Journal of Materials Processing Technology 157–158 (2004) 150–158

Journal of Materials Processing Technology

www.elsevier.com/locate/jmatprotec

Designing the layout of single- and multiple-rows flexible manufacturing system by genetic algorithms

M. Ficko*, M. Brezocnik, J. Balic

Laboratory for Intelligent Manufacturing Systems, Faculty of Mechanical Engineering, University of Maribor, Smetanova ulica 17, SI-2000 Maribor, Slovenia

Accepted 26 July 2004

Abstract

The paper presents a model of designing of the flexible manufacturing system (FMS) in one or multiple rows with genetic algorithms (GAs). First the reasons for studying the layout of devices in the FMS are discussed. After studying the properties of the FMS and perusing the methods of layout designing the genetic algorithms methods was selected as the most suitable method for designing the FMS. The genetic algorithm model, the most suitable way of coding the solutions into the organisms and the selected evolutionary and genetic operators are presented. In the model, the automated guided vehicles (AGVs) for transport between components of the FMS were used. In this connection, the most favourable number of rows and the sequence of devices in the individual row are established by means of genetic algorithms. In the end the test results of the application made and the analysis are discussed.

Keywords: Flexible manufacturing systems (FMS); Optimization; Facility layout; Genetic algorithms (GAs)

1. Introduction

Layout of flexible manufacturing system (FMS) involves distributing different resources in a given FMS and achieving maximum efficiency of the services offered. With this in mind FMS are designed to optimize production flow from the first stages as raw material to finished product. The layout has an important impact on the production time and cost, especially in the case of large FMS [1]. It was estimated that 20–50% of the manufacturing costs are due to handling of work pieces; by a good arrangement of devices it is possible to reduce the manufacturing costs for 10–30% [2]. Some other authors report even higher percentage of material handling based costs, for example Chiang and Kouvelis report that 30–70% of total manufacturing costs may be attributed to materials handling and layout [3]. Therefore, already in an early stage of designing of the FMS it is necessary to have an idea of the layout of the devices.

Usually the selected fitness function is the minimum total costs of handling of work pieces. In general, those costs are the sum of the transport costs (these are proportional to the intensity of the flow and distances) and other costs.

Section 1 of the paper presents the problem and the aim of designing the FMS. Section 2 introduces the FMS and its specific properties with respect to transport and design. Section 3 makes survey of researches in the area of designing the FMS. Section 4 briefs the reader on the genetic algorithms (GA) method used in our work. Section 6 gives detailed information about the method itself of searching for solution by GA and the evolutionary and genetic operators used. Section 7 summarizes the results obtained by the model. The discussion and the concluding findings follow.

2. Characteristic of layout of FMS

The manner of arranging of working devices largely depends on the type of production [4]. The FMS have some

* Corresponding author.
E-mail address: fs@uni-mb.si (M. Ficko).

0924-0136/$ – see front matter © 2004 Elsevier B.V. All rights reserved.
doi:10.1016/j.jmatprotec.2004.09.012

specific properties decisively influencing the designing and the construction of the system.

The FMS started to be used due to changed conditions on the market. The following two trends, which have greatest influence on the change of manufacturing system, can be noticed [5]:

- Influence of customer's special desires and requirements, i.e., greater complexity and versions of products;
- Increased share of small and custom order production.

It is practically impossible to cope with these two trends by conventional manufacturing systems. Therefore, the introduction of FMS ensuring maximum concentration of machining and operating activities started. Such system is profitable in small lot and even individual production. Here must be mentioned that the development of FMS was conditioned upon the fast development of information technology, since efficient control of FMS would be almost impossible without suitably supported information sub-system.

A well-designed transport system for transport of work pieces between the individual devices in the FMS is of key importance for successful operation of the FMS. Such devices include:

- computer controlled machine tools;
- automated handling systems (for blanks, work pieces, cutting tools, clamping devices);
- integrated coordinate measuring devices;
- auxiliary machines and devices (e.g., washing machine for products).

The transport system of the FMS combines all devices into one unit. FMS is planned for machining of products from the beginning to the end; the work pieces never leave the system. That fact ensures automatic following up of each phase in the process [5].

We can conclude that the optimum arrangement of devices and machines in the FMS is one of the basic requirements in designing of the FMS, since good solutions in the design of such a system are a basis for its efficient operation and for low operating costs. However, because of the abovementioned facts the FMS have somewhat different requirements for transport than the other manufacturing systems. Heragu and Kusiak pointed out the fact that the FMS differ from the conventional production systems [6]. The FMS include the devices and the machines that usually do not have identical dimensions and also the distances between the individual machines are not firmly determined [6]. Therefore, it is not possible to determine in advance the locations and then to place the devices on them. Due to those facts it is practically impossible in the FMS to locate the working device and workplaces by methods based on the principle "one place one device".

In the initial stage of the development of the FMS the sequential transport devices were used as a result of the strong influence of conventional transfer lines [5]. However, later on it was established that for greater flexibility it is favourable to use freely guided automatic vehicles (also, automatic guided vehicles (AGV)).

The machines fed by AGVs are usually placed in one or multiple rows. Also the machines fed by the crane robot are placed in such way. An example of such placing is shown in Fig. 1.

The AGVs are very flexible and increasingly present in modern factories, particularly in the FMSs. In case of bad layout of machines more AGVs are required but they are insufficiently utilized. Also the software for the control of transport is very complicated and difficultly reaches the optimum states. Therefore, it is of key importance how the devices should be arranged in order to assure optimum execution of transport of materials and work pieces. In principle, the devices fed by AGVs, are arranged into different layout in one or multiple rows. Often the size and the form of the space available are limited.

3. Survey of facility layout methods

Designing a FMS has to do with arranging unequally large devices. Therefore, only the methods for arranging differently large devices can be used. Generally, unequal-area layout problems are more difficult to solve than equal-area layout problems, primarily because unequal-area layout problems introduce additional constraints into the problem formulation [7].

The problem of arranging of devices is one of so-called NP problems. NP-hard problems are unsolvable in polynomial time [4]. Accurate mathematical solutions do not exist for such problem. The complexity of such problems increases exponentially with the number of devices. For instance, a FMS consisting of N machines will comprise a solution space with the size N. The problem is theoretically solvable also by testing all possibilities (i.e., random searching) but practical experience shows that in such manner of solving the capabilities of either the human or the computer are fast exceeded. For arranging the devices in the FMS the number of possible

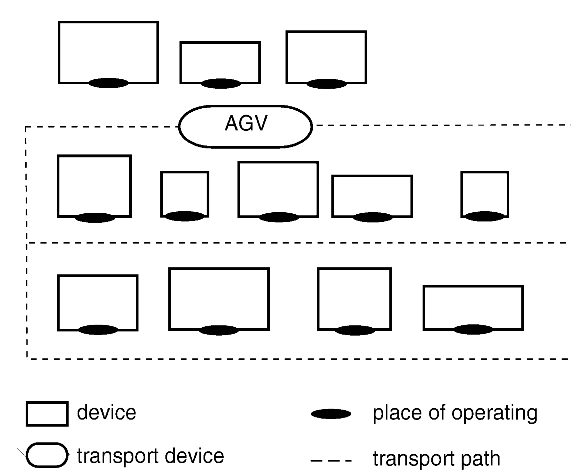

Fig. 1. Layout of devices fed by AGVs in multiple rows.