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SKALOWALNOŚĆ ZDOLNOŚCI PRODUKCYJNYCH REKONFIGUROWALNEGO SYSTEMU WYTWÓRCZEGO

Streszczenie: Artykuł dotyczy zagadnienia skalowalności zdolności wytwórczych. Jest to krytyczna cecha rekonfigurowanych systemów wytwórczych. Analizując pewien proces produkcyjny, koniecznym jest przeanalizowanie możliwych czynników wpływających na wydajność stosowanych konfiguracji wytwórczych oraz kosztów zmian bieżących zdolności produkcyjnych. Skalowanie zdolności wytwórczych może być dokonywane na poziomie systemu/systemowym, ale także na poziomie maszyn. Celem jest zaprojektowanie takiego system, który będzie efektywnie reagował na zmiany wymagań (zakresu produkcji).

Słowa kluczowe: skalowalność, rekonfiguracja, wytwarzanie, zdolności wytwórcze

SCALABILITY OF MANUFACTURING CAPACITIES OF RECONFIGURABLE MANUFACTURING SYSTEMS

Summary: The article deals with the issue of scaling manufacturing capacities, which is one of the decisive features of reconfigurable manufacturing systems. During the given process, it is necessary to analyse the possible impacts on the productivity of the manufacturing configurations and the costs of changing the current capacities. The scaling of manufacturing capacities can be implemented at the system level as well as at the machine level. The goal is to design such a system that will respond effectively to changes in demand.

Keywords: scalability, reconfiguration, manufacturing, capacity

1. Introduction

Reconfigurable manufacturing systems are independently scalable from time. This time depends on the initial design of the system, which is dependent on market conditions [1]. A new system is proposed when it is necessary to realize

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the manufacturing of new variants of a product or component family [2]. A new system offering reconfigurability must be designed as follows [3]:

- Implementation of the design of a new system and machines with adjustable functionality, which will enable its capacity scaling in response to market requirements. The given system capability is responsible for system and machine convertibility within the requirements for the manufacturing of new products. Adjustable system functionality should guarantee: 1. Increasing manufacturing capacities at the system (adding layout devices) and machine level (adding modules and changing movements, functions or accessories). 2. Easy integration of advanced control modules (reconfigurable software)
- Implementation of the design of the manufacturing system with functionality adapted to the component family, which guarantees the manufacturing of all parts within the given family

Manufacturing facilities offer reconfigurability if they are designed for alternative implementation simple changes in their physical structure and at the same time for the manufacturing of a specific component family [4]. The design of the initial system configuration is based on the implementation of system modifications. The aim of the modifications is to adjust the manufacturing capacity with regard to the current demand requirements and at the same time to subsequently reduce the manufacturing times of the products.

2. Requirements for the design of a new system and scaling of manufacturing capacities

When designing a new system, the following assumptions must be taken into account [5]:

- System throughput with reliability lower than 100%.
- Scaling of manufacturing capacities, which is ensured by adding or removing equipment.
- Usability of surfaces, which can be calculated as the length of the configuration (number of subgroups) x its maximum width (number of devices in a subgroup).
- Initial investment costs associated with setting up a new system (costs associated with time to adapt the system's functionality).

If we need to implement 24 manufacturing operations that last 20 seconds to make a part, then the manufacturing of each part will take 480 seconds (8 minutes). The desired demand is 500 parts for 7.5 hours of operation (450 minutes). And for that reason, the required cycle time is 0.9 minutes per piece. We can calculate the required number of machines as:

$$N_{min} = \frac{D_S\ x\ (P_{op} * t_{op})}{tj} * S \quad S < 100\% \tag{1}$$

where:

N_{min} – the number of necessary machines,
D_s – current demand,
P_{op} – the number of necessary operations,
t_{op} – the time required to perform the operation,

tj – daily working time,
S – machine reliability.

If we do not consider system reliability, then 500 x 8/450 = 9 machines are needed. Subsequently it is necessary to choose a configuration according to figure 115a, in which each machine can perform at least 5 operations. When our demand increases to 560 pieces per day, we need 10 machines. During a change in manufacturing volumes, it is necessary to assign additional machines to the current configuration, the presence of which will increase the current productivity of the system.

We can calculate the maximum possible number of machines in the system configuration based on the following formula:

$$N_{max} = \frac{D_s * N_{sk}}{p} - N_x \quad (2)$$

where:

N_{max} – maximum number of machines,
N_{sk} – number of standing subgroups,
p – current system throughput,
N_x – the total number of machines in the system,

The system throughput at the current demand expresses the number of performed machine works of the manufacturing line per hour (3600/60). Using this indicator, we can express the overall productivity of the future system. The most convenient configuration in terms of system throughput corresponds to Figure 1.

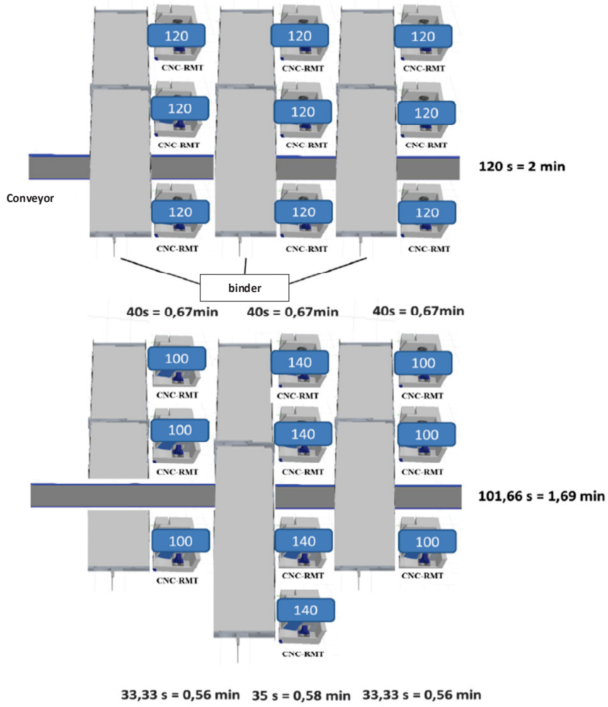

Figure 1. Scaling current capacities with function convertibility support to increase system productivity

One operation in the first subgroup is assigned to the second and at the same time from the third to the second.
The initial investment costs in the formation of a new system configuration are large, but due to the given fact, the background is created for future changes in capacities. The system can be scaled by another machine only if it sees an event associated with a new request. These investments no longer represent a big burden for the manufacturing company.

3. Modeling the capacities of reconfigurable manufacturing systems

The capacity model must meet the following requirements [6]:
- Time horizon (consisting of individual periods) within which capacity changes are to occur
- Demand within individual periods (t, t-1)
- Deciding on capacity scaling in individual periods
- Identification of the period in which there is a decreasing tendency of the usability of the current manufacturing plant capacities

The scaling frequency of system capacities is calculated as follows:

$$f_{ks} = \frac{D_{s(t)} * Sk(t)}{X_s(t)} \tag{3}$$

where:
f_{ks} – frequency of system capacity scaling
$D_s(t)$ – changes in demand over a period of time
$Sk(t)$ – capacity scaling within individual periods
$X_s(t)$ – time horizon characterizing the time deviation of capacity scaling when demand changes.

4. Cost analysis

As part of the cost analysis, it is necessary to re-evaluate the required capacity. This value represents the costs incurred at the relevant time. The presented function consists of the costs that need to be spent on the capacity of the manufacturing equipment with which the system is to be scaled and the reconfiguration costs that are associated with scaling the system. Scaling can be achieved not only by adding but also by removing modules or the devices themselves.

At the same time, it is necessary to take into account other costs such as:
- Downtime costs that need to be implemented for the sake of system scaling or the start of a new configuration with a changed capacity.
- Costs for adapting the functionality, which is necessary for the implementation of the system reconfiguration.

Capacity costs per manufacturing unit are determined based on the change in manufacturing equipment capacity that can be achieved through the addition or removal of machine modules.

We can calculate the costs of changing the capacity of manufacturing equipment as follows:

$$N_k = N_{kz} + K_s(t) \tag{4}$$

where:

N_k – capacity costs,
N_{kz} – costs of capacity change of manufacturing equipment,
$K_s(t)$ – current capacity of manufacturing equipment.

To calculate the cost of system capacity scaling, we must use the following formula:

$$N_{sk} = N_{kzx} * \left(D_s(t) - K_{ss}(t)\right) + N_p \tag{5}$$

where:

N_{sk} – system scaling costs,
N_{kzx} – costs of changes in current machine capacities (modular equipment configuration),
$K_{ss}(t)$ – current system capacity,
N_p – downtime costs that need to be realized in order to scale system capacities.

Figure 2 shows, module to support the generation and evaluation of system configurations

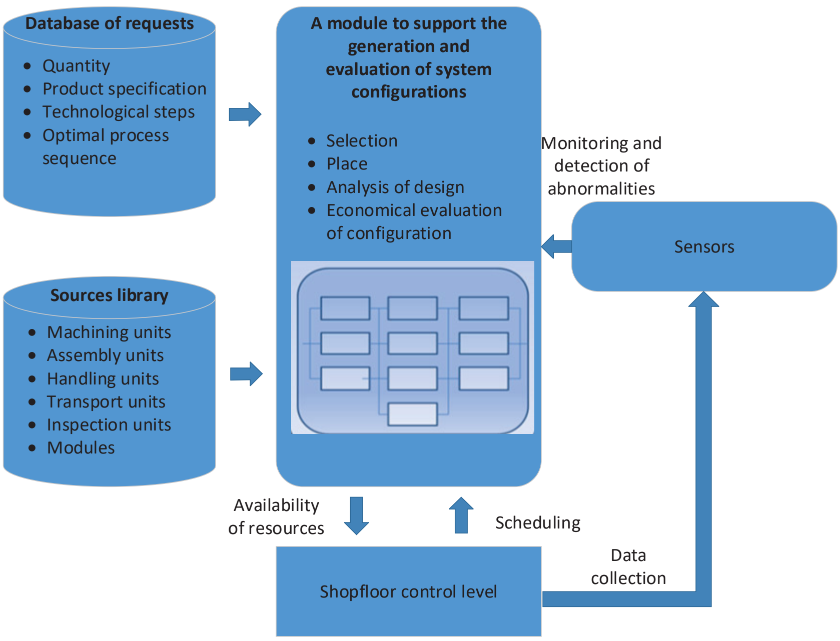

Figure 2. Module to support the generation and evaluation of system configurations

The most suitable approach in the design of system configurations would be if the system could self- sufficiently revaluate the given facts and adequately decide on the most suitable configuration. It should use different databases and libraries within the given claim. Based on the calculations, the module would prove to assign and remove virtual devices and components to the digital enterprise environment while reviewing possible alternatives.

5. Conclusion

Scheduling within the given approach should be implemented through genetic algorithms. It is necessary for the algorithm to be able to work with data that represents demand and costs for scaling system capacities. Possible solution candidates represent feasible schedules during capacity scaling planning. The evaluation function must measure the quality of a particular solution. Furthermore, it is necessary to carry out an analysis of the costs necessary for the implementation of the corresponding plans. The assessment is carried out by calculating the capacity costs of the device and the related physical costs associated with system scaling. The algorithm must further generate costs for scaled capacity schedules and subsequently reduce the population of given candidates. Subsequently, it is necessary to ensure the backup of the best obtained values. At the end, the most suitable variant is marked and real operation is resumed.

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