predefined damage geometries, certain repair logics, the position of the damage on the component, the context of an individual point of damage in a damage cluster, technological information, for example available milling cutter sizes and repair strategies which have been defined in the past, are involved in defining the processing strategy. Preferably, data is continuously transferred between automatic inspection and automatic processing.

The method according to the invention also makes it possible to document, in a component-specific manner over the entire service life of the component, all damage and the repair measures which are carried out. For this purpose, a computer program is preferably provided which automatically stores all the results and component-, repair- and technological information in a database. As a result, damage can be tracked over the service life of the component in order to draw conclusions on the significance or necessity of a repair measure.

Using the method according to the invention, the process times can be reduced and the productivity, reproducibility and process stability and quality can be significantly increased.

For example, the size of the heat-affected zone during welding can be decreased or highly reduced by the automated repair welding, and this has a positive effect on the material properties.

The automated repair welding is therefore preferably automatically scheduled by the data processing unit on the basis of the altered geometric data of the component. The cracks and/or other damage which have been prepared in this way are then , according to the invention,closed by a robot unit using a laser powder build-up welding method.

In a further preferred embodiment, the altered geometric data are gathered by automatically scanning the component and are preferably taken into account in the respective processing programs. In this case, the milling path is optically detected and the geometric information is passed to the next process step, for example to the path planning for the welding process.

Preferably, after the automated repair welding, the need for finishing work is automatically calculated. More preferably, the weld volume geometry is calculated in an intermediate step and the need for finishing work is automatically determined on the basis of the weld volume geometry.

Similarly to the welding program, this can take place automatically on the basis of the available data and nominal programs without the component actually having to be re-measured. Nominal programs are general processing strategies for components as they would be if the component were in a new condition and had the related geometry. Adaptive programs include adaptations to the actual available component, for example certain path parameters for equalising particular geometries, whereas component-independent parameters, such as the cutting speed, remain the same. In the previously-described preferred embodiment, an adapted processing program is automatically produced for finishing milling work.

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Since comparatively little distortion occurs owing to the automated welding, the finishing work can also be reduced or even omitted. Welding without allowance may also be made possible.

The welding process preferably has separate online process monitoring. This is capable of identifying errors or variations in the process on the basis of certain information, for example

The method according to the invention is well suited to those aircraft or gas turbine components which are used as combustion chamber components of an aircraft engine. Combustion chamber components are subjected to high stress and checking for cracks and repair is usually associated with high complexity, which can be significantly reduced by the method according to the invention. In this case, the gas turbine component may for example have a nickel or cobalt base material.

Preferably, the component is a gas turbine component made of a superalloy. Repairing components made of superalloys is generally complex owing to the particular material properties combined with the aviation requirements for repairs. The method according to the invention makes it possible to repair such highly stressed and expensive components in an automated manner.

In order to solve the problem, according to the invention a device is proposed for repairing an aircraft or gas turbine component, wherein the device comprises at least one rotary table for receiving the component, for example an aircraft or gas turbine component, and/or a workpiece carrier, and is set up to carry out the above-described method, wherein a robot unit is provided which is set up to perform a repair welding using a laser powder build-up welding method, wherein a database which is linked to a data processing unit contains predefined cases of damage and shapes which can be compared with the damage which is currently present in each case.

The rotary table may preferably be rotated about its own axis, whereby the component placed thereon can be well processed, for example by a robot unit.

Preferably, the device comprises an automated storage rack, one or more rotary tables and one or more robot units. Different components are stored in the storage rack and are transported via a transport system to the respective processing stations on which the robot units are arranged.

The invention is explained in the following on the basis of preferred embodiments with reference to the accompanying drawings, in which:

Fig. 1 is a view of a device according to the invention comprising a plurality of robot units; and

Fig. 2 shows another embodiment of a device according to the invention.

Claims

1. Method for repairing an aircraft and/or gas turbine component (31), characterised in that the method comprises the automated steps of:
   a) checking the component (31) for cracks using an optical measurement method, wherein gathered geometric and/or damage data are stored in a component-specific manner,
   b) generating an adaptive processing strategy on the basis of the gathered geometric and/or damage data in a data processing unit (1),
   c) machining the component (31),
   d) gathering the altered geometric data of the component (31),
   e) carrying out repair welding, characterised in that the repair welding is performed by a robot unit using a laser powder build-up welding method,
   f) checking the component (31) for cracks using an optical measurement method, wherein
   a database which is linked to the data processing unit contains predefined cases of damage and shapes which in process step b) are compared with the damage which is currently present in each case.

2. Repair method according to claim 1, characterised in that milling paths and/or a milling strategy are automatically generated in step b) by the data processing unit (1).

3. Repair method according to any of the preceding claims, characterised in that the component (31) is automatically adjusted before step a) and/or f).

4. Repair method according to any of the preceding claims, characterised in that, while checking for cracks, current is individually regulated in each individual pixel.

5. Repair method according to any of the preceding claims, characterised in that, in order to gather the geometric and/or damage data within the context of checking for cracks, the detected individual images are put together by transformation and registration processes to form a full image of the component (31).

6. Repair method according to claim 5, characterised in that, in order to analyse the total point cloud of the component (31), it is broken up into portions which are individually checked for damage, and structural features and damage being determined, and differentiated on the basis of model parameters.

7. Repair method according to claims 5 and 6, characterised in that damage detected in portions which reaches to the edge of the portion is marked and is taken into account for analysing the adjacent portion.

8. Repair method according to any of the preceding claims, characterised in that a data processing unit (1) automatically defines a repair strategy using the geometric and/or damage data gathered in step a) and predefined technological parameters, and produces a global repair program for the component (31).

9. Repair method according to any of the preceding claims, characterised in that the automated repair welding is automatically scheduled by the data processing unit (1) on the basis of the altered geometric data of the component (31).

10. Repair method according to any of the preceding claims, characterised in that the altered geometric data are gathered by automatically scanning the component (31).

11. Repair method according to any of the preceding claims, characterised in that the method steps a) to f) are carried out multiple times in succession on the same component (31).

12. Repair method according to any of the preceding claims, characterised in that the component (31) is a gas turbine component made of a superalloy.

13. Device for repairing an aircraft or gas turbine component (31), characterised in that the device comprises at least one rotary table for receiving the component (31) and/or a workpiece carrier (32) and is set up to carry out the method according to any of claims 1 to 12, wherein a robot unit is provided which is set up to perform a repair welding using a laser powder build-up welding method, wherein a database which is linked to a data processing unit contains predefined cases of damage and shapes which can be compared with the damage which is currently present in each case.

14. Device according to claim 13, characterised in that the device comprises an automated storage rack (21), one or more rotary tables and one or more robot units (52, 62, 72, 82).