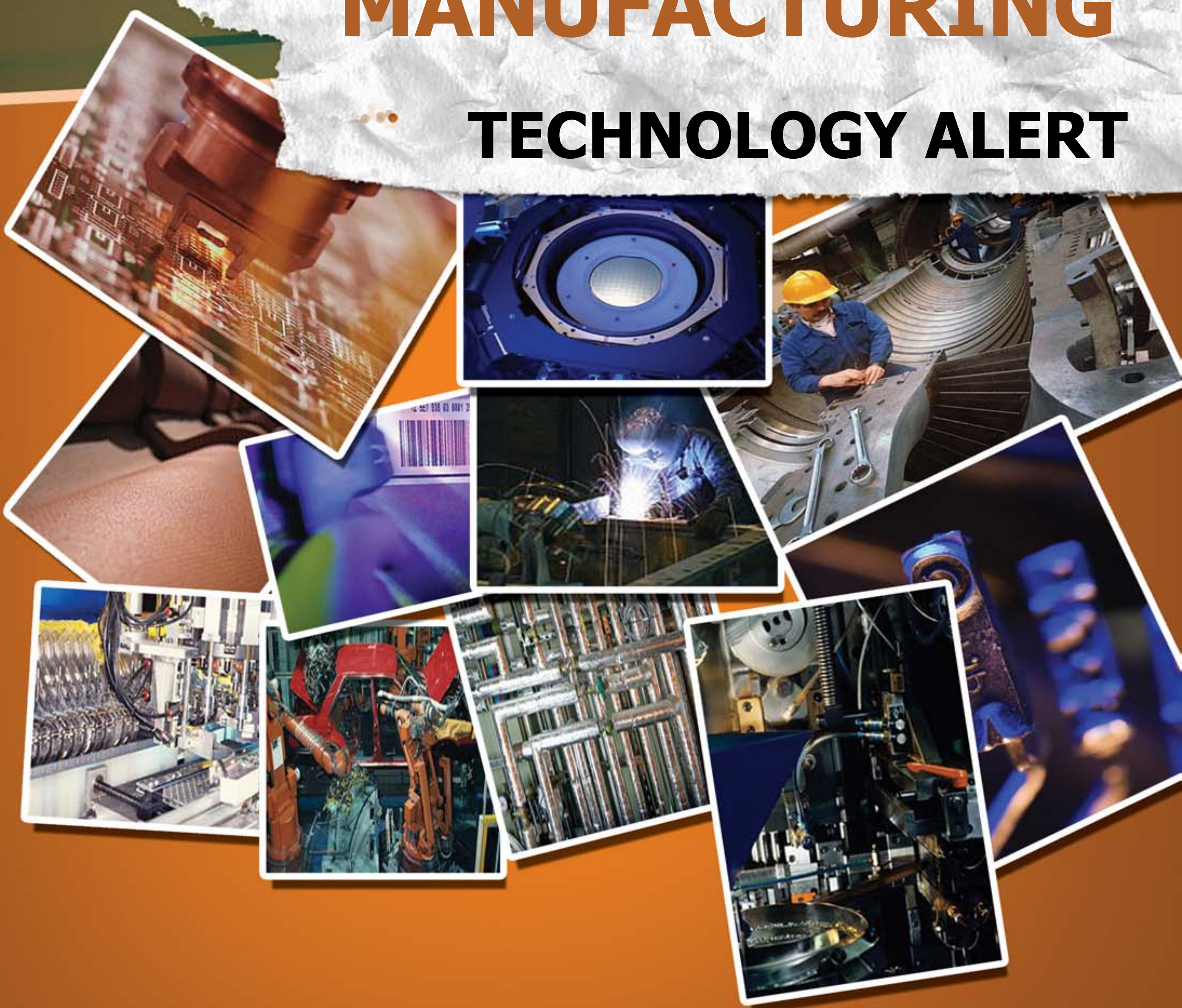
TECHNICAL INSIGHTS

ADVANCED MANUFACTURING

TECHNOLOGY ALERT



31st October 2014

1. ULTRAVIOLET CURING TECHNOLOGY IN MANUFACTURING

Curing of photo-sensitive material by exposure to ultraviolet (UV) rays, an invisible form of electromagnetic radiation (with wavelengths much shorter than visible light, ranging from around 400 nm down to 10 nm), is an established manufacturing process associated with certain applications. The UV band is split into A, B, and C sections, with C having the shortest wavelength and the most destructive impact on humans.

One key advantage over other curing methods, such as thermal (baking or autoclaving) and infrared (IR), is that no destructive heat is put into the material, which is important for many industrial applications that involve plastic or wood substrates. UV exposure can quickly transform liquid-state coatings and adhesives into cured solids. The printing industry is probably the largest beneficiary, where UV curing has long been used. The medical/dental industry is another key user, for curing of adhesives on medical devices and photo-sensitive polymer dental fillings.

The UV source can be an electric lamp, such as a mercury vapor high intensity discharge (HID) lamp, which is connected to a high-voltage ballast (typically providing hundreds of volts to strike or start the lamp arc) and is fairly energy intensive (generating a huge amount of waste heat). A more recent innovation is the use of LED UV light sources, which are longer lasting, cooler running, and less power-intensive. However, their UV power delivery is limited. LED curing systems usually operate in a narrow UVA bandwidth of around 365 nm to 405 nm (please refer LED UV curing system in Exhibit 1).

Exhibit 1 depicts a typical LED UV curing system: irradiation chamber plus controller.

Picture Credit: http://www.digitallightlab.com/DigitalUV.php?11

UV-curable coatings can be 100% solids, with no volatile constituents, or water-based coatings. In printing on paper, various methods of photosensitive ink application can be applied (rolling, spraying, dipping, flooding, silk screen). Printed paper with UV-cured coatings can have a range of finishes, from very shiny (highly reflective) to a dull matte.

Aluminum beverage cans have multi-color inks applied by rollers. After the image is finished, a clear UV curable coating is applied to protect against wear and tear. Can manufacturers may use 6 to 8 high-wattage UV lamps to cure coatings outside and inside the can. This curing will not take much time.

Wood finishes are another commercial use of UV curing. Traditional urethane coatings can take days to be fully cured at room temperature. UV curing is much faster. UV curable coatings do cost more than conventional curing (air dry) coatings and so have to justify the premium with better and faster end results.

Polymeric coatings that are UV curable involve computer screens, keyboards, and personal electronic devices. They can enhance optics (glare and reflection reduction), resist wear, provide microbial resistance, enhance chemical resistance and so on.

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2. ELECTRON BEAM WELDING TECHNOLOGY

For difficult-to-weld/high-value metallic materials that must be joined in a vacuum, electron beam (EB) welding is a very sophisticated solution. Invented in 1958, EB welding has come a long way. It generates a smaller heat-affected zone (HAZ) than other welding technologies, yielding less heat damage to substrates. The largest EB welding machines have beam power levels up to 100 kW (power is the product of accelerating voltage--kV, and beam current--ma). The depth of the weld dictates power needs. A powerful stream of electrons is generated (emitted from a tungsten cathode connected to a power supply), accelerated by electric fields between the cathode and anode, focused and manipulated by magnetic fields (electromagnetic lenses) to provide a narrow high-velocity beam for melting and fusion (localized casting) of sensitive target metals. The impact of electrons on the work piece transforms kinetic energy into localized heating and melting, enabling the welding process.

Exhibit 2 depicts the electron beam welder (150 kV) from Cambridge Vacuum Engineering.

Picture Credit:http://www.directindustry.com/prod/cambridge-vacuum-engineering/welding-machines-electron-beam-17327-400541.html

Formerly ubiquitous cathode ray tube (CRT) TV, computer, and instrument display monitors also accelerate and guide electron beams, in this case to a phosphor-loaded metal mask behind the face plate. Due to the risk of radiation leaks (EB accelerators can generate harmful X-rays as a byproduct, which becomes a safety issue), the face plate is always leaded glass, and side shielding exists in the CRT. EB welding apparatus also takes seriously the need to protect and shield operators.

The EB can trace the desired weld geometry by mechanically manipulating the workpiece in the vacuum chamber, but sometimes it is preferred to leave the work piece stationary and deflect the electron beam around. The heating rate from EB impact is impressive: on the order of 10^8 to 10^9 K per second. If the operator is not careful, the EB will not only melt the metal, but evaporate it. The beam typically moves at between 2 and 50 mm/second, traversing the weld path. It must be noted that certain volatile metals (high vapor pressure of melt), such as magnesium, zinc, and cadmium, are not candidates for EB welding.

Researchers at the US DOE Lawrence Livermore National Lab (LLNL) in Livermore, California have explored a means to measure EB current flow at various angles. They invented an EBeam Profiler device, a diagnostic tool with automated data acquisition, which allows EB welders to measure and replicate proper weld parameters (such as sharp focus aspects and beam power-density distribution) every time. In the days before automated assist, operators had to manually adjust for sharpest focus and move the work piece around for EB impingement, but that was tricky considering that an electron beam is invisible. The properties of the beam were not consistent from work piece to work piece and from day to day. That produced QA issues with the welds. With critical aerospace and nuclear energy applications at stake (no defects permitted), that was unacceptable. The LLNL EBeam Profiler solved the problem and has been commercially licensed to Sciaky, Inc. in Chicago, Illinois.

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3. 3D PRINTING IMPROVES BRAILLE FLEXIBILITY

Since it was published by French citizen Louis Braille in 1829, the tactile writing system that bears his name has been used by the visually impaired and partially sighted individuals to read text, including music. There are some limitations to braille printing, even in the 21st century, including the size and volume of larger printed works, and their durability. More complex forms, such as pictures and other images, are difficult to depict in braille.

A team of researchers at the Korea Institute of Science and Technology (KIST) in Seoul, Korea, have combined 3D printing and 3D thermal reflow treatment that promises to provide braille text and picture books greater flexibility in terms of height, size, and even color. The technique does not require ultraviolet coatings or chemical treatment that might be harmful to users. KIST is a multi-disciplinary research institute that was founded in 1966 whose more than 1,800 staff scientists, visiting scientists, fellows, and students conduct basic research in scientific and technological fields.

The present printing of braille documents and books uses a series of raised dots on paper to represent letters, and to outline basic shapes such as a tree. This makes it difficult to create braille text on public buildings, or directions in mass transit systems. In braille books, the depiction of complex images such as geographic map contours, or the occurrence of an earthquake, is also difficult.

The KIST team, led by Myoung-Woon Moon, chose the Fused Deposition Modeling, or FDM, technique, for their braille research. FDM presses a thermoplastic filament with a nozzle that immediately heats the material to create successive thin layers of thermoplastic that are built into durable objects. This method is used to make, for example, automotive, construction, and industrial parts. The thermal reflow method Moon and his colleagues used heats the board upon which the 3D printed part is made until the temperature reaches the melting point of the thermoplastic material. This lowers the viscosity of the thermoplastic, causing the surface tension of the layers to lower surface energy by filling the structures. The flowing and reflowing of material makes a smoother surface, and during remelt phases, will absorb the thermoplastic filament into the crevices of the board to enhance adhesion.

The KIST method will enable braille developers to manufacture more detailed figures and tables into their documents, broadening the context of documents and books for vision impaired readers. Braille manufacturers will be able to adjust the number of filament layers to alter the shape, size, and thickness of their creations.

For the partially-sighted readers, the KIST technique can be used to apply thermoplastic filaments of different colors to illustrate geographic features on maps. Just as importantly, because 3D printing technologies such as FDM create finished parts by following a computer aided design model, the Korean team's approach will reduce the time taken for the manufacture of educational materials for the visually impaired from months to several hours. The other advantage of the KIST 3D printed braille method is greater durability of its plastic forms in the face of external impact, compared to paper dots. According to Moon, his team's

3D printed method can apply braille forms to paper, ceramics, and metal equally well.

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4. PATENT ANALYSIS OF CENTRIFUGAL CASTING

Casting is a manufacturing process in which the object is obtained by pouring liquid material into a mold and then allowing it to solidify. The shape of the object is determined by the shape of the mold cavity. In centrifugal casting, the objects are produced by causing molten metal to solidify in rotating molds. Generally, the molten metal is poured while the mold is spinning, however, for certain applications, in vertical casting, it is preferable that the mold be stationary when the pouring begins. The speed of the rotating mold is increased during filling of the mold or after the pouring is completed. In horizontal centrifugal casting, the mold will be rotating at lower speeds during the pouring followed by rapid increase in the rotating speed during the solidification. A dense cast can be obtained by applying the centrifugal force to a molten metal during the solidification phase. The centrifugal casting process is used for manufacturing cast iron tubes, pipes, cylinder liners and other axis symmetry parts. Centrifugal casting has various advantages over static casting. For example, low pouring temperatures are possible in centrifugal casting than those used for static casting. Centrifugal casting has high casting yield and produces dense metal structures. Moreover, the thermal gradient is steeper in centrifugal casting than in static casting which results in characteristic columnar grains.

In the last 5 years, patents related to centrifugal casting have been filed at a steady rate. Among the recent patents provided in Exhibit 3, one patent explains the apparatus for centrifugal casting under vacuum (US8167023 B2). Another patent (US6776214 B2) explains the method for making various titanium base alloys and titanium aluminides into engineering components such as rings, tubes and pipes. Patents related to the production of turbine blades and precision castings using centrifugal casting have also been published.

Title	Publication Date/Publication Number	Assignee	Inventor	Abstract
Method and apparatus for centrifugal casting of metal	Aug 23, 2005 / US6932143 B2	Charles H. Noble	Charles H. Noble	A method and apparatus for centrifugal casting of metal articles uses a rotating mold body that can be pivoted from a vertical orientation to a horizontal orientation during the centrifugal casting of the metal article. The resulting metal article has a closed end and an open end defining a hollow cavity. The mold body has a closed end that is oriented in a vertical position with the longitudinal axis extending vertically. While the mold body is rotated, an amount of molten metal is introduced into the mold body so that the molten metal is distributed along the closed end of the mold body. In one embodiment, the bottom end of the mold body has a frustoconical shaped surface defining the mold cavity. The mold body is then pivoted to a horizontal position while continuously rotating to distribute and cast the metal against the inner surface of the mold body. In one embodiment, the mold body has a refractory lining of a compacted refractory material. The refractory material is introduced into the rotating mold and a blade is contacted with the layer of the refractory material formed on the inner surface while the mold is rotated in a first direction to compact and densify the layer of particles with a flat end of the blade. The rotation of the mold body is then reversed and the sharp edge of the blade is contacted with the compacted layer to shape and contour the mold lining.
Centrifugal casting method and apparatus	May 27, 2014 / US8733424 B1	United States Pipe And Foundry Company, Llc	Kenneth J. Watts, Terry M. Wood	A method and apparatus for centrifugal casting, in which transfer functions are developed relating the fluidity of molten metal, for example iron of varying composition, to casting machine movement for a particular mold in order to cast objects, for example pipe, having desired and uniform characteristics, including wall thickness. Fluidity is calculated for each pour of molten metal based on the measured pour temperature and measured liquidus arrest temperature. A drive system controlled by a programmable logic controller moves the casting machine in accordance with the output of the transfer functions based on the calculated fluidity.
Centrifugal casting of titanium alloys with improved surface quality, structural integrity and mechanical properties in isotropic graphite molds under vacuum	Aug 17, 2004 / US6776214 B2	Santoku America, Inc.	Ranjan Ray, Donald W. Scott	Methods for making various titanium base alloys and titanium aluminides into engineering components such as rings, tubes and pipes by melting of the alloys in a vacuum or under a low partial pressure of inert gas and subsequent centrifugal casting of the melt in the graphite molds rotating along its own axis under vacuum or low partial pressure of inert gas are provided, the molds having been fabricated by machining high density, high strength ultrafine grained isotropic graphite, wherein the graphite has been made by isostatic pressing or vibrational molding, the said molds either revolving around its own horizontal or vertical axis or centrifuging around a vertical axis of rotation.
Centrifugal casting method, centrifugal casting device, hollow casting mold and feed trough forming device	Apr 19, 2005 / US6880615 B2	Sandor Cser	Sandor Cser	A centrifugal casting method is provided for the manufacture of hollow molds and applications of this apparatus and method are provided. A centrifugal casting apparatus has a hollow mold (**13**) suitable for the centrifugal casting. For the manufacture of cast workpieees by the centrifugal casting method a plurality of mold cavities (**14**) formed by at least one hollow mold (**13**) are arranged and driven such that the mold cavities (**14**) rotate about a common axis of rotation (**18**). At least three mold cavities (**14**) which rotate in a single plane are provided.

Title	Publication Date/Publication Number	Assignee	Inventor	Abstract
Mold releasing agent for centrifugal casting mold	Mar 2, 2004 / US6699314 B2	Honda Giken Kogyo Kabushiki Kaisha	Arai Takeo, Murakami Manabu, Yokoyama Kouriki, Nakaya Shoichi, Miyanishi Masahiro, Suzuki Sadahiro	A mold releasing agent suitable for easily casting a cylindrical cast member which is superior in adhesion on cast parts at low cost, is provided. A mold releasing agent for a centrifugal casting mold comprises a binder, a heat insulating agent, and a foaming component having a foaming property, is dissolved in a solvent so as to form a slurry having a specific viscosity, and a mold releasing agent layer having crater shaped concave portions is formed by coating on the inside of an integral centrifugal casting mold.
Apparatus for centrifugal casting under vacuum	May 1, 2012 / US8167023 B2	Manfred Renkel	Manfred Renkel	An apparatus for centrifugal casting under vacuum includes a rotor having a shaft extending in an essentially vertical direction and being rotatable around an axis defined by the shaft. The rotor has at least one mold, at least one crucible, and a gas-tight housing in which the mold and the crucible are accommodated. The apparatus also includes a vacuum source to create a vacuum in the housing, a heating device that melts a metal, a drive device that drives the shaft in order to rotate the rotor, and an auxiliary acceleration device configured to generate a force to further rotate the rotor to overcome a moment of inertia of the rotor. The auxiliary acceleration device includes a jet propulsion and/or at least one pushing actuator accelerating the resting rotor.
High pressure centrifugal casting of composites	Aug 30, 2005 / US6935406 B2	Massachusetts Institute Of Technology	Merton C. Flemings, Jessada Wannasin, Hoe Phong Tham	A system and method for centrifugal casting of composites, especially metal-matrix composites. According to the system and method, a porous preform is infiltrated with matrix material using a centrifugal force to pressurize the matrix material against the preform. The pressure head of the matrix material is maintained at an approximately constant level throughout infiltration.
Cast wheel produced by centrifugal casting	Aug 27, 2003 / EP1189713 B1	Vacuumschmelze GmbH	Ewald Grote, Giselher Herzer, Dieter Nuetzel	The invention relates to novel cast wheels for the rapid solidification technique which are produced by centrifugal casting. Said wheels consist of an alloy with a non-equiaxial granular structure, whereby the grains are elongated and their longitudinal axis lies substantially perpendicular to the cast-wheel surface.

Title	Publication Date/Publication Number	Assignee	Inventor	Abstract
Method for the production of precision castings by centrifugal casting with controlled solidification	Jun 26, 2001 / US6250366 B1	Ald Vacuum Technologies Gmbh	Alok Choudhury, Harald Scholz, Matthias Blum, Georg Jarczyk, Marek Gorywoda, David Francis Lupton	In the production of precision castings by centrifugal casting with controlled solidification, a melt is cast under vacuum or shield gas into a pre-heated mold (**15**) with a central gate (**19**) and several mold cavities proceeding from the gate toward the outer circumference (D_a) of the mold (**15**). To prevent the formation of shrink holes and porous areas in the castings, to save energy, and to increase the production rate, the mold (**15**) is operated at temperatures which decrease from the inside toward the outside. The mold consists of a material or material combination with a coefficient of thermal conductivity lower than that of copper. Before the melt is poured, the mold (**15**) is heated, starting from the gate (**19**), by a heating device (**20**), which projects into the gate, so that the gate (**19**) reaches a temperature which is a function of the material being cast. Heating is carried out at a rate sufficient to produce a temperature gradient of at least 100° C., preferably of 200-600° C., even more preferably of 300-500° C., between the inside circumference (D_i) and the outside circumference (D_a). The invention is used preferably for the production of precision castings of metals of the group titanium, titanium alloys with at least 40 wt. % of the titanium, and super alloys.
Centrifugal casting equipment	May 22, 2007 / CA2461232 C	Honda Giken Kogyo Kabushiki Kaisha, Hideshi Sato, Shiro Naito, Fumio Hirai, Haruki Kodama, Masayoshi Kai, Setsumi Hatanaka, Noboru Miyao, Takeshi Sasaki	Hideshi Sato, Shiro Naito, Fumio Hirai, Haruki Kodama, Masayoshi Kai, Setsumi Hatanaka, Noboru Miyao, Takeshi Sasaki	A centrifugal casting apparatus has a workpiece withdrawal mechanism (24), a cleaning mechanism (26), and a facing material applying mechanism (28) which are disposed parallel to each other on an axial side of a centrifugal casting mold (22), a unit drive mechanism (30) for moving the workpiece withdrawal mechanism (24), the cleaning mechanism (26), and the facing material applying mechanism (28) in unison with each other in the direction indicated by the arrow B across the axial direction indicated by the arrow A, and a pouring mechanism (32) disposed in an opposite axial side of the centrifugal casting mold (22).

Exhibit 3 depicts patents related to centrifugal casting.

Picture Credit: Frost & Sullivan

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