

Research of the optimization methods for mass customization (MC)

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Abstract

A group of graphical models and mathematical models are used to describe the methods of mass customization (MC). First, an efficiency optimization model for MC is used to show that the implementation of MC is a gradual process. Second, two optimization methods for minimal customization quantity are presented, which are to widen the optimization breadth in a product's family and to reduce the customized quantity in every section of the production process. Finally, two optimization methods for minimal customization depth are presented, which are to increase optimization depth in a product's family and to move the customer order de-coupling point (CODCP) backwards in the production process. All of these works integrate the methods for MC, which can help in the overall use of these methods.

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Keywords: Mass customization; Optimization; Systematic engineering

1. Introduction

At the present time, because of the globalization of competition in the manufacturing industry and the diversification of customers' demands, more requirements for enterprises have been put forward, such as more product variety, shorter time-to-market, lower product cost and higher quality. Therefore, mass customization (MC) has developed quickly and has gradually become one of mainstream production modes of manufacturing industry in the 21st century. In MC, customized products are produced with the efficiency of mass production. No doubt MC is an ideal mode that the manufacturing industry will pursue far into the future. In fact, the thinking of MC can be found in many advanced manufacturing systems. The realization of MC is a type of gradual process [1–4].

The implementation of MC is a systematic engineering operation, which involves the integration and optimization of product and process, manufacturing enterprise and group of companies.

There are many problems worthy of being studied deeply, such as a full-scale description of the various thinking, methods and optimization goals of MC, and the building up of mathematical models, and so on. In the paper, a group of graphical models and mathematical models are presented and used to describe the methods and direction of optimization for MC.

2. Efficiency optimization model for MC

The implementation of MC is a gradual process. Fig. 1 shows an efficiency model for MC and reflects the concept of the gradual process. In the figure, production efficiency is described in the Y -coordinate, and the logarithm of product batch is described in the X -coordinate. The production efficiency has an inverse correlation with the average single piece cost of products, and for the different products, the definitions of single piece, small batch, medium batch and mass production are different. Accordingly, the slope of the lines is different in Fig. 1 for different products.

Here, when the cost of products is taken into account, the production efficiency E is represented by the reciprocal of the product average cost and the dimension is "1/US \$". When the lead time of products is calculated, the production efficiency E may be represented by the reciprocal of the average lead time of product and the dimension is "time". The product batch is denoted as B , and its dimension is "piece". So the equation of the line representing traditional production modes in Fig. 1 can be shown as follows:

$$E = E_0 + B_0 \log B \quad (1)$$

E_0 is used to describe the efficiency of a single customized product. B_0 is used to represent the slope of the line. The bigger the product batch B , the lower the average cost (or lead time) of the product and the higher the production efficiency. The reason for using $\log B$ as the X -coordinate is that the increasing speed of cost (or lead time) will gradually decrease with the increment of product batch.

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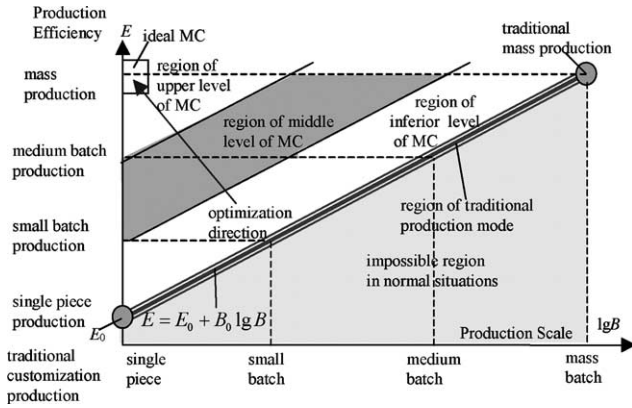


Fig. 1. The efficiency optimization model for MC.

The region under the line is an impossible one in normal situations. That is to say, implementing mass production with the efficiency of small batch production is impossible in general. The region of the efficiency of MC is located at the upper of the line. The greater is the value of $E/\log(B + 1/B_0)$, the greater is the benefit of MC. The value of E embodies the production efficiency, and the value of C represents the average cost (or lead time). The value of $E/\log(B + 1/B_0)$ reflects the level of MC at a certain extent. Therefore, F_1 , one of the optimization objects of MC, is as follows:

$$F_1 = \max \left\{ \frac{E}{\log(B + 1/B_0)} \right\} = \max \left\{ \frac{1}{C \log(B + 1/B_0)} \right\}, \quad B > 0, C > 0 \quad (2)$$

The model is just used for accounting for the optimization direction of MC from two aspects, product batch and efficiency. The optimization direction is to reduce the batch, cost and lead time of products: it does not involve concrete methods.

Enterprise has to consider how to meet a variety of customers' demands on the whole. MC optimizes manufacturing systems and products in two aspects: product and process, namely the optimization of the product dimension (or space dimension) and of the process dimension (or time dimension).

The main methods of optimization in the product dimension are as follows: (1) to differentiate and classify customers' common and individual demands rightly; (2) to differentiate and classify common and individual parts in products rightly; (3) to merge common portions of different products in the product dimension; (4) to decrease customized parts in products; (5) to extend the optimization range of a product's family as widely as possible; (6) to deepen the optimization depth of products, and enhance the modularization level of the products.

The main content of the optimization of the process dimension is as follows: (1) to differentiate the process of mass production and the process of customization rightly;

(2) to decrease the processes of customization production and to increase processes of mass production; (3) to move the customer order de-coupling point (CODCP) backwards. The CODCP refers to the changing point at which the production mode is transformed from mass production to customized production.

3. The optimization methods for minimal customization quantity

3.1. An optimization model for minimal customization quantity

Fig. 2 shows an optimization model for a minimal customization quantity facing MC. The model describes the optimization methods in product dimension and process dimension in view of the minimal customization quantity.

Parts of products are divided into two big kinds by the optimization model in Fig. 2. One is customized parts, their quantity being represented as N , whilst other is commonly used parts, their quantity being represented as J . The optimization in the product dimension is to decrease the quantity of customized parts N .

In Fig. 2, the production process is divided into two parts. One is the customizing process, its number of steps being represented as K . The other is the process of mass production, its number of steps being represented as L . The optimization of the process dimension is to decrease the quantity of the steps of the customizing process K .

In general, the essential of MC is to decrease the area of the small rectangle (the customization quantity NK) as much as possible.

Therefore, in view of minimizing the customization quantity, F_2 , one of the optimization objects of MC can be expressed as follows when a batch of a product is given:

$$F_2 = \min\{NK\}, \quad N < J, K < L \quad (3)$$

3.2. Method for widening the breadth of optimization in the product dimension

In order to decrease the quantity of customized parts N in Fig. 3, one method is to widen the breadth of optimization in

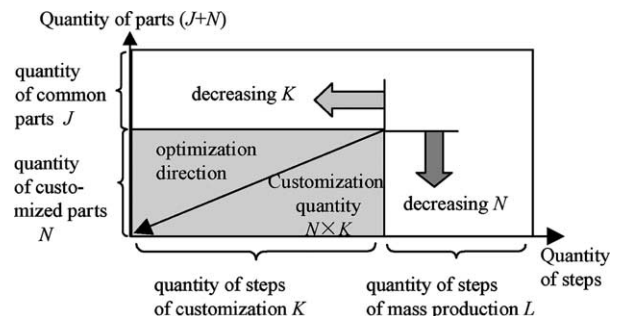


Fig. 2. An optimization model for minimal customization quantity.

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