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SCIENCE DIRECT®
Computers & Operations Research 33 (2006) 263–283
computers & operations research
www.elsevier.com/locate/cor

Forming part families by using genetic algorithm and designing machine cells under demand changes

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Available online 30 April 2005

Abstract

This study develops a methodology which can be used to form manufacturing cells using both a new similarity coefficient based on the number of alternative routes during machine failure and demand changes for multiple periods. The methodology is divided into two phases. A new similarity coefficient, which considers the number of available alternative routes when available during machine failure, is suggested in Phase I. The primary objective of Phase I is to identify part families based on the new similarity coefficient by using a genetic algorithm. One of the major factors contributing to the success of cell implementation is flexibility for demand changes. It is difficult to reorganize the cells according to changes in demand, available machine capacity, and due date. Most of the suggested approaches in the literature tend to use a fixed demand for cellular manufacturing systems. Due to demand changes, cell design should include more than the one period that most researchers of cellular manufacturing systems consider. A new methodology for cell formation, which considers the scheduling and operational aspects in cell design under demand changes, is introduced in Phase II. Machines are assigned to part families by using an optimization technique. This optimization technique employs sequential and simultaneous mixed integer programming models for a given period to minimize the total costs which are related to the scheduling and operational aspects.

Keywords: Group technology; Cellular manufacturing; Alternative routes; Machine failure; Demand changes; Genetic algorithm

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doi:10.1016/j.cor.2005.03.033

1. Introduction

1.1. Background

Batch manufacturing is a dominant manufacturing activity in the world, generating much industrial output. The major characteristics of batch manufacturing are a high level of product variety and small manufacturing lot sizes. The product variations present design engineers with the problem of a design stage that significantly affects manufacturing cost, quality, and delivery times. The impacts of these product variations in manufacturing are high investment in equipment, high tooling costs, complex scheduling and loading, lengthy setup times and costs, excessive scrap, and high quality control costs. However, to compete in a global market, it is essential to improve the productivity in small batch manufacturing industries. For this purpose, some innovative methods are needed to reduce product cost, reduce lead time, and enhance product quality to help increase market share and profitability. Group technology provides such a link between design and manufacturing. The adoption of group technology concepts, which allow small batch production to gain economic advantages similar to mass production while retaining the flexibility of job shop methods, will help address some of the problems.

1.2. Group technology

The philosophy of group technology (GT) is an important concept in the design of manufacturing cells. GT can be defined as a disciplined approach to identifying items such as parts, processes, and machines by their attributes; analyzing those attributes by looking for similarities between and among items; grouping the items into families according to similarities; and, finally, increasing the efficiency and effectiveness of managing the items by taking advantage of the similarities [1]. Similar parts are arranged into part families. Each family would possess similar design and manufacturing characteristics. The processing of each member of a given family would be similar, which results in manufacturing efficiencies.

1.3. Cellular manufacturing

Cellular manufacturing (CM) is one of the major applications of group technology. CM is described as a manufacturing procedure which produces part families within a single line or cell of machines serviced by operators and/or robots that function only within the line or cell. The main objective of designing manufacturing cells is to develop a production environment of machining centers, either as a line or in cells, operated manually or automatically for the production of part families that are grouped according to a number of similarities in their design and manufacturing features. This type of manufacturing is known as CM and is used for manufacturing a product in batches. A fundamental issue in CM is the determination of part families and machine cells. This issue is known as the “cell formation” problem.

The cell formation problem in cellular manufacturing systems involves the decomposition of the manufacturing systems into cells. Part families are identified such that they are fully processed within a cell. The cells are formed to capture the advantages of GT such as reduced setup times, reduced in-process inventories, improved product quality, shorter lead times, reduced tool requirements, improved productivity, and better overall control of operations. The common disadvantages are lower machine utilization and higher investment due to the duplication of machines and tools.