

Advanced Manufacturing Systems: A Review

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Abstract

The developments of numerically controlled machines, group technology, cellular manufacturing, and just-in-time production systems have changed the role of human operators in the manufacturing environment. The highly specialized work force of the low-tech manufacturing system has evolved into the multi-skilled work force of the high-tech manufacturing system. Throughout the manufacturing evolution, from the mass production era to the present advanced manufacturing systems (AMS), human sensory detection capabilities have been a vital but often ignored component of the quality inspection task.

The paper takes a review of development of advanced manufacturing systems and various types of AMS

Introduction

Mass production was the prevailing manufacturing system of the first half of the twentieth century. Some of the manufacturing concepts that shaped the mass production era were: Babbage's division of labor, Taylor's scientific management, the Gilbreths' motion studies, and Ford's specialization of labor (Konz, 1995; Niebel, 1993; Turner, Mize, Case, and Nazemetz, 1993). During World War II, the demand for war materiel pushed mass production to its peak, causing a significant expansion for many industries. Such growth resulted in increasing employment of unskilled personnel (Banks, 1989). Quality control inspection became a very important and specialized task. Statistically based acceptance sampling and 100% inspection were the main quality control tools used to detect and reject unacceptable products. Even though the quality inspector's performance was significantly less than 100%, more emphasis was placed on meeting the large production demands than on understanding or improving the performance of the inspectors. Advanced manufacturing systems (AMS) is a generally accepted term for production systems that are based on advanced manufacturing technology (AMT). The main AMT components are: computer aided design (CAD), computer aided engineering (CAE), computer assisted manufacturing (CAM), computer integrated manufacturing (CIM), and flexible manufacturing systems (FMS) (Karwowski and Salvendy, 1991). Some of the AMT contributions to manufacturing systems are:

- 1) High flexibility in product design, mix, and fabrication,
- 2) Rapid response to changes in market demand,
- 3) Greater control, accuracy, and repeatability of processes, and
- 4) Faster throughput. In addition to AMT,

A wide range of production strategies are used in AMS: product-based cell manufacturing, group technology, JIT, total quality control (TQC), and optimized The AMT and production strategies configuration used in AMS varies among manufacturing organizations. However, JIT and TQC are the production strategies most recommended for AMS, to make production processes more visible and to enable the elimination of waste, the cutting of required lead times, and the optimization of manufacturing activities (Zairi, 1992; Pinochet, Matsubara, and Nagamachi, 1996). This integration of AMT and JIT/TQC strategies represented a major conflict with the original organizational assumptions of AMS (Berniker, 1990). When AMS was originally conceived, its goal was to improve productivity by creating a fully automated factory, often referred to as the factory of the future, where the operator's role on the

manufacturing shop floor would be minimized or eliminated. This contrasts with JIT, which is highly dependent on a flexible work force's mental capacity and problem solving abilities to increase productivity. After several alarming failures in the implementation and operation of the technocentric "factory of the future," the manufacturing leaders realized that the key to success in WCM is the effective integration of people, organization, and technology (Brödner, 1991; Wilson, 1991; Wobbe, 1992; Bessant, Levy, Ley, Smith, and Tranfield, 1992). Furthermore, Wilson (1992) stated that "Implicit in WCM developments involving AMT and JIT and similar principles of manufacturing organization, must be a human-centered rather than a technocentric approach."

By the mid-1960's, competition for consumer goods had increased, and consumer interest in more variety and availability of products had started to drive the market (Talavage and Hannam, 1992). Batch manufacturing became the answer to a consumer-driven market. High volume production of the same product was replaced by shorter production runs of products with different designs and a shorter life cycle. With this variety of products manufactured in batches, the different types of defects that the inspector was expected to detect increased significantly. As a result, the difficulty of the quality inspection task also increased. Once again the sensory limitations of human inspectors were in most cases overlooked. Instead, more interest was placed on developing production scheduling and inventory strategies to protect the manufacturer from demand fluctuations and quality problems. During the 1970's, many Japanese companies adopted the just-in-time (JIT) production system developed by the Toyota Motor Corporation. Highly influenced by the loss of market share, some of the major North American companies adopted JIT by the early 1980's (Schonberger, 1986). The main objective of JIT is to increase productivity and reduce cost by completely eliminating waste; this is done by producing just what is needed, in the needed quantity, when needed (Monden, 1993). A key concept of the JIT production system is a flexible work force. In order to avoid excess work force, operators must be trained to be skilled in multiple jobs of various processes (Monden, 1993). This caused a significant shift in the quality inspection task responsibilities. The specialized quality inspector was replaced by an operator who, in addition to the inspection task, concurrently conducted other tasks such as job scheduling, inventory planning, dissimilar machines setup, and problem solving. Various production systems have been developed and implemented since the introduction of JIT. Although most of them modify JIT to some extent, their cornerstones remain the same as for JIT: quantity control and quality assurance. Numerically controlled machines, group technology, and cellular manufacturing have become instrumental elements of quantity control, while quality assurance has been relying mostly on the performance of a flexible work force performing multitasking. A significant number of these current production strategies take place in manufacturing environments referred to as advanced manufacturing systems (AMS). These systems are characterized by a high degree of human-computer interaction during practically every aspect of manufacturing. Most of the on-line tasks (such as machine setup, problem solving, and quality inspection), as well as the off-line tasks (such as job scheduling and inventory control), are conducted using video display terminals (VDTs). This has minimized the operator's physical contact with both the process machine and the unit being produced.

In the present highly competitive world class manufacturing (WCM) scenario, where manufacturers in almost every industry sector find themselves competing with companies from every part of the world, quality is a key element for survival and success. A better understanding of the operator's performance in a quality inspection task while multitasking in AMS is essential for the continuous improvement of the manufacturing industry.

Techno centric AMS. The techno centric AMS was supposed to herald the coming of the "factory of the future." Davies (1986) described the "factory of the future" as an almost workerless, paperless, and fully automated production facility that was going to alter manufacturing "at least as dramatically as large-scale industrialization changed earlier guild forms of industrial organization." It has been suggested that for the technocentric AMS to succeed, there should be a full integration of engineering, design, production scheduling and control, quality control,

and manufacturing systems in a single computerized network (Berniker, 1990; Davies, 1986; Davidow and Malone, 1992). By the mid-1980's there was a growing realization of the unfulfilled promise of the techno centric AMS (Bessant, et al., 1992; Mize, 1988; Unterweger, 1988). Some of the most publicized cases of failure have been in the automotive industry. Under the heading of "Tricky Technology: American Car Makers Discover 'Factory of the Future' Is Headache Just Now," the Wall Street Journal (1986) reported that all U.S. automakers were having significant difficulties with their factory modernization programs. Business Week (1987) reported that after investing \$60 billion in vast amounts of AMT, General Motors was unable to achieve the anticipated results. Some of the factors identified as the most significant barriers to the successful implementation of the techno centric AMS according to Mize (1988) are:

- 1) Unanticipated difficulties in transferring technology from the isolated pilot projects to the manufacturing real world,
- 2) Underestimation of the magnitude of the task resulting in an organization's inability to absorb the vast amount of change in a short period of time,
- 3) The misunderstanding of the critical role played by humans as operating systems integrators,
- 4) Inadequate internal technical skills leading to excessive dependency on external consultants and vendors, and
- 5) Unrealistic expectations of standalone automation. The major weakness of the techno centric AMS was best described by Unterweger (1988), when he stated that "the attempt to eliminate the gaps or deficiencies in machine designs by means other than skilled human operators leads to a vicious circle that can only add cost and complexity to a system that is already overly complex."

Human-Centered AMS. The objective of human-centered AMS is to employ the best technological and organizational qualities of AMT and of people, with complete integrated roles and functions. Wilson (1991) indicated that in this AMS the actual manufacturing processes will be computer controlled, but setup, programming, monitoring, intervention, maintenance, diagnosis, rectification, innovation, and optimization will be the responsibility of operating and supervisory staff. For these tasks the operating and supervisory staff will have any recourse from the information and technical systems to aid their decision. In essence, this manufacturing system stresses re-skilling rather than a de-skilling perspective, emphasizes operator local control, follows the human factors principles of good job design, and encourages social communication and interaction (Corbett, 1987).

Wilson (1991) indicated that operator local control is related to the job characteristic of autonomy, seen at the core of individual and group work design changes as well as of job design models and theories. Bainbridge (1982) expressed the opinion that "the more advanced a control system is, so the more crucial may be the contribution of the human operator." The degree of control and breadth of influence exerted by operators will be determined by the skill-, rule-, or knowledge-based behaviors that the task interface will support (Rasmussen, 1986). Rasmussen (1983) described his skill/rule/knowledge-based classifications as follows:

- 1) skill-based behavior represents psychomotor behavior without conscious control, consisting of automated routines that are driven by information received from the environment,
- 2) rule-based behavior represents consciously controlled, goal-oriented behavior guided by sets of rules or stored patterns that have been empirically derived during previous occasions or communicated as instructions from an external source, and
- 3) knowledge-based behavior represents goal-controlled, problem solving performance in unfamiliar situations, requiring a functional understanding of the system, analysis of the current state, and response of the environment based on conscious, advanced reasoning while utilizing feedback control for error correction. According to Schott and Wilkinson (1989), the process of developing control down to the operator level requires that AMS designers be able to allocate functions optimally.

From a human-centered AMS perspective it is widely recognized that people, just like machines, have limitations and weaknesses. Still, they have to be involved in the operation and management of AMS. Some of the reasons for this inclusion are:

- 1) AMT limitations in receiving information and decision making,
- 2) AMT has the potential to diagnose the origin of failures, but have difficulties in repairing the system that failed,
- 3) human complex knowledge-based skills for problem solving in novel situations, and
- 4) Human flexibility and adaptability (Salvendy, 1992; Pinochet, et al., 1996). According to Mize (1988) and Wilson (1991), the success of the human-centered AMS will be significantly dependent on the effective integration of people, organization, and technology. A human factors knowledge base is vital for this integration (Karwowski, Salvendy, Badham, Brodner, Clegg, Hwang, Iwasawa, Kidd, Kobayashi, Koubek, LaMarsh, Nagamachi, Naniwada, Salzman, Seppala, Schallock, Sheridan, and Warschat, 1994). Critical human factors issues particularly pertinent to AMS are presented in Figure 1 (Wilson, 1991).

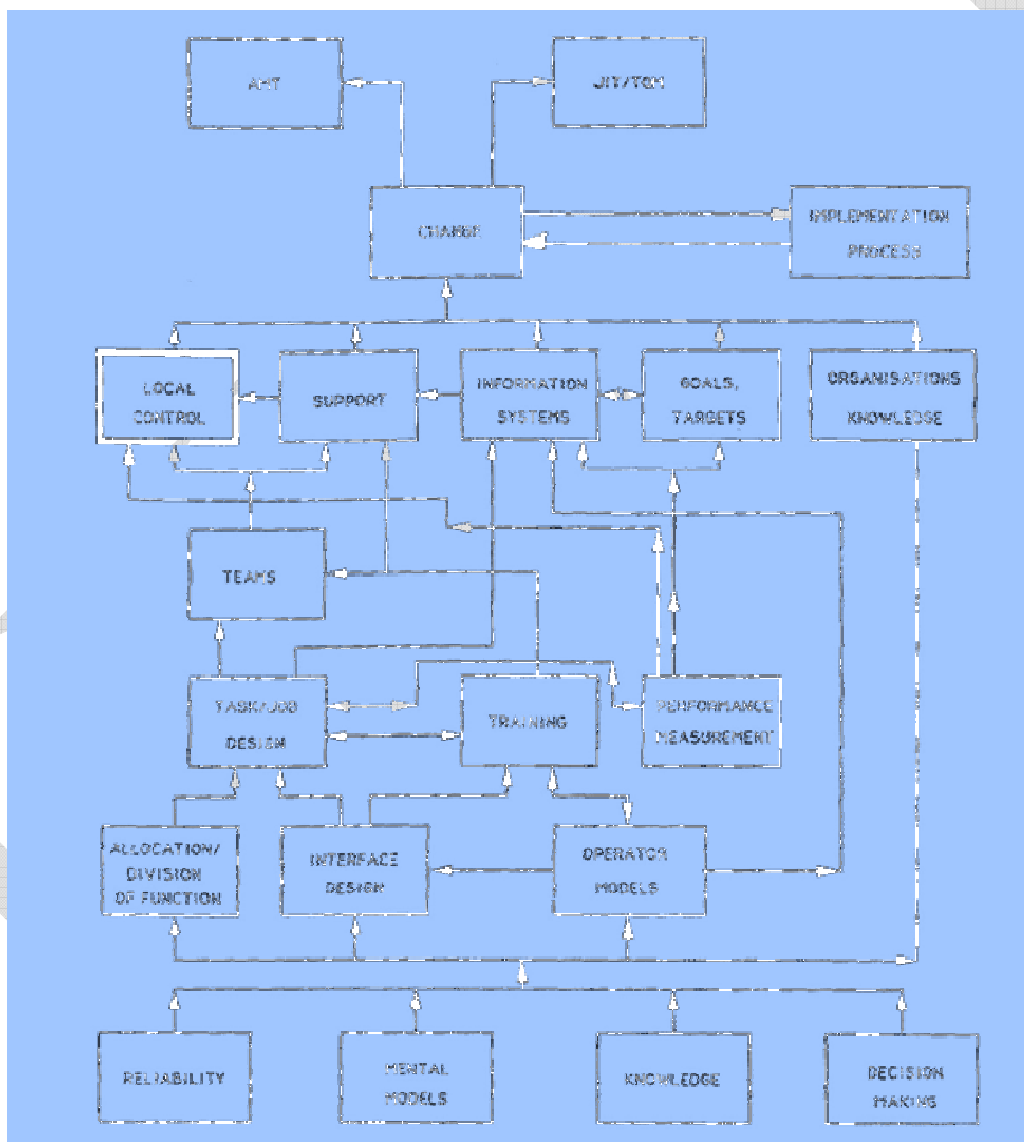


Figure 1. Framework of human factors issues in AMS

Conclusion

The paper reviews various developmental stages in the AMS technologies used in various industries worldwide. And also highlights the types of AM systems. The importance of AMS and other technologies in the industries today are also been discussed on a short scale, which will be helpful for the researchers to take an insight of advanced manufacturing systems.

References:

1. Karwowski, Salvendy, Bad ham, Brodner, Clegg, Hwang, Iwasawa, Kidd, Kobayashi, Koubek, LaMarsh, Nagamachi, Naniwada, Salzman, Seppala, Schallock, Sheridan, and Warschat, 1994
2. Human flexibility and adaptability (Salvendy, 1992; Pinochet, et al., 1996)
3. Social communication and interaction (Corbett, 1987)
4. the attempt to eliminate the gaps or deficiencies in machine designs by means other than skilled human operators Unterweger (1988)
5. Factory of the future.” Davies (1986)
6. “Implicit in WCM developments involving AMT and JIT and similar principles of manufacturing organization Wilson (1992)”