

A METHOD OF REPAIRING A METAL COMPONENT

Technical Field

[0001] The present disclosure generally relates to a cold gas dynamic spraying process. More particularly, it relates to a method of using cold gas dynamic spraying on metallic components for repair of metal components used in various industries, including aviation, defense, rail, transportation, marine, and manufacturing sectors.

Background

[0002] The following discussion of the background to the invention is intended to facilitate an understanding of the present invention. However, it should be appreciated that the discussion is not an acknowledgment or admission that any of the material referred to was published, known or part of the common general knowledge in any jurisdiction as at the priority date of the application.

[0003] Historically, the repair of metallic components for critical applications has posed significant challenges. Traditional repair methodologies, such as welding, often result in distortion of components due to localized heating and the accumulation of residual thermal stresses. Moreover, the outright replacement of damaged components entails substantial costs and operational disruptions, particularly in applications where downtime is a critical factor.

[0004] In response to these challenges, alternative repair solutions have been sought. Cold gas dynamic spraying has emerged as a promising alternative, offering a non-invasive and cost-effective method for restoring damaged metallic components to their original specifications. Some applications for restoration of damaged metallic components include

aircraft wing/fuselage repair following lightning strikes, missile launcher rail repair due to wear, boat deck leakages repair, motor part repair, and pontoon leakages repair, and railway tracks.

[0005] There is therefore a need to provide convenience and ease of repair for metallic components utilized in critical applications with minimal downtime. By harnessing the capabilities of cold gas dynamic spraying, the present invention seeks to extend the lifespan of components that would otherwise be deemed irreparable or slated for costly replacement. The present invention seeks to address the immediate need for efficient repair solutions and contribute to significant cost savings and operational efficiencies in industries where downtime can have far-reaching implications.

[0006] Therefore, the present invention attempts to overcome at least in part some of the aforementioned disadvantages and to provide for an improved approach for addressing the foregoing challenge.

Summary of the Invention

[0007] One aspect of the present invention relates to a method of repairing metal components. A metal component refers to any piece of machinery made primarily from metals such as nickel, aluminum, copper, iron, steel or alloys. The need for repair arises when these components undergo wear and tear or damage due to various factors like corrosion, fatigue, impact, etc.

[0008] Identifying a repair surface area on the metal component involves locating the damaged part of the component that requires restoration. In some embodiments, the repair surface area refers to an area on the surface of the component that is damaged, worn or is not compliant with acceptable tolerance levels prescribed by a design specification of the

component or as prescribed by an industry standard. Preparing the repair surface area for cold gas dynamic spraying is an essential step in ensuring effective bonding between the new material and the existing one. This preparation can be achieved through treatments such as grinding, machining, or cleaning to create a smooth, clean, and rough surface for optimal adhesion.

[0009] It may be provided that a cold gas dynamic spraying device is configured for this method. A cold gas dynamic spraying device refers to an apparatus designed to deposit powdered materials onto surfaces using high-velocity jets of compressed gases. The device comprises three main components: a powder feeder, a gas supply, a gas flow controller and a nozzle assembly.

[0010] The powder feeder is responsible for receiving the powdered repair material that will be sprayed onto the metal component's surface. This arrangement allows easy loading and unloading of various materials suitable for different types of repairs.

[0011] The gas supply serves to provide the carrier gas, which acts as a propellant medium during the spraying process. The gas heater within this system is used to heat up the pressurized carrier gas and powdered repair material before they are combined in the nozzle assembly. This heating ensures that the particles remain in their gaseous state at high velocities, enabling them to penetrate deep into the surface cracks for effective coating.

[0012] The nozzle assembly is where the actual spraying takes place. It consists of a converging-diverging nozzle and an orifice plate that control the shape and direction of the gas jet, respectively. The distance between this arrangement and the repair surface area can be adjusted to ensure optimal coverage while minimizing potential damage to surrounding areas.

[0013] One advantage of using cold gas dynamic spraying for metal component repairs is its ability to deposit thick coatings uniformly over large surfaces without causing significant heat input or distortion, making it suitable for repairing complex geometries and large structures like aircraft engines or industrial machinery components. Additionally, the process allows for the use of various materials with different properties such as metals, alloys, ceramics, and composites to be deposited directly onto the metal component's surface without requiring extensive pre-treatment or post-processing steps.

[0014] In summary, this method involves identifying a repair area on a metal component, preparing it for cold gas dynamic spraying by treating its surface, configuring a cold gas dynamic spraying device to deposit powdered material onto the repaired area using high-velocity jets of compressed gases, and taking advantage of the process's unique features like uniform coating deposition, minimal heat input, and versatility in materials used.

[0015] According to various embodiments, the powdered repair material is substantially the same material as the component.

[0016] According to various embodiments, the carrier gas includes one of the following: nitrogen and helium.

[0017] According to various embodiments, the predetermined pressure is between 140 psi – 200 psi.

[0018] According to various embodiments, the predetermined temperature is between 350°C to 500°C.

[0019] According to various embodiments, the stand-off distance is between 10-30mm.

[0020] According to various embodiments, the coating meets the technical data requirements of a design specification for the component.

[0021] According to various embodiments, the technical data requirements include one or more of the following: tensile strength, bearing load, yield strength, peel strength, bearing strength and bending strength.

[0022] A second aspect of the present invention relates to a method of repairing a metal component containing aluminium, comprising: identifying a repair surface area on the metal component, preparing the repair surface area for a cold gas dynamic spraying process by one or more of the treatments: grinding, machining and cleaning, configuring a cold gas dynamic spraying device to cold spray a powdered material onto the repair surface area of the component, wherein the cold gas dynamic spraying device comprises a powder feeder for receiving a powdered repair material, a gas supply for supplying a carrier gas to a gas heater and a nozzle assembly through a gas flow controller.

[0023] The steps of configuring the cold gas dynamic spraying device include:

- (i) providing the carrier gas comprising nitrogen to the gas supply;
- (ii) setting a predetermined pressure of between 150-200psi on the gas flow controller to be applied to the carrier gas from the gas supply;
- (iii) setting a predetermined temperature of between 350°C - 400°C to be applied to the pressurized carrier gas and the powdered repair material; and
- (iv) adjusting the stand-off distance between the nozzle assembly and the repair surface to between 10-30mm.

[0024] Following the aforesaid step, the next step is cold spraying the powdered repair material onto the repair surface area with the cold gas dynamic spraying device to form a

coating defined by a predetermined thickness and a predetermined dimension to cover the repair surface area.

[0025] A third aspect of the present invention relates to a method of repairing a metal component including one of: Al-7075 and Al-2024, the method comprising: identifying a repair surface area on the metal component, preparing the repair surface area for a cold gas dynamic spraying process by one or more of the treatments: grinding, machining and cleaning; configuring a cold gas dynamic spraying device to cold spray a powdered material onto the repair surface area of the metal component, wherein the cold gas dynamic spraying device comprises a powder feeder for receiving a powdered repair material, a gas supply for supplying a carrier gas to a gas heater and a nozzle assembly through a gas flow controller.

[0026] The steps of configuring the cold gas dynamic spraying device include:

- (i) providing the carrier gas comprising helium to the gas supply; and
- (ii) setting a predetermined pressure of between 140psi on the gas flow controller to be applied to the carrier gas from the gas supply for transport to the powder feeder and the gas heater;
- (iii) setting a predetermined temperature of 400°C on the gas heater to be applied to the pressurized carrier gas and the powdered repair material; and
- (iv) adjusting the stand-off distance between the nozzle assembly and the repair surface area to between 10-30mm.

[0027] Following the aforesaid step, the next step is cold spraying the powdered repair material onto the repair surface area with the cold gas dynamic spraying device to form a coating defined by a predetermined thickness and a predetermined dimension to cover the repair surface area.

[0028] A fourth aspect of the present invention relates to a method of repairing a metal component comprising one or more of the following: cast iron, steel and nickel, comprising: identifying a repair surface area on the metal component, preparing the repair surface area for a cold gas dynamic spraying process by one or more of the treatments: grinding, machining and cleaning, configuring a cold gas dynamic spraying device to cold spray a powdered material onto the repair surface area of the component, wherein the cold gas dynamic spraying device comprises a powder feeder for receiving a powdered repair material, a gas supply for supplying a carrier gas to a gas heater and a nozzle assembly through a gas flow controller.

[0029] The steps of configuring the cold gas dynamic spraying device include:

- (i) providing the carrier gas comprising nitrogen to the gas supply; and
- (ii) setting a predetermined pressure of approximately 175-200psi on the gas flow controller to be applied to the carrier gas from the gas supply for transport to the powder feeder and the gas heater;
- (iii) setting a predetermined temperature of approximately 400-500°C on the gas heater to be applied to the pressurized carrier gas and the powdered repair material; and
- (iv) adjusting the stand-off distance between the nozzle assembly and the repair surface area to between 10-30mm.

[0030] Following the aforesaid step, the next step is cold spraying the powdered repair material onto the repair surface area with the cold gas dynamic spraying device to form a coating defined by a predetermined thickness and a predetermined dimension to cover the repair surface area.

Brief Description of the Drawings

[0031] In the drawings, like reference characters generally refer to the same parts throughout the different views. The drawings are not necessarily to scale, emphasis instead generally being placed upon illustrating the principles of the invention. The dimensions of the various features or elements may be arbitrarily expanded or reduced for clarity. In the following description, various embodiments of the invention will be better understood with reference to the detailed description when considered in conjunction with the non-limiting examples and the accompany drawings, in which:

[0032] Fig. 1 illustrates an block diagram of a cold gas dynamic spraying device according to various embodiments;

[0033] Fig. 2 illustrates a flow diagram of a method of repairing a metal component according to various embodiments.

Detailed Description

[0034] Reference will now be made in detail to an exemplary embodiment of the present invention, examples of which are illustrated in the accompanying drawings. While the invention will be described in conjunction with the embodiment, it will be understood that they are not intended to limit the invention to these embodiments. On the contrary, the invention is intended to cover alternatives, modifications, and equivalents, which may be included within the spirit and scope of the invention as defined by the appended description. Furthermore, in the following detailed description of embodiments of the present invention, numerous specific details are set forth in order to provide a thorough understanding of the present invention. However, it will be recognized by one of ordinary skill in the art that the present invention may be practiced without these specific details. In other instances, well-known methods, procedures, components, and circuits have not been described in detail as not to unnecessarily obscure aspects of the embodiments of the present invention.

[0035] In the specification the term “comprising” shall be understood to have a broad meaning similar to the term “including” and will be understood to imply the inclusion of a stated integer or step or group of integers or steps but not the exclusion of any other integer or step or group of integers or steps. This definition also applies to variations on the term “comprising” such as “comprise” and “comprises”.

[0036] Features that are described in the context of an embodiment may correspondingly be applicable to the same or similar features in the other embodiments. Features that are described in the context of an embodiment may correspondingly be applicable to the other embodiments, even if not explicitly described in these other embodiments. Furthermore, additions and/or combinations and/or alternatives as described for a feature in the context of an embodiment may correspondingly be applicable to the same or similar feature in the other embodiments.

[0037] In the context of various embodiments, the articles “a”, “an” and “the” as used with regard to a feature or element include a reference to one or more of the features or elements.

[0038] As used herein, the term “and/or” includes any and all combinations of one or more of the associated listed items.

[0039] Cold gas dynamic spraying ("cold spray") is a spray deposition process that uses high-velocity gases to deposit metal powders from a “de Laval” nozzle with a converging-diverging internal geometry at velocities of more than Mach 1. This technique is advantageous in that it provides sufficient energy to accelerate particles to high enough velocities such that, upon impact during an initial pass, the particles plastically deform and bond to the surface of the component on which they are being deposited so as to build a

relatively dense coating or structural deposit. On subsequent passes, the particles bond to the previously deposited layer. Cold spray does not metallurgically transform the particles from their solid state.

[0040] The present invention represents a significant advancement in the field of metallic component repair for critical applications. By harnessing the power of cold gas dynamic spraying, the invention not only addresses the shortcomings of traditional repair methodologies but also provides a transformative solution for extending the lifespan and enhancing the reliability of vital systems with by providing efficiency, reliability, and sustainability in metallic component repair.

[0041] The present invention offers several advantages. By leveraging cold gas dynamic spraying as a repair solution, the invention obviates the need for disruptive and costly component replacements. This not only minimizes downtime but also enhances the operational readiness and reliability of critical systems. Furthermore, the non-invasive nature of cold gas dynamic spraying mitigates the risk of additional damage to repaired components, ensuring the integrity and performance of vital systems in aerospace, defense, marine, and industrial applications. Additionally, the method can be performed directly on the component without disassembly, avoiding the need for transportation of large components to off-site facilities and minimizing equipment downtime. Moreover, the versatility of cold gas dynamic spraying enables its application across a diverse range of components and materials, providing a comprehensive and scalable solution for repair challenges in various sectors. Whether addressing lightning strike damage on aircraft wings, wear on missile launcher rails, or leakages on boat decks and pontoons, the invention offers a tailored and effective approach to component restoration.

[0042] The present invention also addresses the gaps in aviation standards regulating the application of cold spray in aviation component repair. Significant research efforts have

been dedicated to exploring the intricacies of cold spray bonding and consolidation mechanisms. Investigations have covered a wide range of topics, including suitable materials for cold spraying, material behavior after post-processes like heat treatment, and diverse methods for material characterization. Additionally, researchers have examined potential applications of cold spray technology. However, despite the wealth of work documented in open literature, there remains an unaddressed gap concerning aviation standards governing the application of cold spray in aviation components. This critical area requires further attention to ensure safe and effective utilization of cold spray techniques in the aviation industry.

[0043] To achieve the stated features, advantages and objects, the present invention is directed to a method for repairing a metal component using cold gas dynamic spraying. The metal component includes components with aluminium. Suitable aluminium containing materials that may be used to effect repairs in accordance with the present invention, include, but are not limited to, aluminium alloys Al-7075 and Al-2024.

[0044] FIG. 1 illustrates a block diagram of a cold gas dynamic spraying device for repairing a repair component according to various embodiments. As shown in FIG. 1, the device 100 comprises a powder feeder 130 for providing a powdered repair material, a gas supply 110, a gas heater 140 for heating the gas and a gas flow controller 120 and a nozzle assembly 150 for accelerating particles of the powdered repair material. In operation, the device 100 transports the powdered repair material with a suitable pressurized gas from the gas heater 140 to the nozzle assembly 150. In various embodiments, a carrier gas, such as helium, nitrogen, compressed air or other inert gases, or mixtures thereof, enters the gas flow controller 120 from the gas supply 110. The gas flow controller 120 controls the pressure of the pressurized carrier gas so that the pressurized carrier gas does not exceed a predetermined pressure or is maintained within a predetermined pressure. The gas flow controller 120 may include pressure regulator and/or pressure gauges to determine the

pressure of the pressurized carrier gas. The pressurized carrier gas is split between the powder feeder 130 and the gas heater 140. Particles of the powdered repair material are accelerated by the pressurized carrier gas through the nozzle assembly 150. The nozzle assembly can be but not limited to a de Laval nozzle. The accelerated gas and powdered repair material exit the nozzle assembly 150 towards the repair surface area of the repair component. When the particles strike the repair surface area, converted kinetic energy of the particles cause plastic deformation in the repair surface area of the repair component permitting the particles to partially embed into the repair surface area, thereby forming a coating over the repair surface area.

[0045] In various embodiments, the device 100 includes a first conduit connecting the nozzle assembly 150 to the gas heater 140 so that the nozzle assembly 150 is in fluid communication with the gas heater 140. In various embodiments, a mixing chamber before the nozzle assembly 150 is in fluid communication with the first conduit. The mixing chamber receives the heated pressurized gas and the powdered repair material, and feeds the particles of the powdered repair material into the nozzle assembly 150. The nozzle assembly 150 includes an adjustable aperture that can be adjusted to a desired size to optimize the gas pressure, and in turn, the particle velocity as it passes through the nozzle assembly 150. The pressurized carrier gas is preferably heated by the gas heater so that the temperature of the pressurized carrier gas temperature can be at a predetermined or a desired temperature for accelerating the particles of the powdered repair material to form the coating on the repair surface area of the repair component. The pressurized carrier gas is heated to keep it from rapidly cooling and freezing once it expands past the mouth of the nozzle assembly. In various embodiments, the powdered repair material suitable for use includes powders comprising metal. The powdered repair material may include the same material as the repair component, or any other suitable material. For example, the powdered repair material comprises aluminum, such as aluminium-alumina alloy, Al-7075 and Al-2024.

[0046] In various embodiments, the nozzle assembly is equipped with a converging/diverging nozzle such as a de Laval nozzle. This nozzle facilitates the controlled deposition of the powdered repair material onto an affected area of the repair component. During the deposition process, the repair component can remain stationary or be subjected to articulation or translation using suitable methods. Alternatively, the nozzle assembly itself may be held stationary or manipulated. In certain scenarios, both the repair component and the nozzle assembly may undergo manipulation to achieve precise repair outcomes.

[0047] Figure 2 shows a flow diagram of a method of repairing a component in accordance with an embodiment of the invention. The component includes, but not limited to, components containing aluminium, cast iron, steel or nickel. Suitable materials that may be used to effect repairs in accordance with the present invention, include, but are not limited to, aluminium alloys (aluminium-alumina, Al-7075 and Al-2024) or nickel alloys. In some embodiments, the component is a typical sheet metal assembly with a fastener joint. In various embodiments, the component includes aircraft components such as aircraft wing/fuselage which have been damaged by lightning strikes, aircraft skin, panels, brackets and stiffeners that are prone to corrosion and fastener hole wear, airborne components which have been damaged by excessive wear or found with casting defects and floating platforms with leakages due to wear and tear. Other components can also include railway track components, missile launcher rail components, boat deck components, motor part components, pontoon components.

[0048] At step 201, a repair surface area on the component is identified. The repair surface area refers to an area on the surface of the component that is damaged, worn or is not compliant with acceptable tolerance levels prescribed by a design specification of the component or as prescribed by an industry standard. For example, when the corrosion depth

of the sheet metal or fastener hole of an aircraft component exceeds stipulated limits, these parts need to be repaired or restored to within acceptable levels. Other examples of a typical repair surface area include surface corrosion, nicks, pitting and elongation of fastener holes. Cold gas dynamic spraying can restore the dimensions and load-bearing capability of the component that will meet the technical data requirements of relevant regulations as prescribed by an industry standard. In various embodiments, in order for a cold spray repair component to be approved, such as those relating to Al-2024 or Al-7075 components, it is a requirement by aviation or key relevant regulations that the cold sprayed repair component meets the minimum acceptable standards to substantiate the repair. For example, some of the key relevant regulations include:

- EASA CS25.603—Materials: Assurance of material sources and handling;
- EASA CS25.605—Fabrication methods: Assurance of fabrication process and controls; and
- EASA CS25.613—Material design values: Determination of statistically significant design values that considers variability introduced in material and fabrication.

[0049] In some embodiments, the identified technical data required for cold spray repair are (1) the microstructure examination to ensure reliability and (2) the tensile, peel, bearing and bending strength from the repair process and powder materials.

[0050] At step 202, the repair surface area is prepared for cold gas dynamic spraying. Preparing the repair surface area includes applying a treatment on the repair surface area. Treatments may include, but not limited to, grinding, machining, cleaning or any combination thereof of the repair surface area. In various embodiments, the repair surface area may be cleaned before cold gas dynamic spraying in order to remove surface contamination. Such contamination can take various forms. An example is the presence of

oxide layers that may develop between the material of the repair surface area and the surrounding environment. These layers can hinder effective bonding during the cold gas dynamic spraying process. Another example is foreign matter that includes organic particulates and non-combustible substances. These contaminants may adversely affect the cold spray bonded system and could alter the properties of the deposited repair material over time. They may impact the properties of the original material surrounding the repaired surface. In combination, they could compromise the bond formed between the repair surface area and the deposited repair material.

[0051] In various embodiments, the repair surface area may be machined. Machining includes any suitable operation for removing material from the repair surface area. For example, machining includes surface finishing processes such as abrasive blasting, grinding, polishing or any combination thereof. Machining can also be used to remove oxide layers.

[0052] At step 203, the cold gas dynamic spraying device is configured to cold spray a powdered material onto the repair surface area of the component to a predetermined thickness and a predetermined dimension by the following steps:

- (i) supplying a carrier gas from the gas supply;
- (ii) setting a predetermined pressure on a gas flow controller to be applied to the carrier gas;
- (iii) setting a predetermined temperature on the gas heater to be applied to the pressurized carrier gas and the powdered repair material;
- (iv) adjusting a stand-off distance to a predetermined distance from the nozzle assembly to the repair surface area.

[0053] In various embodiments, the step of configuring the aforesaid parameters is important and critical to forming a suitable coating over the repair surface area that will ensure that the coating and the component will meet the relevant technical data requirements of the design specification of the component or be compliant with acceptable tolerance levels prescribed by an industry standard. In some embodiments, the cold gas dynamic spraying device used in this work is the commercially-available Series P or PX low-pressure cold spray system from Centreline (Windsor Limited, Windsor, ON, Canada).

[0054] In various embodiments, for aluminium-7075 (or Al-7075) or aluminium-2024 (Al-2024) components requiring repair, the cold gas dynamic spraying device is configured based on the following parameters:

- (i) Supplying helium as the carrier gas from the gas supply;
- (ii) Setting a predetermined pressure of approximately 140psi on the gas flow controller to be applied to the carrier gas;
- (iii) Setting a predetermined temperature of approximately 400°C to be applied to the pressurized carried gas and the powdered repair material; and
- (iv) adjusting the stand-off distance between the nozzle assembly and the repair surface area to between 10-30mm.

In some embodiments, the powdered material for feeding the powder feeder includes the same material as the repair component, for example, Al-7075 or Al-2024. For this embodiment, the feeder may be pressurized using a carrier gas, helium, at a pressure at approximately 140psi. The helium is supplied from the gas supply and is heated by the gas heater to approximately 400 degrees Celsius. The nozzle assembly or the end of the nozzle assembly closest to the repair surface area, is held at a distance from the repair surface area. This is known as the stand-off distance. The preferred stand-off distance is between 10-30mm.

[0055] In various embodiments, for aluminium components requiring repair, the cold gas dynamic spraying device is configured based on the following parameters:

- (i) Supplying nitrogen as the carrier gas from the gas supply;
- (ii) Setting a predetermined pressure of approximately 150-200 psi on the gas flow controller to be applied to the carrier gas;
- (iii) Setting a predetermined temperature of approximately 350-400°C to be applied to the pressurized carried gas and the powdered repair material; and
- (iv) adjusting the stand-off distance between the nozzle assembly and the repair surface area to between 10-30 mm.

For this embodiment, the feeder may be pressurized using a carrier gas, Nitrogen, at a pressure at approximately 150-200 psi. The nitrogen is supplied from the gas supply and is heated by the gas heater to approximately between 350 to 400 degrees Celsius. The preferred stand-off distance is between 10-30 mm.

[0056] In various embodiments, for components containing one or more of the following: cast iron, steel and nickel requiring repair, the cold gas dynamic spraying device is configured based on the following parameters:

- (i) Supplying nitrogen as the carrier gas from the gas supply;
- (ii) Setting a predetermined pressure of approximately 175-200psi on the gas flow controller to be applied to the carrier gas;
- (iii) Setting a predetermined temperature of approximately 400-500°C to be applied to the pressurized carried gas and the powdered repair material; and
- (iv) adjusting the stand-off distance between the nozzle assembly and the repair surface area to between 10-30 mm.

For this embodiment, the feeder may be pressurized using a carrier gas, Nitrogen, at a pressure at approximately 175-200psi. The nitrogen is supplied from the gas supply and is heated by the gas heater to approximately 400-500 degrees Celsius. The preferred stand-off distance is between 10-30 mm.

[0057] At step 204, the powdered material is cold sprayed onto the repair surface area with the cold gas dynamic spraying device to form a coating on the repair surface area. In this step, a metal coating is formed on the repair surface area of the component. Specifically, the coating comprise one or more metals and is carefully formed over the repair surface area. The outer surface of each coating is precisely defined, extending to cover all or nearly all of the undersized dimensions. By continuing the cold spraying process for an appropriate duration, the goal is to eliminate or significantly reduce these undersized dimensions, ensuring that the final dimensions fall within the design tolerances specified for the design specification of the component or compliant with acceptable tolerance levels prescribed by an industry standard.

[0058] In various embodiments, a post-coating finishing may be performed on the cold sprayed coating. Various techniques such as those employed in step 202 above can be used, including abrasive blasting, grinding, polishing, superfinishing, or combinations thereof. For example, surface finishing can be performed for thickness control by selectively removing portions of the coating that exceed the upper tolerance limits specified in the component design. Also, this ensures that the coating thickness aligns precisely with design requirements. Additionally, surface finishing is also used to create a uniform texture across the coated surface and ensures consistent texture between coated and uncoated areas. In other embodiments, other machining techniques (such as abrasive blasting, grinding, polishing, and superfinishing) help achieve a more uniform profile for the repair surface

area. These methods can achieve dimensional precision beyond what is strictly required by the tolerance limits.

[0059] While the invention has been particularly shown and described with reference to specific embodiments, it should be understood by those skilled in the art that various changes in form and detail may be made therein without departing from the spirit and scope of the invention as defined by the appended claims. The scope of the invention is thus indicated by the appended claims and all changes which come within the meaning and range of equivalency of the claims are therefore intended to be embraced.

CLAIMS

1. A method of repairing a metal component, comprising the steps of:
 - identifying a repair surface area on the metal component;
 - preparing the repair surface area for a cold gas dynamic spraying process by one or more of the following treatments: grinding, machining and cleaning;
 - configuring a cold gas dynamic spraying device to cold spray a powdered material onto the repair surface area of the metal component, wherein the cold gas dynamic spraying device comprises a powder feeder for receiving a powdered repair material, a gas supply for supplying a carrier gas to a gas heater and a nozzle assembly through a gas flow controller, wherein the steps of configuring include:
 - (i) providing the carrier gas to the gas supply;
 - (ii) setting a predetermined pressure on the gas flow controller to be applied to the carrier gas;
 - (iii) setting a predetermined temperature on the gas heater to be applied to the pressurized carrier gas and the powdered repair material;
 - (iv) adjusting a stand-off distance to a predetermined distance from the nozzle assembly to the repair surface area; and
 - cold spraying the powdered material onto the repair surface area with the cold gas dynamic spraying device to form a coating defined by a predetermined thickness and a predetermined dimension to cover the repair surface area.
2. The method according to claim 1, wherein the powdered repair material is substantially the same material as the component.
3. The method according to claim 1, wherein the carrier gas includes one of the following: nitrogen and helium.

4. The method according to claim 1, wherein the predetermined pressure is between 140 psi – 200 psi.
5. The method according to claim 1, wherein the predetermined temperature is between 350°C to 500°C.
6. The method according to claim 1, wherein the stand-off distance is between 10-30mm.
7. The method according to claim 1, wherein the coating meets the technical data requirements of a design specification for the component.
8. The method according to claim 7, wherein the technical data requirements include one or more of the following: tensile strength, bearing load, yield strength, peel strength, bearing strength and bending strength.
9. A method of repairing a metal component containing aluminium, comprising:
 - identifying a repair surface area on the metal component;
 - preparing the repair surface area for a cold gas dynamic spraying process by one or more of the following treatments: grinding, machining and cleaning;
 - configuring a cold gas dynamic spraying device to cold spray a powdered material onto the repair surface area of the component, wherein the cold gas dynamic spraying device comprises a powder feeder for receiving a powdered repair material, a gas supply for supplying a carrier gas to a gas heater and a nozzle assembly through a gas flow controller, wherein the steps of configuring include:
 - (i) providing the carrier gas comprising nitrogen to the gas supply;

- (ii) setting a predetermined pressure of between 150-200psi on the gas flow controller to be applied to the carrier gas from the gas supply;
- (iii) setting a predetermined temperature of between 350°C - 400°C to be applied to the pressurized carrier gas and the powdered repair material; and
- (iv) adjusting the stand-off distance between the nozzle assembly and the repair surface to between 10-30mm;

cold spraying the powdered repair material onto the repair surface area with the cold gas dynamic spraying device to form a coating defined by a predetermined thickness and a predetermined dimension to cover the repair surface area.

10. A method of repairing a metal component including one of: Al-7075 and Al-2024, the method comprising:

identifying a repair surface area on the metal component;

preparing the repair surface area for a cold gas dynamic spraying process by one or more of the following treatments: grinding, machining and cleaning;

configuring a cold gas dynamic spraying device to cold spray a powdered material onto the repair surface area of the metal component, wherein the cold gas dynamic spraying device comprises a powder feeder for receiving a powdered repair material, a gas supply for supplying a carrier gas to a gas heater and a nozzle assembly through a gas flow controller, wherein the steps of configuring include:

- (i) providing the carrier gas comprising helium to the gas supply; and
- (ii) setting a predetermined pressure of between 140psi on the gas flow controller to be applied to the carrier gas from the gas supply for transport to the powder feeder and the gas heater;

- (iii) setting a predetermined temperature of 400°C on the gas heater to be applied to the pressurized carrier gas and the powdered repair material; and
- (iv) adjusting the stand-off distance between the nozzle assembly and the repair surface area to between 10-30mm; and

cold spraying the powdered repair material onto the repair surface area with the cold gas dynamic spraying device to form a coating defined by a predetermined thickness and a predetermined dimension to cover the repair surface area.

11. A method of repairing a metal component comprising one or more of the following: cast iron, steel and nickel, comprising:

identifying a repair surface area on the metal component;

preparing the repair surface area for a cold gas dynamic spraying process by one or more of the following treatments: grinding, machining and cleaning;

configuring a cold gas dynamic spraying device to cold spray a powdered material onto the repair surface area of the component, wherein the cold gas dynamic spraying device comprises a powder feeder for receiving a powdered repair material, a gas supply for supplying a carrier gas to a gas heater and a nozzle assembly through a gas flow controller, wherein the steps of configuring include:

- (i) providing the carrier gas comprising nitrogen to the gas supply; and
- (ii) setting a predetermined pressure of approximately 175-200 psi on the gas flow controller to be applied to the carrier gas from the gas supply for transport to the powder feeder and the gas heater;
- (iii) setting a predetermined temperature of approximately 400-500°C on the gas heater to be applied to the pressurized carrier gas and the powdered repair material; and

- (iv) adjusting the stand-off distance between the nozzle assembly and the repair surface area to between 10-30mm; and

cold spraying the powdered repair material onto the repair surface area with the cold gas dynamic spraying device to form a coating defined by a predetermined thickness and a predetermined dimension to cover the repair surface area.