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Smart Adaptable Assembly Systems

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Abstract

In today's manufacturing environment, change has become a constant. Modern assembly systems must adapt to products, markets, technologies and regulatory requirements. The assembly industry is undergoing vast changes with the rapid development of production automation, process control, information technologies and networking. Variant-oriented assembly systems have been developed to achieve more flexibility and adaptability to enable adding product variants and scaling production. Smart assembly systems where intelligence is embedded in the products, work stations and system are emerging to achieve more autonomy in communication between entities in the system and more adaptable control of assembly flow and system performance. This paper highlights some advances in assembly technologies and systems and new trends of modularity and reconfigurable using a modular and reconfigurable assembly system. Future directions and challenges are outlined.

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Keywords: assembly; advances; technologies; products; processes; systems; changeability

1. Introduction

Assembly is a very important process in manufacturing. Assembly of manufactured goods accounts for over 50% of total production time and 20% of total production cost. In the automotive industry, 20% - 70% of the direct labour costs are spent on assembly. These statistics indicate the relative importance of assembly and point to the potential savings to be achieved by improving assembly technology and systems. Assembly is more than placing parts together. It is the capstone process in manufacturing and brings together all the upstream processes of design, engineering, manufacturing, and logistics to create a functional product [1, 2]. A major concern in manufacturing is the management of increased product varieties [3, 4, 5]. Large companies are gradually embracing and applying the concept of flexible manufacturing introduced more than 2 decades ago. Small and medium size companies are slower to adopt and implement automation and advanced manufacturing technologies in their operations. The wide scope of products variants driven by customers' preferences and dynamic fluctuation in the number of variants to be produced annually introduce manufacturing challenges which directly impact the manufacturing systems design and operation to cope with products and markets changes efficiently and cost effectively. Reconfigurable, adaptable and smart manufacturing paradigms all aim at dealing with these challenges. ElMaraghy et al. keynote paper [5] investigated methods of managing products variety and developing variant-oriented manufacturing systems capable of meeting those requirements in modern manufacturing systems. Manufacturers respond to such fluctuations by controlling product customization and personalization, production volume, manufacturing lead time and product cost and quality. Logical entities such as controls, programs, communication protocols as well as human resources form an important part of the manufacturing enterprise and planning effort. Manufacturing systems are a complicated combination of tools, machines, computers, human workers and managers. Modern manufacturing systems are becoming increasingly complex [6, 7]. The assembly industry is experiencing huge changes with the rapid development of production automation, process control, information technologies and networking. Many manufacturing and assembly enablers emerged to manage the proliferation of product variety and changes in their manufacturing systems [8, 9]. More agile and responsive assembly methods and strategies have to be developed to meet the dynamic requirements of customers and the shortened product lifecycle. More efficient assembly systems must be

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designed in order to remain profitable and competitive [10, 11]. Intelligence and collaboration between machines and humans allow modern systems to evolve and quickly respond to the volatile markets and increasing product variety.

Customers today demand products that can provide easy solutions to their particular needs of manufacturing companies often operate in a dynamic environment driven by fluctuation in market conditions, customer demands, product design and processing technology, and the introduction of new manufacturing systems paradigms.

This paper is not an exhaustive survey, rather it highlights some advances in assembly technologies and systems as a response to changing conditions and increasing variety. Recent developments in joining, material handling, assembly processes, micro assembly, inspection and quality control, robotic assembly, digital and virtual factories, augmented reality, Information and Communication Technology (ICT), planning and control, disassembly and remanufacturing and intelligent and changeable assembly systems are overviewed. In particular, intelligent, reconfigurable and changeable assembly systems are discussed. A typical network of assembly activities is shown in Figure 1. Furthermore, the various advances are grouped in three main areas as shown in Figure 2.

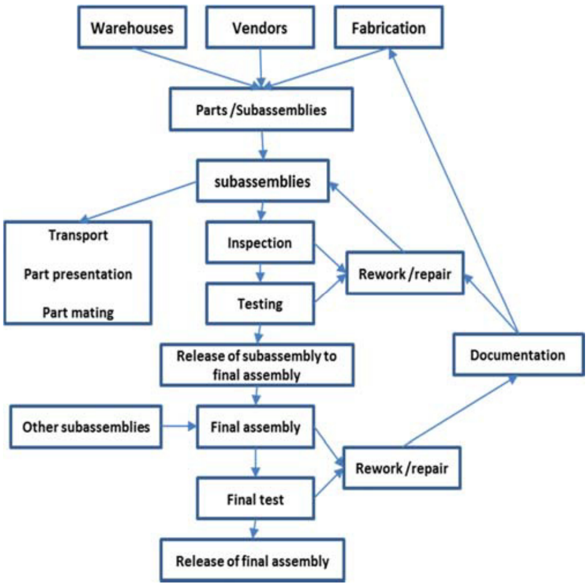

Figure 1 The main processes of assembly [adapted from 1]

2. Advances in assembly processes

2.1. Material handling

The increasing number of product variants, smaller lot sizes, reduced time to market and shorter lifecycles of products have led to increasing demands on automation equipment and concepts. Material handling is a critical component of today's manufacturing processes. Material handling systems are found in almost every manufacturing and distribution company for various goods [12, 13, 14]. A material handling system comprises equipment (conveyors, vehicles, robots, etc.) that transport materials between various locations in the facility. Material handling makes production flow possible, as it gives dynamism to static elements such as materials, products, equipment, layout and human resources. Management and production of customized products requires material handling systems which are flexible and responsive enough to accommodate dynamic and real-time changes in material handling tasks [15]. Material handling management is among many factors that contribute to improve a company's performance as it has direct influence on transit time, resources usage and service levels [16, 17, 18]. The development of new markets increased the manufacturing demands for a large variety of components and final product assemblies increased. This demand growth led to increases in speed and changes in how materials and tools were being handled and transported in order to monitor manufacturing requirements. Conveyors equipped with radio frequency identification (RFID) technology is an example of intelligent conveyors [19]. Such conveyors have a microprocessor, LCD touch screen, reader modules. The conveyor can perform a real-time and synchronous update with the system server.

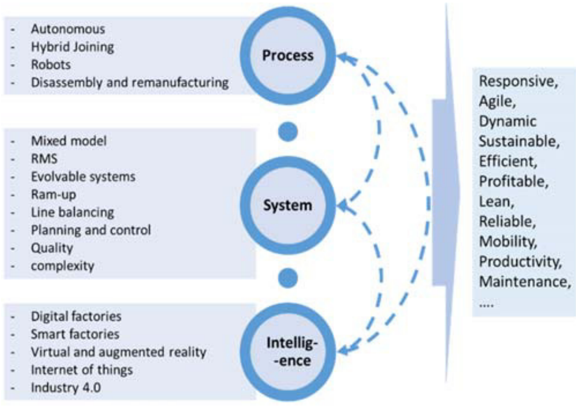

Figure 2 advances in assembly

The unpredictable machine failures, asynchronous among various sections in the assembly line, coupling of sections through finite buffers, and coupling between the production and material handling system increasing the complexity of handling systems [20]. The transport of loads in a complex transport system involving multiple transport equipment requiring a sequence of multiple transport jobs. Efficient and effective models are necessary to evaluate and optimize the material handling system design to improve the flexibility and responsiveness of material handling systems. Online decision and control for job routing plan and resource dispatching in complex transport systems can be controlled using dynamic discrete event controller [15]. The dynamic change of the handling system under various conditions, such as starvation caused by material handling is mathematically described using max-plus algebra [20].

2.2. Robotic assembly

The use of robotic manipulators increases manufacturing productivity. This increase depends on the possibility of re-