DYNAMIS-P - DEVELOPMENT OF NEW METHOD FOR DYNAMIC DIMENSIONING

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Abstract

This lecture refers to the contents of the research project “Development of a method for dynamic dimensioning of flexible production systems“. The project is funded by the DFG, German Research Foundation and processed by the Institute of Science of Management and Plant Systems at the Technical University Chemnitz.

The basic conditions of plant design have changed radically in the last years. The installation of a high flexibility in static structures is normally not to be realized from the financial point of view. Arranging a capacity according to the requirement is one possibility of manufacturers both to respond immediately to fast movements in the product range and to deal with the increasing cost pressure. Thus flexible planning procedures and planning methods are equally needed whereon the research project approaches. The overall objective of the research project is to develop a method for the dynamism of the structure of production systems and is based on the "DynamisP“ method by Ms Prof. Kobylka. Dynamism of the structure of production systems means that depending on the capacity requirement of a production system its structure is time-variant. This method is the only existing approach that applies dimensional and structural changes of the production system as significant control unit for an optimal workflow. Therefore the demand of increasing production flexibility is met without a cost explosion.

Within the research project new procedures are developed for simulation based dynamic dimensioning which are integrated in the overall methodology and tested referring their effectiveness.

Keywords: dynamic dimensioning, Digital Factory; production planning, planning method, simulation.

Presenting Author’s biography

Andreas Krauss studied industrial engineering at the Chemnitz University of Technology. Since 2005 he is working in the Department of Factory Planning and factory Management at Chemnitz University of Technology. Andreas Krauss is specialized in production planning, simulation und virtual reality.

1 Introduction

The basic conditions of plant design have changed radically in the last years. The dimensioning of production systems and also of complete plant systems becomes according to economics and efficiency more important. It is essential to exclude excessive or too low capacities by using dimensioning procedures at the outset and as well to present transparently and plausibly the necessary financing and investment needs. Flexibility shall be focused as strategic target value. When just having established or new control strategies and procedures alone, market requirements will likely not be realised in many cases. It is often already obviously that installed flexibility is insufficient for production systems with static, which means long-term unchanging, structures to ensure the survivability of companies. Also very effective control strategies and procedures that are aimed at the maximum use of the installed flexibility of static structures are not able to solve the problem on their own. The installation of a high flexibility in static structures is normally not to be realised from the financial point of view. Arranging a capacity according to the requirement is one possibility of manufacturers both to respond immediately to fast movements in the product range and to deal with the increasing cost pressure. The difficulties of short-term adjustments of type, numbers, arrangement and/or connection of resources are

- there is only insufficient knowledge about the dynamic behaviour of production systems and this knowledge is not adequately regarded on dimensioning,
- although the existing methods of the production planning and control are oriented on fluctuating capacity requirements but which are arranged on static production structures, primarily consider orders and/or operational duration of (available) resources as influencing terms and
- there are only static procedures (except DYNAMIS-P) which are established for dimensioning the production systems and that a fluctuating capacity requirement is solely considered by options which consistently result in static structures.

Thus flexible planning procedures and planning methods are equally needed whereon the research project approaches. The overall objective of the research project is to develop a method for simulation based dynamic dimensioning, the analysis of its application area and criteria and the description of its software based application. The project is funded by the DFG, German Research Foundation and processed by the Institute of Science of Management and Plant Systems at the Technical University Chemnitz. The research work is based on the "DynamisP" method by Ms Prof. Kobylka. This method is the only existing approach that applies dimensional and structural changes of the production system as significant control unit for an optimal workflow.

Within the research project the following results are aimed:

- get an overview over the existing dimensioning procedures and their problem related classification
- gain insights over the dynamic behaviour of production systems
- achieve general methods for the dynamic dimensioning of flexible production systems using an optimiser

2 Survey of dynamic dimensioning

Dimensioning of production systems is the quantitative definition of required operating facilities (flow system elements/equipment), worker and areas as well as the resulting costs and the required investment needs [1]. Furthermore it is possible to determine the demand for supply and disposal as for example energy, heating, water and sewage. Operating facilities are important characteristics of the dimensioning, they are the basis for calculating the other parameters [2]. On dimensioning it is essential to define the load capacity of a production system above the evaluated load limit. The maximum load arises from a predetermined production/service programme. This fundamental calculation approach is called balance sheet approach of dimensioning and may be described as follows [3]:

Load capacity ≥ load

Load capacity of an element × number of elements ≥ load

Number of elements ≥ load/load capacity of an element

There are two different approaches for defining the load which are graphed in Figure 1. On the hand there is the static dimensioning where a constant load of the system during the time is assumed and on the other hand the dynamic dimensioning where load variations during the time are regarded.

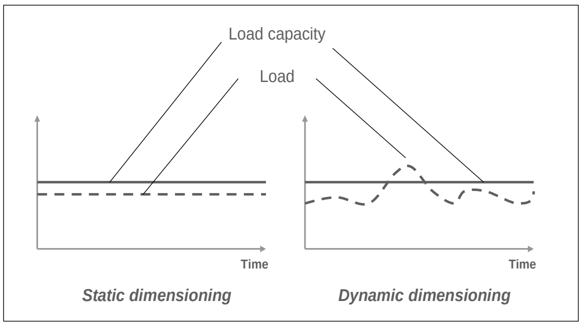

Figure 1: Static and dynamic dimensioning [4]

In contrast to the static dimensioning, the dynamic dimensioning considers the requirement dynamic within a certain reference period that means time-based relations are included in the calculation. Thus also complex processes may be represented by dynamic methods which results in a process-oriented and detailed definition of dimensioning values. The simulation technology may be used expediently for representing and processing complex correlations and dependencies in time flows on the dynamic dimensioning.

The demand of operating facilities and worker at run time of the production system is the basis for defining the required numbers. Amongst others Gantt-charts are used for representing the strain of operating facilities during the term. The following dynamic parameters can be drawn from the chart. [5]:

- Input time of production orders
- Output time of production orders
- Processing or cycle time of production orders
- Flow level or inner cyclic parallelism
- Working hours of production places
- Utilisation of production places within processing time or working hours
- Number of required storage space
- Definition of numbers of transport

With DYNAMIS-P [6] a method for simulation based dynamic dimensioning is provided with the target to adapt and optimise the capacity of the required resources of production systems to the varying demands. Optimisation targets may be understood as minimum resource demands where predetermined processing time restrictions must be observed and at the same time as the most cost and efficient differentiation of these demands in implicitly installed and temporary extensible resources.

The procedure of dimensioning is effected by the following planning steps:
1. Generating the base model
2. Dynamic dimensioning
3. Derivation of planning solutions

However, due to complexity and extent of that theme, only the second planning step, showed in Figure 2, shall be considered.

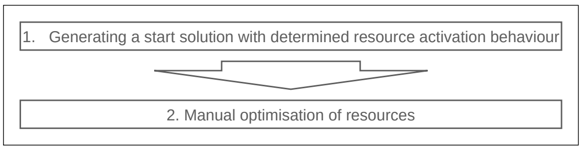

Figure 2: Dynamic dimensioning

DYNAMIS-P contains three different procedures for generating a start solution which shall be shortly explained as follows [7].

2.1 Switch -free dimensioning (SFD)

On switch-free dimensioning (SFD) the number of resources is practically unlimited, meaning that the resources are not controlled concerning needs. Stocks are never arranged in simulation models. By the unlimited number of free resources, queues do not result during the simulation and the minimum processing time is achieved for all orders. Thus the advantage of this method is the definition of the minimum processing time and bottlenecks are avoided which may interfere the simulation process. Furthermore for defining the start solution per system load version only one test run each is required. The disadvantage is the flexibility potential since the flexibility that the system is able to perform is considerably above the flexibility need.

2.2 Processing time-oriented resources approval procedure (DOR)

On processing time-oriented resources approval procedure, the separate processing time of orders is focused. Figure 3 exemplifies the processing behaviour of an order in a production system. The processing chart shows on the one hand an idealised processing behaviour as a straight line and records on the other hand the real pass of an order. Is the order at the end of the process over the idealised graph, processing buffer times exist. The opposite case means that the order is delayed.

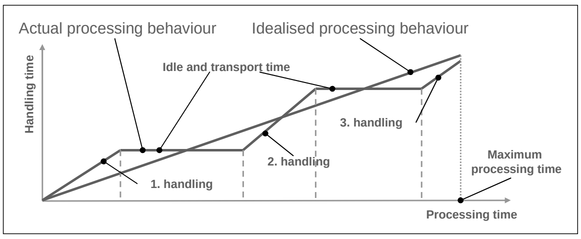

Figure 3: Processing behaviour of an order

According to the idealised processing behaviour, the latest moment of the processing start for all production facility types (FE-types) is to be determined for every handling step of orders. The evaluation period is divided into cycle time segments. Afterwards the queue being in front of a FE-type is sorted by the latest handling start time in ascending order. On this basis it is possible to determine at the beginning of every cycle time segment the orders whose latest possible start time lies within the cycle time segment. These handling times and the handling times for already existing orders on the production facilities are added and give the handling time to be realised in this cycle time segment and the urgent supply of this FE-type. The FE-type may now be dimensioned for the present cycle time segment and an appropriate number of production facilities is operated actively. This avoids an unnecessary activation of not required resources.

The advantage of this procedure is the strict adherence of processing time. The method's disadvantage is that the handling of long order queues starts only after achieving the latest possible start time. Therefore it may be in individual cases that unacceptably large stocks and a wide standard variance occur for the resource number.

3 Procedures for demand-oriented resource activation in stages (BSR)

On procedures for demand-oriented resource activation in stages, there is a strictly stepwise activation of resource types depending on a specified activation number and an activation time, both are to be determined. The evaluation period is also divided into cycle time segments. Activation numbers shall be defined as follows [8]:

$$NA_x = (x-1) * NS$$

NA_x … activation number of resource x
x … number of resource
NS … specified activation number

A reference value for the specified activation number may be determined with the following formula:

$$NS = \frac{t_m}{I}$$

NS … specified activation number
tm … medium occupancy period of operating facilities at the resource type
I … target value of inner cyclic parallelism

The number intervals of each resource are to be produced via the defined activation numbers. Within the next step the determination of numbers follows which are arranged at the beginning of every cycle time segment in front and behind a resource type. They will be compared with the stock to be processed within the present capacity level. In case of a larger actual number, another level will be activated. The opposite case causes the shutdown of the present level.

The advantage of this method is the avoidance of unacceptably large stocks. It could be in individual cases that the maximum processing time is not observed which is the method's disadvantage.

Result of the three above-described procedures for generating a start solution is not a certain number of resources but the respective capacity and resource requirement profiles. They are the basis for the manual reduction of resources (MRD-procedure). Based on a base model with unlimited resources, a stepwise reduction in the form of top down procedures is carried out. Within a first step the base model is strained with a volume of orders of a system load option and simulated to determine the capacity and resource requirement profiles of each resource type. This is the basis for the following stepwise limitation of the individual resources. The simulation assumes the knowledge that costs fall and the processing time rises with decreasing resource number. The reduction in stages shall be continued until a predetermined maximum processing time is exceeded or the minimum inner cycle parallelism is fallen below. However, it must be observed that a linear behaviour of the system is not expected as dynamic interactions between the individual resource types may occur. The order of the stepwise reduction follows the above-described interactions and the intercapacitive influences of resource types, according to the following schedule:

1. Reduction of production facilities,
2. Reduction of worker,
3. Reduction of storage space / definition of storage strategy (decentral, central, combined),
4. Reduction of transport facilities.

The order reveals what interdependencies are implicated. For example, the reduction of production facilities leads to a lower need of worker. On condition that a production facility is only operated by one worker, the highest possible need of worker is equal to the number of required machines. In contrast determining the transportation effort and the resulting dimensioning of transport facilities depends on the used storage strategy and the number of decentral storage space. A further crucial criterion for defining the reduction order are the particular resource costs. At first resource types have be minimised where a maximum cost reduction may be achieved by a minimum degradation of processing time. The minimisation shall be based on capacity and resource requirement profiles. The MRD-procedure firstly reduces the resources by whole static units. If the repeated simulation run shows that the processing time restriction is interfered, the resource's activation time is accordingly modified (increase the dynamism of the resource). The capacity requirement profile demonstrates the dynamism needs in case of an overload situation. The necessary dynamism period is deviated by the resource requirement profile. During the complete run of the dimensioning process, a permanent change is effected between the reduction of static resources and the subsequent dynamism.

Within the third phase of the DynamisP method the planning solution is derived. For this, the required scope and the required reaction rate have to be determined by the simulation results. The scope includes the economically justifiable modification of each considered system concerning quantitative, qualitative, local and/or chronological criteria. The reaction rate describes the period from identifying the modified capacity need to the latest possible time of activation/deactivation of the respective capacity. The required scope shall be derived by the predefined overlap profiles. The overlap profiles show the minimum, the possible and the maximum system load together. From the overlap profiles arises normally a spectrum of dynamism periods for each resource. Dynamism periods may be understood as limited time segments in which a resource is required. Determining the necessary reaction rate may be realised by various ways, for example by comparing different resource requirement profiles. An indicator resource type may be used to indentify peak capacities and to specify the necessary reaction rate.

The selection of a more flexible measure is effected on the basis of the given scope, reaction rate and action readiness of the respective flexible measures. Flexible measures comprise buying, leasing, renting, external production/commissioned production. Assuming that there are several suitable flexible measures, the most favourable flexible measure may be defined via a present value comparison.

In summary the following weak points or proposals for improving the existing approach of DynamisP may be pointed out:

1. The individual procedures for generating the start solution are either based on the processing time or the stock. The necessity to consider stock and processing time at the same time as target values is not fulfilled.

2. On generating the start solution, solely the operating facilities are dynamically dimensioned. Worker, transport facilities and storage facilities are not dimensioned.

3. The reduction of resources is not followed automatically after generating the start solution but manually. Thus capacities of high qualified simulation specialists are tied up unnecessarily.

4 Further development of the DynamisP mehtod

To find out for what types of planning problems the simulation based dynamic dimensioning is suitable, a systematisation of production systems is developed. With the help of the determined criteria the analysis area could be defined to series or job shop production with similar or varying technological processing sequence of parts whereas the dynamic dimensioning is focused on worker, production facilities and means of transport.

A production system is dimensioned on the basis of given production/service programme. The primary target value is the efficiency which is the number of manufactured products per time unit. Further target values are the processing time and the stock of products within the production system. Between these three target values efficiency, processing time and stock exist relations that are presented in Figure 4 [9].

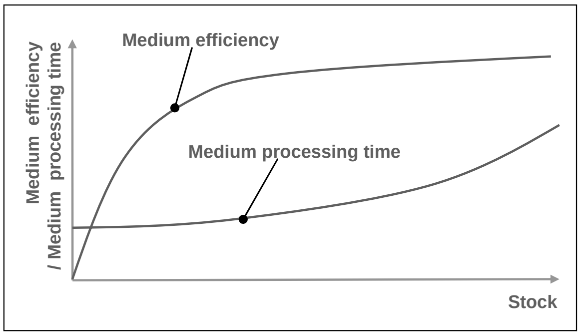

Figure 4: Interrelation between capacity, stock and processing time

Therefore it is essential to consider as many target values as possible on dimensioning of product systems. The procedures “processing time-oriented resources approval (DOR)” and “demand-oriented resource activation in stages (BSR)” for generating a start solution take this issue not into consideration. For this reason, new procedures shall be developed which consider these competing target values together.

The present procedure uses for generating the start solution either the target criteria processing time or stock as only control factor, followed by the manual reduction or dynamism of operating facilities. The simulation specialist has to verify after each simulation run that every target criteria is kept. To assure the compliance with all target criteria, any possible state of the control factors of the production system must be displayed before. The activation or shutdown of individual operating facilities is based on these control factors.

The processing time-oriented resources approval procedure (DOR) controls the activation or shutdown of operating facilities independent by the stock in the following way:

1.1: Capacity requirement of urgent orders > Available capacity - Activation of operating facilities
1.2: Capacity requirement of urgent orders = Available capacity - No activation
1.3: Capacity requirement of urgent orders < Available capacity - Shutdown of operating facilities

The procedure for demand-oriented resource activation in stages (BSR) controls the activation or shutdown of operating facilities independent by the processing time in the following way:

2.1: Actual stock > Stock interval of the present operating facility - Activation of operating facilities
2.2: Actual stock = Stock interval of the present operating facility - No activation
2.3: Actual stock < Stock interval of the present operating facility - Shutdown of operating facilities

To activate or shutdown operating facilities both time-oriented and demand-oriented, the cases 1.x and 2.x have to be considered together. Chart 1 presents the created matrix.

Chart 1: Method matrix for activation of resources

	Case 2.1	Case 2.2	Case 2.3
Case 1.1			
Case 1.2			
Case 1.3			

Each matrix field may be filled with one of the three following activation cases:

1. Activation of resource (+1)
2. No activation (0)
3. Shutdown of resource (-1)

Thus 19681 possible procedures for the activation of resources exist theoretically from which only a fraction is practically applicable. The two existing procedures are showed in Chart 2 and Chart 3.

Chart 2: processing time-oriented resources approval procedure

	Case 2.1	Case 2.2	Case 2.3
Case 1.1	+1	+1	+1
Case 1.2	0	0	0
Case 1.3	-1	-1	-1

Chart 3: demand-oriented resource activation in stages

	Case 2.1	Case 2.2	Case 2.3
Case 1.1	+1	0	-1
Case 1.2	+1	0	-1
Case 1.3	+1	0	-1

Chart 1 presents one of various further possible procedures for the activation of resources. This procedure avoids the disadvantages of the existing methods for generating a start solution by integrating the target values processing time and stock at the same time.

Chart 4: new procedure for activation of resources

	Case 2.1	Case 2.2	Case 2.3
Case 1.1	+1	+1	0
Case 1.2	+1	0	-1
Case 1.3	0	-1	-1

Activation case 1.3 (capacity requirement of urgent orders < available capacity) - 2.1 (actual stock > stock interval of the present operating facility) would reduce the resource number on strict application of the processing time-oriented resources approval procedure in spite of the large stock. This process is avoided by the procedure in Chart 4. Activation case1.1 (capacity requirement of urgent orders > available capacity) – 2.3 (actual stock < stock interval of the present operating facility) would reduce the resource number on strict application of the procedure of demand-oriented resource activation in stages and hence interfere the processing time restrictions. This process is also impossible with method 4 which is presented in Chart 4.

Innumerable further procedures could be represented by the method matrix for the activation of resources. The use of an optimiser shall help to identify the optimal resource activation behaviour according to the appropriate problem. After finding the optimal resource activation behaviour including the respective start solution, the optimisation of resources shall be arranged. The reduction or dynamism of resources is automatically operated as long as the determined target values for stock and processing time are no longer be kept.

Figure 5 displays the new procedure for dynamic dimensioning.

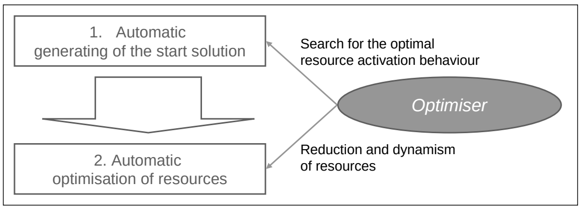

Figure 5: New procedure for dynamic dimensioning

For describing the new method, event-driven process chains (EPKs) are used within the ARIS software. Parallel thereto a general conceptual data model for the simulation is created. This is the basis for modelling various applications and for verifying the method within the eM-Plant simulation system. The implementation of the method in software based tools could follow in the next steps which may be realised within the simulation software or by external programmes. However, the method's implementation in software is not part of the actual project.

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