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Advanced Manufacturing

Advanced manufacturing is a key part of the Government's 'Plan for Growth'. This POSTnote looks at the opportunities for growth through advanced manufacturing and related new business models. Policy initiatives to encourage advanced manufacturing, barriers to its adoption and the skills required for the advanced manufacturing workforce are also considered.

Overview

- Advanced manufacturing processes can provide a competitive advantage for both high and low tech products.
- The UK's strong research base is well placed to take advantage of global drivers for growth in advanced manufacturing.
- There are a number of new business models that make use of new technology and could alter the nature of the manufacturing sector.
- The Government has established a network of 'Catapult' centres where universities and industry can collaboratively trial industrial scale processes without undue commercial pressure.
- Barriers to growth in this sector include a lack of access to finance and a skills shortage, exacerbated by negative public perceptions of manufacturing.

Background

Advanced manufacturing is a term used to describe production processes that rely on cutting-edge science and technology research. This includes the development of manufacturing techniques for specific new technologies, such as plastic electronics and composites. It also includes generic high-tech processes, such as automation and robotics, which can give a range of products a competitive advantage in terms of cost or environmental impact. The term 'advanced' refers to the manufacturing process, rather than the product. For example, the food and drink sector does not make technological products but relies on high-tech processes, investing around £1bn annually in R&D.

The Technology Strategy Board (TSB), a business led non-departmental public body reporting to the Department for Business Innovation and Skills, emphasises the importance of 'high-value manufacturing', which is characterised by a combination of high R&D intensity and a high potential for economic growth. The terms 'high value' and 'advanced' manufacturing are used almost interchangeably and the differences between the two terms are not well defined. However, high value manufacturing is usually considered to include innovation in manufacturing systems, supply chains and business models, which may be based on new business ideas rather than new science or technology.[1]

Drivers for Growth in Advanced Manufacturing

Advanced manufacturing has been identified as having potential for growth for a number of reasons, including:

- the rising costs of production in Asia and overseas freight, which make domestic manufacturing increasingly advantageous - innovation in high-tech production processes that boost productivity will enhance this trend
- growing demand for products made using advanced manufacturing, such as luxury electronic goods or products required for a low-carbon economy - the global market for 'green' products and services is worth £3.3 trillion and is predicted to grow by about 4% a year
- increasing resource scarcity, which will require production processes and business models that minimise raw material and energy use and maximise product lifetime[2]

The UK is well placed to take advantage of these drivers as it has a strong research base, with three of the world's top ten universities in engineering and technology and a 14% global share of the most cited papers.[3]

Advanced Manufacturing Technologies

Science and technology research can give rise to new materials, enable new manufacturing techniques or make established techniques more efficient in terms of time, resources or energy.

- New materials can give products new or improved properties. Examples include composites (described below) and smart materials (POSTnote 299).
- New manufacturing techniques can have many benefits, such as minimising resource usage or removing design constraints. Examples include additive manufacturing (described below) and industrial biotechnology, which uses biological cells or enzymes to manufacture a range of products, including pharmaceuticals and fertilisers. Biological processes can offer a reduction in the use of energy or environmentally harmful chemicals.
- Technology can make existing processes more efficient. For example, robots with improved dexterity can complete complex assembly tasks faster and at lower cost than humans. Computer simulations can help to optimise the design of products, processes or factories.

Composite Materials

A composite is a combination of two or more materials, resulting in a structure with improved properties. Usually, one material is embedded within the other, rather than the materials mixing. Composites have been replacing metals in a range of applications for a number of years, as they often offer a higher strength to weight ratio. For example, railway and motorway footbridges have been made from carbon fibre composite (carbon fibres embedded in a moulded polymer). These bridges can be lifted into place without the usual road or rail closure required with metal bridges.

Research into novel composite materials is investigating new properties that go beyond metal replacement, such as self-healing and shape-changing composites. Research is carried out at a number of UK institutions. The National Composites Centre is based in Bristol and is part of the High Value Manufacturing Catapult described in Box 1. A disadvantage of current composites is that they are not easily recycled but research into thermo-plastic composites, which can be reformed at high temperature, is underway.[4]

Additive Manufacturing

Additive manufacturing processes create physical objects by building them up directly from a 3D computer model, usually by 'printing' them in thin layers. Various techniques are employed to produce an object in metal or plastic, generally using powders or jets of liquid material. For example, ‘3D printing’ is a polymer-based system that is now becoming affordable to small businesses and home users. Metal components can be built by selectively bonding powder using either lasers or an electron beam.

A key advantage of additive manufacturing is that products can often be manufactured ‘complete’ without the need for assembly. This can reduce design limitations and lead to dramatic improvements in cost and performance. For example, the machining of titanium aircraft components can result in the waste of around 90% of the initial material, which can be almost entirely avoided with additive manufacturing. There is also potential for making products considerably lighter, which can lead to environmental benefits over the product lifetime. Products, such as hearing aids and medical implants, can be customised rapidly for individual requirements. For example, in February 2012, an 83-year-old woman was successfully fitted with a custom made, additively manufactured titanium jaw implant.

UK additive manufacturing research takes place at several institutions, including the Centre for Innovative Manufacturing in Additive Manufacturing at Nottingham and Loughborough Universities (Box 1) funded by the Engineering and Physical Sciences Research Council (EPSRC). The centre is developing multi-material printing to enable the manufacture of more complex products.

Business Models

Advanced manufacturing can enable the use of a number of emerging business models, which may alter the structure of the manufacturing sector. These models range from the provision of services, which add value to manufactured goods, to small-scale local production, which takes advantage of versatile manufacturing technology.

Through-life Engineering

Through-life engineering is typically used for high-value products that require a high level of reliability, such as jet engines. In this model, the product is leased to the customer and its performance and maintenance become the responsibility of the manufacturer. One example is the Rolls-Royce ‘TotalCare’ service for jet engines in which a fee is paid for a set period of reliable operation. ‘Totalcare’ is now used on over 90% of new civil large engine planes. Technologies that enable this model include systems for in-situ component repair and degradation analysis and self-healing systems. In addition to improved reliability for the customer, this model can also provide a prolonged product lifetime, helping to reduce resource wastage. One disadvantage is that it can be difficult to predict a product’s performance decades into the future, so long term, unprofitable contracts are a potential risk.

The Circular Economy

As raw materials and energy become scarcer, the lifecycle of manufactured products, including recycling and reuse, will become integral to their design. In the ‘Circular Economy’, leasing models similar to those used in through-life engineering may be used to prolong the lifetime of consumer goods. Mobile phones may be leased and be able to receive regular hardware upgrades, rather than being discarded for a new model. Washing machines may be leased on a ‘pay-per-cycle’ basis.[5]

Licensing Models

Licensing models allow companies to exploit the UK’s strong R&D base without investing heavily in production infrastructure. Licensing is becoming more widely used by ICT companies, such as ARM Holdings based in Cambridge. ARM designs low-energy microprocessors and licenses the designs to manufacturers in Asia and the US. ARM works closely with a network of around 900 hardware and software companies who use its chips, earning additional money from royalties and support services. ARM chips are used in over 95% of smart phones and tablet computers.

Distributed and Personalised Manufacturing

Adaptable production processes, such as additive manufacturing, have the potential to be the basis for multi-purpose factories in the future. This could lead to manufacturing being distributed to local hubs, at which a range of different products is produced. The potential advantages of this system include:

- reduced freight with many components manufactured within a short distance of their final destination, reducing both cost and CO_2 emissions
- increased responsiveness to local market changes - products could easily be modified without reconfiguring the production line
- the ability to rapidly prototype products and trial a small batch without needing an 'economy of scale', reducing fear of commercial failure and stimulating innovation
- the ability to manufacture replacement parts on demand to prolong product lifetime and reduce waste

Distributed manufacturing is also likely to alter the role played by the consumer in the supply chain. By using Computer Aided Design (CAD) software, end users will be able to either modify and personalise existing designs or design their own new products, becoming consumer-designers. Personalised manufacturing using a 3D printer is already available with a limited range of materials. Personalised manufacturing raises a number of standards and intellectual property issues, outlined in Box 2.

Government Policy

Over the past two decades manufacturing's share of the economy has fallen from 20% to 10%. 'Rebalancing' the economy towards manufacturing is a key part of the Government's 'Plan for Growth'. A number of policies targeting advanced manufacturing have been announced. It should be noted that estimating the potential value of UK advanced manufacturing is difficult as the statistics used to monitor trends in manufacturing are not well suited to tracking growth in advanced processes, which can appear in many different sectors.

Collaborative Manufacturing Research Centres

The commercial development of manufacturing research often takes place at collaborative centres, used by universities and industry. There are strong international examples, such as the German Fraunhofer Institutes, a network of 60 centres with an annual budget of €1.65bn. Many in UK manufacturing attribute the Fraunhofer model's success to its consistent level of funding since the 1970s.[6]

Box 1. UK Collaborative Manufacturing Research Centres

The High Value Manufacturing Catapult
The Technology Strategy Board's Catapult programme consists of seven networks of centres, each working on a different theme, such as Future Cities or Cell Therapy. The first Catapult network to be established was in High Value Manufacturing (HVM), consisting of seven centres and launched in 2011. Each centre has a number of industrial investor members, including small companies, who collaborate on the centre's core research programme and use the facilities to find solutions to their own industrial problems. One example is a recent £100m investment by Jaguar Land Rover, in a collaborative project with the Warwick Manufacturing Group, one of the HVM Catapult members. Around a third of the Catapult's funding is for industry led projects in contrast to the Fraunhofer Institutes where industrial partners collaborate on projects defined by the centre, rather than lead their own projects. Rolls-Royce sees this input as key to the rapid commercialisation of industrial research.[7]

EPSRC Centres for Innovative Manufacturing
EPSRC funds a series of Centres for Innovative Manufacturing. These centres tend to work on exploratory research, generally at an earlier stage of a technology's development than the HVM Catapult centres. There are currently 12 EPSRC centres, which work directly with manufacturing companies and with the HVM Catapult centres across a range of manufacturing topics, technologies and sectors.

In 2009 BIS commissioned the Hauser report on the current and future role of such 'technology and innovation centres' in UK manufacturing. The report suggested that the UK was not taking full economic advantage of its research base and that the scale of the existing centres was 'sub-critical', making it difficult for them to have an impact. The report made 14 recommendations including the creation of a new network of industry-focussed centres and the development of a unique brand identity, similar to that of the Fraunhofer Institutes.[8] A programme called the 'Catapult' has now been established, which complements a pre-existing network of Centres for Innovative Manufacturing, funded by the EPSRC. Box 1 describes these centres.

Box 2. Issues with Personalised Manufacturing
Current UK regulations might not cover a product if the design were modified by the end-user before manufacture. Health and safety laws for manufactured goods may have to be updated to take account of personalised manufacturing.

There are concerns that personalised additive manufacturing could enable terrorist organisations to easily manufacture improvised explosive devices and other weapons. As the manufacturing would occur locally, the dependency on developed countries for weapons supplies would be reduced. This may also allow weapons to be disguised at the manufacturing stage, making it more difficult to maintain security.

Future use of home 3D printers may result in 'object piracy' through peer-to-peer sharing of CAD designs. Online communities of 3D printing enthusiasts already share designs in this way. The additive manufacture of high-value electronic products is some decades away from widespread availability but the replication of lower-value goods is already prompting legal cases. For example, in May 2012 Games Workshop, a UK games company, invoked the Digital Millennium Copyright Act to make Thingiverse, an online CAD repository, remove a modified design of their product.[9]

Government Funds, Resources and Initiatives

Recent measures targeted specifically at advanced manufacturing include:

- the Advanced Manufacturing Supply Chain Initiative, a £125m fund announced in 2012 for companies aiming to grow their UK supply chains and improve international competitiveness - a lack of effective supply chains has been identified as a barrier to growth in manufacturing
- the R&D tax credit scheme, which encourages companies to invest in research and development by offering corporation tax relief or tax credits - the value of the credits is related to the company's R&D expenditure and is enhanced for small companies
- the Foresight Future of Manufacturing Project, which is investigating the UK's potential to benefit from manufacturing up to 2050 - the study is expected to be published in autumn 2013

A number of other measures have been introduced to encourage growth across the manufacturing sector and the economy in general (see House of Commons Library Standard Note SN/EP/1942).

Policy Issues Raised by Industry

The manufacturer's organisation, EEF, and the Institution of Mechanical Engineers (IMechE), have called on the Government to develop a coherent and long-term industrial strategy to nurture advanced manufacturing. EEF would like to see focused support for a limited number of sectors chosen with the help of the forthcoming Foresight report. A recent IMechE survey showed that changing taxation was the most popular form of financial incentive among manufacturers. There is support from EEF and others for an increase in capital allowances to encourage companies to invest in advanced manufacturing technology.

IMechE and others have identified the lack of access to finance, particularly for small companies, as a barrier to growth in advanced manufacturing. One reason suggested for this problem, specific to advanced manufacturing, is a lack of technical knowledge at regional branches of banks. This is recognised by banks. For example, Lloyds TSB is working with Warwick Manufacturing Group to set up a training course for its staff. There are many other issues affecting lending to business, across the whole economy (see House of Commons Library Standard Note SN06056).

Skills and Training

The advanced manufacturing workforce will require more highly skilled technicians, running automated factories, than low skilled assembly and production line workers. Clive Hickman of the Manufacturing Technology Centre suggests that the workforce should be comprised of 30% graduates, 40% high level apprenticeships and 30% lower skilled workers. SEMTA, the science, engineering and manufacturing skills council, also emphasises the industrial demand for chartered engineers with high level apprenticeships. There is currently a shortage of people with the required skills, which is exacerbated by an aging workforce[10] and negative public perceptions of manufacturing (Box 3). To ensure that the required skills base is developed, new courses are being developed in collaboration with industry.

- The engineering diploma is a course for 14-19 year olds designed by a consortium of educational and industrial bodies. It offers a high level of industry relevant training, including advanced manufacturing. In 2011 the Government downgraded some diplomas, including the engineering diploma, despite recognition of its high quality. SEMTA says that this has reduced incentives to run the course.
- University Technical Colleges (UTCs) are Government funded academies for 14-19 year olds, steered by consortia of industry and universities. They follow a semi-vocational curriculum with some focusing on advanced manufacturing. Two UTCs are already open and another 22 will open over the next two years.
- In March 2012, a new programme of advanced manufacturing and engineering higher apprenticeships was announced. So far, around 400 places have been made available.
- EPSRC has a network of 19 Industrial Doctorate Centres, awarding industry focussed EngD doctorates. These centres are developing links with the HVM Catapult and EPSRC Centres for Innovative Manufacturing to allow the students to engage in industry-oriented projects, similar to those offered at the German Fraunhofer Institutes.[11]

Box 3. Public Perceptions

Successive Governments have been concerned that negative public perceptions are acting as a barrier to growth in manufacturing. A recent Institute for Manufacturing survey found that 50% of people thought that manufacturing was a high-tech industry but only 16% thought that manufacturing jobs were well paid. In fact, the median salary for manufacturing is £25,000 compared to £20,000 across all service sectors. A fifth of respondents would encourage their children to follow a career in manufacturing, compared to a third in the US.

The Government has launched a series of initiatives to improve the image of UK manufacturing, including the 'Make it in Great Britain' campaign consisting of an exhibition at the Science Museum and a national competition to find the most promising pre-market products. The Institute for Manufacturing suggests that a biannual perceptions survey should be conducted to track the impact of such promotional schemes.[12]

Endnotes

1 Technology Strategy Board, *High Value Manufacturing Strategy*, 2012
2 Institute for Manufacturing and TSB, *A Landscape for the Future of High Value Manufacturing in the UK*, 2012
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7 Technology Strategy Board, *Catapult Update - Shaping the Network of Centres*, 2011
8 Herman Hauser for BIS, *The Current and Future Role of Technology and Innovation Centres in the UK*, 2010
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POST is an office of both Houses of Parliament, charged with providing independent and balanced analysis of policy issues that have a basis in science and technology. POST is grateful to Jack Snape for researching this briefing, to the Institute of Physics for funding his parliamentary fellowship, and to all contributors and reviewers. For further information on this subject, please contact the co-author, Dr Martin Griffiths.