

METHOD AND SYSTEM FOR REPAIRING METALLIC ARTICLE

[001] The present invention relates to repairing metallic articles. More particularly, the present invention relates to a method and system for repairing at least one targeted defective area of a metallic article to be repaired via a robotic spray device utilising a cold spray technique with a wide spray angle, and further post processed with heat treatment.

BACKGROUND OF THE INVENTION

[002] In the repair industry, particularly in the fields of marine, oil and gas, and aerospace, parts that have been exposed to high temperatures and stress exposure in the field often require dimensional restoration due to distortions and distress.

[003] The current industry practice for repairing such parts involves the manual application of semi-solid premixed powders or slurries, or weld build-up using TIG (Tungsten Inert Gas) / MIG (Metal Inert Gas) / laser welding where the application volume and thickness are not controlled.

[004] One example of prior art is disclosed in the United States patent application US 4381944, which discloses a method for repairing high-temperature superalloy articles using a powder alloy mixture. This prior art discloses a method that involves cleaning the article, applying the powder mixture to the damaged portion, and then heating it in a vacuum. The heating allows for inter-diffusion between the alloy powders as the first alloy powder remains mostly solid during heating while the second alloy powder melts. However, the method disclosed lacks precise control over the volume and thickness of the powder mixture during its application, leading to the need for significant material removal after post-heat treatment processing.

[005] Another example of prior art is disclosed in the United States patent application US 4008844, which discloses a method for repairing surface and near-surface defects in metallic articles. The method disclosed involves mechanically removing the defects, and creating a cavity to be filled with a metallic filler material mix comprising at least two distinct particulate components. However, the method disclosed in this prior art is lengthy and

expensive, especially for large or complex articles. Additionally, the method is only suitable for repairing defects that are relatively shallow and are unable to cover micro-indentations or micro-bumps on the surface. Additionally, deep defects may be difficult to repair using this method, as the filler material may not be able to reach the bottom of the defect.

[006] Therefore, there is a need for a method and system of repairing metallic articles capable of achieving precise dimensional accuracy without the need for a labour-intensive post-repair processes.

SUMMARY OF INVENTION

[007] The objective of the present invention is to provide a method and a system for repairing at least one targeted defective area of a metallic article which may overcome the drawbacks discussed above.

[008] The present invention intends to provide a method for repairing at least one targeted defective area of a metallic article, comprising the steps of preparing filler material, computing, via a computing module one or more motion paths that are required to be followed by the robotic spray device, and a predetermined amount of the filler material required for repairing the article, based on the targeted defective area of the article, and processing, via a robotic spray device provided with the filler material, actions for repairing the targeted defective area of the article. The robotic spray device propels filler material towards the targeted defective area for the filler material to be either or both dispersed over an area on the article that includes the targeted defective area and streamed towards the targeted defective area in a concentrated manner, based on its processing and computations of the computing module.

[009] Preferably, the step of processing, via the robotic spray device filled with the filler material, actions for repairing the target defective area of the article comprises the steps of spraying, via utilising a cold spray technique, the predetermined amount of the filler material over the targeted defective area of the article for the filler material to uniformly cover the targeted defective area.

[0010] Preferably, the step of computing, via a computing module, one or more motion paths that are required to be followed by the robotic spray device comprises the steps of identifying the targeted defective area of the article to be repaired, analyzing the targeted defective area, determining a portion of the predetermined amount of the filler material required that is to be sprayed over the targeted defective area, providing a model data file for being used by the robotic spray device for spraying the filler material over the targeted defective area, and generating a plurality of parameters for the movement of the robotic spray device for carrying out the spraying of the filler material.

[0011] Preferably, regarding the method, the plurality of parameters comprises any one or a combination of a distance of the spray device from the targeted area, a path to be followed by the spray device, a kinetic velocity, and cold spraying technique parameters.

[0012] Preferably, the step of processing, via the robot spray device filled with the filler material, actions for repairing the targeted defective area of the article, further comprises the steps of masking non-targeted areas of the metallic article prior to spraying the filler material, heat treating the filler material after they are sprayed onto the article for a formation of a homogenous metallurgical bond between the filled material and the article, and blending the targeted defective area with the filler material for the targeted defective area and the metallic article to substantially become a single uniform piece.

[0013] Preferably, the step of heat treating the filler material after they are sprayed onto the article for a formation of a homogenous metallurgical bond between the filled material and the article is performed using a furnace or a laser source to ensure uniform material build-up and fusion bonding between the filler material and material of the article.

[0014] Preferably, the step of spraying, via utilising a cold spray technique, the predetermined amount of the filler material over the targeted defective area of the article for the filler material to uniformly cover the targeted defective area, involves spraying the filler material at a spray angle that is substantially less than or equal to a straight angle, which aids the filler material to uniformly cover one or more micro-indentations or micro-bumps on the surface of the article to be repaired.

[0015] Preferably, the step of processing, via the robotic spray device filled with the filler material, actions for repairing the target defective area of the article further comprises the

steps of determining a portion of the predetermined amount of the filler material required that is to be sprayed over the targeted defective area for enabling uniform deposition of the filler material over the targeted defective area of the article.

[0016] Preferably, regarding the method, the filler material comprises alloy powders that include one or more powders that include a first alloy powder and a second alloy powder.

[0017] Preferably, regarding the method, the first alloy powder has a melting point that is lower than the second alloy powder.

[0018] The present invention further intends to provide a system for repairing at least one targeted defective area of a metallic article, comprising a robotic spray device that is provided with filler material that processes actions for repairing the targeted defective area of the article, and a computing module operated by a processor to compute one or more motion paths that are required to be followed by the robotic spray device, and a predetermined amount of the filler material required for repairing the article, based on the targeted defective area of the article. The robotic spray device propels filler material towards the targeted defective area for the filler material to be either or both dispersed over an area on the article that includes the targeted defective area and streamed towards the targeted defective area in a concentrated manner, based on its processing and computations of the computing module.

[0019] Preferably, the robotic spray device sprays the filler material utilising a cold spray technique for the predetermined amount of the filler material to cover the targeted defective area of the article in a uniform manner.

[0020] Preferably, the computing module further determines a portion of the predetermined amount of the filler material required that is to be sprayed over the targeted defective area, provides a model data file for being used by the robotic spray device for spraying the filler material over the targeted defective area, and generates a plurality of parameters for the movement of the robotic spray device for carrying out the spraying of the filler material.

[0021] Preferably, regarding the system, the plurality of parameters comprises any one or a combination of a distance of the spray device from the targeted area, a path to be followed by the spray device, a kinetic velocity, and cold spraying technique parameters.

[0022] Preferably, the system further comprises a heating device to enable treatment of the filler material after they are sprayed onto the article for a formation of a homogenous metallurgical bond between the filled material and the article.

[0023] Preferably, the system further comprises an abrasive device to enable blending of the targeted defective area with having the filler material for the targeted defective area and the metallic article to substantially become a single uniform piece.

[0024] Preferably, the robotic spray device sprays the filler material at a spray angle that is substantially less than or equal to a straight angle for the aids filler material to uniformly cover one or more micro-indentations or micro-bumps on the surface of the article to be repaired.

[0025] Preferably, regarding the system, the filler material comprises alloy powders that include a first alloy powder and a second alloy powder.

[0026] Preferably, regarding the system, the first alloy powder has a melting point that is lower than the second alloy powder.

[0027] Preferably, the first alloy powder is mixed with temperature depressant material.

[0028] The present invention is to be applicable in the repair of a variety of metals, including those that are sensitive to heat, and it can be used to create very complex shapes. In particular, the implementation of a cold spray technique utilising filler material composed of a combination of powders according to the present invention enables the present invention to be a good choice for applications where precision is important, such as medical implants or aerospace components.

[0029] Together with the other aspects of the present invention along with various features of novelty that characterised the present disclosure is pointed out with particularity.

[0030] One skilled in the art will readily appreciate that the invention is well adapted to carry out the objects and obtain the ends and advantages mentioned, as well as those inherent therein. The embodiments described herein are not intended as limitations on the scope of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0031] To facilitate an understanding of the invention, there is illustrated in the accompanying drawings the preferred embodiments from an inspection of which when considered in connection with the following description, the invention, its construction and operation and many of its advantages would be readily understood and appreciated.

[0032] **FIGURE 1** illustrates a schematic representation of an example system for application of the filler material over the targeted defective area of the metallic article to be repaired, according to various embodiments of the present invention.

[0033] **FIGURE 2** illustrates a graphical representation of the velocity profile of the filler material particles against spray distance being a distance between a nozzle of the robotic spray device and the targeted defective area of the article to be repaired, according to various embodiments of the present invention.

[0034] **FIGURE 3** illustrates a flow chart representing an example method for repairing a targeted defective area of a metallic article to be repaired via a robotic spray device, according to various embodiments of the present invention.

[0035] **FIGURE 4** illustrates a flow chart representing example steps that relates to computation of one or more motion paths that are required to be followed by the robotic spray device, according to various embodiments of the present invention.

[0036] **FIGURE 5** illustrates a flow chart representing the processing steps required to be followed by the robotic spray device while repairing the target defective area of the article, according to various embodiments of the present invention.

[0037] **FIGURE 6** illustrates microscopic images of a repaired metallic article via the method of the present invention in as sprayed condition, and **FIGURE 7** illustrates the microscopic images of repaired article post heat treatment, according to various embodiments of the present invention.

[0038] **FIGURES 8 – 9** illustrate microscopic images of a laser treatment section of the repaired metallic article, according to various embodiments of the present invention.

[0039] **FIGURES 10 – 11** illustrate microscopic images of a plate as an article that had been sprayed with filler material, and then subsequently underwent post-processing by means of heat treatment.

DETAILED DESCRIPTION OF THE INVENTION

[0040] The present invention relates to a method and system for repairing metallic articles. More particularly, the present invention relates to a method and system for repairing at least one targeted defective area of a metallic article to be repaired via a robotic spray device.

[0041] The exemplary embodiments described herein detail for illustrative purposes are subjected to many variations. It should be emphasised, however, that the present invention is not limited to as disclosed.

[0042] It is understood that various omissions and substitutions of equivalents are contemplated as circumstances may suggest or render expedient, but these are intended to cover the application or implementation without departing from the scope of the present invention.

[0043] From hereon, the following terms have the meanings indicated below.

[0044] The terms “a” and “an” herein do not denote a limitation of quantity, but rather denote the presence of at least one of the referenced items.

[0045] The terms “having”, “comprising”, “including”, and “variations” thereof signify the presence of a component.

[0046] The inventive aspects of the invention along with various components and engineering involved will now be explained with reference to **FIGURES 1 – 11** herein.

[0047] **FIGURE 1** illustrates a schematic representation of an example system **100** according to various embodiments of the present invention.

[0048] As shown in **FIGURE 1**, the system **100** comprises a gas control unit **1**, a gas heater unit **2**, a manifold **3** that distributes the gas, a filler material feeder **4**, a robotic spray device **5** equipped with a nozzle **51**, and a computing module **6**.

[0049] The gas control unit **1** and the gas heater unit **2** preferably work in conjunction to produce a pressurised gas so that the nozzle **51** of the robotic spray device **5** may spray filler material by propelling the filler material in an accelerated manner and/or a high velocity at substantially supersonic speed towards a targeted defective area of a metallic article **7** to be repaired. By way of example, the pressurised gas may be substantially about 5MPa, or the like. Whilst not shown, further included is a gas heater that increases the temperature of gas and hence pressurises the gas, and the powder feeder manipulates the flow rate of the sprayed filler material by changing the rpm from 1 to 2 revolution per minute.

[0050] The filler material feeder **4** preferably receives filler material and feeds the filler material into the nozzle **51** of the robotic spray device **51**. Preferably, the filler material is a blend of at least two alloy powders. Furthermore, filler material feeder **4** is to receive pressurised gas so that it received filler material may be in a pressurised state.

[0051] In particular, the filler material comprises a combination of dry alloy powders that includes a first dry alloy powder and a second dry alloy powder, which are both combined or substantially blended to form the filler material. The ratio of the first dry alloy powder to the second dry alloy powder may be, by way of example, 50:50, 60:40, or the like. Furthermore, it is preferable that the first alloy powder has a melting point that is lower than the second alloy powder.

[0052] Preferably, the first alloy powder includes material(s) having a melting point or a melting point substantially below 1100 °C, which may be, by way of example, silver, tin, zinc, copper, nickel, or the like. It is to be noted that the first alloy powder is preferably dry.

[0053] Preferably, the first dry alloy powder includes alloys mixed with temperature-depressant material(s). These temperature-depressant material(s) which may be, by way of example, silicon, boron, etc. It is to be noted that the second alloy powder is preferably dry.

[0054] In particular, during the post-processing of the sprayed filler material by means of heat treatment, the first alloy powder that has the temperature-depressant material(s) shall melt at a temperature lower than the second alloy powder so that the filler material bonds to the article 7.

[0055] It is to be noted that the composition and mixture of alloy powders are to be based on the composition of the article to be repaired and the thickness of build-up required.

[0056] In particular, as the robotic spray device 5 sprays filler material by propelling the filler material through its nozzle 5 towards the article 7 in an accelerated manner or at a high velocity at substantially supersonic speed, the filler material may either be dispersed over an area on the article that includes the targeted defective area and/or streamed towards the targeted defective area in a concentrated manner. The spray operation of the robotic spray device 5 may be based on processing of the robotic spray device 5 and computations of the computing module 6. Furthermore, the spray operation of the robotic spray device 5 may spray one or more layers of the filler by performing one or more spray cycles. The number of spray cycles may depend on the computations provided by the computing module 6. With this, the alloy powder particles of the filler material are deposited on the targeted defective area of the metallic article 7 for it to be repaired in a uniform manner whereby areas of unequal heights areas and/or having micro-bumps or micro-indents are covered.

[0057] In particular, the filler material is sprayed as a thin precise layer on the whole article 7. Alternatively, the filler material is sprayed as a thin precise layer on a selected targeted defective area of the article 7.

[0058] The computing module **6** is preferably a module that exerts control over the filler material feeder **4** and the robotic spray device **5**. Preferably, for the filler material feeder **4**, the computing module **6** shall compute a predetermined amount of the filler material required for repairing the article **7**, based on the targeted defective areas of the article **7**. Preferably, for the robotic spray device **5**, the computing module **6** shall compute one or more motion paths that are required to be followed by the robotic spray device **5** for it to perform repair upon the article **7**. Whilst not shown, the computing module **6** may be operated by at least one processor of a computing system. While this module may be in a software embodiment, it may also be a hardware embodiment where it is directly connected to the processor, or it is its own independent computer system. The processor may be, but shall not be limited to, a conventional processor, an application-specific integrated circuit (ASIC), a field-programmable gate array (FPGA), or a combination thereof.

[0059] Preferably, the robotic spray device **5** sprays the filler material at a spray angle that is wide, most preferably at an angle is substantially less than or equal to a straight angle (180°), for the dispersion of the filler material to uniformly cover one or more micro-indents or micro-bumps on the surface of the article **7** to be repaired. Preferred angles include 45° , 135° , or the like.

[0060] Furthermore, robotic spray device **5** may be configured to spray the filler material in a very specific pattern and thus it can be used to create very complex shapes, depending on the configuration of its equipped nozzle **51** and/or the computations provided by the computing module **6**.

[0061] **FIGURE 2** illustrates a graphical representation of the velocity of particles of the filler material against spray distance. In particular, the graph indicates an initially logarithmic relationship before falling off after a certain spray distance is reached.

[0062] Further shown in **FIGURE 2** is a window of the filler material adhesion, which is marked with a rectangular box. The window of the filler material adhesion represents the opportunity to compensate for the deposition of the filler material on the targeted defective area of the metallic article **7** to be repaired. Preferably, the window of the filler material adhesion is the area between the spray distances where there are minimal changes to the particle velocity prior to the graph falling off.

[0063] From **FIGURE 2**, it may be inferred that an adhesion area of the sprayed filler material is based on the distance of the robotic spray device **5** from the targeted defective area and the velocity profile of the filler material.

[0064] It is to be noted that the window of the filler material adhesion is to be followed by the robotic spray device **5** as this window allows particles of the filler material that is cold-sprayed onto the article **7** to undergo an instantaneous deformation and mechanically adhere to the article **7**, for a uniform buildup of one or more layers to be formed onto article **7** up until a thickness as determined by the robotic spray device **5**. With this, when the article **7** undergoes post-processing by means of heat treatment, the filler material shall melt and bond to the article **7** to form to a uniform metallurgically-bonded structure.

[0065] From hereon, one or more flowcharts pertaining to the method of the present invention. It is noted that the steps described in these flowcharts are not to be interpreted as non-limiting, and minor modifications to the steps (e.g. additions, omissions, or swaps) are permissible by a skilled person without substantial deviation from as described.

[0066] **FIGURE 3** illustrates a flow chart representing an example method **700** that pertains to repairing a targeted defective area of a metallic article **7** via a robotic spray device **5**, according to various embodiments of the present invention.

[0067] The steps of **FIGURE 3** may begin with step **702**, which involves preparing a filler material that has a blend of at least two alloy powders, as described beforehand.

[0068] Following step **702** is step **704**, which involves computing, via a computing module **6**, one or more motion paths that are required to be followed by the robotic spray device **5**, and a predetermined amount of the filler material required for repairing the article **7**. Preferably, these are computed based on the defective area(s) of the article **7**.

[0069] Finally, following step **704** is step **706**, which involves processing, via a robotic spray device **5** provided with the filler material, actions for repairing the defective area(s) of the article **7** to be repaired.

[0070] **FIGURE 4** illustrates a flow chart representing example steps of computing, via a computing module, one or more motion paths that are required to be followed by the robotic spray device **5**, according to various embodiments of the present invention. The steps described in **FIGURE 4** may be regarded as sub-steps of step **704** previously described in **FIGURE 3**.

[0071] The steps of **FIGURE 4** may begin with Step **302**, which involves identifying the defective area(s) of the article **7** to be repaired.

[0072] Following step **302** is step **304**, which involves analysing the defective area(s) of the metallic article **7** to be repaired.

[0073] Following step **304** is step **306**, which involves determining at least one portion of the predetermined amount of the filler material required that is to be sprayed over targeted defective area(s) to enable uniform deposition of the filler material over the targeted defective area(s) of the article.

[0074] Following step **306** is step **308**, which involves providing, by the computing module **6**, a model data file for being used by the robotic spray device **5** for spraying the filler material over the targeted defective area of the article **7** to be repaired.

[0075] Finally, following step **308** is step **310**, which involves generating a plurality of parameters to facilitate the movement of the robotic spray device **5** for carrying out the spraying of the filler material. By way of example, the plurality of parameters includes any one or a combination of the (i) distance of the robotic spray device **5** from the targeted area of the article **7** to be repaired, (ii) a path to be followed by the robotic spray device **5**, (iii) a kinetic velocity, and (iv) cold spraying technique parameters. The parameters may further include a spray angle.

[0076] **FIGURE 5** illustrates a flow chart representing the processing actions required to be followed by the robotic spray device while repairing the target defective area of the article **7**, according to various embodiments of the present invention. The steps described in **FIGURE 5** may be regarded as sub-steps of step **706** previously described in **FIGURE 3**.

[0077] The steps of **FIGURE 5** may begin with step **202**, which involves spraying, via the robotic spray device **5** over the targeted defective area of the article **7** to be repaired by utilising a cold spray technique with a wide spray effect, to cover the targeted defective area and its substantial surroundings.

[0078] In particular, by utilising the cold spray technique, the accelerated particles of the filler material may collide with the targeted defective surface area of the article **7** to be repaired at a very high velocity. Thereafter, the kinetic energy of particles of the filler material is converted into thermal energy, and the particles of the filler material shall stick to the targeted area of the article **7** to be repaired. The high-velocity impact causes particles of the filler material to deform and bond to the surface of the article **7** to be repaired.

[0079] Furthermore, by spraying the filler material with the wide spray effect i.e., a wide spray angle, the filler material may uniformly cover one or more micro-indentations or micro-bumps that may be present on the surface of the article **7** to be repaired. The spray angle may be controlled by varying parameters like the (i) nozzle diameter of the robotic spray device **5**, (ii) gas temperature, (iii) size and density of filler material, and (iv) movement of the robotic spray device **5**.

[0080] Finally, following step **202** is step **204**, verifying, via a verifying module of the robot spraying device **5**, the predetermined amount of the filler material being the amount required to be sprayed over the targeted defective area, thereby enabling uniform deposition of the filler material over the targeted defective area of the article **7** to be repaired.

[0081] Whilst not shown, within the present invention, after the spraying of the filler material via a cold spraying technique is performed, it is followed by heat treating the targeted defective area(s), now having the filler material, to melt the filler material. This results in the formation of a homogenous metallurgical bond between the filler material and the surface of the article **7** to be repaired. Heat treatment of the targeted defective area(s) may be conducted via a furnace or a handheld laser torch to ensure fusion bonding between the filler material and the material of the article **7**. In particular, heat treatment by use of furnace shall provide repair for the whole article **7**, while heat treatment by use of handheld

laser torch shall provide a localised repair upon portions of the article **7** having the filler material.

[0082] Furthermore, during heat treatment of the article **7** to be repaired, the temperature depressants present in the filler material melts. This facilitates gap filling and the conversion of the bond between the article **7** and the filler material into a metallurgical bond.

[0083] Whilst not shown, following heat treatment of the targeted defective area(s), there may be a final step wherein the targeted defective area(s) may be blended with the metallic article, thereby forming the targeted defective area and the metallic article **7** as a single piece. The step of blending may be performed manually or in an automated manner by use of abrasive device(s).

[0084] In embodiments of the present invention, the robotic spray device **5** moves in a specific pattern, based on the provided model data file and parameters generated, so that the filler material is evenly sprayed on the targeted defective area of the article **7** to be repaired.

[0085] In embodiments of the present invention, prior to the repair of the metallic article **7**, non-targeted area(s) of the article **7** are masked prior to spraying the filler material.

[0086] In one embodiment of the invention, datasets that pertain to filler materials of various alloy powder compositions and their deposition results are gathered and stored in a database that may be used for machine learning (ML) and artificial intelligence (AI) to be used for future automation. More specifically, the datasets stored in the database may be utilised to train ML or AI models to predict the optimal cold spray parameters and movement of the robotic spray device **5** for (i) a given article **7**, and (ii) alloy powder composition for the filler material. This may help to ensure that the filler material is applied evenly and effectively in an automated manner.

[0087] From hereon, one or more evaluations that were carried out to validate the present invention will be described. It is to be noted that parameters defined or determined in said evaluations are not meant interpreted as limitations to the scope of the invention.

[0088] In one example evaluation, a filler material composition comprising a first alloy powder being NB 200 (low melting component), and a second alloy powder being INCONEL 718, was sprayed from the same point on two defective articles with a difference in thickness of 5mm. The resulting deposition on both defective articles was found to be the same.

[0089] Referring to **FIGURES 6 – 7**, the microscopic images of an example metallic article are shown. The microscopic images of the metallic article show thickness uniformity of the deposited filler material which is found to be satisfactory, as there is a bond line between the filler material and the targeted area to be repaired of the article.

[0090] Referring to **FIGURES 8 – 9**, the microscopic images of the laser treatment section of the sample (repaired metallic article) are shown. The microscopic images show's homogenous structure and an acceptable bond between the sprayed filler material and the base metal as no bond lines appeared post-laser treatment of the repaired article. More specifically, the repaired metallic article shows good build-up after localised laser melting and metallurgical bonding .

[0091] Referring to **FIGURES 10 – 11**, the microscopic images of a plate as an article is shown. In particular, **FIGURE 10** illustrates the plate after it is sprayed with filler material, while **FIGURE 11** illustrates the plate after it has been made to further undergo heat treatment. The filler material had a ratio of first alloy powder to second alloy powder of 60:40. Furthermore, parameters of the spray operation include (i) the gas being pressurised to be at substantially about 5 MPa and heated to be at a temperature of 800°C, (ii) the flow rate of the sprayed filler material being based on a powder feeder operating at substantially about 2 revolutions per minute, and (iii) a spray cycle of 18 to form layers of filler material having a thickness of between 450µm and 500µm. Based on **FIGURE 10**, it is apparent that the filler material was well-mixed and had been sprayed onto the article in a uniform manner with minimal delamination and very low porosity between layers. Based on **FIGURE 11**, after the article that had been sprayed with the filled material underwent heat treatment, it is apparent that the filler material had a good build-up. Furthermore, after the heat treatment, and the repaired article has minimal to no porosity and diffusion of temperature depressant

(e.g. in the case where boron is used as the temperature depressant, borides), and furthermore, some eutectics are seen.

[0092] Moreover, the present invention had been experimented on using different shapes of articles to be repaired which have shown similar results.

[0093] Advantageously, by the use of filler material composed of alloy powders, issues associated with distorted parts and the inability to control the metal flow during the furnace process can be avoided.

[0094] Advantageously as well, by performing post-processing that includes heat treating the filler material on the targeted defective area of the article, and blending the filler material on the targeted defective area of the article, the overall metallurgical integrity of the repaired article is maintained or enhanced as porosity is eliminated.

[0095] Advantageously as well, by implementation of a cold spray technique utilising filler material composed of a combination of alloy powders according to the present invention, the filler material may bond to the targeted defective area in a consistent manner without the need for organic bonding agents.

[0096] Advantageously as well, by implementation of a cold spray technique utilising filler material composed of a combination of alloy powders according to the present invention, unequal distortions in the article to be repaired shall be repaired in a uniform manner.

[0097] The present disclosure includes as contained in the appended claims, as well as that of the foregoing description. Although this invention has been described in its preferred form with a degree of particularity, it is understood that the present disclosure of the preferred form has been made only by way of example and that numerous changes, modifications, or variations in the details of construction and the combination and arrangements of parts may be resorted to without departing from the scope of the invention.

[0098] Further, the embodiments were chosen and described to best explain the principles of the present invention and its practical applications, and thereby enable others skilled in

the art to best utilize the present invention and various embodiments with various modifications as are suited to the particular use contemplated.

[0099] It is understood that various omissions and substitutions of equivalents are contemplated as circumstances may suggest or render expedient, but such omissions and substitutions are intended to cover the application or implementation without departing from the scope of the present invention.

CLAIMS

1. A method for repairing at least one targeted defective area of a metallic article, comprising the steps of
 - preparing filler material;
 - computing, via a computing module
 - one or more motion paths that are required to be followed by the robotic spray device;
 - and
 - a predetermined amount of the filler material required for repairing the article, based on the targeted defective area of the article;
 - and
 - processing, via a robotic spray device provided with the filler material, actions for repairing the targeted defective area of the article;
 - wherein the robotic spray device propels filler material towards the targeted defective area for the filler material to be either or both dispersed over an area on the article that includes the targeted defective area and streamed towards the targeted defective area in a concentrated manner, based on its processing and computations of the computing module.
2. The method according to claim 1, wherein the step of processing, via the robotic spray device filled with the filler material, actions for repairing the target defective area of the article comprises the steps of
 - spraying, via utilising a cold spray technique, the predetermined amount of the filler material over the targeted defective area of the article for the filler material to uniformly cover the targeted defective area.
3. The method according to claims 1 or 2, wherein the step of computing, via a computing module, one or more motion paths that are required to be followed by the robotic spray device comprises the steps of
 - identifying the targeted defective area of the article to be repaired;
 - analysing the targeted defective area;
 - determining a portion of the predetermined amount of the filler material required that is to be sprayed over the targeted defective area;

providing a model data file for being used by the robotic spray device for spraying the filler material over the targeted defective area; and

generating a plurality of parameters for the movement of the robotic spray device for carrying out the spraying of the filler material.

4. The method according to claim 3, wherein the plurality of parameters comprises any one or a combination of a distance of the spray device from the targeted area, a path to be followed by the spray device, a kinetic velocity, and cold spraying technique parameters.

5. The method according to any one of claims 2 – 4, wherein the step of processing, via the robot spray device filled with the filler material, actions for repairing the targeted defective area of the article, further comprises the steps of

masking non-targeted areas of the metallic article prior to spraying the filler material,

heat treating the filler material after they are sprayed onto the article for a formation of a homogenous metallurgical bond between the filled material and the article, and

blending the targeted defective area with the filler material for the targeted defective area and the metallic article to substantially become a single piece.

6. The method according to claim 5, wherein the step of heat treating the filler material after they are sprayed onto the article for a formation of a homogenous metallurgical bond between the filled material and the article is performed using a furnace or a laser source to ensure uniform material build-up and fusion bonding between the filler material and material of the article.

7. The method according to any one of claims 2 – 6, wherein the step of spraying, via utilising a cold spray technique, the predetermined amount of the filler material over the targeted defective area of the article for the filler material to uniformly cover of the targeted defective area, involves spraying the filler material at a spray angle that is substantially less than or equal to a straight angle, for the filler material to uniformly cover one or more micro-indentations or micro-bumps on the surface of the article to be repaired.

8. The method according to any one of claims 2 – 7, wherein the step of processing, via the robotic spray device filled with the filler material, actions for repairing the target defective

area of the article further comprises the steps of determining a portion of the predetermined amount of the filler material required that is to be sprayed over the targeted defective area for enabling uniform deposition of the filler material over the targeted defective area of the article.

9. The method according to any one of the preceding claims, wherein the filler material comprises alloy powders that include a first alloy powder and a second alloy powder.

10. The system according to any one of the preceding claims, wherein the first alloy powder has a melting point that is lower than the second alloy powder.

11. A system for repairing at least one targeted defective area of a metallic article, comprising

- a robotic spray device that is provided with filler material that processes actions for repairing the targeted defective area of the article; and

- a computing module operated by a processor to compute

- one or more motion paths that are required to be followed by the robotic spray device;
 - and

- a predetermined amount of the filler material required for repairing the article, based on the targeted defective area of the article;

- wherein the robotic spray device propels filler material towards the targeted defective area for the filler material to be either or both dispersed over an area on the article that includes the targeted defective area and streamed towards the targeted defective area in a concentrated manner, based on its processing and computations of the computing module.

12. The system according to claim 11, wherein the robotic spray device sprays the filler material utilising a cold spray technique for the predetermined amount of the filler material to cover the targeted defective area of the article in a uniform manner.

13. The system according to claims 11 or 12, wherein the computing module further determines a portion of the predetermined amount of the filler material required that is to be sprayed over the targeted defective area;

provides a model data file for being used by the robotic spray device for spraying the filler material over the targeted defective area; and

generates a plurality of parameters for the movement of the robotic spray device for carrying out the spraying of the filler material.

14. The system according to claim 13, wherein the plurality of parameters comprises any one or a combination of a distance of the spray device from the targeted area, a path to be followed by the spray device, a kinetic velocity, and cold spraying technique parameters.

15. The system according to any one of claims 11 – 14, further comprising a heating device to enable treatment of the filler material after they are sprayed onto the article for a formation of a homogenous metallurgical bond between the filled material and the article.

16. The system according to any one of claims 11 – 15, further comprising an abrasive device to enable blending of the targeted defective area with having the filler material for the targeted defective area and the metallic article to substantially become a single piece.

17. The system according to any one of claims 11 – 16, wherein the robotic spray device sprays the filler material at a spray angle that is substantially less than or equal to a straight angle, for the filler material to uniformly cover one or more micro-indentations or micro-bumps on the surface of the article to be repaired.

18. The system according to any one of claims 11 – 17, wherein the filler material comprises alloy powders that include a first alloy powder and a second alloy powder.

19. The system according to any one of claims 11 – 18, wherein the first alloy powder has a melting point that is lower than the second alloy powder.

20. The system according to any one of claims 11 – 19, wherein the first alloy powder is mixed with temperature depressant material.