Re-tooling Industry For The Digital Age

Industry trends towards the 'smarter factory' in 2019 and beyond

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Industry 4.0 – the so-called fourth industrial revolution – is seeing the convergence of automation, new technologies and techniques, and big data analysis across manufacturing and the supply chain. The 'smart factories' this creates will come to dominate most industrial sectors.

Manufacturers recognize that to remain competitive, they must invest in new products, processes and services, while generating real returns on investment.

Making profits in the longer term means producing better products that command premium prices, and/or making them more cheaply, exploiting more efficient manufacturing processes, supply chains and distribution networks.

However, intense competition imposes other essential requirements. Companies must be capable of responding quickly to changing demand, with new product designs and through flexible manufacturing processes.

Recent developments in the aerospace and automotive sectors illustrate the point.

Airbus Industries is stopping production of its A380 double-decker aircraft as 'jumbos' are out-manoeuvred by smaller, more fuel-efficient and faster-selling airliners capable of flying long distances, yet able to land in smaller regional airports.

Meanwhile in the automotive sector, after heavy investment in diesel car manufacturing, carmakers are scaling back operations as consumers turn away – to petrol, hybrid or electric vehicles with a lower carbon footprint – partly in response to fiscal measures from governments reacting to global warming.

"A profound digital transformation is currently shaping the future of global manufacturing. As with any transformation, the opportunities for growth are enormous – but so are the challenges."[1]

Mark Hughes, regional vice president UK & Ireland, Epicor [a software supplier]

[1]www.themanufacturer.com/reports-whitepapers/manufacturer-annual-manufacturing-report-2019/

Manufacturers are also being forced to respond to rapidly changing retail and digital trends. The growth of internet sales is imposing complicated demands on FMCG manufacturers' supply chains. The 'omnichannel' model demands **seamless delivery of products or services to consumers** whether they buy them via the internet on their smartphone, PC or TV, or through 'bricks and mortar' high street stores.

Industry 4.0 enables manufacturing to adapt to this new reality and other emerging changes. This means linking hardware and software together to tap into production, supply chain and other market 'intelligence' that is now available.

At factory level, it means connecting production machinery via their programmable logic controllers (PLCs), supervisory control and data acquisition (SCADA) systems, and condition monitoring sensors with high-level manufacturing execution systems (MES) and enterprise resource planning (ERP) software systems. Using fast onsite communications through fiber-optic data highways, real-time connectivity is provided as part of the Internet of Things (IoT).

In a recent survey of UK manufacturers, **91% of respondents said that 'smart factory' technologies would enable staff to work smarter.** The Annual Manufacturing Report 2019 found that **81% were ready to invest in new digital technologies to boost productivity.**

This is a reflection of the tectonic plate movements occurring in capital investment strategy for manufacturing – from materials and design to process management systems, machining and production methods. As in other sectors, manufacturers are increasingly opting for cloud-based 'software as a service' (SaaS) systems.

These packages are capable of **handling the vast quantities of data now being captured by 'smart' devices and sensors on equipment,** as well as products in transit. The data collected is then analyzed using algorithms armed with artificial intelligence (AI) to identify actions required in a timely and effective manner.

This article describes how five technologies together, under the umbrella of Industry 4.0, will be crucial in **providing solutions to manufacturers' emerging needs.** The optimization they bring not only offers the prospect of vastly improving the overall equipment effectiveness (OEE) of a company's manufacturing operations, but they can also raise the bar for efficiency across a whole enterprise.

The five trends

1. Intelligent Manufacturing Systems (IMS)
2. New Materials
3. Advanced Machining Techniques
4. 3D printing and Additive Manufacturing (AM)
5. AI and 'Big Data Analysis' (BDA)

1 Intelligent Manufacturing Systems (IMS)

Intelligent manufacturing systems (IMS) play an important role in Industry 4.0 and the internet of things (IoT) by linking the machines and manufacturing cells used in factory production with warehousing – both inbound and outbound – and the rest of the supply chain.

IMS makes use of the latest sophisticated controls and sensors on individual machines, connecting them to high-level software that **enables managers and supervisors to interrogate the operational performance of the equipment on the factory's shop floor.** In this way, potential faults can be identified using predictive analytical techniques before machinery breaks down, with the associated costs of lost production. This is particularly important for critical items of plant within factories. The latest systems even permit equipment to be monitored remotely, thereby optimizing the effectiveness of skilled maintenance engineers who are in increasingly short supply.

IMS – also known as 'smart' manufacturing – **requires certain underpinning technologies in order to enable devices or machines to vary their behaviours in response to different situations and requirements,** based on past experience and learning capacities.

These technologies **enable direct communication with manufacturing systems,** thereby allowing problems to be solved and adaptive decisions to be made in a timely fashion. Some technologies also have AI, which allow manufacturing systems to learn from experience and thereby create an intelligent manufacturing environment. Major players, such as Amazon, Google and Microsoft, are all in a race to create the first self-learning AI systems based on neural network technologies to improve machine learning, providing this as a service (MLaaS) to manufacturers and other enterprises.[2]

Suppliers of PLCs, such as Rockwell Automation, Siemens, Hitachi and Mitsubishi, are also at the forefront of developments in this area. They work with car manufacturers such as Toyota and Nissan, as well as those in other areas of manufacturing, including food, drink and pharmaceuticals, and with the oil, gas and petrochemical sectors.

Toyota and Hitachi have entered into a partnership to implement a smart manufacturing system in Toyota's manufacturing plants based on Hitachi's Lumada IoT platform technology.[3] This **uses AI to take mountains of data and transform it into useful information and insights to help with critical decision-making** and predicative analysis.

In the aircraft sector, Airbus has been developing an AI system to help it design and 3D-print fuselage components. Working with Autodesk Research, it used 'generative design' software, which mimics nature's evolutionary approach (in this case, slime mould and mammal bones) to test and refine millions of configurations before arriving at its 'bionic partition'. An apparently random lattice structure of metal alloy (also developed in-house), this offers optimal lightness and strength with minimal material use for the more efficient jetliners of the future.[4]

The initial cost of implementing IMS and AI is likely to be a barrier for many companies. Manufacturers need to demonstrate a clear return on investment, though the potential rewards from getting it right – in terms of efficiency, effectiveness and competitive advantage – are significant.

[2] https://www.forbes.com/sites/moorinsights/2018/01/17/google-microsoft-and-amazon-place-bets-on-ai-in-the-enterprise/#1e9513814d78
[3] https://insights.hitachiconsulting.com/post/102f2pa/hitachi-helps-toyota-drive-their-digital-transformation
[4] https://www.autodesk.com/customer-stories/airbus

2 Advanced materials

If the evolution of metallurgy and materials science began with the development of steelmaking in the first industrial revolution, it is accelerating with Industry 4.0. The field is witnessing the development of a whole raft of new and composite materials that promise to be lighter, stronger and more sustainable, among other advantages.

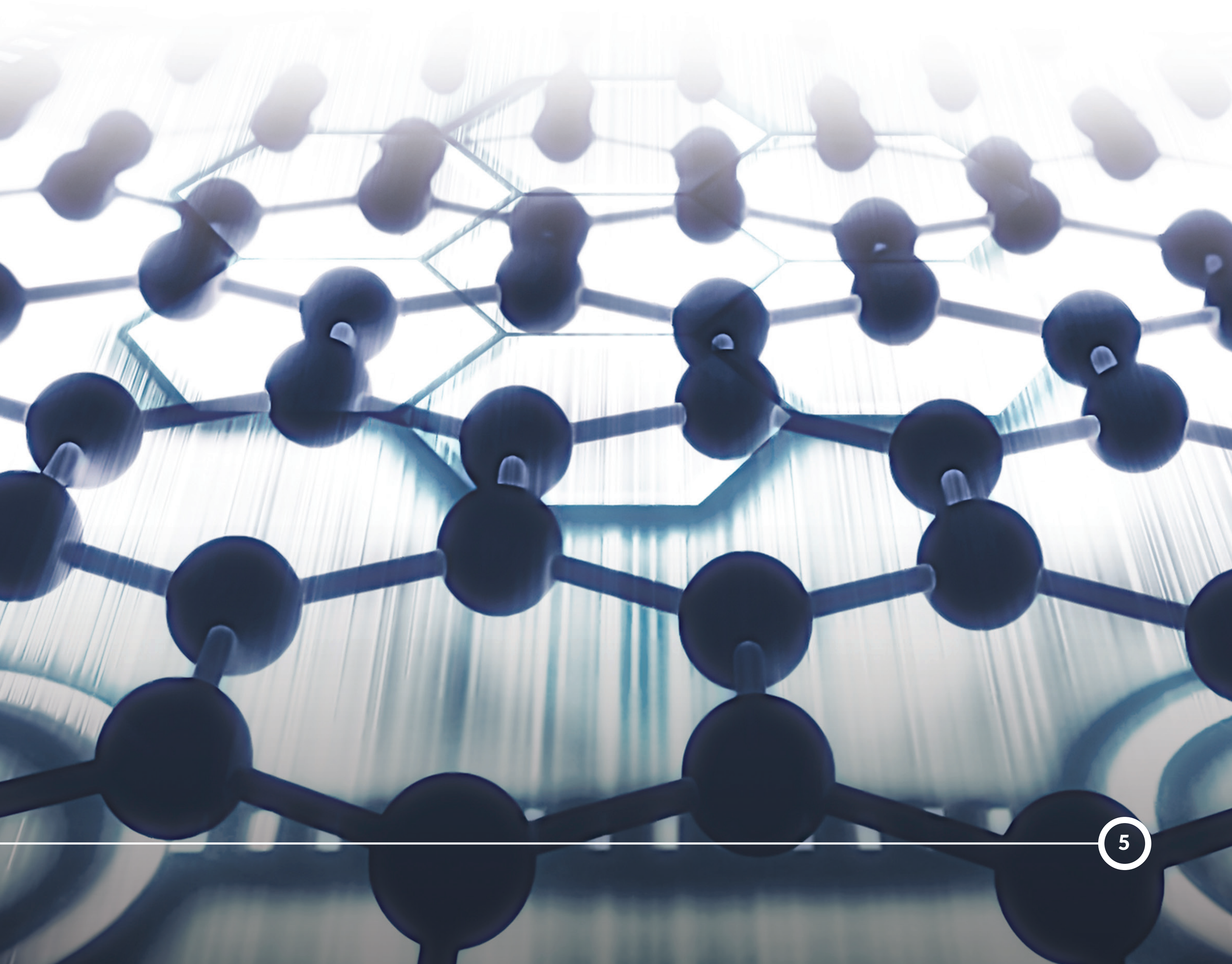
Plastics have long been a core packaging material and continue to provide an essential means of protecting vulnerable products, such as foodstuffs, along the supply chain, especially to consumers. However, **increasing alarm at the damage plastics are causing to the environment has forced a major rethink by consumers, governments, NGOs and companies alike.** Consumers, and retailers, have started to reject single-use plastics.

Mounting concern over climate change is reinforcing the drive across Europe and elsewhere to achieve a 'circular economy' that conserves precious natural resources, while reducing carbon emissions and other pollution. As pressure builds for this more sustainable, low-carbon environment, research into finding alternative materials is intensifying.

From steel to aluminium, plastics to biodegradable polymers, and carbon fiber reinforced plastics (CFRP) to graphene, man-made materials play, and will continue to play, essential roles in our everyday lives, though the cast is changing. Given the pressures to reduce our carbon footprint, materials engineering has to make an increasingly important contribution in manufacturing. It can help **reduce energy consumption, through developments such as lightweighting, and the consumption of materials through better design.**

While the aerospace industry has been in the vanguard of materials development and adoption, the automotive industry is coming up fast on the learning curve.

Aircraft manufacturers have **reduced the weight of their planes, using computer aided design (CAD) tools** together with light, yet strong materials, such as titanium and aluminium alloys, as well as hybrid materials like aluminium-sandwiched CFRP, in fuselage and aero-engine construction.



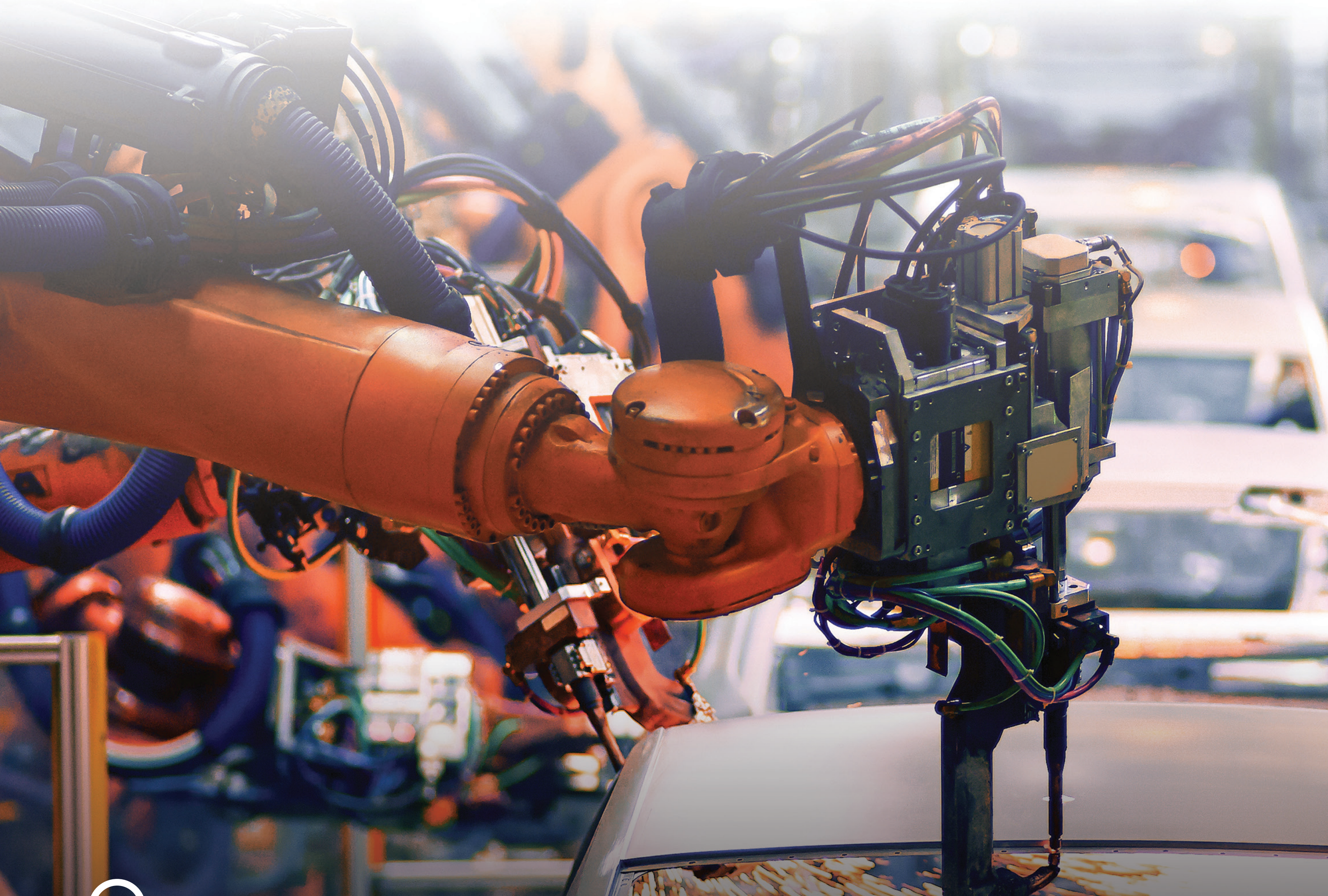
Carmakers have taken up the baton. While the cost of carbon fiber composites remain prohibitively expensive for the mass market, they are **using increasing proportions of aluminium alloys in their vehicles as a substitute for steel.** This reduces their overall weight, making cars more fuel-efficient, without compromising rigidity and durability of construction, and safety. Jaguar Land Rover has been among the leaders in this field, incorporating more recycled aluminium from supplier Novelis in vehicles' chassis to reduce their overall weight.[5]

The shift away from petrol and diesel combustion engines to electric power for cars and trucks is fuelling the research into new types of batteries. Using **advanced materials in their manufacture can make cells lighter and increase their lifespan.** Breakthroughs in energy storage are also likely to depend on the outcomes of research into new materials. Toyota is investigating a solid-state battery using sulphide superionic conductors that could charge in seven minutes, making it ideal for cars.[6] The potential of graphene is particularly exciting. Made from single layers of carbon molecules, this material has many properties, and can provide lightweight, thin and flexible electric and photoelectric circuits in solar cells and many other devices and applications – from medical implants to chemical and industrial processes. In cars, for example, graphene could solve the problem of storing hydrogen fuel, or electrical charge through supercapacitors.[7]

Meanwhile, the global impact of plastics has **caused a shift towards more recyclable and biodegradable materials for the food and beverage industry.** But much more work needs to be done in this area. Research is now focused on plant-based biopolymers, including polylactic acid (PLA) produced from sugarcane, as an alternative to plastics produced from petrochemicals. Most of the major drinks brands, including Coca-Cola[8] and Innocent[9], that have traditionally used polyethylene terephthalate (PET) plastic drinks bottles, are investigating their use.

Advances in materials technology are therefore providing a gateway to new design opportunities – many yet to be discovered. They are likely to result in far more innovative products as well as assisting in the redesign of existing products to improve their functionality and performance.

As with the work by Airbus on fuselage design (see IMS above), scientists are learning lessons from nature itself and the way that organic species evolve. This process of 'biomimicry' holds promise for more sustainable materials in areas such as packaging.[10] It is also behind developments of so-called 'self-healing' materials with a myriad of potential applications in manufactured goods.



[5]https://www.cisl.cam.ac.uk/resources/press/in-press/novelis-works-with-jaguar-land-rover-to-create-rc5754-high-recycled-content-aluminum-alloy-for-automotive-industry
[6]https://www.pocket-lint.com/gadgets/news/130380-future-batteries-coming-soon-charge-in-seconds-last-months-and-power-over-the-air
[7]https://www.graphene.manchester.ac.uk/learn/applications/energy/
[8]https://plasticsinpackaging.com/online/cokes-plantbottle-is-not-being-ditched-claims-ccep-gb-head-of-sustainability/
[9]https://www.innocentdrinks.co.uk/us/recycling-revolution
[10]https://www.iflscience.com/environment/meet-next-generation-waste-free-food-packaging/

3 Machining technology

Manufacturers are always seeking greater efficiencies from their processing equipment. **Automation has boosted efficiency in assembly and other areas of production, and its use in machining is set to expand rapidly in coming years.** There will be more adoption of robotics, including collaborative robots or 'cobots' that work alongside humans, taking over repetitive tasks, such as tending machines. By minding machines, these robotic helping hands free up employees to add value in other ways, according to specialists such as Universal Robots.[11]

However, advances in the design of a product and manufacturing process, and the use of new materials in construction, often bring **increased complexity and other machining challenges.** Accommodating these trends, while still providing the enhanced efficiency required, is no easy task.

This is where the latest computer numerically controlled (CNC) machining and other advanced tooling technologies are coming into their own. Examples include techniques such as **low-pollution machining (LPM), high-speed machining (HSM), and high-precision machining (HPM)**, from equipment suppliers such as global engineering technology specialist Renishaw.

Industry 4.0 factories make full use of these new approaches to manufacture, especially when they are combined with IMS, exploiting advanced process control and sensor technologies for predictive maintenance and remote diagnostics. In this interconnected world, the ability to gather and analyze all relevant data enables the factory floor and management suite to make better, faster decisions, improving yield and speeding up production, according to machine specialist Mazak.[12] The **result is more productivity and better-quality products with less machine downtime.**

Other techniques, such as low-vibration machining (LVM), provided by CNC machine suppliers such as Citizen Machinery, are also having a big impact on the sector. The low-frequency vibration technology developed by the industrial equipment supplier, which is headquartered in Japan with UK bases, **increases performance, while improving levels of surface finish and chip control.** Cutting trials both in Japan and Europe demonstrated significant improvements to cutting efficiency, not only on exotic materials, but also on difficult-to-cut ferrous and non-ferrous materials, obviating the need for integrated high-pressure coolant systems and fume extraction in some cases.[13]

Titanium and nickel-based alloys, and CFRPs, are among the new materials that are testing the capabilities of conventional machining methods. These can result in high scrappage rates, reduced tooling life and increased power consumption for manufacturers. But CNC machine specialists have responded by developing new designs, types of tooling – for example, **exploiting advances in tool coatings[14] – and innovative approaches to machining that increase efficiency and reduce energy consumption.**

One such innovation is trochoidal milling, promoted by machine tool specialist Sandvik and others, and used in the aerospace sector in particular. Trochoidal milling, in which the cutting tool creates a slot wider than the tool's cutting diameter, is an optimized method of machining Inconel (a family of austenitic nickel-chromium-based superalloys) and titanium alloys used in gas turbine fan blade construction. It **decreases cutting forces, reduces heat generation, while providing greater machining accuracy, faster cycle times and longer tool life.**

These machining techniques are often combined with other technologies such as cryogenic machining, which uses **liquid nitrogen (LN2) to freeze cutting tools, and minimum quantity lubrication (MQL), in which lubrication is concentrated on the cutting tool instead of flooding the whole area,** thereby reducing lubricant and energy use. US aerospace company Lockheed Martin has invested in a number of cryogenic CNC machines for machining titanium alloys used in the construction of its F-35 stealth multirole fighter jets. The use of 5ME's patented technique increased cutting speed by more than 50% while improving surface integrity and part quality.[15]

CNC machine manufacturers are continuously refining and developing advanced machining techniques. These are not only essential in exploiting alternative materials in manufacturing, but also to enhance efficiency and sustainability in the programmable and data-driven smart factories of the future.

[11]https://www.universal-robots.com/applications/machine-tending/
[12]https://www.mazakeu.co.uk/industry4/

4 3D printing and additive manufacturing

Additive manufacturing (AM) or 3D printing, involves **making a solid component by building material up in layers – one on top of the other until the component is complete** – rather than machining away material from a single block in a 'subtractive' way. A 3D model must first be created using CAD, and subsequently transferred into an AM device to make the part required.

While AM poses some challenges, it also offers a number of advantages as a method of prototype or short-run production. Probably the most important benefit is the **greater flexibility it provides in the design and manufacture of complex parts,** which can be accomplished more rapidly and with less waste. AM has had a significant impact on the aerospace, automotive and biomedical manufacturing sectors. It is also proving helpful in the **manufacture of complex injection-moulded tooling.**

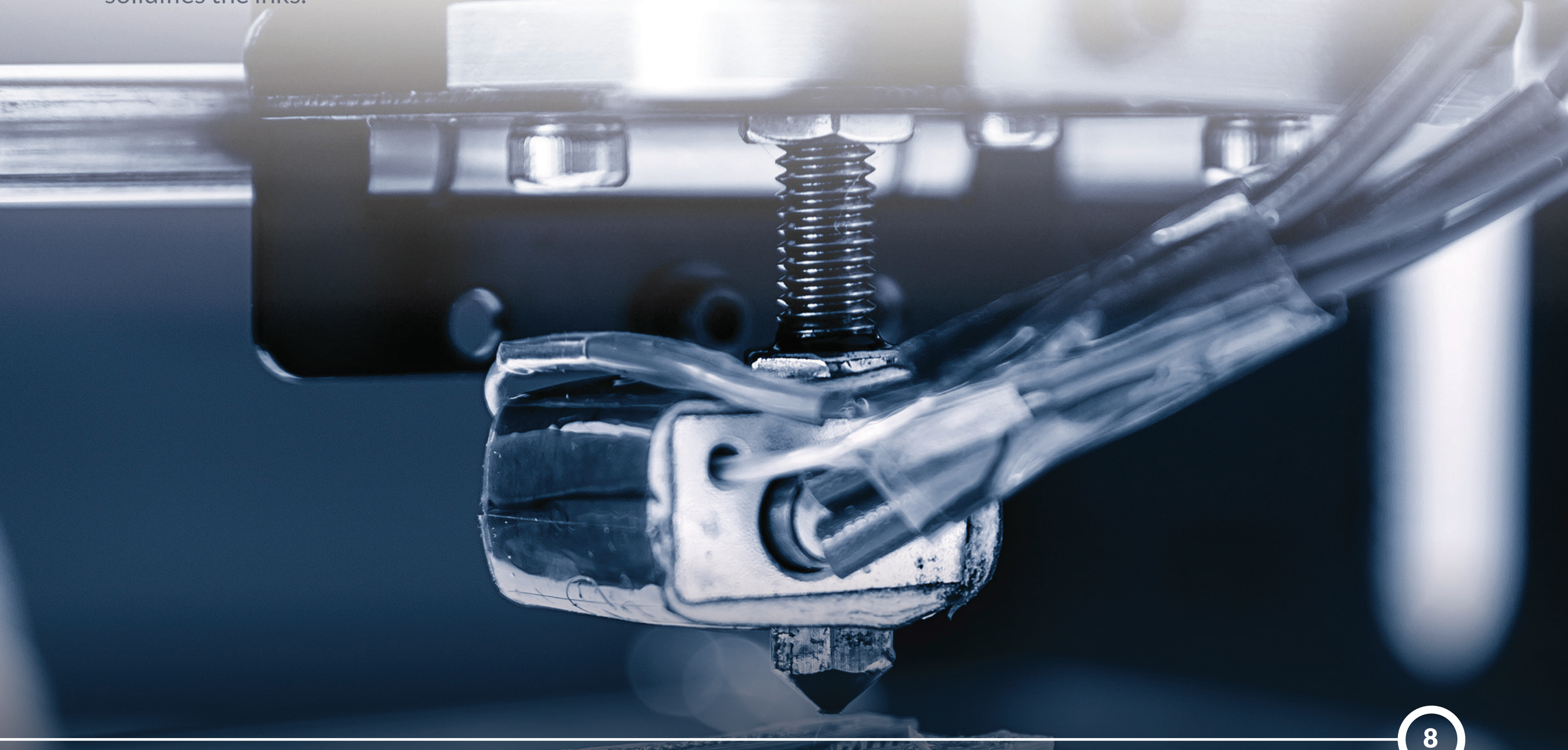
Two of the first commercial uses in the UK of hybrid machines combining additive/subtractive manufacturing techniques have recently taken place at injection-moulder OGM, based in Yarnton, Oxfordshire, and cable harness specialist Cable First, of Poole in Dorset.[16] Also championing this technology in the UK is the Manufacturing Technology Centre in Coventry which, with public sector backing, aims to bridge innovation's 'valley of death' between academia and industry.[17]

In another development, researchers at the University of Nottingham have pioneered a method of rapidly 3D-printing fully-functional electronic circuits.[18] The circuits, which contain electrically-conductive metallic inks and insulating polymeric inks, can now be produced in a single inkjet-printing process where a UV light rapidly solidifies the inks.

This technique is expected to pave the way for the electronics manufacturing industry to produce fully-functional components such as 3D antennae and fully printed sensors from multiple materials, including metals and plastics.

In the biomedical field, AM is being used to **produce high-quality, high-precision prosthetics and their components, using materials such as titanium and polyetheretherketone (PEEK).** These systems are being used, for example, in custom medical device manufacture of titanium alloy skull and facial implants.[19] The possibilities for personalization opened up by the technology are also being used by various suppliers for applications such as the prosthetic hands developed by Bionicohand and Youbionic and Hero Arm from Open Bionics.[20]
In the aerospace industry, Airbus Industries is among those investigating the combination of AM with AI in the design and manufacture of lighter fuselage, as already mentioned (see IMS above). For its 787 Dreamliner, Boeing commissioned Norsk Titanium AS to print structural components made from titanium using AM.[21]

This technology is opening up new opportunities for manufacturing by **drastically reducing waste and increasing output** as well spurring innovative approaches to making more complex products.



[16]http://www.machinery.co.uk/machinery-features/hybrid-3d-printing-and-metalcutting-machine-tools-matsuura-lumex-avance-25-sodick-opm250l-ogm-cable-first
[17]http://www.the-mtc.org/
[18]https://www.nottingham.ac.uk/news/pressreleases/2017/november/new-method-developed-to-3d-print-fully-functional-electronic-circuits.aspx
[19]https://www.renishaw.com/go/en/craniomaxillofacial-implants-and-software--42111
[20]https://www.3dnatives.com/en/3d-prostheses-100420184/
[21]https://www.reuters.com/article/us-norsk-boeing-idUSKBN17C264

5 Artificial intelligence and 'big data'

Some of the most significant developments – of recent years and ongoing – stem from the capture of vast quantities of data – big data – and its analysis using mathematical algorithms or AI. Using the latest cloud-based systems, on platforms such as Microsoft Azure and Amazon Web Services, these approaches are being democratized, helping to improve decision-making in a wide range of enterprises. In manufacturing this is happening at both board and plant level.

The experience of other sectors shows that the benefits can be significant. Studies have shown that **retailers could increase their return on investment by up to a 15-20% by introducing big data analytics (BDA).**

BDA is being used by online platform providers, such as Google and Amazon, to target offers to individuals. Amazon also uses BDA within its warehouses for handling customer orders, making efficiency improvements. And it is also being used by retailers worldwide to analyze their point-of-sales data and better target advertising and promotional campaigns.

By analyzing ideas collected through crowd sourcing, also known as 'open innovation', BDA is also being used by some major food and drink brands, such as Nestlé, General Mills, Coca-Cola, PepsiCo, Danone, Red Bull and Budweiser, to help to ensure the success of new product launches.[22]
However, BDA has even wider applications, extending back through production and the supply chain. Data can be collected from sensors on machinery and other production equipment, as well as on cartons and pallets used in distribution. By feeding this information into **higher-level enterprise resource planning (ERP) and supply chain management (SCM) software**, and using AI, it is possible to identify and resolve potential bottlenecks, plus other production and supply chain problems before they become critical.

By linking historical information and real-time data from PLCs and sensors on equipment, pallets and cases of product – as well as information captured from social media – **AI can drill down into areas that need attention and suggest actions that reduce problems associated with equipment downtime or distribution**, including those arising from sudden changes in consumer demand.

In the future, real-time feedback control and machine learning systems should enable impending problems to be identified and corrected before they arise. This might include products starting to drift out of specification or even impending equipment failure – both of which would result in lost product, waste and increased costs.

[22] https://www.foodmanufacture.co.uk/Article/2014/03/24/Internet-helps-food-brands-innovate

General Electric is known to be optimizing its production and maintenance activities by making use of BDA. Meanwhile, the biopharmaceutical sector is using real-time **statistical process control in its manufacturing plants** with BDA to reduce process flaws and make production changes as required.

Unlike conventional analytical methods, which aren't up to the job, AI can analyze vast amounts of complex data to **identify hidden patterns, unknown correlations, market trends, customer preferences, and other useful business information.**

AI will also become increasingly important as manufacturers adopt **more automation and robotic processing in their endeavours to reduce shopfloor labour costs**, while having to maintain ever more complex equipment. Electric car-maker Tesla's Gigafactory 1 factory, near Reno, Nevada in the US, which sub-assembles lithium-ion battery and electric vehicles, is an example of this. While humans are still required for production, and around 3,000 people are still working at the plant, **the factory is expected to become fully automated by 2020.**

More and more manufacturers and retailers are collaborating with software systems suppliers and process control experts to **assist in capturing data from production equipment and elsewhere to better manage rapidly changing supply chains**. For example, US retail giant Walmart, which operates on Microsoft's Azure platform, is collaborating with IBM on a major blockchain project which, through the encryption of data, provides better security in supply chain transactions.[23]

Meanwhile, another global provider of supply chain systems, JDA, whose systems also run on Microsoft Azure, is working with various companies – such as PepsiCo, Kraft-Heinz, AB Inbev, Coca-Cola European Partners (CCEP) and Heineken – using AI and machine learning to optimize data analysis. JDA has recently announced a new partnership with Panasonic to develop the next generation of integrated digital supply chain technologies.[24]

By mining value from big data to inform artificial intelligence, Industry 4.0 is seeing software and hardware technologies mesh in the pursuit of solutions that optimize operations from supply chain through the factory and warehouse to retail stores and the end consumer.

[23] https://www.fool.com/investing/2018/09/30/ibm-and-microsoft-are-upgrading-walmarts-digital-s.aspx
[24] Global leaders combine leadership in software and hardware technologies to co-develop solutions that optimize factory, warehouse and retail digital supply chain operations

Some final thoughts

The manufacturing sector is undergoing a radical transformation as multiple disciplines and fast-developing technologies converge for Industry 4.0.

Advances in systems engineering, process control, materials development, and machining and manufacturing techniques are being exploited – in harness with sophisticated data processing, and through the interconnectivity made possible by sensor technologies and the IoT. Accurate real-time information and knowing what to analyze, and what not to, is the key to smart manufacturing and more efficient, agile and sustainable production.

The companies that invest wisely in these emerging technologies will be able to react to changing events far more quickly and effectively, staying several steps ahead of those that are slow to make the leap. **It's not a question of whether manufacturing firms invest in these areas; it's now a question of when and how they exploit the possibilities of the fourth industrial revolution to secure their long-term future.**

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