

SIMULATION BASED JOB SHOP PRODUCTION ANALYSER

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ABSTRACT

With the Simulation based Job Shop Production Analyser a powerful analysis tool has been developed by use of modern Java and database technology. This straight forward approach offers the possibility to model the production flow of even complex job shop production systems efficiently. It provides a professional decision base for the daily operative production business. System integration, automated modelling from the database and very fast simulation runs are key features of this approach. As an industrial application for the Job Shop Production Analyser the simulation of a complex semiconductor production plant is shown.

JOB SHOP PRODUCTION

In job shop production the routing and scheduling of jobs is much more complex than in other production systems. The workflow of each production job is given by a job description which defines the required sequence of the necessary production steps. The decision when to schedule a job and which resource shall be used for each production step depends on the job requirements, the actual availability of the resources and other circumstances.

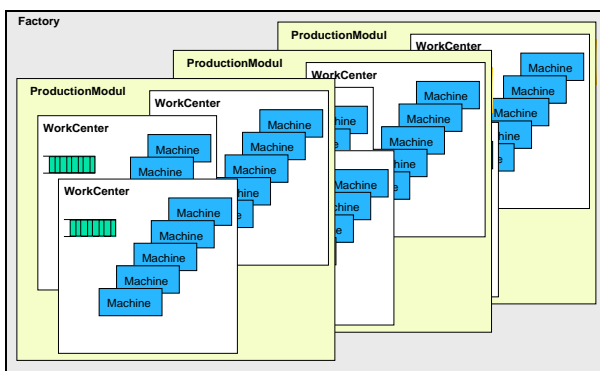


Fig. 1: Job Shop Production

For operative planning and control a rule based dispatch system (RBD) can be applied to calculate the sequence of the jobs for each resource respectively machine. The

production sequence created by such a rule based production planning and control system depends on defined priorities, applied rules and the actual state of the shop.

SIMULATION BASED ANALYSE

The Simulation Based Job Shop Production Analyser offers the possibility of a flexible and efficient approach to model and simulate large job shop production facilities very fast. Therefore the routing and scheduling of the jobs through the production is modelled in detail. The Simulation Based Job Shop Production Analyser offers:

- automatic model generation
- integrated simulation concept
- powerful separated/independent simulation kernel
- integrated database interface
- fast and powerful simulation runs
- fully integrated in a client server environment
- open concept for user specific extensions

The Simulation Based Job Shop Production Analyser is based on modern Java and database technology and can be used for:

- research on future production concepts
- operative production planning and control,

The system can be integrated in existing computer networks for production planning and control. Therefore interfaces for input data, for running and controlling the system and for result output are necessary.

Data Import from PPS – and ERP-Systems

The required data import from any production planning system can be performed directly via database interface or XML interface. The data are processed by means of definable data filter for the simulation. Three categories of input data are required:

Resource data: parameter of production resources, work centres, machines etc.

Operating data: production data, workflow definition, individual process definitions, calendar assignment etc.

Job data: job lists, job dates, priorities etc.

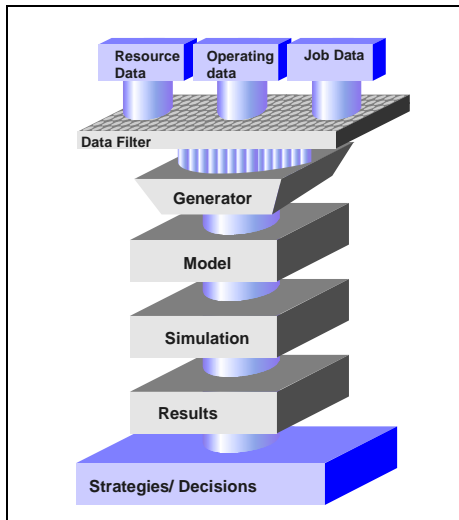


Fig. 2: Production analyse with automatic model generating

The resource data are static data, which are related to the plant structure and production equipment. These data normally are fixed and will change only if the plant structure or the equipment is modified. Operating data are data related to the processes, and provide principle definitions for operating processes. These data are changed, when processes are modified. Job data provide the information of actual jobs. These data are always changed in the daily business. The data described above can be used for an automated model generation.

Automated Model Generation

The automated generation of simulation models is performed with input data from a database. This automatic model generation allows a rapid and flexible modelling approach also of large production areas. Problems from manual data input and data inconsistencies are minimized by this approach. Further a great advantage of this procedure is that the maintenance effort for the simulation is reduced considerably, since the model in each case is directly generated from the current data base automatically again. So the state of the data from the database and that of the simulation model matches always.

If necessary due to customers needs some specific areas may be modelled more in detail. This normally should be performed by use of more specific building blocks. Further for the check of very specific production details it is also possible to modify an automatically generated model manually. However for this option some programming knowledge is required.

SOFTWARE ARCHITECTURE

The first prototype of the Simulation Based Job Shop Production Analyser was realized by use of the simulation tool emPlant (Tecnomatix). For the professional version an advanced Java structure has been chosen. This approach has a lot of advantages.

Native Java Structure

The software architecture of the second generation Simulation Based Job Shop Production Analyser is based on native Java and very flexible. The object oriented features of Java are directly used for the simulation model structure. Towards a very modular and flexible software approach there is a clear separation between the simulation task, the result analysis and the user interface. The simulation model is running as an independent thread. The simulation task is connected by an JDBC interface to a database. The model is created from the content of the database and the required results are written into the database. The user interface interacts with the simulation through defined interfaces. The result analysis can be performed by interaction with the simulation task directly or with data from the database.

In order to speed up the simulation process and the data base interaction the main simulation task is performed independent from the user interface. E.g. on a LINUX server it is even possible to run more than one simulation task parallel and in a second step it would also be possible to simulate different job shop productions at the same time and to interact between these in a distributed simulation network.

Integration in a Client Server Environment

The user interaction for preparing simulation experiments and the analysis of simulation results can be located on client computers somewhere in the network. The model building and simulation process can be started and controlled by interface technology on base of RMI, CORBA or XML-RPC. This offers a fully integration of the simulator into advanced software architectures, e.g. in an application server environment. Such architecture allows an advanced integration of simulation with production planning and control systems.

Due to the advantage that the user interface on the client computers is separated from the main simulation task it can be designed independently to the customers needs. For the operative business the production planner and controller shall be able to operate the software without special knowledge of simulation or programming technology.

Java Simulation Library

The applied Java based Simulation Library is not limited to a certain simulation level like many other simulation tools. The architecture of the library uses an object oriented approach. It is modular and open for additional extensions. The library offers features similar to the flexibility of a simulation language, over the level of general building blocks, such as workstations and assembly stations, up to the efficiency of simulators with highly specialised building blocks for a special purpose.

Job Shop specific Classes

For the Simulation Based Job Shop Production Analyser some specific classes have been developed on top of the general simulation classes. These are special classes for modelling the job shop such as *Shop*, *Department*, *WorkCenters*, *ShopMachines* and *Scheduler*. With these it is possible to build hierarchical models of the job shop facility. Some more special model classes may be added due to specific customer requirements. Further customer specific rules for the routing and scheduling can be integrated into the production control module.

The *Shop* module represents the upper level of a job shop production model. A *Shop* may contain several *Departments* which represent the organisational structure of the facility.

The *Department* module is used to model production areas. A *Department* may contain several *WorkCenters* which are assigned to a certain processing tasks. A *Department* does not provide processing features itself; it serves as organisational unit to group production facilities.

The *WorkCenter* is the module which offers certain processing tasks for the jobs. In a *WorkCenter* there may be several machines located which fulfil the required processing tasks. A *WorkCenter* contains an input and an output buffer. All material flow is sent into the input buffer. For the jobs in the input buffer it has to be decided, which lot shall be produced next on a particular machine respectively resource. This production control decision is done by the *Scheduler* using rule based dispatch algorithms.

The *ShopMachines* are the material flow modules to perform an operation. In a job shop model machines are always located in a *WorkCenter*.

The *Scheduler* is a very flexible production control module which allows to model rule based production planning and control algorithms. A scheduler can be used on different model levels. On the upper model level the *Scheduler* is used to schedule jobs into the system, on level of a *WorkCenter* it is used to decide which job shall be processed next.

New Job Shop Models

New job shop models are generated completely from the database. This is a very powerful and flexible feature towards efficient modelling. Through this approach models can be even defined in third party software products for production planning and control. Further, if necessary the job shop class library can be extended by additional customer required classes in order to fit to the needs of the respective project.

The Simulation Based Job Shop Production Analyser is open for modelling and simulation of any job shop production. However the system has been developed due to the need of complex semiconductor production systems. In the following an industrial application of the

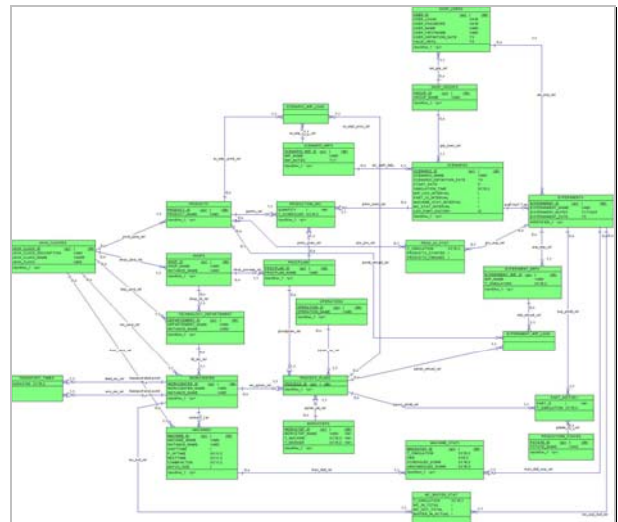


Fig. 3: Database model

Simulation Based Job Shop Production Analyser in the field of semiconductor production shall be shown.

INDUSTRIAL APPLICATION: SEMICONDUCTOR PRODUCTION

The production of semiconductors is a typical job shop production and it is characterized by very extensive processes with a wide span of processing times, even partly with very long machining times, which cannot be interrupted. Due to the complicated processes and the clean room production environment the investment for the plants and even the operation of the shop is very expensive. The necessary work schedules for the processing of the wafers consist of more than 350 single steps. A product may be routed in bows to the same resource up to 20 times again. Therefore the planning and control of the manufacturing chain is extremely complex and requires a very powerful software tool. The modelled production consists of several production areas with more than 100 work centers, more than in total 350 machines as well as more than 500 work schedules for more than 1000 different products. A special characteristic of this particular semiconductor production is the relatively high amount of urgent development lots, which require a high priority and a very fast throughput time, in order to fit the demands of the developers for customer definable wafers.

For this reason the simulation of the evaluated semiconductor production requires a considerable expenditure due to the described complexity of the production. With the aid of automatic model generation from a database hierarchical models can be generated conveniently always from actual production data. In this concept the actual simulator kernel is encapsulated and may run as a separate task on a simulation server. The model creation shall be operated by employees in the field of the production control without particular simulation and programming know-how by use of a convenient user interface. The manual modelling of large size companies is very time consuming and

inflexible. Therefore an automatic model generation offers a considerable advantage. The production data necessary for the simulation are kept in a database, converted according to the requirements and used then for the automatic model generation.

Rule Based Production Control

In a complex semiconductor production with a high number of different products, the production planner and / or operator must decide frequently, how lots and tasks shall be routed and scheduled through the production facility in order to fulfil different production goals at a maximum. The sequence of the lots for the production chain can be generated by use of production strategies according to a rule based job scheduling strategy (RBD = Rule Based Dispatch). A particular production strategy can be built up from several priority classes, filtering and sorting rules, that are defined as default rules in order to improve local production areas or to optimize the global production.

The production planning system used in this semiconductor production offers more than 50 different operation rules for the production control, such as:

EDD, DD (Earliest Due Date)	Next job to process is the one with the earliest due date among the waiting jobs
CR (Critical Ratio)	Next job to process is the one with the least time (time to due date divided by total remaining processing time) among the waiting jobs
SST (Shortest Setup Time)	Next job to process is the one with the shortest setup time
LS, MS (Least Slack, Minimum Slack)	Next job to process is the one with the least time [time to due date minus total remaining processing time] among the waiting jobs
CP (Critical Path)	The Job on the critical path is processed first
Rush (Emergency)	Jobs with special demand to be processed very urgently
...	...

In the daily business the semiconductor manufacturer employs a very few of these rules to the daily operation of the production only. And even these rules are used very conservatively since the production is very complex and has a relatively long reaction time. For the production planner and production controller in the plant it is very difficult to judge the influence of particular rules respectively parameter settings for the entire system. However the goal to reduce e.g. the flow factor in the production requires considerable modifications of the production control. Here simulation offers a powerful tool to test various strategies and modifications without risk for the current production.

USE OF THE SIMULATION BASED JOB SHOP PRODUCTION ANALYSER

The use of simulation technology has the goal to improve the production system by optimizing a combination of production strategies under consideration of the respective status of the job shop facility. For this purpose the Simulation Based Job Shop Production Analyser has been applied. The model generated for the analyses consists mainly of production modules, work centres and machines. Each production module consists of work centres, which itself may contain several job shop machines. With the Simulation Based Job Shop Production Analyser the effect of various parameters to the production process chain can be examined in a dynamic model, such as:

- effect of additional tasks
- changes of scheduling sequence in the production system
- change of the rule based production control
- changes in the workflow sequence
- changes the lot size
- effect of special and hot lots
- changes in the plant structure

Prototype based on emPlant

The first modelling of the semiconductor plant has been performed with the prototype version of the Simulation Based Job Shop Production Analyser, which was developed on base of the simulation tool emPlant (Tecnomatix) and an Oracle Database.



Fig. 4: Hierarchical simulation model

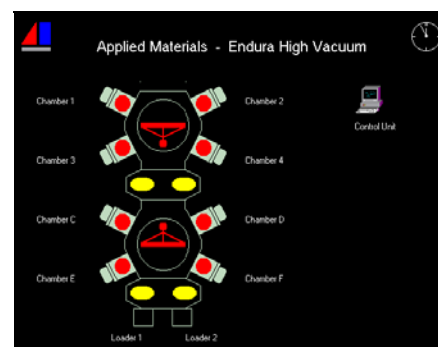


Fig 5: Detailed simulation of the Custer Tools Endura High Vacuum chamber. Meanwhile the simulation tool has been changed in order to improve simulation speed, robustness and the

integration possibilities. The new advanced approach is based on a very efficient Java simulation library.

Improvement by Next Generation Analyser

The second generation Simulation Based Job Shop Production Analyser is based on an advanced Java simulation library. It offers a faster optimized simulator kernel and powerful model classes approving a most extremely efficient modelling and simulation approach.

The library follows an object oriented design. It offers general simulation objects, material flow objects, information flow objects, decision making objects and applied material flow objects. For the internal information flow the features of Java are used directly to implement information flow for the simulation model very efficiently.

With the prototype on base of emPlant and Oracle the model building took some minutes. With the new Java based version the time generating the complete model building process of the plant described above takes now less than 10 seconds. Further due to the very clear structure the simulation speed has been increased by a factor of 10^2 to 10^3 . The database interactions are much more flexible through the use of JDBC.

Operative Planning and Control

The Simulation Based Job Shop Production Analyser can be integrated into the production planning software used for the daily business. The stuff running the plant can apply the simulation results for the operative production planning and control without the requirement of specific simulation and programming knowledge.

The input of data, the change of control strategies etc. as well as the graphical presentation of the results can be adapted by use of modern software tools in a user-friendly way to the respective requirements. The model can be generated automatically from the database. Interaction of the user is not necessary, even not reasonable. The actual simulation process runs in a separate task in the background, this may be even possible through the network somewhere else on a separate simulation server. This integrated approach offers a very powerful and user friendly concept which can be adapted to the respective application very flexibly due to the requirements.

Simulation Results

Results of the simulation can be processed efficiently by use of the database. In freely definable statistic intervals parameters can be gathered and analysed, such as:

- finished lots
- maximum and mean utilisation of input buffers for selected or all resources
- utilization from resources, production areas, work centres, machines

- number, location and processing status of all lots in the system
- WIP and entire flow factor
- standby, scheduled down and unscheduled down of resources
- overall equipment efficiency (OEE)
- additional customer specific measures

Further various measures can be gathered for a product or a product group over a freely definable time period, such as:

- flow factor
- number of finished lots
- number of lots in the production system
- throughput times
- adherence to schedules
- additional customer specific measures

Analyses of the Semiconductor Production

The analyses of the complex semiconductor production described above has been performed with various data sets for specific scenarios. For the customer it was very helpful to get some knowledge about the influence of special lots and hot lots in this particular production. A certain percentage of lots with a high or very high priority have the effect that the large volume main business with about 90% of all jobs will be disturbed very much by 3 to 8 % of urgent jobs. However for the research and development department at least a part of the urgent jobs is necessary. Some of these may be unnecessary if the entire system is running more efficient and the flow factor is reduced anyway.

By use of simulation it can be considered, how this necessary part of very urgent development lots can be routed and scheduled through the production without disturbing the large volume business to much. There is no general rule to improve. However simulation can show for any actual situation, based on the actual state of the system, different possibilities to handle the high priority lots without too much disturbance. The operator is able to check for the best possibility and to run the production system due to the actual situation with a minimum of disturbance.

SUMMARY

For the modelling of rule based job shop production systems a modern simulation concept has been developed. This concept is based on modern Java technology and an automatic model generation with production data from a database applied directly before performing each simulation run. The concept of the Simulation based Job Shop Production Analyser is based on a strict object oriented Java simulation kernel which is designed in a modular approach with open interfaces. In order to offer a maximum on flexibility and robustness the concept allows a fully automated generation of the actual simulation model by use of production data from the database. The Simulation

Based Job Shop Production Analyser allows running simulation models on various hardware platforms and operation systems.

The Job Shop Production Analyser has been successfully applied to model the simulation of a complex semiconductor production plant. Due to its structure the Job Shop Production Analyser can be integrated into existing production planning and control systems. It offers the possibility to model the production flow of even complex job shop production systems efficiently in detail and in order to provide a professional decision base for the daily operative production business.

The comparison between the prototype realised on base of the simulation tool emPlant and the second generation based on Java technology shows a strong improvement. Speed is increased considerably by a factor of 10^2 to 10^3 . The database interactions for input data and for writing results to the database have been improved and are much more flexible. Further the analyser modules can be fully integrated into other production planning and control systems. With the powerful simulation and integration features an advanced analysis tool with great flexibility has been achieved.

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BIOGRAPHY

WOLFGANG KUEHN studied mechanical engineering at the University of Brunswick, Germany. Afterwards he worked two years with Blaupunkt. At the University of Bremen he got 1991 his PHD in production engineering and 1997 his habilitation in the area of simulation of production systems. From 1993 to 1995 he worked as Associated Professor at the Asian Institute of Technology in Bangkok. 1996 he founded the SIPOC Simulation based Planning, Optimization and Control GmbH in Bremen. Since 1997 he is working as professor for production planning and control in the department of Electrical, Information and Media Engineering at the University of Wuppertal.

CLEMENS DRASCHBA got 1996 his degree of production engineering at the University of Bremen. He has industrial experience with the Meyer-Werft and AEG-Lloyd-Dynamo-Werke. For the SIPOC GmbH he performed simulation studies of production processes, such as semiconductor production and international catering facilities. Since 1998 he is general manager of the SIPOC GmbH and responsible for software development.