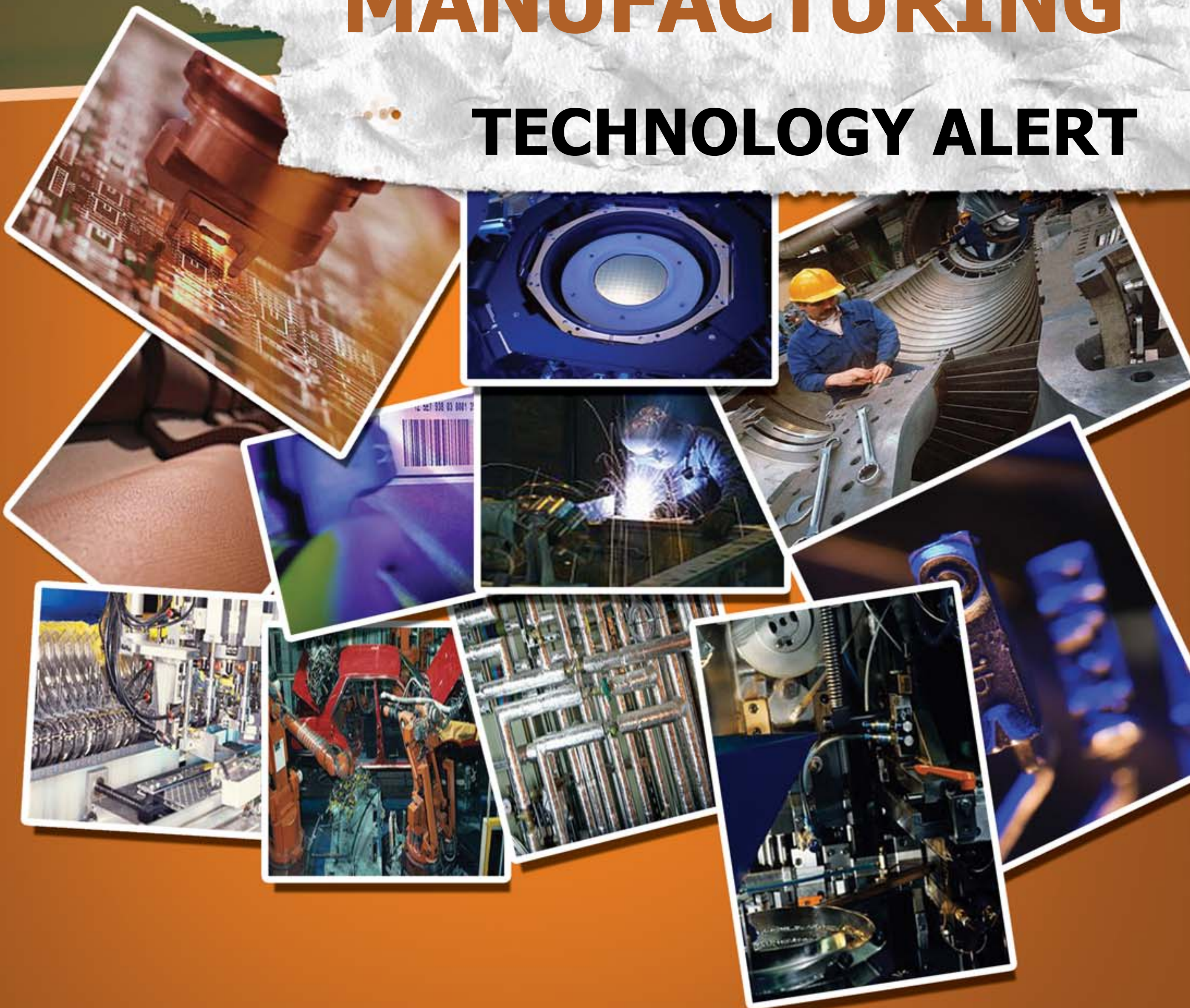
# TECHNICAL INSIGHTS

## ADVANCED MANUFACTURING

### TECHNOLOGY ALERT



20th June 2014

## 1. EXPANDING ACCESS TO DIGITAL MANUFACTURING

A key trend of three-dimensional (3D) printing is to improve the access to these devices so even start-up designers can use additive manufacturing techniques. One way to accomplish this is to reduce the size, as well as minimize the price of 3D printers to create so-called desktop printers. Asiga in Anaheim Hills, California, has raised the ante by shrinking its aptly named Pico 3D printer to 22 centimeters and 10 kilograms in weight. The device has a build size of 50 millimeters (mm) by 32 mm by 76 mm, sufficient for smaller parts such as industrial fasteners, dental, jewelry, medical, animation, and electronics.

The chief executive officer of Asiga said that he became fascinated with 3D printing many years ago after using it for an engineering project he was working on. The executive saw the benefits this technique offered for direct manufacturing applications, but realized that the high cost of high-resolution 3D printers meant that it was not economically compelling for the overall cost/benefit equation in some applications.

The Asiga CEO said that computer-aided design (CAD)/computer-aided manufacturing (CAM) offers wonderful opportunities for improving productivity. However, high-resolution 3D printers required to output CAD designs 'for direct manufacturing' applications have been prohibitively expensive. He wanted to make a 3D printer with resolution fine enough for jewelry and dental applications that any individual could afford. This resulted in Asiga developing a new technology, which the CEO dubbed 'slide-and-separate.' The executive explained that Asiga's patented process imparts the lowest fabrication forces on the model of any upside-down stereolithography process. This reduction of forces eliminates model damage and breakage observed in comparable systems, resulting in better accuracy and reliability.

Asiga makes the Pico available in several build modes ranging from 27 micrometers to 39 micrometers XY resolution, with Z thicknesses ranging from a single micrometer to 200 micrometers. The California company equips the desktop printer with an ultraviolet light-emitting diode (LED) to enable the Pico to print in a variety of advanced materials including those that are pure white or transparent. The LED has a long operating life of 50,000 hours to cut replacement costs. Asiga also manufactures materials for their printers including direct investment casting resins, medical-grade biocompatible materials, high temperature resistant materials and general modeling resins.

The Asiga Pico retails for approximately $7,000, which the CEO compared to tooling-grade resolution 3D printers with competitive quality costing tens of thousands of dollars. The Pico's resolution is borne out by American Jewelry Supply of New Brunswick, New Jersey, a prominent supplier of jewelry tools. The organization touted the Pico's tooling-grade resolution, solid-state reliability, and affordability in a compact package as being well-suited for industries such as dental, jewelry, medical, animation, electronics, architecture and industrial design where high resolution, low cost of ownership and extreme reliability are critical. American Jewelry Supply also lauded Asiga's 'slide-and-separate' technology's ability to build ultra-smooth precision models, and the years of service life provided by the 3D printer's ultraviolet LED light source.

The CEO of Asiga remarked that while CAD design software was a mature technology in the larger players in dental, hearing aid, and jewelry manufacture, the high cost of tooling-grade resolution 3D printers put this advanced manufacturing technology beyond the reach of smaller firms. Asiga designed its Pico desktop printers to level the playing field by putting more sophisticated digital manufacturing within reach of smaller companies.

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## 2. 3D PRINTER MAKES STRONGER PARTS

One of the limitations of 3D printers, particularly the smaller desktop versions, is that they fabricate parts out of non-engineering grade materials such as acrylonitrile butadiene styrene (ABS) or polylactic (PLA). Prototypes made of these materials may not be strong enough for rigorous testing, much less as finished parts. While 3D printers exist that can fashion parts made of more durable materials, such as nylon and polycarbonate, they are much larger and expensive than the desktop versions favored by engineers.

Airwolf 3D of Costa Mesa, California, recently introduced its AW3D HDx 3D printer to enable engineering firms, government agencies, and academic institutions to make prototypes and finished parts out of nylon and polycarbonate on an affordable ($3,000 to $4,000) desktop-sized unit. Airwolf 3D specializes in developing and supplying high performance, economical, durable, and user-friendly 3D printers that it manufactures in its 12,000 square foot facility in Costa Mesa.

There was a long standing need for a desktop 3D printer that could use stronger materials than ABS and PLA, according to the chairman of Airwolf 3D . He said that his team received customer feedback to print larger objects, all the way from prototype to small runs, of materials including nylon and polycarbonate. The executive noted that nylon is available in different variants for use in 3D printing, but that the standard desktop heating range of 250 degrees C to 260 degrees C would cause the adhesion between layers to split. A 3D printer requires 270 degrees C to 290 degrees C to print nylon to make a strong nylon part, and because there must be sufficient space between the cold and hot end of the printer, that was beyond the reach of standard desktop printers. In addition, Airwolf 3D customers wanted to make larger parts, on the order of 12 inches high by 8 inches deep by 12 inches wide, of nylon and heat resistant polycarbonate. The chairman noted that if the material maintained at a high temperature, it would print better. These reasons led the company to develop the HDx.

The Airwolf 3D design team has the advantage of using the company's AW3D HD 3D printer, recently introduced in November 2013, to use as a platform. The challenge was to develop a higher temperature version, with primary design focus on the hot end. Another issue to address was the tendency for polycarbonate layers to warp. Airwolf 3D solved this by building in more head room in the heated bed of the HDx and using an oversized power supply, explained Wolf.. Rather than the 120 degrees C in ABS printing, the HDx can bring the bed to 145 degrees C for 20 + hours for larger prints.

The chairman and his colleagues use the Computer-Aided-Design (CAD) program they used to design the predecessor HD printer to design their new HDx printer. They also knew that it was important to use high temperature resistant materials around the new print head. Airwolf 3D scientists knew that polycarbonate has a 40 degrees C higher glass transition temperature than ABS, so they 3D printed the print head enclosure for the HDx out of this material, recalled the executive.

The HDx uses a fused deposition modeling (FDM) technology that lays down a plastic filament from the hot end that is melted in successive layers to build the part. Airwolf 3D is using its latest generation desktop printer to make functional prototypes that allow a greater degree of testing. Presently, the California company is 3D printing polycarbonate parts used in the remote controlled cars--capable of up to 60 miles per hour--that are currently appearing on the Golden State's roads. The cars used ABS parts that shattered when testing curb impacts, but Airwolf 3D make these parts out of polycarbonate and they survive rigorous testing, reported the chairman, who cited aerial drones as another ideal application for the HDx.

Drones are a major application for 3D printing because polycarbonate is strong enough and has the impact strength to enable most components of a lightweight drone to be made in one print, declared the executive. This includes parts for working drones as well as prototypes, especially as these remotely controlled aircraft are becoming more customizable for scaling up or down to accommodate different missions.

The chairman agreed with Technical Insights' research indicating that desktop printers are coming down to more realistic levels, that is, around $3,000 to $4,000 per unit. Corporations can afford to put 3D printers on their engineers' desks for a cost equal to a CAD license, pointed out Wolf. The Airwolf 3D chairman said his company has observed additive manufacturing being done on an ongoing basis due to more affordable material prices. For example, a company can buy two pounds of polycarbonate for $95 that will last for a long time. The Airwolf 3D chairman added that greater integration of CAD programs with 3D printing is another trend he has observed.

In early June 2014, Airwolf 3D announced that the former president and chief executive officer of Toshiba America Business Solutions, had joined the former company as president. The chairman expressed confidence that the new president can take Airwolf 3D to the next level quickly. He concluded that Airwolf 3D will build on its technological success by raising capital and potentially making acquisitions.

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## 3. INNOVATIVE TOOL FOR FRICTION STIR WELDING USED IN THE AUTOMOTIVE INDUSTRY

Vehicles that are currently manufactured consist of a large number of lightweight parts that require multi material joining techniques such as rivets, clinch joints, or spot welding. These techniques are used to bond different parts of the vehicle. There are number of drawbacks that are seen with the above mentioned manufacturing techniques. For instance, rivets are expensive and do not provide sufficient strength for certain parts. Spot welds can be carried out only for when the thickness is low, which in turn reduces the cost of production. Automotive manufacturers are currently looking for novel ways of multimaterial joining techniques for manufacturing products and parts that are used in the vehicles.

One such multimaterial joining technique that is currently used on a large scale is friction stir welding. The drawback seen with friction stir welding is that the overall quality of the final product is not satisfactory. To improve the quality of the product, the melting temperature of the welding is kept below the melting point of the material. But, with the current friction stir welding tools that are available, it can be quitedifficult to achieve the exact temperature required for manufacturing a part of product. To overcome the above mentioned drawbacks of the multimaterial joining techniques in the automotive industry, a group of researchers from the University West in Trollhättan, Sweden, have developed a novel welding tool consisting of the functions of temperature sensor.

 

The temperature in the welding process is continuously measured and when the temperature exceeds the melting point of the material, the heat is regulated by controlling the force and rotation of the tool. This tool has been tested with the help of an industrial robot, which further increases the welding quality of the parts and products. With this new tool, the researchers have said that the quality of the products have increased significantly from the various prototypes that were created. The other key advantage in addition to the precision, is the reduction in time taken for programming the three-dimensional joints. By integrating the tool with the robot, the researchers have been able to weld small and more complicated parts with curved surfaces. Also, the energy consumption using this novel friction stir welding tool is said to be significantly low when compared to conventional tools that are being currently employed. This research project by University West has been carried out by collaborating with Volvo Aero, SAAB Automobile, and the welding equipment company ESAB. This novel tool for friction stir welding process is expected to be commercially available for large scale adoption by 2016.

Some of the advantages of this tool are that it significantly increases the quality of the products that are manufactured using frictions stir welding and also reduces energy consumption in this process.

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## 4. PATENT ANALYSIS OF BRAZING PROCESS

Brazing is a type of joining method where the merging of the two parts is done by heating them to a suitable temperature. The filler metal used in this process has a liquidus temperature (the lowest temperature at which the alloy is completely liquid) of above 4270 degrees C, and this temperature is below the solidus temperature (the highest temperature at which the alloy is completely solid) of the base metal. The fillers used in this process are usually non-ferrous metals or alloys and these filler metals are evenly distributed throughout the parts that are to be fitted and joined. In the brazing process it is not necessary to melt the base metal, instead the filler metals with low-melting point are employed against the base metal. In this joining process, the base metals are cleaned to remove impurities such as oxides, oils, and so on. The filler metal is then used to wet the surface of the base metal and it is spread along the consecutive joint. In order to further aid the brazing process, fluxes are additionally employed to increase the wet properties of the base metal surface. The capillary attraction between the filler and the base metal is significantly higher than the flux and base metal. Fluxes used in this process help in making the filler metals flow into the minute gap of the parts that are to be joined together. The advantages of the brazing process are that it can be employed for a large number of dissimilar metals and for a variety of material thickness. The other advantage is that complex and multi component assemblies can be joined together in an economical way and the strength of the joints obtained is also very high.

From the patents that are exhibited below it can be seen that there has been work on enhancing the brazing process on developing the brazing process and braze assembly, including work on conductor bars, a process to join components having ceramic oxide surfaces, and superior braze material.

 

| Title | Publication Date/Publication Number | Assignee | Inventor | Abstract |
|---|---|---|---|---|
| Brazing process, braze assembly, and brazed article | October 14, 2011/ US 20130095342 A1 | General Electric Company | David Edward Schick, Dean William MORRISON, Srikanth Chandrudu Kottilingam, Yan Cui, Brian Lee Tollison, Dechao Lin | A brazing process, a braze assembly, and a brazed article are disclosed. The brazing process includes applying a braze material to an article within a vacuum chamber while the vacuum chamber is substantially evacuated. The braze assembly is capable of applying a braze material to an article within a vacuum chamber while the vacuum chamber is substantially evacuated. The brazed article is devoid of re-formed oxides. |
| Rotor for electric motor and brazing process | August 15, 2011/ US 20130043760 A1 | GM Global Technology Operations LLC | Richard J. Osborne, Qigui Wang, Yucong Wang | A plurality of conductor bars are positioned within slots of a laminated electric steel disc stack, and the ends of the conductor bars are brazed to end rings to manufacture a rotor. The method includes inserting the conductor bars into the slots of the disc stack, providing the end rings with slots for receiving the ends of the conductor bars; positioning spacers of braze material adjacent each end of each of the conductor bars to create a gap between the end rings and the steel disc stack; and applying heat to melt the braze material of the spacers whereby braze material is furnished by the spacers of braze material to braze the first and second ends of the conductor bars to the first and second end rings. Channels are provided in the face of the end rings facing the steel disc stack to drain away excess braze material. |
| Brazing process | July 10, 2010/ US 20120225306 A1 | Ceramic Fuel Cells Limited | Paul Zheng | A brazing process for joining at least two components having ceramic oxide surfaces is described. The brazing filler used in the process comprises a noble metal and a second metal. During the brazing process, the filler is heated in an oxidising atmosphere such as air. The heating is undertaken until at least the noble metal is molten. The molten filler comprises a surface oxide formed from a stable, non-volatile oxide of the second metal that does not significantly alloy with the molten noble metal. The molten filler is able to wet the ceramic oxide surfaces and is subsequently cooled between them to thereby join them together. |
| Innovative braze and brazing process for hermetic sealing between ceramic and metal components in a high-temperature oxidizing or reducing atmosphere | April 19, 2010/ US 8511535 B1 | Aegis Technology Inc.. | Quan Yang, Chunhu Tan, Zhigang Lin | A superior braze material, along with a method of producing the braze material and a method of sealing, joining or bonding materials through brazing is disclosed. The braze material is based on a metal oxide-noble metal mixture, typically Ag—CuO, with the addition of a small amount of metal oxide and/or metal such as $TiO_2$, $Al_2O_3$, YSZ, Al, and Pd that will further improve wettability and joint strength. Braze filer materials, typically either in the form of paste or thin foil, may be prepared by a high-energy cryogenic ball milling process. This process allows the braze material to form at a finer size, thereby allowing more evenly dispersed braze particles in the resultant braze layer between on the surface of the ceramic substrate and metallic parts. |

| Title | Publication Date/Publication Number | Assignee | Inventor | Abstract |
|---|---|---|---|---|
| Vacuum brazing process for honeycomb structure of heavy-duty combustion engine | December 23, 2009/ CN 102107307 B | Shenyang Liming Aero-Engine (Group) Co., Ltd. | Du Jing, Shen Qu, Kongqing Ji, Jin Ying, Yang Shuo, Zhang Lei | Heavy-duty gas turbine honeycomb structure vacuum brazing process method, material to be welded to one or a combination of the following: GH536, 1Cr18Ni9Ti, GH4708, K4104; brazing material is B-Ni73CrSiB-40Ni-S; brazing process parameters as: (5 ~ 10) °C / min heating rate to (500 ~ 550) °C, heat (15 ~ 30) min; then (5 ~ 10) °C / min heating rate to (950 ~ 1000) °C, heat ( 15 ~ 25) min; finally (5 ~ 10) °C / min heating rate to (1100 ~ 1110) °C, insulation (10 ~ 20) min brazing; welding followed by furnace cooling to 1000 °C after rapid cooling, the sample is cooled to below 100 °C baked. The invention has strong operability, technology and good effect, with great economic value and technical value. |
| Process for fluxless brazing of aluminium and brazing sheet for use therein | November 04, 2009/ EP 2382087 A1 | Aleris Aluminum Koblenz GmbH | Adrianus Jacobus Wittebrood | The invention relates to a process for controlled atmosphere brazing comprising, brazing an aluminium alloy without flux in a controlled atmosphere, while using brazing sheet comprising of an aluminium alloy core upon which on at least one side a layer of filler alloy is clad, the filler clad layer having an inner-surface and an outer-surface, the inner-surface is facing the core and the outer-surface is devoid of any further metallic based layers, and wherein the filler alloy has a composition which is Na-free, Li-free, K-free, and Ca-free, and comprising, in wt.%: Si 3% to 15%, Mg 0.05% to 0.5%, one or more elements selected from the group consisting of: (Bi 0.03% to 0.2%, Pb 0.03% to 0.2%, Sb 0.03% to 0.2%, and the sum of these elements being 0.2% or less), Fe 0 to 0.6%, Mn 0 to 1.5%, the balance aluminium and incidental impurities. |
| Microwave brazing process | November 27, 2007/ EP 1927420 A3 | General Electric Company | David E. Budinger | A process for heating a braze alloy by microwave radiation (26) so that heating of the alloy is selective and sufficient to cause complete melting of the alloy and permit metallurgical bonding to a substrate (14) on which the alloy is melted, but without excessively heating the substrate (14) so as not to degrade the properties of the substrate (14). The process entails providing metallic powder particles (12) having essentially the same metallic composition, with at least some of the particles (12) being sufficiently small to be highly susceptible to microwave radiation (26). A mass (10) of the particles (12) is then applied to a surface of a substrate (14), after which the mass (10) is subjected to microwave radiation (26) so that the particles (12) within the mass (10) couple with the microwave radiation (26) and sufficiently melt to metallurgically bond to the substrate (14). The microwave radiation (26) is then interrupted and the mass (10) is allowed to cool, solidify, and form a solid brazement. |

| Title | Publication Date/Publication Number | Assignee | Inventor | Abstract |
|---|---|---|---|---|
| Microwave brazing process for forming coatings | December 15, 2006/ US 8574686 B2 | General Electric Company | Laurent Cretegny, Daniel Joseph Lewis, Jeffrey Reid Thyssen | A process for forming a coating on a surface of a substrate, so that heating of the coating material is selective and sufficient to cause at least partial melting of the coating material and permit bonding to the substrate without excessively heating the substrate so as not to significantly degrade its properties. The process generally entails forming a brazing paste containing powder particles dispersed in a binder. The particles are formed of a composition that is susceptible to microwave radiation. The brazing paste is then applied to the surface of the substrate and subjected to microwave radiation so that the particles couple with the microwave radiation and are sufficiently heated to burn off the binder and then at least partially melt to form an at least partially molten layer on the substrate. The microwave radiation is then interrupted to allow the at least partially molten layer to cool, solidify, and form the coating. |
| Two tier brazing process for joining copper tubes to a fitting | April 6, 2005/ EP 1584398 B1 | United Technologies Corporation | Stephen L. Mayers | The invention relates in general to joining copper or copper alloy tubes to metallic tubes such as manifolds, and more specifically to a two step brazing method for joining such tubes and manifolds according to the preamble of claim 1. A brazing method of this kind is disclosed in JP 2001 087 853 . |
| Method and arrangement for a martensite-free brazing process | May 13, 2002/ CA 2385985 C | Safetrack Baavhammar Ab, Ola Pettersen | Ola Pettersen | An apparatus for brazing a connecting piece of electrically conducting material such as metal, to a metal surface by means of a new type of temperature-controlled brazing whereby for certain types of material a brazing is obtained that is free of martensite formation underneath the brazed joint in, for example, railway track and/or pipework. The apparatus has an electrode and processing circuitry by which a voltage applied in electrical circuit with the electrode causes an electric arc to be struck between the electrode and an adjacent workpiece to generate the heat necessary for brazing. |

**Exhibit 1 depicts patents related to brazing process.**

*Picture Credit: Frost & Sullivan*

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