Industry 4.0: hope, hype or revolution?

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***Abstract*—Overview of Laser Processing as enabling technology for Industry 4.0. Role of DPM (Direct Part Marking) in modern industries and in Industry 4.0 perspective Analysis of Laser Marking applications for Automotive Electronics traceability, with focus on dynamic/automatic generation of codes in combination with Smart Cameras and AutoID devices. Flexibility as key to small production batches.**

Keywords—Industry 4.0; laser processing; laser marking

Walking along industrial automation trade shows or attending to industrial conference and seminars, you'll be literally blitzed by "INDUSTRY 4.0 READY" messages.

The term Industry 4.0 is meant to imply nothing less than a "Fourth Industrial Revolution": the First Industrial Revolution is generally considered to be the steam machine which made the steam power exploitable opening the industry age, the Second Industrial Revolution is generally seen as the application of electricity to create mass production, especially in the new automotive industry; Third Industrial Revolution is generally linked to the extensive use of electronics and information technology to automate production.

The three revolutions were linked to inventions based on break-through scientific discoveries and to their first application in a new industrial environment, even if revolutionary inventions, such as Marconi's wireless telecommunication backbone of today's communication and IOT are not considered as revolutions for industry. Hence, the Industry 4.0 concept is not a technical revolution linked to a scientific break-through discovery, and probably has not scientific fundaments [1].

Industry leaders, mainly from Germany where the term "Industry 4.0" born in 2011, are extremely optimistic and are creating great expectations around this new industry "revolution", probably with the unspoken goal to respond to the huge investments of the new "USA's Big Four" (Amazon, Google, Apple, Facebook) that are revving their activities to enter new industrial fields grabbing a disproportionately large market share from today consolidated market leader. (this should remind you an old story about Nokia and Apple…).

Following the Industry 4.0 marketing buzz, most of the industrial suppliers have moved quite fast to update their commercial offers to match the market expectations, sometimes with valuable and effective proposals, sometimes just sticking a new label on existing products creating a certain level of skepticism in public mind, just like another "Palm Oil Free" marketing pitch.

During last year, huge effort has been made to better define and decode principles of Industry 4.0, in this respect, the publication of government plans for "super" tax incentive for investments [2] in "Smart Factory" and important publications from university and research centers, greatly helped to clarify in details which are the benefits, the "enabling technologies" and the boundaries of this new industrial Revolution.

Several different sets of "fundamental principles of Industry 4.0" have been introduced; some of them, even with different assumption are recurring: use of internet, production flexibility, virtualization of process

A. *Extensive use of Internet*

In most of "Industry 4.0 Ready" product presentation and roadshows, you can hear product managers speaking ecstatically about the ability to control a machine from remote via mobile phone application leveraging the deep use of internet.

Industry 4.0 should be much more than a smartphone-based remote control. An industrial revolution cannot be just an updated version of the technology we used in the 80's to remotely control our telephone answering machine via DTMF (dual-tone multi-frequency signaling). One of the pillars of Industry 4.0 is the extensive use of internet not only as an inexpensive channel to connect machines, devices, sensors, and people, but as a way to create new product functions and features related to the capability to use the Internet as a source of information. In this respects advanced diagnostic and predictive maintenance based on data collection of large volumes of sensor data from multiple locations and plants will significantly reduce maintenance cost, increase asset availability, and create new usage-based business models.

Recently I read an article about how Tesla, the electric car company, addressed a potential recall situation in comparison to the approach of another "traditional" car company. Tesla simply released a software fix "over-the-air" or OTA (like the upgrade that your smartphones go through so often). The other company required its customers to take their car to a dealership and wait for the fix. Many business writers talk about how the future of automotive servicing will be dramatically remade over the next couple of years, based on this example.

Moreover extensive use of internet enables the capability to collect, several GB of data per hours from millions of vehicles

978-1-5386-3906-1/17/$31.00 ©2017 IEEE

to be analyzed in real time (that is…Big Data!), finding clusters of potential issues or problems to be used for predictive maintenance, shortening dramatically the loop of collecting diagnostic information through dealership and traditional channel . In industrial environment the capability to plan a preventive maintenance service instead of react upon a blocking issue can dramatically cut production downtime; imagine a component able to inform maintenance service that it will have a blocking malfunction within 5 days with a probability of 90%.

In laser industry, one of the biggest high power laser manufacturer recently introduced on their top product line the ability to collect and share all the condition data and process parameters from hundreds of measurement sensors, including laser output , all internal and external signal outputs, the use rate of the beam source, and the condition of additional components. Final goal is to analyze data parameters, optimize power consumptions, carry out algorithm-based trend analyses, and take targeted measures to determine the risk of potential laser failure in advance preventing unscheduled downtime.

B. Flexibility – Handling High-Mix, Low Volume

One of the most attractive feature of a Smart Factory is the capability to operate on small batches, down to batch-size-one.

After years of massive and undifferentiated production, often with a minimal or even zero flexibility, Industry 4.0 will provide real-time, "zero-setup-time" production flexibility to fulfill the new demand of personalization and mass customization not just in a B2C perspective, but also in the B2B context where highly customized products (like Private Label) but also pre-series and prototype are vital assets for industry. Industry 4.0 will probably introduce the ability to manufacture at the same time thousands of identical parts and a batch of one piece seamless on the same production line, with no additional costs or setup.

1) 3D Printing (& Laser Sintering) as a key to flexible production.

Among the Industry 4.0 "enabling technologies" additive manufacturing and 3D printing is the most discussed.

Forget about the small, poor quality, useless red or blue plastic gadget; this technology produces real objects by adding material rather than by mechanically removing or milling material from a solid block. Additive Manufacturing refers to a process by which digital 3D design data is used to build up a component in layers by depositing material in fine powder form.

Despite some intrinsic process limitation, a wide range of different metals, plastics and composite materials may be used. Initially used for construction of functional prototypes (Rapid Prototyping), additive manufacturing, is now being used increasingly in real production, boosting the capability to provide complex, high quality components, in small batches at reasonable costs. In conventional manufacturing, the cost of each manufactured item is initially high and decreases as more units are produced, the initial investment is recouped over time with mass production.

Alongside an initial higher investment, Additive manufacturing systems offer cost advantages for small volumes, capability to produce more complex design (less components), shorter time-to-market, and huge production flexibility down to batch-size-one.

Fig. 1 SpaceX's SuperDraco engine chamber

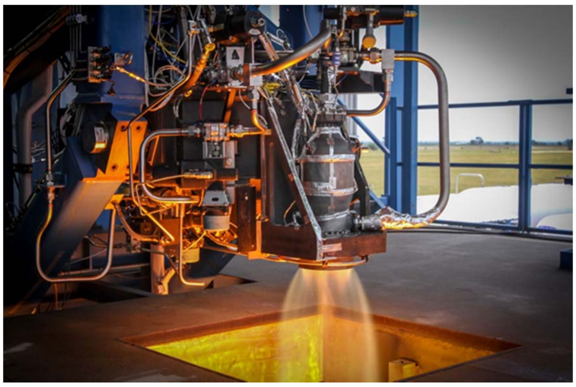

Fig. 2 SpaceX's SuperDraco engine test

Laser 3D printing or DMLS (Direct Metal Laser Sintering) today is the technology chose by SpaceX for their SuperDraco engine chamber (fig. 1), a component printed in Inconel that ensure 8.000 kg of axial thrust with incredible toughness and reliability (fig. 2).

2) Traceability & Product Identification

Optical machine readable codes are definitely not new on the market, the very first commercial application of barcode was in 1974 (a chewing gum pack), only two of these original machines are known to exist, one is in Datalogic museum in Eugene Oregon and the other is in the Smithsonian Museum in Washington DC. Not so long ago, traceability was predominantly a function required only by certain quality sensitive manufacturers, particularly those within the automotive, medical, military and aerospace sectors.

Principally in these market segments production was and indeed still is impossible without strict adherence to legal requirements (RoHS, WEEE, CE, etc.) and with it the necessity for scrupulous measures and processes that identify, track and record each manufacturing step to achieve compliance.

Today data marking and reading ability is a prerequisite for a Smart Factory where machinery, products and systems are connected along the Value Chain. The capability to assign a unique ID to each component is a fundamental aspect of Industry 4.0 “production flexibility” as well as total and real time control the complete value chain over the entire product lifecycle. In this perspective, unique component’s ID make every single component individually identifiable alongside entire production process, enabling dynamic, more efficient production paths, down to batch-size-one; information regarding origin, storage, state and location of materials, components and products will be instantly retrievable. The capability to store inside a high density dimensional code, specific information about the components characteristics may dramatically improve the production process.

Fig. 3 - Traceability of fuel injectors

For example, automotive fuels injectors are tracked with a specific mark (Fig 3) not just to identify model and production batch; each injectors are have an individual QR-code that contains individual physical characteristics and correction data to compensate intrinsic variability and manufacturing tolerances.

When an injector is installed or replaced the new injector code is scanned and automatically transferred to the engine control unit to record the necessary correction parameters, to adapt the injected quantity of fuel.

The use of laser system to permanently mark components, dramatically extends the capability to track components, not only along the entire production process down to the end user but it also extends the components identification to their end-of-life supporting the decision makers in the best end-of-life strategies (re-use re-manufacturing, or recycling).

Laser marking consists of focusing a low-powered laser beam on the surface of a material, slightly altering the physical properties or the optical appearance of the target material. Depending on the laser properties (wavelength, pulse width, energy or peak power density) and on the material characteristics, several different processes are possible: localized oxidation, ablation, carbonization, foaming, melting, charring and more. Most of them include material color change.

Thanks to this strong interaction with target material, laser marking is permanent, counterfeit proof and resistant even in harsh environments (fig 4), and does not involves any toxic solvents, inks or acids in the process.

The absence of mask or predefined patterns makes laser marking extremely flexible and dynamic in generating codes and graphics. It also enables the capability to interact with vision systems, displacement sensors and autoID systems in order to dynamically adjust laser process component by component.

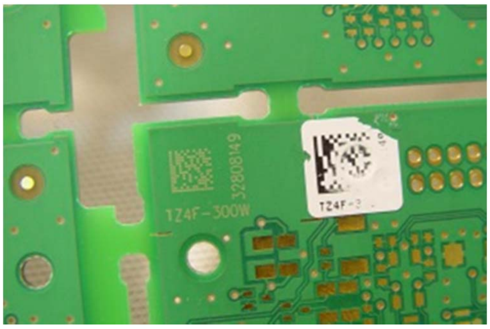

Fig. 4 - Wear effect on printed label compared to laser marking

At Datalogic we are currently working on application similar to the following example (fig. 5) where the combination of a smart vision system and of a laser marker allow precise and repetitive positioning of texts and codes on randomly positioned ball bearings.

Fig. 5 Aerospace ball bearings individually located, laser marked and verified

This solution not only dramatically simplifies components loading/unloading, removes the need (and cost) of customized, high-precision trays but also introduces a new level of production flexibility that handles seamless, partially-filled trays and different bearing models.

A number of different M2M (machine to machine) combination are possible to enhance the performance of individual machine and system to allow self-configuration and auto-adjustment, locally (Ethernet based fieldbus and protocols) or remotely (internet based communication).

C. Comunication, virtualization And Cyber-Physical systems

For a long time industrial automation big players had used connectivity as a constrain to keep customer within a certain brand.

In a world where consumer electronics succeed in converging to USB and WiFi from inexpensive digital frame to workstation computer, the high level industrial environment is still divided in tens (hundreds ?) of different protocols and fieldbuses: BACnet, CC-Link IE, EtherCAT, EtherNet IP, Powerlink, Profinet, Modbus TCP, SafetyNET, Sercos III, SynsNET, VARAN and many other (just to mention some of the Ethernet based fieldbuses) creating functional incompatibility but also geographical barriers.

Today communication is vitally important. Industry 4.0 need a reliable stable and powerful common language to drive the revolution, especially if this spreads across the globe through cloud technologies.

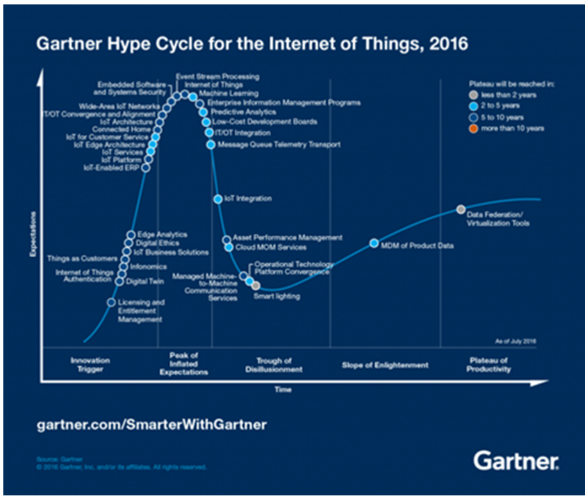

Fig.6 - IOT Hype Cycle (Gartner 2016)

An open source communication standard, based on Ethernet, OPC-UA, seems to be the best candidate to aid users to share information across the entire infrastructure. This communication is not real time but capable of providing security to data overcoming software and hardware differences working on the client server model [3].

Once a common communication frameworks is available, it is possible to connect workpiece carriers, assembly machines, sensors and products, describe and define their functionalities and treat them as virtual computational entities, creating a link between physical process and their virtual representation.

As an example, today's automotive industry is characterized by static production lines, with rigid sequences of operations which are often hard-wired and complex to reconfigure to make new product variants or alternative product flows. Also the software Manufacturing Execution Systems (MES) is typically designed around production line's hardware and therefore is rigid and static with minimal possibility of configuration.

Tomorrow Industry 4.0 car manufacturing will be based on dynamic and fully-configurable production lines where production flows and production mixes will be designed and implemented at computational level. The design of non-physical product flows will also enable downstream process autonomous modifications.

CONCLUSION

Industry 4.0 hype or revolution?

For sure this industrial revolution is not linked to inventions based on break-through scientific discoveries and, more important, it is the first time that an industrial revolution is predicted a-priori, not observed ex-post [4].

Definitely too early to define this new industrial approach a Revolution.

So Industry 4.0 is just an hype? The American research, advisory and information technology firm Gartner developed a useful graphical & conceptual map (Fig. 6) of the maturity of the emerging technologies through five phase: Innovation Trigger, Peak of Inflated Expectations, Trough of Disillusionment, Slope of Enlightenment, and Plateau of Productivity [5].

IOT (Internet Of Things) and IIOT (Industrial Internet Of Things) in the last three years keep on moving up and down on the slope of "innovation trigger", according to Gartner will take 5 to 10 years to gain mainstream adoption in an industrial environment where most of the time production lines are not even connected to internet and where several company networks connect independently AGVs, maintenance services, single productions lines and office automation

So, what is Industry 4.0? Probably too early to say, probably it's the hope to revitalize the automation industry after the economic paradigm change of 2008 (don't call it economic crisis), and to react to the attack of the USA Big 4.0 dreaming about their impressive grow rate.

What's the first step approaching Industry 4.0?

Answer will probably have to be found in a fundamental theory of physics: Sattinger's Law "It works better if you plug it in." (Arthur Bloch, Murphy's Law, 1977)

In my humble opinion what is really missing in today Industry environment is Internet connectivity at production level; while internet connectivity is taken for granted at "office level", in the same building, production floor not connected to the Internet to reduce the vulnerability to cyber-attacks especially on legacy machines and production lines.

How to embrace the Industrial Internet Of Things if the internet connection if Internet is still considered a "tool of the Devil"?

In this "internet-free" scenario, when remote control is mandatory, is not difficult to find suspicious "remote maintenance boxes" to connect production machines, via 3G/4G network, to proprietary clouds, through proprietary softwares and firewalls.

Extensive use of Internet cannot be fragmented in a multitude of different, branded, remote services.

Machine builders and system integrators must invest now in Internet-based productions networks with serious cyber risks analysis and serious countermeasures to preserve integrity of the system, to avoid to have in a short future , alongside hundreds of different fieldbuses, hundreds of isolated systems connected independently to the web.

This will be a reasonable starting point for Industry 4.0.

Anyway, there is no doubt that when you’ll face a real Industry 4.0 factory you’ll immediately recognize it.

Fig. 7 - Dark and cold – the aspect of a hypothetical future factory

It will be totally dark and cold … since … no humans there.

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