An Expert System for Assembly Based on Axiomatic Design Principles

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Abstract. Increasing demands for lower cost of goods, due to international competition, has developed a new area of rationalization for increased productivity which can be achieved by applying new radical methods of production principles. Design for Assembly (DFA) is one of such methods that should be considered in the early design stage in order to cope with the increasing demands of lower cost, improved working environment, and higher wages. When Axiomatic Design (AD) is implemented with DFA in an intelligent way, a new area of design concepts would be realized. This study examines some elements of intelligent design systems to assess manufacturability of a product through the development of a knowledge based expert system for assembly (KBESA). The knowledge base has been acquired from DFA along with AD concepts with emphasis on the conceptual design stage where the structure of the product as a whole is considered. These concepts have been implemented in a case study illustrating its applicability.

Key words. Axiomatic design, design for assembly, knowledge base, expert systems.

1. Introduction

Many large companies in the world have found that up to 85% of a product's manufacturing costs are determined before their manufacturing department becomes involved with new product design [1]. By applying Design for Assembly (DFA) concepts that integrate both design and manufacturing functions and people into one group, tremendous success can be achieved in the transition of research and development (R&D) to manufacturing. This success is accompanied by involving a wide range of people; product managers, engineers throughout different departments, sales people, supervisors of manufacturing, vendors, and the most important factor, the hourly people. When DFA approach is appropriately used the following benefits can be realized:

- optimization of manufacturing process from the beginning;
- proper use of available manufacturing and inspection environment;
- manufacturable and cost-effective product design;
- inter-disciplinary creativity.

The major goal of DFA is concerned with reducing the cost of a product by simplification of its design. This can be accomplished during the conceptual stage of design (at initial attempt) or downstream of the design stage (to improve an existing design). The important criteria is to reduce the number of individual parts that are to be assembled and to ensure that all parts are easily manufacturable and assembleable.
In many current practices, assembly processes are not studied in advance and, as a result during the manufacturing stage, high costs result due to insufficient assembly.

DFA provides guidelines for the better design of a product by reducing the number of components and by avoiding tedious movements of assembly motions such as lifting or turning. It also simplifies inventory and record keeping, improves material and production flow, reduces the number of parts in a product, replaces certain parts with better alternatives, and improves the assembly process.

Boothroyd [3] has pointed out this costly problem and developed a new area of DFA with special emphasis on reducing the number of components. Even though his classification of assembly methods is divided into three categories, depending on production volume (manual assembly, high-speed automatic assembly, and robotics assembly), all of them strive for the one goal of reducing the total number of components which, in turn, reduces the assembly cost. For many products, comparing the assembly cost is a good way of analyzing product design efficiencies since this is one of the major criteria for all industrial organizations.

A product design can be evaluated using two criteria. Firstly, by examining product components and searching for the elimination of or combination with other components. During this search, production feasibility should not affect the idea generation, since this will discourage possible search. Components which can be combined, but are hard to produce, can be reanalyzed at a later stage for an alternate production method. Secondly, by estimating the time of assembly (picking, moving, inserting, positioning, etc.). This should be made with the ultimate aim of comparing different product designs. Eliminating or combining components do not always bring advantageous effects, but resulting components can lead to 'impossible to manufacture' components or unusually high production or assembly costs. The following steps are used in order to generate the DFA evaluation of product design efficiency [3]:

- Break the product into a number of components and organize them by list of component names. For each component, determine if it needs orientation during the handling process. Also study how is it fastened to the existing components.
- For each component, determine whether it belongs to a rectangular envelope or a cylindrical envelope. Determine the dimensional and handling requirements (grasp, manipulate, etc.) for corresponding envelopes. Also determine if it needs more orientation before it gets combined (assembled) to the existing components.
- Reassemble all components and study the assembly processes. Determine what kind of assembly processes (insertion or other joining) are required.

2. Contribution of Research

The objective of this research is to develop a knowledge-based expert system for assembly (KBESA) that integrates DFA and AD concepts. This will be achieved by the following steps:

(1) Design and develop a new expert system structure to integrate design for assembly concepts.