PERGAMON

Computers & Industrial Engineering 38 (2000) 479–491

computers & industrial engineering

www.elsevier.com/locate/dsw

Re-engineering of the design process for concurrent engineering

Dunbing Tang[a,*], Li Zheng[a], Zhizhong Li[a], Dongbo Li[b], Shiqi Zhang[b]

[a]*Department of Precision Instruments and Mechanology, Institute of Manufacturing Engineering, Tsinghua University, Beijing 100084, People's Republic of China*

[b]*School of Manufacturing Engineering, Nanjing University of Science and Technology, Nanjing 210094, People's Republic of China*

Accepted 12 September 2000

Abstract

According to the requirements of concurrent engineering, three interdependency relationships (uncoupled relationship, coupled relationship and decoupled relationship) between design activities are presented in this paper. And the coupled relationship plays an important role in concurrent product design process. To represent the precedence relationships among design activities, a directed graph is used to describe the design process. And the interdependency relationship between activities is illustrated by a Design Structure Matrix which is the transpose of the accessibility matrix of the corresponding graph. Using the DSM, an algorithm of recognizing the coupled activities during the design process is presented. Moreover, an algorithm to figure out the order levels of activities during the design process is proposed. And both algorithms are illustrated with a die design example.

Keywords: Concurrent engineering; Design structure matrix; Directed graph; Product development process re-engineering

1. Introduction

The difficulties in designing complex engineering products do not arise simply from their technical complexity. The managerial complexity, necessary to manage the interactions between the different engineering disciplines, imposes additional challenges on the design process (Assine, Falkenburg & Chelst, 1999). In recent years, concurrent engineering (CE) has become increasingly important for product development. CE is a philosophy that suggests the need to consider design issues simultaneously where they were considered sequentially in the past. The sequential design process has been considered inefficient, since this type of design process typically leads to

* Corresponding author.
E-mail address: tangdb@ntl.pim.tsinghua.edu.cn (D. Tang).

0360-8352/00/$ - see front matter
PII: S0360-8352(00)00059-0

greater development time, greater cost, and lower overall design quality, all of which lower the overall profit generated by the design. The remaining challenge of managerial complexity is to transform the product design process from a SE (sequential engineering) environment to a CE environment. The important transformation approach practically relevant to this paper is the product design process re-engineering (Huang & Mak, 1998). When applied to re-engineer the product development process, it is mainly concerned with the rationalization of the product development activities, with the belief that a rationalized product development process is more likely to result in better product design decision.

The managerial complexity of the design process is contained by using management tools that model the interface and dependencies among the decomposed tasks. Assine et al. (1999) considered that managing the design process includes four major steps: (1) model the information and dependency structure of the design process; (2) provide a design plan showing the order of execution for the design tasks; (3) reduce the risk and magnitude of iteration between design tasks; (4) explore opportunities for reducing the project cycle time. And some design process modeling and management tools have been developed. The Project Evaluation and Review Technique (PERT) method is a digraph of a project (Spinner, 1989). In the PERT method, three probabilistic time estimates are given to each task. The critical path method (CPM) (Spinner, 1989) is a variation of the PERT method. And CPM assumes a time-cost tradeoff rather than probabilistic times used in PERT. Both methods improve the process flow only by crashing the critical activities, but they do not consider iterations and feedback loops that are characteristics of engineering designs, and they ignore the concurrency and overlapping of the design process. To study information management processes the standardized IDEF0 modeling technique is a useful tool. IDEF0 was driven from Structural Analysis and Design Technique (SADT (Ross, 1977)). The IDEF0 technique supports the needs of modeling the process in a formalized manner to be able to compare and refine the modeled process. However, the IDEF0 methodology is inefficient to support the modeling of concurrent activities. And iterations between activities are difficult to analyze with the help of the IDEF0 technique. A more compact representation of a design process is the Design Structure Matrix (DSM) (Steward, 1981). It overcomes the size and visual complexity of all graph-based techniques. And matrices are amenable to computer manipulation and storage. Kusiak and Park (1990), Kusiak, Larson and Wang (1994) and Malmström, Pikosa and Malmqvist (1999) have used DSM in their researches for CE implementation. In this paper, we also use DSM representation to describe the product design process. And a new method using simple and understandable algorithms is presented to re-engineer the product development process for CE.

This paper is organized as follows. In Section 2, the interdependencies among activities during design process are analyzed and summarized into three types: uncoupled relationship, coupled relationship, and decoupled relationship. Section 3 presents and interprets the DSM. CE calls for the simultaneous execution of coupled product development phases (Fu & Gu, 1997). Moreover, the coupled relationship between activities plays an important role in concurrent design process. Thus, Section 4 presents an algorithm to recognize the coupled activities during the product development process. Section 5 proposes an algorithm to figure out the order levels of every design activities. And the design process re-engineering is executed according to the order levels. The algorithms above have been applied to re-engineer the traditional stamping die development process to meet the needs of CE. Section 6 gives the conclusions of this paper.