Integrated Control of the Manufacturing System

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Abstract: - In this paper, we propose a method to control the entire production process, starting with customer enquiry up to product delivery, for the make-to-order (MTO) manufacturing system. Method for integrated control of the job shop type manufacturing system proposed in this paper aims to facilitate the connection between the two departments and to achieve integrated control of job shop type manufacturing system on the basis of Earning Power (EP) evaluation. It gives a more accurate picture of a firm's profitability than gross income. The purpose of this paper is to demonstrate the ability of the proposed method on a real case and to illustrate the applicability of mathematical models that were proposed. The main problems for a MTO company manager, i.e. problems related to order acceptance and machine control are solved by the new integrated control method, which is included in this paper.

Key-Words: - Earning Power estimation, control of manufacturing system, order acceptance, MTO manufacturing system, process simulation

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1 Introduction

Manufacturing companies differ in how they respond to customs demands. Some, called make-to-stock (MTS) companies, anticipate customer needs, producing series standard products, and deliver the products when customer order occur. At these companies, all given products are usually used for general purpose, and therefore does not cover the exact customer needs. The estimated delivery periods required by customers can be easily observed. On the other hand, as there is repetitive production, the products can be manufactured on manufacturing systems as single production line. Therefore, manufacturing systems (and even workstations forming these manufacturing systems), are product dedicated. Changing a product that one MTS manufacturing system performs is time consuming. In additions, inventory costs are high.

Others, called make-to-order (MTO) companies, start the manufacturing process only after the order content was acknowledged and accepted. Compared to MTS companies, these have a better responsiveness, because they can deliver products more varied and even customized. As a result, customer's requirements are fully satisfied and inventory costs are low. However, these advantages can be realized only if the lead times can be reduced enough so that the delivery period required by the customers is respected. In additions, MTO manufacturing must be job shop and its workstations must be process dedicated.

Order Acceptance (OA) is a managerial activity that deals with translation of the customer enquiries into orders. It may also deal with related decisions, such as due date and price determination. The order acceptance strategy has a large influence on the performance of a company. However, many enquiries only request a delivery time or a delivery quantity for a product without really committing them. This is especially true in today's e-marketing environment. The approach to processing customer enquiries varies widely. There are two common cases: sequential enquiry processing and concurrent enquiry processing. In the first case, only one enquiry is considered at a time. Generally, an enquiry requesting a large quantity or short delivery time needs to be treated in this sequential enquiry processing style. In second case, a set of enquiries jointly at periodical intervals is concurrently processed. For enquiries that are processed concurrently, an optimization model is built to evaluate them against limited capacity in order to select a subset which will be fulfilled.

The main disadvantage of methods of acceptance or rejection decision of an order is that this decision shall be based on time factor and capacity factor and takes too little account of performance that could be obtained if a particular order would be accepted.

Many articles discuss the problem of integrated process planning and scheduling, defined as: giving the *N* jobs which are to be processed on *M* machines find an operations-machines sequence and schedule for each job, which is optimal with respect to some criteria. The main approaches of this problem are agent - and algorithm - based. The goal is always implementation of CAD/CAPP/CAM integration [1].
In conclusion, the performance for each level of operation will not be evaluated thus the operation structure and tool used in process must be properly selected from a number of options so the operation performance to be maximized. In addition, there aren't established any alternatives for situations where the technological flow is affected by bottleneck.

The criterion considered the most important when analyzing the profit capacity of a MTO company, i.e., to be competitive on one segment of the market, this criterion it is called earning power, EP. EP modeling is a solid strategy when selecting orders that bring profit to companies. Based on an EP determined for each order, one order can be accepted or rejected. Thus, there are going to be accepted just those orders that can bring significant profit to company and increase of market shares. A selection takes place for each job, i.e. only the jobs that can have a favorable economical EP are kept, and the other ones are outsourced to some other processing companies. Regarding operations, optimal parameters for processing system are determined depending on the maximum EP value. In this way, it can be achieved an integrated control of manufacturing process.
By "Integrated Control of the Manufacturing System" the manager has the opportunity to organize all received orders in order to increase company competitiveness.
Manager can interact with the economic environment to make an offer and a price quotation so that the company is competitive.
The EP evaluation is made at the level of processing operations, job, and ultimately the order level.

2. Problem formulation

In this paper, we propose a method to control the entire production process, starting with customer enquiry up to product delivery, for MTO manufacturing system. Control achieved with the proposed method is based on modeling the relationship between cost and time, two very important elements of manufacturing process performance evaluation.

In order to better represent the specified goal of manufacturing process we propose (as a novelty) as a criteria the Earning Power (EP). It is both synthetic (because it reflects the essential motivation of manufacturing process) as compliant with the most important five performance aspects, namely: profitability, conformance to specifications, customer satisfaction, return on investment and materials/overhead cost, selected by researchers in order of importance.
By definition, Earning Power is an operating income divided by total assets. Operating income is an income resulting from a firm's primary business operations, excluding extraordinary income and expenses. It gives a more accurate picture of a firm's profitability than gross income.
Asset is something that an entity has acquired or purchased, and that has money value (its cost, book value, market value, or residual value). An asset can be: something physical, such as cash, machinery, inventory, land and building; an enforceable claim against others, such as accounts receivable; right, such as copyright, patent, trademark or an assumption, such as goodwill.
For determination of EP it must be estimated: cost, time, asset, and price.
Current methods for estimating the cost and time are based on breakdown of the product into elements, cost estimation of each element and summing of other costs. As an element, we can consider one product component, one manufacturing component or one activity component. To estimate the cost for each element there are used element's different features that are closely related to cost. With few exceptions, estimation methods lead to cost estimation without a mathematic model describing relation between cost and element's different features. As a plus, those methods have a slight adaptation capacity to different specific situations because the information that is provided in order to estimate is general and does not adapt to specific case.
Therefore, in this paper, cost and time will be estimated by techniques that are based on analytical modeling, neuronal modeling, or k-nearest neighbor regression. Each of these techniques cover a range of specific cases, namely: analytical technique covers process cases with all known regularities. The technique based on neuronal modeling covers cases when a large number of similar products are manufactured, slightly different. Moreover, k-NN regression technique covers cases when there is little data to produce a model (production is diverse and manufactured series are few).

It is not difficult to estimate the asset because in the balance sheet there are quite accurate and updated data.
Price estimation goes from costs and represents the company mission in relation to the market.
Order acceptance problem is usually treated in the literature considering the single resource case with deterministic processing time. The acceptance criterion is based mostly on capacity-driven approach. We cannot take into consideration that company performance is essentially dependent on the manner in which accepted orders are appropriate to all characteristic elements of the manufacturing system. In accordance with the method proposed in this paper, order acceptance is Earning Power-driven, while work-load, due-date and price are considered as restrictions.
In present, machine control it is made independent to order features, such as price. This is why, although the local control of the machine is optimal, the order performance level is not maximum. The method presented in this paper removes the disadvantage in that the machine control is based on simultaneous optimization of all manufacturing processes caused by order fulfillment.
Finally, in present order acceptance, planning and scheduling of the production process, and machine control can be solved separately. In this paper, we propose an integrated control method for the three aspects where Earning Power it is used as decision criterion when accepting and rejecting the order.

3. Earning Power modeling

In this paper, cost and time will be estimated by some techniques based on analytical modeling, neuronal modeling, or modeling by k-nearest neighbour regression.

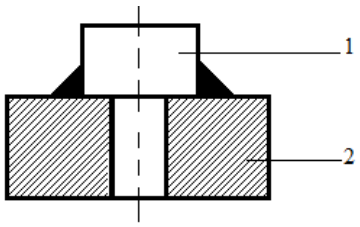

Fig. 1 Manufacturing part
1 - rod, 2- plate

We consider that we have to manufacture the part from Fig. 1 and the manager must decide whether to accept this order. The technological process needed to process the part consists of the following operations: turning, drilling and welding.

In order to evaluate the order EP we have to calculate job EP and operation EP. To do this, the order will be divided in job 1 (rod 1, Fig. 1) and job 2 (plate 2, Fig. 1).
To perform job 1 it is necessary to use the turning operation. For job 2 we need drilling and welding operations.
From the analysis of appropriate literature we can provide the following observations:
- Generally, cost-estimating approaches can be broadly classified as qualitative estimation methods (intuitive or analogical methods) and quantitative estimation methods (parametric or analytical methods).
- Method implementation consists of either the application of an algorithm, or the developing of a knowledge-based estimation system.
- Algorithm or knowledge-based systems are design so that the field in which they can be used for cost estimation is either a class of processes or a class of geometrical shapes of product, but never a workstation (or group of workstations). It comes often in the situation to use several different models for calculating cost activity which a workstation makes on a semi-manufactured. Also frequently we can have the case when none of the models take into consideration the specific behavior of that workstation. On the other hand, this field is extended to the level of processing operations of one part or of any stage of that operation, but never the entire batch processing. Therefore, the total manufacturing cost is estimated by adding the machining cost, material cost, set-up and changeover costs, calculated for one part.
- The data bases on which to build models or knowledge-based systems are collected from machining handbooks, from experts or from records about previously manufactured products. This last source contains only global data because, currently there's no concern to record specific data.
- Finally, after being built, models or knowledge-based systems are not updated, not even periodically. Therefore, evolution of workstations behavior is not considered and recent experience is not used.
Taking into consideration the fact that a job consists of several operations and knowing the price P_{ijk} for each operation, the cost c_{ijk}, the asset A_{ijk} and the time t_{ijk} we can build the job model, meaning the *EP* for each job (1):

$$EP_{ij} = \frac{P_{ij} - \sum_k c_{ijk}\left(p_{jkn}\right)}{\sum_k A_{ijk} \cdot t_{ijk}\left(p_{jkn}\right)} \qquad \left[\frac{Euro}{Euro \cdot \min}\right] \qquad (1)$$

For job 1 containing a single operation, EP's job is just the EP for turning operation.
The calculation for job EP is an effective tool for making decisions about accepting or outsourcing the job. The company will keep only those jobs that bring favorable EP and the other ones are given to other manufacturing companies for execution. The manager can easily make a selection of more favorable jobs for its company.
We can calculate the EP for the other orders in the order entry pool in a similar manner. In the end, all EP values of all orders are ordered in a decreasing sequence. The orders with a maximum calculated EP that brings economical effect to the company would be kept. The other orders will be outsourced to other manufacturing companies.
It results that the manager will have an overview of the order EP to make an order acceptance. Order acceptance will be made after evaluation of maximal EP values and after selecting only those orders that may bring profit to the company.

4. Conclusion

The authors propose a new method of management of MTO manufacturing system. The method is based on earning power used as an evaluation criterion for accepting and rejection orders that have favorable economic effect. Thus, for each order there are accepted those orders for which the EP has the maximum value. The order acceptance is in descending EP order. For each job, a job selection takes place, meaning that those jobs with a favorable economical effect are kept and the others are outsourced to other processing companies. For an operation, optimal parameters for a process system will be made according to the maximum value of EP. Thus, a manufacturing process control will be performed.

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