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ADVANCED MANUFACTURING TRENDS AND CHALLENGES: A REVIEW

Mr. R. R. Lande

B.E (Production Engg.) Lecturer, Automobile Engg Deptt., G.H.Raisoni Polytechnic, Nagpur, India
ratnakar1977@gmail.com

ABSTRACT — The growing technological advances in the field of computer systems and associated software, enable the modern society to progress in new era. The manufacturing technology which is mainly contributing to the development of the country's growth is advancing rapidly due to invasion of advancement in data storage, automation, micro/Nano fabrication, bio manufacturing etc. . The article is an overview of the advances envisaged in the next decades and associated trends and challenges. A number of issues with respect to knowledge management are being addressed. The technology elements and absorption of the same and knowledge transfer related issues are briefly covered. Overviews of potential growth in this field in coming two decades are highlighted.

Keywords: advance manufacturing, Smart Factories, additive manufacturing, cloud manufacturing, automation, advance materials, Virtual Factories, technology absorption, computational modeling, High Performance Manufacturing, Global Trends.

Introduction

Manufacturing innovations have displaced many of today's traditional manufacturing processes, replacing labor-intensive manufacturing processes with automated processes that rely on sensors, robots, and condition-based systems to reduce the need for human interventions, while providing data and information for process oversight and improvement. In future, manufacturers will also increasingly use advanced and custom-designed materials developed using improved computational methods and accelerated experimental techniques. As computational capabilities increase, materials designs, processing, and product engineering will also become more efficient, reducing the time from product concept to production.

There is much innovation happening in manufacturing technology research, both in universities as well as in industrial firms, and further productivity gains and game-changing processes are on the horizon. In short period, manufacturing technology is expected to advance to new frontiers, resulting in an increasingly automated and data-intensive manufacturing sector that will likely replace traditional manufacturing. In addition to skill based workforce, knowledge intensive one will be essential to develop and maintain advances in manufacturing.

Advanced Manufacturing

Advanced manufacturing improves existing or creates entirely new materials, products, and processes via the use of science, engineering, and information technologies, high-precision tools and methods, a high-performance workforce, and innovative business or organizational models. It's about looking well beyond the factory floor. "You don't say 'this industry's advanced and this one isn't'. This company is advanced in the way it approaches [manufacturing]. Realistically, it starts with the customer, it starts with design led thinking, it includes inbound logistics, includes production, includes outbound logistics, marketing, sales and also the service element. And it's hard to find a company that is in a strong competitive position that doesn't adopt that sort of approach. Conversely, there are examples of companies that are really struggling at the moment who are manufacturing one product for one customer according to the customer's specifications. But they are really only engaged in the production process that they would clearly be hard to define as an advanced manufacturer."

It's about ideas and more. Prior to 2000, manufacturing generally referred solely to the production of goods. Today, manufacturing is about ideas, products, processes and services. This post-industrial global manufacturing system represents a complex and highly integrated value chain. This value chain includes cutting-edge science and technology, innovation, skills, design, systems engineering, supply chain excellence and a wide range of intelligent services, as well as energy-efficient, sustainable and low-carbon manufacturing.

It's about smarter automation. Advanced manufacturing is a step forward from what we're used to. A lot more sensing, is what we specialise in, a lot more vision - making automation smarter. It's about investing in the best equipment. The only way of keeping ahead of the world market is having the latest equipment.

It's about information. Advanced manufacturing is centred on sharing information, and making sure information flows right through the whole production

chain. This is absolutely key. It is not necessarily talking about a unique and dynamic change in manufacturing, it just means a process development. And that's the key. It's about information and science. It's about non-traditional manufacturing. It's about using technology to simplify factories. It is about taking full responsibility for not only what is manufactured but the process from beginning to end. It looks at how the product or material is produced, considering all regulations and communities impacted and how profits are then returned to the business or investors.

It's about globalisation and innovation. Advanced manufacturers as globally-oriented and innovative manufacturers, in general sharing the following characteristics:

- High Intellectual Property component; high knowledge base
- Dependent on global supply chains.
- The only public sector support needed is at the Research & Development phase through tax credits or leveraging public/private partnerships.
- Advanced manufacturers tend to be engaged in collaborations with universities, the CSIRO and other research institutes.
- Advanced manufacturers sell to a global market and compete on distinctive qualities. The domestic market is not a constraint.
- These manufacturers constantly innovate to remain competitive. They leverage the latest thinking in technology and materials.
- They produce high margin products.
- And they have smaller capital and labour footprints but are higher paying, and provide higher quality work."

Typical characteristics of advanced manufacturing

- An advanced manufacturing production system is capable of furnishing a mix of products in small or large volumes, with both the efficiency of mass production and the flexibility of custom manufacturing, to respond rapidly to customer demand and desired quality.
- Advanced manufacturing results from substantive advancements (whether incremental or breakthrough) over the current state of art in the production of materials and products; these advancements include improvements in manufacturing processes and systems, which are often spurred by breakthroughs in basic science and engineering disciplines. These new systems, which are often referred to as "intelligent" or "smart" manufacturing systems, integrate computational predictability and operational efficiency.
- Advanced manufacturing produces goods that minimize use of resources while maintaining or improving cost and performance.

Manufacturing Technology Strategies:

Manufacturing research focus on the transformation of the present factories, towards reusable, flexible, modular, intelligent, digital, virtual, affordable, easy to adapt, easy to operate, easy to maintain and highly reliable one. Manufacturing factories could be visualized as Smart Factories, Virtual Factories, and Digital Factories, the brief functions are as given below

Smart Factories—More automation, better control& optimization of process. The information technology (IT) revolution has finally come to factory floors around the world. Today, manufacturing is becoming highly-automated and IT-driven or simply put, "smart." Every day, advances in modern manufacturing technologies make factories smarter, safer and also more environmentally sustainable. Progressive businesses will strategically investing to transform their operations from cost centers into smart manufacturing profit centers that will dramatically increase their sales.

Virtual Factories-To manage supply chain, and to create value by integrating products & services. It refers to an integrated model that includes variety of software, tools, and methodologies in order to solve any real time problem of manufacturing system. This model sees a real factory as a combination of various sub-systems and includes them. In manufacturing, it creates a virtual simulation exercise that helps in replicating the real life scenario and helps in designing and implementation. The advantage of virtual factory involves:

• It helps in creating capabilities to support the rapid development in manufacturing sector by pooling the experts.

• It helps in providing solutions in a speedy and cost effective manner.

• It eliminates the need for pilot plants or production runs and replaces it with virtual simulation on software.

• It helps in the decision making process.

Digital Factories-To visualize the product before it is realized. The Digital Factory (DF) Division offers a comprehensive portfolio of seamlessly integrated hardware, software and technology-based services in order to support manufacturing companies worldwide in enhancing the flexibility and efficiency of their manufacturing processes and reducing the time to market of their products. The seamless integration of data along

the industrial value chains will gain more and more in importance, becoming a key criterion for the survival of developing / manufacturing companies. The Digital Factory Division aims to provide its customers with a comprehensive portfolio of hardware and software products which enable the comprehensive integration of data from development, production and suppliers. The complete digital representation of the entire physical value chain is the ultimate goal.

Mainly strategies going to be pursued in future are based on (1) high performance manufacturing to the highest level of accuracy to the order of micro/Nano level (2) exploiting special materials thro processing and handling.

(1)**High Performance Manufacturing –strategies:-** Manufacturers are faced with constant pressure to cut costs, improve operations, and offer new products and services in response to ever-changing customer demands and preferences. To remain competitive firms must continually develop and implement new processes, methods, and technologies. The mission of the Center for High Performance Manufacturing (CHPM) is to help manufacturing firms become high-performance manufacturers via research and development of enabling tools and technologies and their successful transfer and implementation.The research, development, and educational activities of the CHPM are coordinated through its major areas of specialization which include:

- Human Factors
- Manufacturing Ergonomics
- Innovation-Based Manufacturing
- Production and Information Systems
- Flexible Automation and Lean Manufacturing
- Manufacturing Logistics and Supply Chain Management
- Rapid Manufacturing and Low-Cost Composite Manufacturing

(2)**Exploiting new materials through manufacturing**

- Net shape manufacturing for structural and functional materials
- New materials manufacturing thro functionalities
- Manufacturing strategies for repair and re use
- Product design using sustainable materials processing technologies.

Advanced manufacturing involves one or more of the following elements:

- Advanced products—advanced products refer to technologically complex products, new materials, products with highly sophisticated designs, and other innovative products.
- Advanced processes and technologies—advanced manufacturing may incorporate a new way of realizing the products with the advanced processes and technologies. Smart manufacturing and enterprise concepts—in recent years, paradigms of "manufacturing as an ecosystem" have emerged. The term "smart" encompasses organizations that create and use data and information throughout the product life cycle with the goal of creating flexible manufacturing processes that respond rapidly to changes in demand at low cost minimum impact on the environment with the concept of efficient production and recyclability.

- Advances in science and technology and the convergence of these technologies are a critical building block of advanced manufacturing. The framework therefore highlights the role of breakthroughs in physics, chemistry, materials science, computational modeling, and biology.

Global Trends

There are four large-scale manufacturing sectors:

- Role of information technology and use of more powerful computers.

- Reliance on modeling and simulation on computer aided Design & Manufacturing.

- Move toward the ability to change manufacturing systems rapidly in response to customer needs and external impediments.

- Acceptance and support of sustainable manufacturing.

These trends allow for tighter integration of R&D and production, mass customization, increased automation, and focus on environmental concerns. The trends in advanced manufacturing technologies for future globally are summarized as below:

- Nano-engineering of Materials and Manufacturing
- Additive and Precision Manufacturing
- Robotics and Adaptive Automation
- Next Generation Electronics Manufacturing
- Continuous Manufacturing Pharmaceuticals and Bio Manufacturing
- Design and Management of Distributed Supply
- Green Sustainable Manufacturing

Several factors have drawn sustainability to the forefront of manufacturing. The first is increasing costs for materials and energy and, perhaps in the future, water. IT based solutions for reducing waste and resource use are growing in popularity and represent one convergence of trends.

Major advances two mature areas and two emerging technologies. The mature areas are semiconductor

fabrication and advanced materials with a focus on integrated computational materials engineering. The emerging technologies are additive manufacturing (aka 3D printing) and bio manufacturing with a focus on synthetic biology.

Technology Challenges

- Rapid shrinking of the supplier base due to the out sourcing of manufacturing activities resulting negative impact on the technology development.
- High level of investment needed in R&D and high risk factor makes technology developers to become a big barrier to technology-based innovation.
- Availability of strategic special Materials, understanding of its characteristics, evaluation technique and processing for designs.
- Simulation capability of electronic device fabrication lags to cope up with the technology development.
- Globally linked manufacturing and enterprise systems and migration to cloud sharing also highlight the increasing need for cyber security and robustness of IT infrastructures.

Techno Managerial Challenges

Small number of developed countries provide most of technological innovations to the developing countries. The factories in developing countries lack initiative and are taking little efforts to absorb the new technology due to poor infrastructure and insufficient information. Isolation of major R&D institutions and their linkage with industry face a lot of hurdles due to different rules, laws and regulations. The skill level enhancement, knowledge transfer and sharing are not dynamic to meet the growing demands. Technology transfer related issues predominantly play a major challenge. In future Advance manufacturing technology and innovation is going to be knowledge based and hence knowledge management methods have to be followed.

Summary

Future scenarios are going to be an increasingly automated that will continue to rely less on labor-intensive mechanical processes and more on sophisticated information technology-intensive processes. Manufacturing will become increasingly globally linked as automation and digital supply-chain management become the norm across enterprise systems. Advanced manufacturing processes will likely be more energy and resource efficient. Increasing demand for flexibility and customization may lead to the proliferation of additive manufacturing for customized geometry and integrated customized materials. Advances in materials and systems design will likely accelerate and transform manufactured products, to move into advanced manufacturing frontiers, scientific advances are needed, especially interdisciplinary approaches, in multiple areas. Among these are creation of models, databases, and tools for rapid integration of new methods and materials; increasing the quality and availability of materials for additive manufacturing; and increasing fundamental knowledge of genetics, bioengineering, standardization, and predictability of working with complex genetic circuits. The Advanced Manufacturing entity makes extensive use of computer, high precision, and information technologies integrated with a high performance workforce in a production system capable of furnishing a heterogeneous mix of products in small or large volumes with both the efficiency of mass production and the flexibility of custom manufacturing in order to respond quickly to customer demands." "In foreseeable future categorical developments facilitated with integration with computers will be largely impacted by state of raw material and energy availability. Over the next 20 years, manufacturers will also increasingly use advanced and custom-designed materials, developed using improved computational methods and accelerated experimental techniques. As computational capabilities increase, materials designs, processing, and product engineering will become more efficient, reducing the time from product concept to production. In 20 years, synthetic biology could change the manufacturing of biological products. Coupled with advances in genomics, proteomics, systems biology, and genetic engineering, synthetic biology will offer a toolbox of standardized genetic parts that can be used in the design and production of a new system. The catalyst to new products will be increased understanding of cellular functions and disease models.

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