TECHNICAL INSIGHTS

ADVANCED MANUFACTURING

TECHNOLOGY ALERT

15th May 2015

1. NOVEL MANUFACTURING PROCESS TO PRODUCE METAL ROTOR BLADES FOR WIND TURBINES

Wind energy is a renewable form of energy that produces environment friendly power. Global efforts to reduce the carbon footprint have promoted research and development of several clean energy sources and distribution systems. Harvested from the wind without causing any damage to the environment, wind energy has now become a more of a mainstream electricity source in many countries, as a result of extensive R&D activities in various aspects of wind energy.

In an attempt to make the wind turbine rotor blades efficient and recyclable, researchers from the Fraunhofer Institute for Machine Tools and Forming Technology IWU in Chemnitz, Germany, along with researchers from the Free University of Brussels have created a steel rotor blade that can replace the existing fiber-reinforced blades. The research project is named 'HyBlade'. The new blade developed by this team is over 90% recyclable, and has a lightweight advantage that makes it suitable for large wind turbine installations. However, there is a larger advantage that this blade offers—it will cost less than its present plastic counterparts.

The researchers explained that the fact that steel rotor blades are recyclable makes them more eco-friendly. Also, they claim that the production costs of the novel blades can be as low as 10% of current production costs. The manufacturing costs are low because metal blades can be manufactured rather speedily in comparison to fiber-reinforced plastic blades.

Fiber-reinforced plastic blade manufacturing typically starts with creation of suitable molds shaped like blades. After the molds are created, they are hardened in ovens for several hours. Before hardening, the molds are layered with several layers of fiber mat, based on the type of blade required, and then the resin is injected into the mold. This entire process of mold creation along with the intermediate steps is very time consuming. Furthermore, each mold created is only a hemisphere of the complete blade, and hence each half has to be trimmed and joined using adhesives. This adds more time to mold making process. Although these processes could be performed concurrently to optimize production time, that would require additional equipment, making the process costlier than it already is.

The steel blade manufacturing process, on the other hand, not only has inexpensive concurrent processes for faster production but also has the advantage of being automated for elevated production rates. This makes the steel blade manufacturing process convenient for series production. In order to make the steel blades, the researchers began by folding a flat sheet of steel to the shape of a blade using a bending die. Later, the edges were given a closed edge using laser welding. To achieve the final shape, the blade was placed on a tool and subjected to pressure in the magnitude of thousands of bar under a water-oil mixture. Under the high pressure, the blade inflated and acquired the desired shape, eliminating the errors of the previous steps. The blades thus produced have accurate geometries with performance on par with reinforced plastic blades.

The research team has successfully demonstrated a prototype of a rotor with steel blades having dimensions of 15 cm in width and 30 cm in length manufactured through the above-mentioned processes. The team is now engaged in optimizing the manufacturing process to produce steel blades of 2.8 meters in length.

Ever since wind turbines have been installed, they have undergone several structural changes for making the best use of wind to produce energy. However, these structural changes and enhanced components are usually costly. But when efficient technology is available at less cost, faster adaptation of the technology is enabled.

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2. INNOVATIVE JOINING TECHNIQUE TO USE ALUMINUM IN THE AUTO INDUSTRY

Materials that weigh less and have higher strength have enormous benefits in the automobile and aerospace industries. In the auto industry, the lighter the vehicle, the less is its fuel consumption. It is not a wonder that the major stakeholders with respect to the research and development in lightweight, composite and high-strength materials are these industries.

Recently, a group of researchers from the US Department of Energy's Pacific Northwest National Laboratory, in coalition with General Motors, Alcoa Inc., and TWB Company LLC, displayed a novel process to use aluminum for making auto parts. Aluminum, being light in weight, could lessen the weight of auto parts by up to 62%. Also, the new process would considerably cut down the production time without compromising the auto industry’s standards for speed, quality, and consistency.

The research team was constituted by carefully considering the challenges and restraints that have thwarted the use of lightweight composites in automobile parts manufacturing. The team consisted of experts from the entire supply chain of the auto industry, who are crucial in addressing the challenges, at different levels, associated with using lightweight composites for automobile parts.

The auto industry uses metal parts of varied thickness and joins them to create big parts. This is crucial in making effective components for an automobile. The new process--a manipulation of a joining technique called friction stir welding (FSW)--is capable of joining aluminum sheets of different thickness. This new FSW process in unique in being able to meet the high-volume assembly demands by delivering joining speeds 10 times as fast as the existing FSW techniques.

Several joining processes were initially considered for using aluminum in making auto parts, including the laser welding process that worked well only in joining steel parts.

Upon inspecting the joints created by several of these techniques against the quality benchmarks for the auto industry, FSW was selected as the most appropriate technique. A friction stir welding machine acts somewhat like a drill press and sewing machine hybrid. The pin tool spins against both edges; and, as it travels, creates friction that heats, mixes, and joins the alloys without melting them.

The use of conventional FSW renders joints at a very slow rate, only half-meter joining per minute. This speed does not satisfy the needs of the high speed production. In order to improve the speed of FSW for meeting production demands, the researchers used various tool designs of different shapes, sizes, and thicknesses. The joints created by these tools were then evaluated against various standards of welding. After extensive analysis of the evaluation data, a standard combination of tool attributes and welding specifications were chosen to match the high-speed production expectations.

This research project is funded by US Department of Energy's Office of Energy Efficiency and Renewable Energy, along with donations from the participating companies. The project timeline is six years and has two phases.

Currently, the project has run for 4 years. With the new breakthrough, the researchers are now focusing to use the funding to further increase the speeds of FSW for enhanced outputs. Alongside, the team is also trying to extend the benefits of this novel process in joining various types of alloys, such as ultra-light, very strong automotive aluminum alloys.

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3. METHOD FOR PRINTING KESTERITE SOLAR CELLS USING INKJET PRINTING TECHNOLOGY

Kesterite solar cells are second generation solar cells; and kesterite belongs to a new class of materials that can be used to produce thin film solar cells. They have a cost advantage over the first-generation wafer-based solar cells and can be produced at a much lower cost. There are three types of thin film materials that are used in solar cell manufacturing: amorphous silicon (a-Si), cadmium telluride (CdTe) and Cu(In,Ga)Se2 (CIGS). Barring silicon, the other two materials have superior efficiency in converting sunlight to energy. However, these materials are rare and expensive. Kesterite, a material consisting of compounds of semiconductors is an excellent alternative to CIGS as it is available in abundance and is made up of constituents that are non-toxic.

A new method has been developed by researchers at Helmholtz-Zentrum Berlin (HZB), Germany, that will print kesterite thin film absorbers (CZTSSe– sulfur- selenide alloy) using inkjet printing technology. This method can produce kesterite solar cells that can convert sunlight to electricity with an efficiency of 6.4%. Normally, the conversion efficiency of these materials is above 10%, but the new method could be optimized in future to achieve higher efficiencies. The big advantage of the new method is that it produces negligible waste and can be used in industries for mass-scale production.

Inkjet printing technology is of great interest in recent times because of its ability to create materials while generating very less waste in the course of the process. The process also minimizes the usage of raw materials and is an eligible candidate to be adapted for roll-to-roll processing. However, the real challenge for inkjet printing technology is to create a suitable ink that will produce high quality films.

In order to create the solar cells, a molecular ink used for spin coating was used by the researchers at HZB. The constituents of the ink are Cu, Zn, Sn metal salt and thiourea and they are dissolved in a solvent named dimethyl sulfoxide. The researchers used this ink to print thin films and they observed that the viscosity of the ink increased with addition of the constituent chemicals. Later, to create the CZTSSe absorbers, the printed thin film was subjected to annealing with selenium.

After exercising optimal measures and suitable parameters for printing the thin absorbers, it was noted that this printing method yielded less waste in comparison to spin coating. A lot of ink is wasted in spin coating process whereas using inkjet technology uses ink only as low as 20 microliter to produce a CZTSSe absorber of 1 micrometer.

The research team is currently working on optimizing the complete printing process to yield solar cells with higher conversion efficiency using inkjet printing technology. This capability will open up possibilities of fabricating more solar cells with kesterite absorbers. The team plans to produce a complete solar cell device using inkjet printing technology, in its next research endeavors. This endeavor would hold promise for eliminating the higher costs associated with the current manufacturing technologies that use vacuum tubes. In turn, these efforts will make cutting-edge technology cheaper for the consumer market.

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4. PATENT ANALYSIS OF LASER DEPOSIT WELDING

Laser deposit welding is a welding process where the filler material, such as wire or powder, and the basic material are first melted using the radiation obtained from a laser and then are metallurgically bonded. It is a high quality and flexible welding process that allows carrying out repairs, improving wear resistance, and making design modifications/correcting flaws in products that are being manufacturing.

The laser beam used in this process makes a precise and high strength connection between the filler wire material, which is manually added during the process, and the work piece. Laser deposit welding process can be used for repairing a wide range of components in addition to being used for applying protective layers to components that prevent wear and corrosion. This process when used with powder can be used for application areas such as tool and mold making. It is also being used in other industries such as oil and gas, aerospace and automotive industries.

From the patents exhibited, it can be seen that research has been conducted to develop systems for carrying out laser deposit welding and increasing the efficiency of this process in industrial sectors. For example, patent # EP2295189 B1, assigned to General Electric Company, pertains to a method of laser beam welding of at least two adjacent superalloy components using first and second filler materials.

Title	Publication Date/Publication Number	Assignee	Inventor	Abstract
System and method of dual laser beam welding using first and second filler metals	July 31, 2013/ EP 2295189 B1	General Electric Company	Daniel Anthony Nowak, Michael Douglas Arnett, Srikanth Chandrudu Kottilingam	A method of laser beam welding at least two adjacent superalloy components (102, 104), comprising:providing a first filler metal (106) within a joint formed between at least first and second superalloy components (102, 104); feeding a second filler metal (504) over the joint formed between the at least first and second superalloy components (102, 104)
Laser narrow groove welding apparatus and welding method	July 9, 2013/ US 8481885 B2	Hitachi Plant Technologies, Ltd.	Takeshi Tsukamoto, Hirotsugu Kawanaka, Yoshihisa Maeda, Shinji Imaoka, Tetsuya Kuwano, Taiji Hashimoto	A welding apparatus and a welding method are employed for laser narrow groove welding which performs welding scanning a laser beam in the welding direction while feeding a solid filler metal into a narrow groove. The welding apparatus includes a laser beam irradiation head having a mechanism periodically oscillating an irradiation point of the laser beam with a predetermined amplitude in the bottom of the groove, and a filler metal control device having a solid filler metal feeder feeding the solid filler metal to the molten pool formed in the bottom of the groove by the laser beam and adjusting the feeding position independent of a motion of the laser beam irradiation head so that the tip position of the solid filler metal detected is constantly positioned in the center of the groove.
Method of laser welding twip steel to low carbon steel	November 29, 2012/ US 20120298637 A1	Johnson Controls Technology Company	Daniel James Sakkinen, Ornela Zekavica, Anthony Kestian	A method of laser welding structures having different steel grades together. The method includes providing a first structure made from a first steel grade and composition and providing a second structure made from a second steel grade composition. The first structure is positioned adjacent the second structure to create a weld zone area wherein at least a portion of the first structure overlaps at least a portion of the second structure. A filler material is selected that has a composition that will create a weld joint between the first structure, the second structure and the filler material such that the weld joint has a predetermined microstructure. The filler material is positioned adjacent the weld zone area. A laser beam is directed at the weld zone area to create a weld joint between the first structure, the second structure and the filler material wherein the weld joint has a predetermined microstructure.
Method of performing a manual laser deposition using a weld filler	June 13, 2012/ EP 2022596 B1	United Technologies Corporation	James J. Moor	A method of performing manual laser deposition comprising: positioning weld filler (106) in proximity to a substrate (100); directing a laser beam (110) toward the weld filler (106) such that a first portion of the weld filler (106) melts and forms a first deposit (102) on a substrate (100) in a first deposit location (132); repositioning the weld filler (106) such that the weld filler (106) is located adjacent to the first deposit location (132)

Title	Publication Date/Publication Number	Assignee	Inventor	Abstract
Low-temperature laser spot impact welding driven without contact	December 27, 2011/ US 8084710 B2	The Ohio State University	Glenn S. Daehn, John C. Lippold	A laser, aimed at a flyer plate tab, causes optical energy to be directed at the tab, specifically, at a top surface thereof. Energy impacting the tab accelerates the tab out of an initial bent position, straightening it into an impact with a target sheet. The impact occurs in excess of 100 m/s, resulting in a metallurgical bond between the tab and the target sheet. The laser preferably strikes the top surface in a normal direction, based upon an initial angularity of the tab relative to the target. The laser emission, preferably in the range of 1 to 100 Joules delivered in a microsecond, may be augmented by an ablative layer on the top surface or a transparent covering on the top surface that reacts against the expanding gas from ablative activity on the top surface. The weld is formed without physical contact between the welding device and the tab.
A method of laser welding twip steel to low carbon steel	May 19, 2011/ WO 2011060432 A1	Johnson Controls Technology Company	Daniel James Sakkinen, Ornela Zekavica, Anthony M. Kestian	A method of laser welding structures having different steel grades together. The method includes providing a first structure made from a first steel grade and composition and providing a second structure made from a second steel grade composition. The first structure is positioned adjacent the second structure to create a weld zone area wherein at least a portion of the first structure overlaps at least a portion of the second structure. A filler material is selected that has a composition that will create a weld joint between the first structure, the second structure and the filler material such that the weld joint has a predetermined microstructure. The filler material is positioned adjacent the weld zone area. A laser beam is directed at the weld zone area to create a weld joint between the first structure, the second structure and the filler material, wherein the weld joint has a predetermined microstructure.
Method and Device for Laser Welding of Components Made from Super Alloys	February 7, 2008/ US 20080029495 A1	Mtu Aero Engines Gmbh	Klaus Emiljanow, Stefan Czerner, Axel Bormann, Karl Lindemann, Peter Stippler, Joerg Werhahn	A method for laser welding super alloys is disclosed. The power of the laser (**12**) is controlled depending on the temperature of the welding bath and a device (**10**) for laser welding a super alloy, including a laser beam source (**12**), a process controller (**30**), a temperature recording unit (**28**) and a feed device (**24**) for additional materials, characterized in that the process controller (**30**) comprises a regulator (**34**), connected to the temperature recording unit (**28**) and the laser source (**12**).

Title	Publication Date/Publication Number	Assignee	Inventor	Abstract
Methods for repair of single crystal superalloys by laser welding and products thereof	July 31, 2007/US 7250081 B2	Honeywell International, Inc.	Yiping Hu, William F. Hehmann, Murali Madhava	Methods for repair of single crystal superalloys by laser welding and products thereof have been disclosed. The laser welding process may be hand held or automated. Laser types include: CO_2, Nd:YAG, diode and fiber lasers. Parameters for operating the laser process are disclosed. Filler materials, which may be either wire or powder superalloys are used to weld at least one portion of a single crystal superalloy substrate.
Dual feed laser welding system	March 9, 2006/US 20060049153 A1	Cahoon Christopher L, Dowding Randall E, Srikanth Sankaranarayanan	Christopher Cahoon, Randall Dowding, Srikanth Sankaranarayanan	The present invention provides an apparatus for automated laser welding repairs. The apparatus is adapted for use with components of gas turbine engines such as compressor and turbine airfoils and blisks. The apparatus comprises a dual means of providing filler material. The filler material may be provided through a wire feeder. Optionally, the filler material may be provided through a powder feeder.
Multi-laser beam welding high strength superalloys	December 6, 2005/US 6972390 B2	Honeywell International, Inc.	Yiping Hu, William F. Hehmann	A method is provided for repairing degraded and/or eroded areas on gas turbine blades and vanes. The method is directed to turbine blades and vanes made of advanced superalloy materials with high elevated-temperature properties. The method uses multiple laser beams to perform steps of preheating the repair area, welding the repair area, and post-welding heating of the repaired area. The method uses an array of two or more lasers to perform the steps of heating, welding, and post-weld heat treatment in nearly simultaneous operation thereby dramatically reducing or eliminating the hot cracking associated with other welding methods used with superalloy materials. The method is further directed to cladding or material buildup of degraded turbine blades where the weld material is the same as the matrix or better superalloy materials.

Exhibit 1 depicts patents related to laser deposit welding.

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