Annals of Warsaw University of Life Sciences – SGGW
Forestry and Wood Technology No 73, 2011: 30-35
(Ann. WULS-SGGW, Forestry and Wood Technology 73, 2011)

Optimization of furniture technology at design stage

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Abstract: The aim of this paper is to present a conception of optimization of furniture technology that can be performed at design stage. The proposed solution allow for assessment and optimization of machining cost of a design alternative during design process. Moreover, it is possible to perform simulations of production flow to check how the introduction of new products affects the performance of the whole production system.

Keywords: design to cost, furniture, optimization, technology

INTRODUCTION

The growing competition on globalized market make furniture companies frequently update their offer, to follow the design and technological trends and changing style of life. The new promising ideas should be quickly introduced to the market and the design stage of new products should be relatively short. Moreover, to compete with cheap mass-produced goods many companies offer make-to-order furniture that can be customized according to customer specification. This, in turn, results in high variety of parts within production plant. On the other hand, even in the case of high quality products, the price of them cannot be neglected. Unfortunately, the design to cost methodology may require much time to determine all cost drivers and to prepare the sufficient number of design alternatives before the target cost is achieved.

Numerical methods may support the design to cost approach. Virtual prototypes may be tested for strength, rigidity, stability and even ergonomics using specialized computer software (Dzięgielewski and Smardzewski 1995, Smardzewski and Matwiej 2005, Smardzewski and Papuga 2004). Moreover the numerical optimization allow for automatic comparison of generated design alternatives “in computer memory” until the minimum of cost function is reached. There is a significant number of solution for optimization of material volume within a piece of furniture with strength and rigidity constraints (Gawroński 2005a, Kłos 2006, Smardzewski 1992). Numerical methods allow for the reduction of material cost without violation of normalized safety requirements and without affecting functionality.

However, there is a lack of similar, numerical solutions dedicated for furniture industry that focus on machining cost.

AIM OF PAPER

The aim of this paper is to present a conception of optimization of furniture technology that can be performed at design stage.

DESIGN TO COST WITH NUMERICAL METHODS

The proposed cycle of preparation and assessment of a design alternative with the use of numerical optimization is presented in figure 1. Particular steps are explained below:

- CAD (computer aided design) – preparation of 3D model of a design alternative;
- CAE (computer aided engineering) – analysis of strength, rigidity, stability and ergonomics; optimization of material volume;

- CAM (computer aided manufacturing) – preparation of programs for CNC machines;
- OPTIMISATION – optimization of technological parameters and unit times of operations; generation of optimized technological routes;
- ERP – (enterprise resources planning) importing of optimized technological routes into computer integrated system; preliminary calculation of labor cost using ERP functionality;
- SIMULATION – simulation of production flow based on predicted demand for existing and new products; determination of the best scheduling policy and analysis of possible tardiness;
- COST – analysis of final cost based on simulation results, including setup cost, tardiness cost and external resources cost;
- MODIFICATION – modification of design alternative if the target cost is not met.

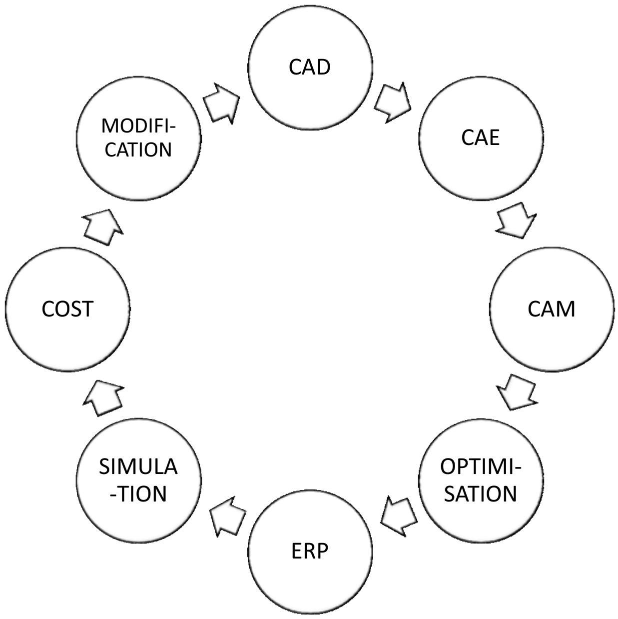

Figure 1. Proposed cycle of preparation and assessment of a design alternative with the use of numerical optimization

Traditionally unit times are determined through chronometrical observation of real manufacturing process. Therefore, it is difficult to assess the labor cost at the design stage. In the optimization of technological routes unit times are determined based on optimized feed rates and tool paths (or workpiece lengths). In case of CNC machines the data on tool path is extracted form control program prepared with the use of CAM software. Then the new optimized control program is generated. The proposed decision variables, limiting conditions and objective functions of the optimization are presented in figure 2.

The technological routes are generated based on optimization results and inference rules. The conception of expert system for building of technological routes in furniture industry is presented in Gawroński (2007).

Simulation step is very important because it provides more information on how the introduction of new products affects the performance of the whole production system. Simulations of production flow are used in scientific research to prove the effectiveness of particular scheduling policies (Kim and Bobrowski 1994, Vinod and Sridharan 2008). The use of production flow simulation in real factory may help choose the best scheduling policy based on the expected demand. The introduction of new products usually increases the variety of manufactured parts and, therefore, it may significantly increase setup times. The use of simulation at design stage should identify such situations and determine the expected setup cost. Moreover such simulation identifies the risk of tardiness. The simulation step provides the following metrics for performance of a whole production plant or department:

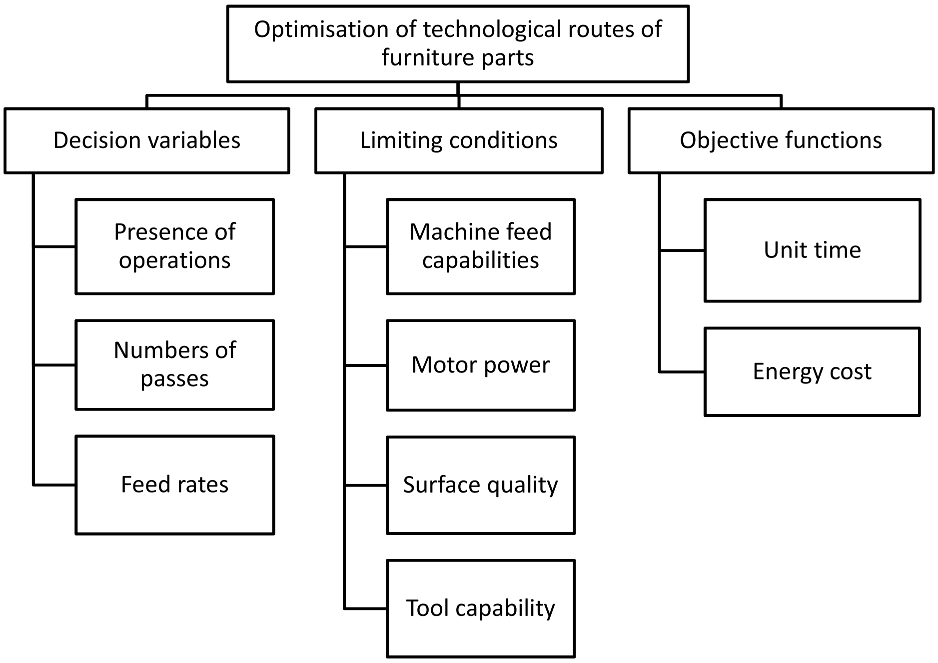

Figure 2. Proposed decision variables, limiting conditions and objective functions of the optimization

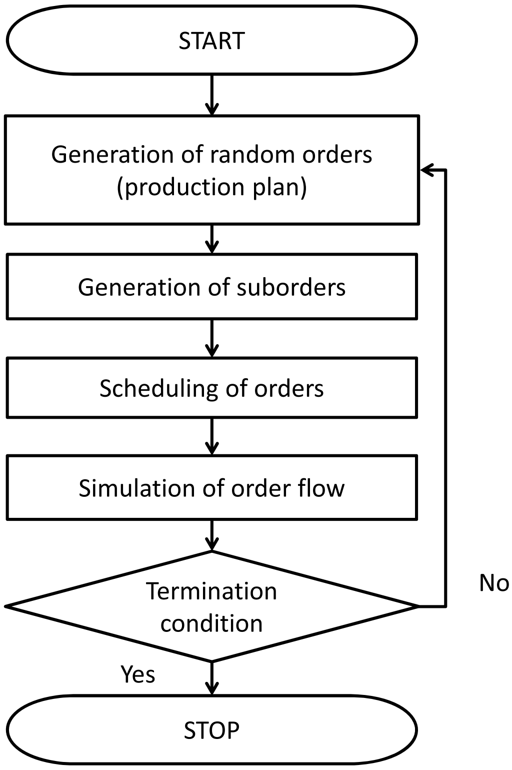

Figure 3. Proposed simulation procedure

- mean flow time,
- mean tardiness,

- maximum tardiness,
- percentage of tardy orders,
- setup time per operation,
- load of particular machines.

Since most technological factors are optimized for particular design alternative, then, if the assumed target cost is still not reached, the redesign of product's construction should be considered.

It is worth noticing that in literature the scheduling problem is considered either to be static (Artigues and Feillet 2008, Balas et al. 2008, Chen 2007) or dynamic (Kim and Bobrowski 1994, Vinod and Sridharan 2008). In static scheduling problem all jobs are known at the beginning of schedule and no more jobs arrive to the production system, until the whole schedule is finished. In dynamic scheduling job arrive to the production system continuously over time, so not all job are known at the beginning of schedule. Scheduling system in most furniture companies in neither fully static nor fully dynamic. Customers' orders are collected over specified period of time and then are aggregated to form a production plan. Due to the rational resource use, the time windows of subsequent production plans do overlap. Therefore, new jobs arrive to the production system, until the schedule is finished. That is why the simulation of furniture production process requires special attention and algorithms.

The simulation algorithm should iterate over significant number of overlapping production plans, first to overcome unstable condition resulting from initially empty production system and second to acquire suitable amount of data for statistical analysis. The proposed simulation procedure is presented in figure 3.

EXAMPLE RESULTS

The research on optimization of furniture technology are performed in the Department of Furniture Design for many years (Gawroński 2005b, 2009). The significant reduction of unit time was observed after optimization of feed rate for some operation for production of solid wood frame and panel furniture doors and drawer faces (table 1). Although these result of numerical calculation have to be verified experimentally, they look promising enough for practical applications.

Table 3. Example results of optimization

Operation	Mean reduction of unit time [%]
Rip sawing	34
4-side planing	60
CNC milling	48

The above applies also to the simulation results (figure 4). The results marked as "before optimization" apply to non-optimised unit times and scheduling policy that does not consider setup time. In turn "after optmisation" result are for optimized unit times with scheduling policy designed for reduction of setup times.

The reduction of mean flow time may enable shorter completion time of orders. In turn the significant decrease of machines' load make possibility for a factory to accept more customers' orders without further investments and without use of external resources.

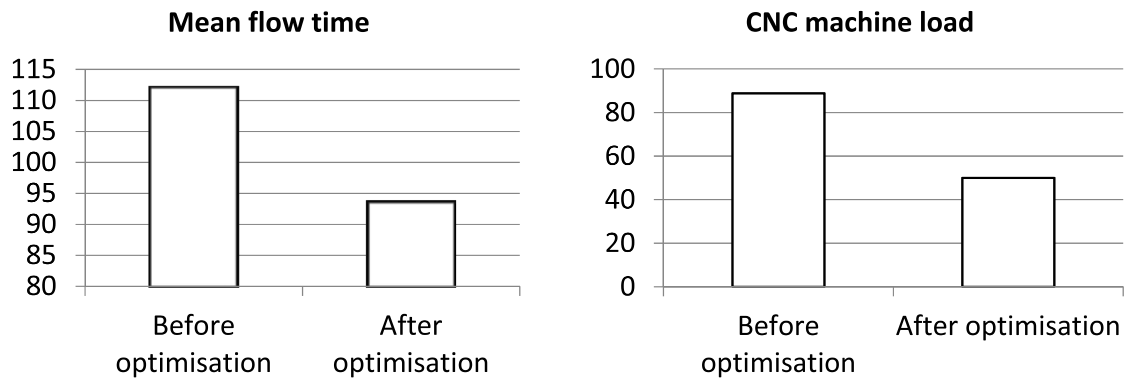

Figure 3. Example simulation results

CONCLUSIONS

1. The numerical optimization of furniture technology at design stage can lead to the significant minimization of operation unit times, order mean flow times and machines' load.
2. The efficient optimization of technology at the design stage requires seamless data exchange between optimization software and CAD/CAM/MRP systems.

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Streszczenie: *Optymalizacja technologii mebli na etapie projektowana.* Celem pracy było przedstawienie koncepcji optymalizacji technologii mebli, która może być prowadzona na etapie projektowania. Proponowane rozwiązane pozwala na ocenę i optymalizację kosztów obróbki maszynowej poszczególnych alternatywnych wersji projektu. Ponadto, możliwe jest przeprowadzenie symulacji przepływu produkcji celem weryfikacji, w jaki sposób wprowadzenie nowych wyrobów wpłynie na funkcjonowanie systemu produkcyjnego.

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