Research Paper Engineering

Design for Production: Basic Concepts and Applications

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ABSTRACT

Design for production (DFP) refers to methods that evaluate manufacturing system performance as a function of product design variables. DFP can advise a product development team to consider changing the product design to avoid problems or improve profitability. In addition, DFP can provoke suggestions to improve the existing manufacturing system. This paper describes the DFP approach and discusses applications to a variety of manufacturing settings, including production lines, factories, and supply chains. The leading product development teams plus those involved in product designs, and those directing product development organizations can use this perspective to guide the product development process and create products which will be more profitable.

Keywords:

I. INTRODUCTION

For successful new product development (NPD), the ability is required to predict, early in the product development process, the life-cycle impacts of a product design. Ignoring downstream issues (or producing poor estimates) leads to poor decisions and product designs that cause unforeseen problems. Consequently, these products must be redesigned. Accurate predictions allow a product development team to create a superior design that performs satisfactorily in all manners. This, obviously, reduces the number of redesign iterations, the time-to- market, and the development costs. Thus, manufacturing companies have developed many design decision support tools that form the class of Design for X (DFX) methodologies.

During product design, the performance of the manufacturing system at all levels, from supply chain to production line, is an extremely important issue. The performance of these systems is disregarded because it is considered hard to model and designers don't know much about the manufacturing system. However, practical manufacturing system models are becoming more available. Moreover, the rapid introduction of new products indicates that existing facilities outlive new products. Instead of designing the manufacturing system around the product, the product must be designed to fit the facility.

Design for Production (DFP) refers to methods that evaluate manufacturing system performance. For example, does the production line have enough capacity to achieve the desired production rate? How long will it take the factory to complete customer orders? How much inventory will be required to maintain superior customer service in an international supply chain? Answering such questions

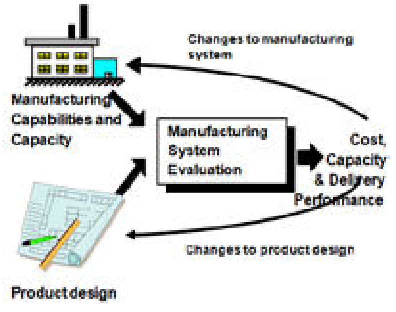
requires information about product design, manufacturing requirements, and production quantities along with information about the manufacturing system that will create the product.

II. DFP OVERVIEW

Much effort is spent trying to improve manufacturing system performance by improving manufacturing planning and control systems and developing more sophisticated scheduling procedures, and these efforts have shown success. However, it is clear that the product design, which requires a specific set of manufacturing operations, has a huge impact on the manufacturing system performance. Hence, understanding the relationship between the two is important to the effort of improving the manufacturing system performance for the product.

The DFP approach requires considering not only the details of the required manufacturing technologies but also a comprehensive view of the entire manufacturing system that will produce and distribute the product. Product development teams must plan how to design new products to exploit the capabilities and capacity that already exist. Suppliers and logistics issues are highly relevant and must be understood as well. The DFP approach can lead a product development team to consider changing the product design to avoid problems and improve profitability.

Figure 1 illustrates the basic idea of the DFP approach. The approach starts with critical design information about a new product and data about manufacturing capabilities and capacity (the type and number of resources available). The critical design information is used to determine the necessary manufacturing operations and the costs and times associated with those operations. In addition, the approach requires similar information about the other products that will be made in the manufacturing system at the same time as the new product. This is the input for the manufacturing system evaluation model, which estimates performance measures such as cost, capacity, delivery performance, inventory, or manufacturing cycle time.



The manufacturing cycle time (also called the throughput time or the flow time) is the interval that elapses as the manufacturing system performs all of the operations necessary to complete a work order. The manufacturing cycle time is the sum of the workstation cycle times at all workstations that works order must visit. Analyzing any inadequate manufacturing system performance leads to suggestions for redesigning the product or the manufacturing system. In some DFP approaches, the manufacturing system performance is used to compare a variety of product designs, which leads to the selection of the best design.

III. DFP AND PRODUCTION LINES

An example of a DFP guideline can be found in automobile manufacturing. The length of a new automobile's chassis is a critical design variable that must be determined early in the vehicle development process. In order to avoid expensive modifications to the robotic assembly line that will make the vehicle, the chassis length is constrained by the size of the existing automated fixtures [11].

Taylor et al. [1] present a DFP technique that provides insight into the impact of different printed circuit board (PCB) designs on the manufacturing system performance. In the setting that was studied, there are four different types of printed circuit boards. The PCB designs include components mounted on both sides of the PCB along with some through-hole components. The design alternatives mainly focus on varying percentages of surface mounted and through-hole components along with different process routings. The boards have different component counts resulting in different processing times at different resources.

The printed circuit boards are manufactured in a flow shop manufacturing system. The processing sequences for the boards have twenty-three processing and assembly operations. Different resources in the manufacturing system have different number of machines. The key performance measures are the relative utilization of various processing resources and the capacity of the system measured in boards per time unit. Due to their different processing requirements, different product designs yield different system capacity.

The objective is to introduce the new product with minimal disruption of the facility. The study shows that one of the four initial designs performs significantly better than the others. By moving components from one part of the PCB to another to allow for more favorable product routings, the adopted design increases system capacity by over forty per cent without reducing the number of components or increasing production equipment or personnel.

Hernandez et al. [12] analyze preliminary designs of an absorber-evaporator module for a family of absorption chillers. The evaporator tube design has six design characteristics: outer diameter, wall thickness, fin density, fin height, fin thickness and material. The absorber tubes have four design characteristics: outer diameter, wall thickness, fin density and material. The chiller designs are combinations of the number and types of these tubes.

The manufacturing system for the chillers is a simple production line with three subassembly fabrication workstation an assembly workstation, and two post-assembly workstations. The authors propose a product family approach to generate alternative designs for the product. The key manufacturing system performance measures are the average manufacturing cycle time and its standard deviation (across the different products in the family). The approach uses a queueing model to estimate manufacturing cycle time. The approach sets goals for these measures and for cost and then forms the product family by selecting tube lengths and tube types that minimize the deviation from these targets. The associated reduction in component variety and cycle time results in a reduction of physical inventory and associated investment with savings of more than $1.25 million.

IV. DFP AND FACTORIES

Herrmann and Chincholkar [8, 15] describe a DFP tool that models a factory as a queueing network. The DFP tool uses queueing network approximations to estimate the average manufacturing cycle time at each workstation. The tool calculates resource utilization, determines the average manufacturing cycle time for a new product, and provides redesign suggestions for improving the manufacturing system performance.

Chincholkar and Herrmann [16, 17] extended this technique to create a DFP tool for evaluating how embedding passives affects manufacturing system performance. Their study analyzed the PCB that serves as the central processing unit for the AS900 controller. In this study, the manufacturing system is a job shop that makes two kinds of products, a conventional CPU board and a new CPU board that contains embedded passive components. The system performance measures considered were resource utilization and workstation and product manufacturing cycle time.

The conventional CPU board is a double-sided board with twelve layers. It is 18 inches long and 12 inches wide. It has 627 discrete resistors, 54 discrete capacitors, 53 bypass capacitors, 71 network parts, 53 diodes, 17 zeners, 64 transistors, 28 inductors, 12 transformers, and 108 integrated circuits. The two products follow different processing sequences. As a result of embedding passive components in the substrate, the assembly requirements for the new CPU board are lower than the conventional CPU board. However, certain processing operations associated with embedding passives are added to the PCB processing sequence. For this scenario, as the percentage of embedded passives in the new CPU board change, the performance of the manufacturing system also changes.

V. DFP AND SUPPLY CHAINS

Hewlett Packard used a DFP approach to determine if a redesigned product could yield better supply chain performance. The approach (described by Lee et al. [4]) includes an inventory model to evaluate alternative product and process designs. The model, applied to the Deskjet-Plus Printer Division, reflects the operational and delivery service considerations for multiple market segments. The manufacturing system for the printer is a supply chain with two stages: printed circuit board assembly and final assembly & test. The supply chain is a network of manufacturing and distribution sites. The manufacturing system operates as a pull

system with smaller incoming material safety stocks and replenishes the distribution centers. The distribution centers operate as inventory stocking points and operate in a make-to-stock mode with large safety stocks. The replenishment lead time for the distribution centers is a sum of the transportation times, manufacturing flow time in the factory and delays due to other contingencies.

V. SUMMARY AND CONCLUSSIONS

It is important that the product development team understand how their design decisions affect the manufacturing system performance. Having this feedback early in the design process avoids rework loops needed to solve manufacturing capacity or other system performance problems. The results described in this paper illustrate the use of DFP techniques to production lines, factories, and supply chains. The DFP techniques include new prototyping techniques, capacity analysis, inventory models, queueing network approximations, discrete event simulation, and product family optimization.

The DFP methodology addresses the relationship between a product design and a given manufacturing system using performance metrics such as manufacturing cycle time, inventory, cost, and capacity. There exist a wide variety of products and manufacturing systems and all can benefit from the design for production methodology. The requirements for the DFP approach will vary depending on the type of product being designed and the manufacturing system characteristics.

Tools based on the DFP approach must be designed based on the specific class of target products and manufacturing systems. This in turn requires understanding specific production line, factory, or supply chain performance metrics. The product development team must identify how different design decisions affect these performance metrics and to what extent.

Design phases that have larger impacts on manufacturing system performance should include DFP techniques. This analysis will help the team develop and validate models that relate the critical design information for the associated design phase to these performance metrics. Identifying key product design characteristics would involve suitably decomposing the design into components and developing modular product architectures.

The development of DFP tools must also take into account the data available about the product and the manufacturing system, the effort involved in making that data accessible to the development team, and the time constraints that limit the amount of analysis that can be done. Herrmann and Schmidt [21] discuss a technique for modeling product development organizations and propose that such models can improve the implementation of design tools.

Finally, a product development team should consider the product's entire life cycle. Different DFX techniques consider different phases of the life cycle and may make contradictory design improvement suggestions. Therefore, successfully employing techniques such as DFP requires using them in a coordinated way to design a more profitable product.

ACKNOWLEDGMENT
The author acknowledges the help provided by Dr. Girish Thakar, who collaborated with the author on research into developing DFP tools. The author would also like to thank some of his colleagues and college authorities for helping him directly or directly.

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