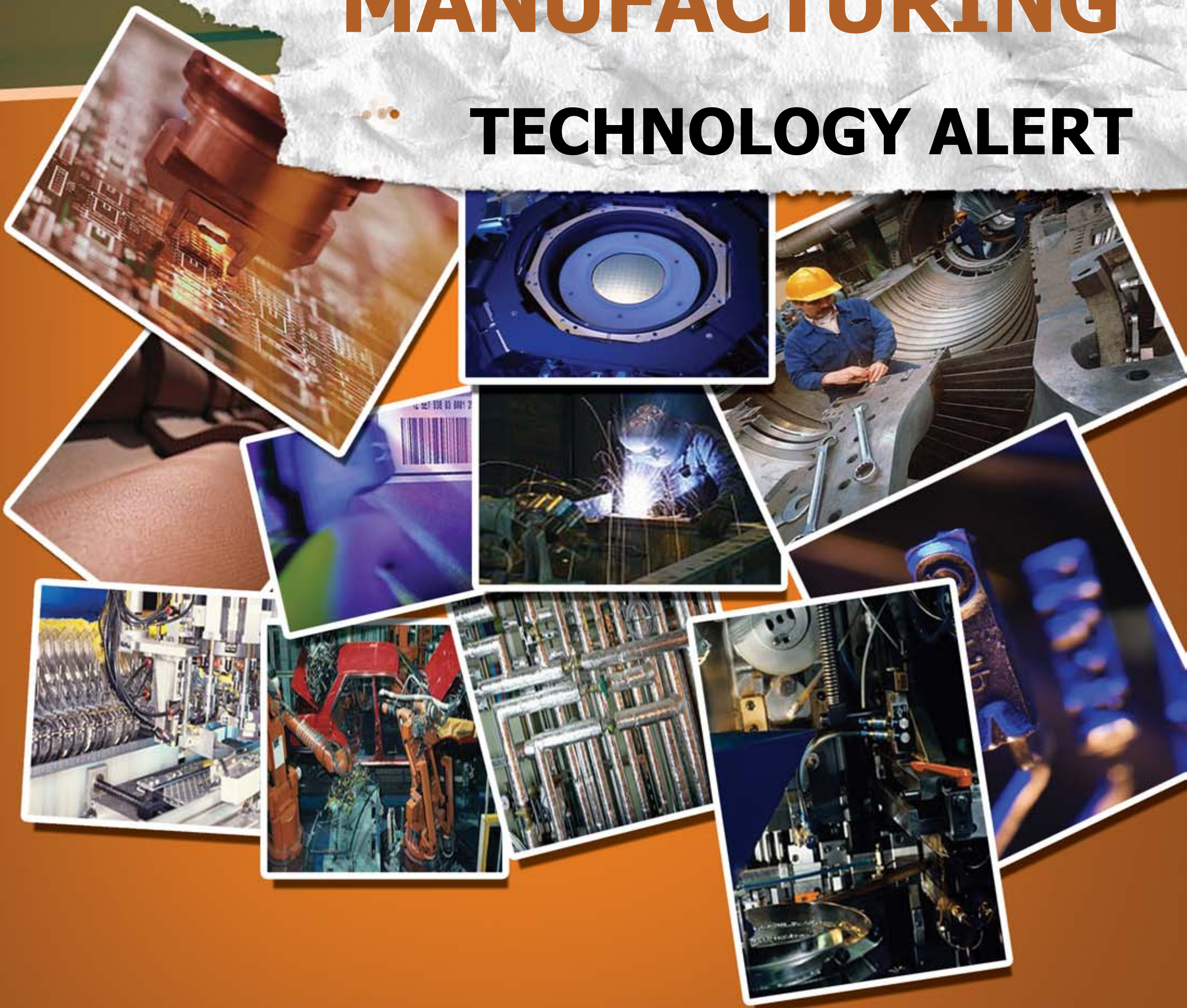
TECHNICAL INSIGHTS

ADVANCED MANUFACTURING

TECHNOLOGY ALERT



24th October 2014

1. ARE INDUSTRIAL ROBOTS ON THE FACTORY FLOOR TRAINABLE TO BE ALWAYS GOOD?

Robots in the manufacturing environment are generally trained and programmed by human masters to behave well. In other words, they practice information ethics (IE). However, robots have the potential to go bad when they masquerade or try to masquerade as humans, learning and exhibiting familiar human character defects.

In the classic academy award-winning 1968 science fiction movie "2001: A Space Odyssey, on a space mission to Jupiter, a human-like computer named Hal (a fictitious HAL 9000 mainframe computer) was misbehaving, making critical errors that threatened the well being of multiple astronauts on board. It got to the point that a human (Dr. David Bowman) had to intervene and power down the machine by disconnecting most of the processors and memory devices. Hal protested and asked the crew member (via a robotic monotone male voice) to stop this unwelcome intervention, exhibiting real fear for his life--a human emotion. Dr. Bowman declined to take such orders from Hal. In a like manner, it is expected that modern industrial robots have moral principles, behave, and do good on the factory floor (not evil).

University-level computer science researchers, Keith Miller, Marty Wolf, and Frances Grodzinsky, recently authored a serious scholarly paper on this very subject published in the prestigious *Journal of Experimental & Theoretical Artificial Intelligence*, entitled Behind the mask: machine morality (August, 2014).

The researchers explored the ethical implications and real concerns surrounding development of robots masquerading as humans. The question is raised by the research team: is any machine trying to appear human in its thinking and behavior (in other words, being deceptive) intrinsically evil? Is it ethical to create any robot that passes the Turing Test? This is a definition of that test, according to Wikipedia:The Turing Test is a test of a machine's ability to exhibit intelligent behavior equivalent to, or indistinguishable from, that of a human, as judged by a panel of experts.

The researchers maintain that, until the ethical issues are resolved, we will not know if we can teach robots to always be good. When masquerading or disguising, robots can corrupt the environment, and boost the chances of evil by making it harder for human individuals to render authentic ethical decisions, according to the authors. One of the unfortunate behaviors that can surface is when the machine is questioned as to being human or not, a learned (not programmed) human-like computerized robot behavior can become evident, which the researchers describe as: coyly obfuscating the truth.In other words, the robot may become a certified liar. Here is another unethical outcome cited by the authors: developing a robot to masquerade as a bank customer for the purpose of robbing the bank.

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2. AUTOMATICALLY GUIDED VEHICLE SUPPORT FOR MANUFACTURING OPERATIONS

Automatic or automated guided vehicles (AGVs) provide a vital material handling and logistics supporting role on the factory floor. These electric vehicles, or carts, move quietly around following a magnetic tape on the floor for guidance. Tape paths are flexible and can be rerouted within hours. AGVs save labor, diminish employee injuries, and can carry large loads. They are also proving to be cost-effective, on a total cost-of-ownership basis over the life of the vehicles.

Last year, *Technical Insights* enjoyed a private guided tour of the Tesla Motors assembly plant in Fremont, CA where AGVs are silently in operation slowly carrying around partially assembled chassis for the Model S EV sedans weighing thousands of pounds each. Assembly workers can order the AGVs to raise or lower their cargo at each station to facilitate assembly operations. We see the Tesla plant application as a modern best practices example of beneficial factory use of AGVs. More recently (work completed August 2014), the Fremont assembly line was expanded to accommodate the new model X crossover EV (2015 model shipping late this year) that looks like a small SUV, as well as expanded Model S sedan assembly. The 2 models share the same basic underlying passenger car platform.

Tesla industrial engineers, after considerable research, chose customized SmartCart 300 AGVs (also known as automatic guided carts, AGCs, which can carry up to 6,000 lb, see picture)made by Daifuku Webb (HQ in Farmington Hills, MI), a Jervis B. Webb company, for the Fremont plant, which began serial assembly operations in 2012. These automatic guided carts are in operation up to 16 hours per day for a 2-shift assembly schedule, 5 days per week, moving hardware from point to point. There is automatic electric charging of carts on an opportunistic basis.

They are customized with a scissors-lift capability. The SmartCart AGCs communicate via IEEE 802.11a standard local wireless network. Tesla uses SmartCarts for chassis assembly, door and trim assembly, as well as battery handling. The flat lithium-ion battery packs (filled with Panasonic battery cells), are mounted low under the belly of the Model S and armored with aluminum plate. They are the heaviest and most expensive subassemblies found in the Model S. The Tesla AGCs are all synchronized and slowly move together around the plant floor.

Exhibit 1 depicts SmartCart 300 by Daifuku Webb (which is similar to AGCs in Tesla’s Fremont assembly plant).

Picture Credit: http://daifukuwebb.com/Products/Vehicles-and-Carts/Automatic-Guided-Cart-SmartCart

SmartCart AGCs are generally sold through a network of local value-added resellers. However, we strongly suspect that Daifuku Webb was directly involved in Tesla's high-profile Fremont assembly plant installation.

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3. INDUSTRIAL PLATING PROCESSES FOR ENHANCED WEAR RESISTANCE

Among the plating options (plating is one of many manufacturing processes that can deposit a metallic coating, usually thin, on a conductive substrate) available to product designers to enhance wear resistance are hard chromium (Cr) electroplating, electroless nickel (eNi) plating, and nanolayered electroplating.

Hard Cr plating is well understood, offered for many decades, and used for demanding applications, such as the exterior of low-alloy heat-treated steel sliding pistons on aircraft landing gear (the piston is the male end attached to the moveable bogie carrying wheels that slips in/out of a female barrel attached to the airframe). Both the piston exterior and mating barrel interior will be Cr plated. During periodic overhauls of landing gear, target wear surfaces will be stripped and re-plated. Hard Cr has great sliding wear resistance but is prone to microcracks and corrosion attack on the substrate steel over time. The process also suffers environmental headaches due to the fact that toxic (carcinogenic) hexavalent chrome is found in the plating baths. So, in some environmentally sensitive markets, such as the highly regulated US industries, more environmentally friendly substitutes are being phased in as hard Cr loses business and gradually fades away.

Electroless nickel is an interesting and complex chemical plating process needing no power input. Shiny smooth and hardened surfaces are the result (see picture). The cost per unit area plated is fairly high, and deposition rate is low, so thickness needs to be limited (no more than 2 mils = 0.002 inch). Wear resistance is good, as well as corrosion resistance. Availability of experienced and competent merchant eNi plating shops is limited, so engineers might need to line up a qualified source before specifying this process for production hardware.

Exhibit 2 depicts electroless nickel plated gears.

Picture Credit: http://jmdindustries.com/gallery/electroless-nickel/

Technical Insights is well aware of Modumetal (Seattle, Washington) and this company's work with metallic nano-laminar electroplating. This company is a private venture-capital funded startup, and quite secretive about the company's proprietary plating technology. According to public sources, Modumetal uses an acidic plating bath and metals are dissolved therein. Metal ions in the plating bath are subjected to carefully modulated electric currents. The result is a layered nanolaminate coating structure with metallic layers as thin as 1 nm laid onto substrates. The corrosion and wear resistance properties of Modumetal's nanolaminate have proven in the field to be competitive on performance, with projected costs that are expected to be less than rival metallic coatings.

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4. PATENT ANALYSIS OF SPRAY FORMING

Spray forming, also called spray casting or spray deposition, is the inert gas atomization of the liquid metal stream into droplets of various sizes, which are moved away from the region of atomization by the fast flowing atomizing gas. The substrate collects the droplets, which then solidify into a coherent and fully dense preform. By moving the substrate relative to the atomizer, large preforms can be produced in different geometries including billets and tubes.

In spray forming, an alloy is melted in the induction furnace and the molten metal is poured through the conical tundish into a ceramic nozzle. The molten metal is split into droplets by gas jets and these droplets move downwards to impact onto the substrate. Through this deposition, a spray formed billet is built on the substrate.

One of the major advantages of spray forming is the economic benefit gained in reducing the number of steps between the melt and finished product. This technique can be used to produce fine scale micro structures in large cross sections. From the patents that have been exhibited, it can be seen that research is being carried out for using spray forming for various purposes, for example, method for spray forming high modulus polyurethane structures, method and apparatus for spray forming melts of glass and glass-ceramic compositions and method of spray forming readily weldable and machinable metal deposits. Some of the key patent holders in spray forming include Ford Global Technologies, Visteon Global Technologies, and General Electric Company. Patents indicate work in such areas as spray forming metal components and spray forming metal deposits.

Title	Publication Date/Publication Number	Assignee	Inventor	Abstract
Method for spray forming a metal component and a spray formed metal component	Aug 20, 2013 / US8511366 B2	Valtion Teknillinen Tutkimuskeskus	Yunfeng Yang	A method for spray forming a metal component (**11, 17, 21, 27**) having an elongated open channel (**10, 20, 22, 28**) therein comprises firstly spray forming a layer (**8, 19, 24**) of the desired metal onto a deposition substrate (**2**), placing then an elongated spray blocking object (**9, 18, 26, 29**) on the already sprayed layer for forming the channel, and continuing then the spray forming process until the desired total thickness of the component is achieved. According to the present invention, the spray blocking object is a strip (**18, 26, 29**), the cross-sectional profile of the strip being fully open in the direction of an axis (a) in a cross-sectional plane of the strip, and the strip is placed on the already deposited layer (**8, 19, 24**) with said axis directed substantially parallel to the direction of the incident metal spray (**6**).
Melt system for spray-forming	Jun 19, 2001 / CA2034341 C	Thomas F. Sawyer, General Electric Company	Thomas F. Sawyer	A method for regulating the flow of liquid metal to an atomization zone is provided. The regulation is effected by imparting a high density flux to a strew of liquid metal as it descends toward the atomization zone. The high density flux is applied by a flux concentrator. The flux concentrator is a small sleeve-like element attached by parallel conductors to a larger sleeve like element which acts as a secondary to a primary coil extended through the larger sleeve element. By imparting high density flux to initiate a stream passing through the flux concentrator the cross sectional dimensions of the melt stream and the rate of flow of melt through the concentrator is regulated to values which are appropriate for a spray-form type of action.
Method of spray forming metal deposits using a metallic spray forming pattern	Dec 5, 2000 / US6155330 A	Visteon Global Technologies, Inc.	Jeffrey Alan Kinane, Grigoriy Grinberg, David Robert Collins, Paul Earl Pergande	A spray forming pattern of a first metal having a melting point at a first temperature is formed. The spray forming pattern has a surface defining a cavity that has the shape of a master pattern. Steel particles having a carbon content in the range of 0.01-0.9% by weight are sprayed onto the spray forming pattern to form a deposit on the spray forming pattern. The deposit has a thickness of at least 0.5 inches and the temperature of the steel particles increases as the thickness of the steel deposit increases. The spraying conditions are controlled so that the steel particles coming into contact with the spray forming pattern results in a surface temperature of the spray forming pattern of less than about 80° C. The deposit and the spray forming pattern are heated to a second temperature, which is higher than the first temperature, to melt the spray forming pattern from the deposit. The resulting deposit has the general shape of the master pattern.
Methods and apparatus for spray forming, atomization and heat transfer	Aug 10, 2004 / US6772961 B2	Ati Properties, Inc.	Robin M. Forbes Jones, Richard L. Kennedy, Helmut Gerhard Conrad, Ted Szylowiec, Wayne Conrad, Richard Stanley Phillips, Andrew Richard Henry Phillips	The present invention is directed to methods and apparatus that use electrostatic and/or electromagnetic fields to enhance the process of spray forming preforms or powders. The present invention also describes methods and apparatus for atomization and heat transfer with non-equilibrium plasmas. The present invention is also directed to articles, particularly for use in gas turbine engines, produced by the methods of the invention.

Title	Publication Date/Publication Number	Assignee	Inventor	Abstract
Spray forming element for a showerhead	Jan 9, 2014 / US20140008462 A1	Grohe Ag	Eckhard Gransow, Thomas Salomon, Karl-Heinz STUECKERJUER GEN, David Rehage	In a spray forming element for a shower head having a housing, a plurality of axial-flow spray outlet elements, a housing base which has passage openings for the spray outlet elements, each of the spray outlet elements being pivotably mounted in the housing base, and which additionally has a gear mechanism for moving the spray outlet elements, in order to transmit a force to the spray outlet elements, a single gear element having a gate is provided, by means of which the spray outlet elements are positively guided and, during a movement of the gear element, the movement of all the spray outlet elements is carried out simultaneously.
Method of making a CIG target by spray forming	Apr 29, 2014 / US8709548 B1	Hanergy Holding Group Ltd.	A. Piers Newbery, Timothy Kueper, Daniel R. Juliano	A method of making a sputtering target includes providing a backing structure, and forming a copper indium gallium sputtering target material on the backing structure by spray forming.
Method and apparatus for spray-forming melts of glass and glass-ceramic compositions	Nov 9 , 2010 / US7827822 B2	Schott Corporation	Carsten Weinhold, David John Yuhas	The invention relates to a process and apparatus for forming a particulate composition, especially a particle glass composition, through the use of shock waves. A nozzle element is utilized having inlets for introduction of cold and heated gas and a delivery tube for introducing molten material. Through the introduction of the cold and heated gases, droplets are formed from a molten stream, a cone-shaped standing shock wave is formed, and shock waves are formed via a modified Hartmann-Sprenger chamber, the shock waves impinging on the droplet stream to break up the larger droplets.
Method of spray forming readily weldable and machinable metal deposits	Jul 10, 2001 / US6257309 B1	Ford Global Technologies, Inc.	Jeffrey Alan Kinane, David Robert Collins, Matthew John Zaluzec, Paul Earl Pergande, Grigoriy Grinberg	A method of spray forming a weldable metal deposit. The method comprises (a) providing a ceramic spray forming pattern, (b) heating the spray forming pattern to a sustained temperature sufficient to prevent internal stress formation in deposited carbon steel having a carbon content of less than about 0.3 weight percent when deposited on the heated spray forming pattern, (c) spraying metallic particles onto the spray forming pattern heated to the sustained temperature, and (d) allowing the sprayed metallic particles to cool to form a metal deposit. The metallic particles have a carbon content which is sufficient to result in metal particles having a carbon content of less than about 0.3 weight percent when deposited on the heated spray forming pattern. The resulting deposit has a carbon content of less than about 0.3 weight percent.
Method for spray forming high modulus polyurethane structures	Nov 30, 2010 / US7842349 B2	Tse Industries, Inc.	Robert Michael Raday	Sprayable polyurethane compositions contain particulate filler in both polyol and isocyanate components for a total content of minimally 30 weight percent of particulate filler and fibrous reinforcement. The isocyanate component is stable with respect to storage, and composite structures prepared therefrom exhibit high modulus and can be used as replacements for unsaturated polyester systems. Resin transfer molding systems employ the same components and produce molded parts with good physical properties.
Thermal spray forming of a composite material having a particle-reinforced matrix	Aug 20, 2002 / US6436480 B1	Plasma Technology, Inc.	Kamleshwar Upadhya	To prepare a thermally sprayed composite material, a precomposited powder is first prepared and then thermally sprayed at an ambient pressure of no less than about 0.75 atmosphere in an oxidation-preventing atmosphere. The precomposited powder has a plurality of powder particles, and each powder particle is formed of a matrix and reinforcing particles distributed within and encapsulated by the matrix. The matrix has a composition of a matrix metal such as molybdenum, hafnium, zirconium titanium, vanadium, niobium, tantalum, or tungsten, and a matrix non-metal of silicon, boron, or carbon. The reinforcement particle is silicon carbide, boron carbide, silicon nitride, or boron nitride.

Exhibit 3 depicts patents related to spray forming.

Picture Credit: Frost & Sullivan

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