Journal of Manufacturing Systems 26 (2007) 188–193

Contents lists available at ScienceDirect

Journal of Manufacturing Systems

journal homepage: www.elsevier.com/locate/jmansys

Technical note

The concept of mobile manufacturing

Carin Stillström [a,b,*], Mats Jackson [c]

[a] Department of Industrial Engineering and Management, Jönköping University, Sweden
[b] Department of Product and Production Development, Chalmers University, Sweden
[c] Department of Innovation, Design, and Product Development, Mälardalen University, Sweden

ARTICLE INFO

Article history:
Received 10 July 2007
Received in revised form
9 November 2007
Accepted 3 March 2008

ABSTRACT

It is increasingly important to locate manufacturing activities close to the most relevant competence or the most interesting market. The possibility to easily and quickly move manufacturing capacity is thus becoming more important. Hence, the demand for mobile manufacturing has increased and requires solutions for a quick, rational, and economical reconfiguration of the production system. Within the research project Factory-in-a-Box, the concept of mobile manufacturing has been investigated through the development and implementation of five operative demonstrators.

This paper will analyze the concept of mobile manufacturing by presenting the results from the Factory-in-a-Box research project and its demonstrator development. The objective is to clarify when mobile manufacturing capacity can be a proper solution to use as well as to discuss future possible industrial manufacturing applications. The results show that there is a large range of applications for the concept of mobile manufacturing and that two dimensions – the geographical distance and the organizational distance – can be used to classify the mobility within manufacturing systems.

1. Introduction

Due to the increasing competitive climate with sophisticated customers, demands on manufacturing companies to quickly adapt to the environment are increasing [1]. The capability to rapidly develop and deliver new products to the customer is of growing importance. Consequently, the ability to easily and efficiently handle information and knowledge will be ever more essential as well as the ability to globally distribute highly competitive production resources [1].

Manufacturing systems should not only have the ability to quickly be adopted due to new demands, but they are also expected to efficiently change and reconfigure their facilities and even location [2]. There have been several investigations about the future manufacturing industry and what characterizes the future of industry both nationally (in Sweden) [3], in Europe [4], and globally [1]. All of these reports give similar indications that the ability to rapidly develop and easily reconfigure the manufacturing system in an effective way will be crucial in the competitiveness of future industry.

An important characteristic that is influencing future industry is thus the ability to change. Changeability is a broad term, including several characteristics, and is discussed by several authors in terms such as reconfigurability [5,6,2], flexibility [7–9], transformability [10,11], and agility [12–15]. The Iacocca Institute Report [16] introduced the term agility in 1991, describing it as one key to future competition. Agility is a comprehensive response to the challenges posed by a business environment dominated by the continual change and uncertainty in the manufacturing climate [17].

To become agile, and thus also to achieve flexibility and reconfigurability, new manufacturing concepts are needed. The concept of mobile manufacturing is one example of such a concept, with the main idea to develop and use mobile manufacturing modules that rapidly can be combined into a complete manufacturing system and be reconfigured for a new product and/or scaled to handle new volumes. Given such a module, the production capacity could be offered as a mobile and flexible resource that rapidly can be tailored to fit the needs of a customer.

Within the research project Factory-in-a-Box, the concept of mobile manufacturing has been investigated by the development of physical demonstrators. The demonstrators have shown the application of mobile manufacturing modules that could be moved either within a manufacturing site, between sites, or between companies. The demonstrators are focusing on the technical hardware as well as solutions to secure, for example, the logistic setup, the education and training of the personnel, and the organization to optimize the output of the concept.

This paper will analyze the concept of mobile manufacturing by presenting the results from the Factory-in-a-Box research project

* Corresponding author at: Department of Industrial Engineering and Management, Jönköping University, Sweden.
E-mail address: carin.stillstrom@ing.hj.se (C. Stillström).

0278-6125/$ – see front matter © 2008 The Society of Manufacturing Engineers. Published by Elsevier Ltd. All rights reserved.
doi:10.1016/j.jmsy.2008.03.002

and its demonstrator development. The mobility element in the different demonstrators is analyzed as well as the distances the mobile manufacturing capacity is moved. The objective is to clarify when mobile manufacturing capacity can be a proper solution to use as well as to discuss future possible industrial manufacturing applications.

2. Theoretical overview

2.1. Mobility as a manufacturing characteristic

Mobility is a rather unexplored area within the manufacturing field, and a small number of papers have previously been published within the area of mobility in a manufacturing perspective [18]. The few definitions of mobility that exist seem to vary depending on author and context.

Upton [8,9] describes mobility as a type of operational flexibility, seen in a short time perspective (day to day), and he refers to the ability of the manufacturing system to switch effortlessly and quickly between products. A similar definition is made by Koste and Malhotra [19], who use the term mobility as an element to define dimensions of flexibility. The mobility element describes the ease with which the organization moves from one stage to another and could be referred to, for example, machine flexibility, labor flexibility, and material handling flexibility.

Also Nyhuis, Kolakowski, and Heger [11] define mobility in the operational domain as a type of flexibility to facilitate switching to another product family. According to Nyhuis, Kolakowski, and Heger [11] and Wiendahl [10], mobility could mean the movement of manufacturing equipment and could, for example, be achieved by placing machines on rollers. Nyhuis, Kolakowski, and Heger [11] adopt a system perspective and argue that mobile manufacturing equipment calls for changes in the whole manufacturing system. Accordingly, mobility demands development in the manufacturing and logistic system, of facilities, in the organizational structure, in process, and regarding personnel [11].

Other authors apply mobility in the strategic domain to describe manufacturing in a long-term perspective. According to Shi and Gregory [20] and Miltenburg [21], mobility is an enabler for dispersed manufacturing in different geographical places. Miltenburg [21, p. 178] defines mobility as *"the ease with which a company can transfer products, processes, and personnel between factories, move facilities to new locations, and change production volumes"*. According to the authors, mobility is a type of strategic output provided by a manufacturing network which describes the geographic dispersion of facilities and the amount of specialization. A worldwide and regional dispersion of facilities represents a high level of mobility [20]. According to Shi and Gregory [20], mobility in manufacturing does thus not necessarily mean that equipment or resources are mobile but instead that a company is able to easily produce at different geographical places.

The conclusions that can be drawn from this theoretical overview are that no explicit definition of mobile manufacturing exists and that mobility is used as a characteristic, in both the operational and strategic domain. In this paper, it is suggested that mobility refers to the movement of physical manufacturing resources. The concept could thus be related to machines on rollers in accordance with Wiendahl [10] and Nyhuis, Kolakowski, and Heger [11], or it could be related to the transfer processes between factories in accordance with Shi and Gregory [20]. Mobility is thus defined in this paper as *the ability to change between geographically different places with little penalty in time, effort, cost, or performance.*

3. The Factory-in-a-Box demonstrators

The results in this paper are based on the Factory-in-a-Box project, which is a joint research project between several manufacturing companies in Sweden and four Swedish universities. The aim of the Factory-in-a-Box project is to provide solutions for mobile production capacity for industry through standardized and mobile manufacturing modules that easily could be transported by, for example, truck or train. The modules must be easy to transport to the manufacturing site as well as within the site. They must be able to adapt to new situations and thus be flexible and reusable. Thus, the mobile manufacturing modules must be reconfigurable as well as modular and scalable to meet changing demands and varying production volumes. These requirements are general, even though the specific requirement depends on each specific application and on the context in which the mobile manufacturing modules will be used. In the research project, five fully operative demonstrators have been developed, realized, and tested in operative settings in industry, where the benefits of the concept have been evaluated.

The research objective of the demonstrators has primarily been to exemplify mobile production capacity in a real manufacturing context. This have been done by gathering ideas, knowledge, experience, and by developing technical solutions in close collaboration between industry and participating academic parties. The demonstrator is not only referring to a physical artifact that is built within each case, but to the whole mobile manufacturing system, where the physical artifact is a part. Other important areas to include in the demonstrators are, for example, education and training solutions for the operators, logistic solutions to handle material, management solutions, or information handling. Each demonstrator in the project has been focused to investigate one or more of these areas. Thus, the demonstrators can be seen as pieces of the concept of mobile manufacturing, where each demonstrator has focused on, for example, a specific technology, characteristic, business area, and/or business concept. Together, the demonstrators are meant to represent a 'complete concept' of mobile manufacturing.

The demonstrators that have been developed are presented in the following sections, and the analysis of those will subsequently be presented.

Demonstrator 1—A mobile and reconfigurable robot cell

The first demonstrator, which has been developed and demonstrated within a company providing industrial robot solutions, is an automatic manufacturing module to assemble robot components. The manufacturing module comprises two robots, a gluing station, a folding station, and robot-handled tools (see Figs. 1 and 2). The company's interest in the Factory-in-a-Box concept is related to making robot automation profitable within its operations. Frequent product and production layout changes, as well as a fairly low production volume, have made traditional robot automation costly and hard to economically justify.

Demonstrator 1 has been designed to be moved anywhere within the company's production system in Västerås, Sweden. Much effort was invested to make this manufacturing module reconfigurable to handle changing volume demands and to handle changes in the product design. Technical solutions such as a software-based "cell" configurator, wireless sensors, reusability of components, and mobile platforms for robots and fixtures were developed and used to realize and implement this demonstrator within the company.

Demonstrator 2—Mobile welding capacity for efficient manufacturing on different sites

The next demonstrator is developed in collaboration with a supplier of modular facilities to the offshore, telecom, and pharmaceutical industries. At present, the company is striving to