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Optimization and modelling of time structure by simulation and planning software

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Abstract. This article presented the using of possibilities simulation and scheduling software for optimization and modelling of time structure in scheduling processes. It describes the compact way of production process planning in terms of optimization of production operations scheduling. Introductory part of article represents the summary of simulation software which is designated for optimization of different production processes in manufacturing companies. This part presents the best known heuristic rules which are used in practice. The second part of article points to possibilities of time structures and this optimization is focused on minimization of time. The simulation model describes the manufacturing of two rotors and one stator. It is created by 10 machines and is uses 3 dispatching rules at the shop floor condition. The time reduction to minimum values was realized by model in Lekin software which is designated for scheduling and optimization of production processes. The results of model optimization are graphically interpreted by Gantt charts. The next part of article presents the verification of proposed organization of manufacturing operation by simulation software Witness which was selected for verification of organization on the basis of redefined criterions.

Keywords: simulation, planning, witness, Lekin, optimization

1 Introduction

In the last years a great deal of works was conducted on scheduling problems[5]. Many authors have used various criteria for the generation of optimum schedule, such as number of tardy jobs, number of completed jobs in process inventory and machine utilization. Montazeri and Wassenhove stress the need for simulation prior to actually setting up the FMS. They use a user-oriented discrete event simulator to mimic the operation of a real life FMS[10]. Stecke and Solberg have carried out a detailed simulation of a real life system. They have tested various alternatives and evolved loading and control methods which significantly improved the systems production rate[15]. OKeefe and Haddock discuss the advantages of data driven generic simulators for FMS. These models have been developed using [11]:

- general purpose programming languages (C, FORTRAN, PASCAL, etc.);
- general simulation languages (GPSS, SLAM, SIMSCRIPT, etc.);
- special purpose simulation packages (WITNESS, SEE-WHY, SIMFACTORY, etc.).

The authors provide a critical review of dispatching rules in FMS. A set of important attributes while selecting simulation software for manufacturing is given by Law and McComas[9].

World “Construction - technology - manufacturing - assembly” it is a series of activities and jobs which are necessary to realization of parts. The first step of parts manufacturing is developmentally - design stage

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which the part is designed. The second step of parts manufacturing is technological production. The technological documentation is drawn up in this step and the part is made on the basis of its. The very important and essential company activity is insurance of manufacturing[12]. This job solves the planning and production control. Large quantities of information are processed during the planning and production control and it necessary needs the support of computer technology. Working with a larger variety of scientific models than the mathematical analysis, computer simulation is used in cases where the models or problems are highly complex for formal mathematical analysis, such as stochastic and dynamic scheduling problems[14]. Material flow is organized material shift in manufacturing process or circulation[6]. It is necessary to ensure active and passive elements from the point of view manufacturing planning. Active elements (transport and handling machines) have energy and they actualize their own shift by its. The shift of passive elements (materials) is the consequence of active elements shift. The results of these shifts are material flow which is not possible to change during the manufacturing process and it is very important that the flow was properly suggested. The remainder of this paper is organized as follows. Section 2 gives material and methods which is necessary to clarify the practical part of article. Section 3 provides the practical example of simulation and planning software combination in manufacturing plant. At the end of Section 3, the experimental results are provides. Section 4 gives the conclusion of work.

2 Material and methods

Simulation has been widely used for manufacturing systems as well as defense operations, healthcare services and public services[3]. One of the advantages of simulation compared to other methods is its cost-effective which possible modifications on the model can be done without disturbing the actual system[13]. Simple, costless and reliable possibility of correctness manufacturing process verification is utilization of planning and simulation software. They are used for easement of production optimization considering manufactured parts. It is necessary to determine these factors for correct choice of simulation and planning software[1, 4]:

- Machines and capacity of machines.
- Number of manufacturing, logistic workers, maintenance workers.
- Order (quantities, dates).
- Information about products (technical procedure, bill of materials).
- Shifts, breaks.
- Transport and handling machines.
- Management system, breakdowns management, limitations.
- Layout of machines, areas, material flows.
- Breakdowns statistics, accessibility of equipment, etc.

Tab. 1 shows the summary of the most popular simulation software which is oriented on simulation of material flow. This article presents the simulation software Witness because it can generate busy of machines[8].

Table 1: Tabular summary of simulation software

AME Sim	Enterprise dynamics	SimFlex	Witness
AutoMod	Flexim	MLDesigner	Simul8
Delmia	C2 Platform	DSM	Arena
EASY	Show Flow	SPAR	Dosimis-3
Plant Simulation	SIMBAX	Universal Mechanism	

The second part of article is using the planning software. The basic parameters for selection of planning software are: simplicity of control, good arrangement of information, complexity of inputs data and possibilities of using predefined heuristic rules[2]. In Tab. 2 is presented the selection of planning software with characteristic.

Table 2: Tabular summary of planning software

Software	Description
SchedulePro	- final capacity planning - reducing cycle time - capacity analysis - maintenance planning - graphical interpretation: Gantt charts - analysis: sources (material, worker, etc., using of machines
JDAs Factory Planning & Scheduling	- synchronisation of production and optimization plans - reduce work-in-process and finished goods inventory - new type of planning based on turn-around times
The PIMSS production software	- production capacity planning - just in time planning - support of what if analyse for capacity planning - plant planning - factory simulation
PLEX	- material requirements planning - capacity planning - production requirements planning, - Kanban scheduling - maintenance planning
Preactor Scheduling Software	- minimization of production time - minimization of costs - maximization of operation efficiency - rules for planning - output: Gantt charts
APS PlanWizard	- production plan - production Schedule - material requirement plant - supply minimization - shortening lead time - cooperation with factors: workforces, equipment, productivity, materials, and so on
Seiki Software	- minimization of production time - creation sequence of production - ensure accuracy of supply - avoiding bottleneck - reduction semi-products
Delfoi Planner	- reduction lead time - reduction work in progress - increase accuracy of supply - monitoring all changes directly by software
Lekin Scheduling system	- heuristic methods - dispatching rules - 6 basic work environment - 60 standard benchmark problem - graphic presentation of results: Gantt charts - import and export of external algorithms

It was used Lekin scheduling system from Tab. 2 for process established problems. This interactive scheduling system is used for planning in machine environment. It was developed in New York University and it used for research and education. It contains dispatching rules, methods and it enables the adding own user algorithms. It enables using external data with standardise input and output parameters, too.

As mentioned, it is necessary to make allowances types of dispatching rules in case of selection of software. Table 3 presents the summary of dispatching rules.

It is possible to state on the basis of technical procedure analysis that the most suitable is application of Lekin scheduling system for the manufacturing optimization (minimize the production time). Software includes predefined dispatching rules. For the realization of research was used following:

Table 3: Tabular summary of dispatching rules

Abbreviation	Name	Principle
EDD	Earliest Due Date	preference of jobs with earliest due date
MS	Minimum Slack	elimination of idle time, job order C slack
FCFS	First Come C First Served	first come C first served
LPT	Longest Processing Time	preference of jobs with longest processing time
SPT	Shortest Processing Time	preference of jobs with shortest processing time
WSPT	Weighted Shortest Processing Time	preference of jobs with weighted shortest processing time
CR	Critical Ratio	preference of jobs needed for meet the deadline

(1) Minimum Slack (MS)

MS is modified rule of EDD (Earliest Due Date). The main principle consists in job preference with the higher processing demand by slack time. This rule is usable in manufacturing planning for minimization of idle time between workstations.

Mathematical conversion of rule is formulated by priority index I_j which is composed by difference reciprocal of remaining time v_j, due date d_j and total time t[16]:

$$I_j = \frac{1}{(d_j - v_j(t) - t)}. \tag{1}$$

(2) First Come - First Served (FCFS)

FCFS is basic static rule and the jobs are fulfilled in arrival order to manufacturing process. In practice, it is mainly used for minimization of stock supply which has limited life time.

It is formulated equation reciprocal of release date r_j to obtain concrete value of given jobs[16]:

$$I_j = \frac{1}{r_j}. \tag{2}$$

(3) Shortest Processing Time (SPT)

SPT consists in jobs ordering in inverse sequence such as LPT rule. Jobs with the shortest processing time are preferred. This rule is possible to use for minimization of jobs average count which are located in system and for optimal time determination of jobs completion in planning. Priority is possible to determine as reciprocal processing time p_j [16]:

$$I_j = \frac{1}{p_j}. \tag{3}$$

3 Example

Example describes the manufacturing of two rotors and one stator. These parts are simple for manufacturing and production process is composed of ten production operations. Fig. 1 presents the production process of manufacturing and the production time is assigned in Tab. 4.

Table 4: Production time

	Frame saw	Lathe 1	Milling machine 1	Drilling machine	Lathe 2	Milling Machine 2	CNC	Shaper	Glowing furnace	grinder
Rotor 1	0	90	210	60	30	330	50	45	35	160
Rotor 2	0	100	72	0	0	270	90	0	0	90
Stator	66	140	0	80	0	45	30	0	0	0

Process of parameter defining is composed of production time determination for particular elements in Lekin. Scheduling system generated Gantt charts, machine and parts of elements for FCFS, MS and SPT rule, automatically. Graphical interpretation is presented in Fig. 2.

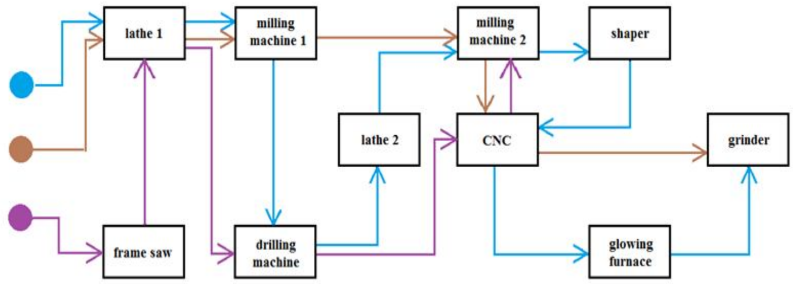
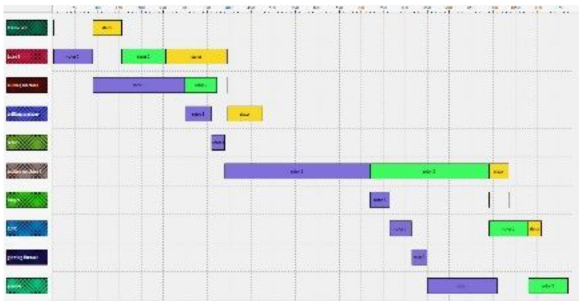
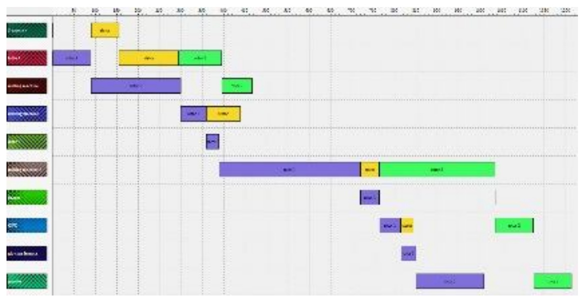


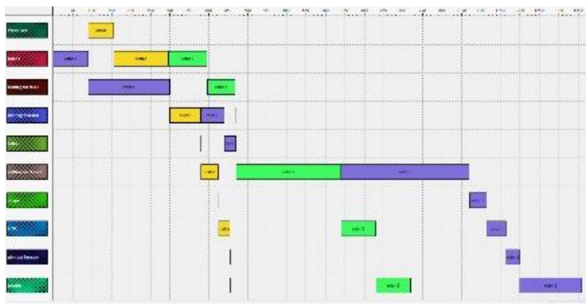
Fig. 1: Graphical interpretation of material flow (blue - rotor 1, brown - rotor 2, purple - stator



(a) MS



(b) FCFS



(c) SPT

Fig. 2: Graphical comparison of MS, FCFS and SPT rules

Schedule	Time	C_{max}	T_{max}	$\sum U_j$	$\sum C_j$	$\sum T_j$	$\sum w_j C_j$	$\sum w_j T_j$
FCFS	1	1215	649	2	3235	1242	6470	3133
MS	1	1170	809	2	3350	1357	6860	3523
SPT	1	1360	350	3	2735	742	4565	1228

Fig. 3: Numerical comparison of MS, FCFS and SPT rules

From the Fig. 2 and Fig. 3, it is possible to claim that the best rule is MS (1170 s) in consideration of maximum total production time Cmax. The most appropriate rule will be SPT in the case, when they are took all parameters into consideration, especially Total Weighted Tardiness and Total Weighted Flow Time.

For verification of this rule, it was selected simulation software Witness under the conditions of digital company which allows generation of various statistics focus on machine exploitability[7]. The basic model is presented in Fig. 4. It was modified production flow according to defined order from Gantt charts for every one rule.

After the manufacturing simulation and the setting of part quantity (one for every one element) was gained the total statistics which are presented in Fig. 5.

After the simulation, it is possible to claim that it is the most suitable possibility the using of MS rule on the basis of busy. On the operation "frame saw" is setting on blocking machines FCFS rule -1.98% and SPT

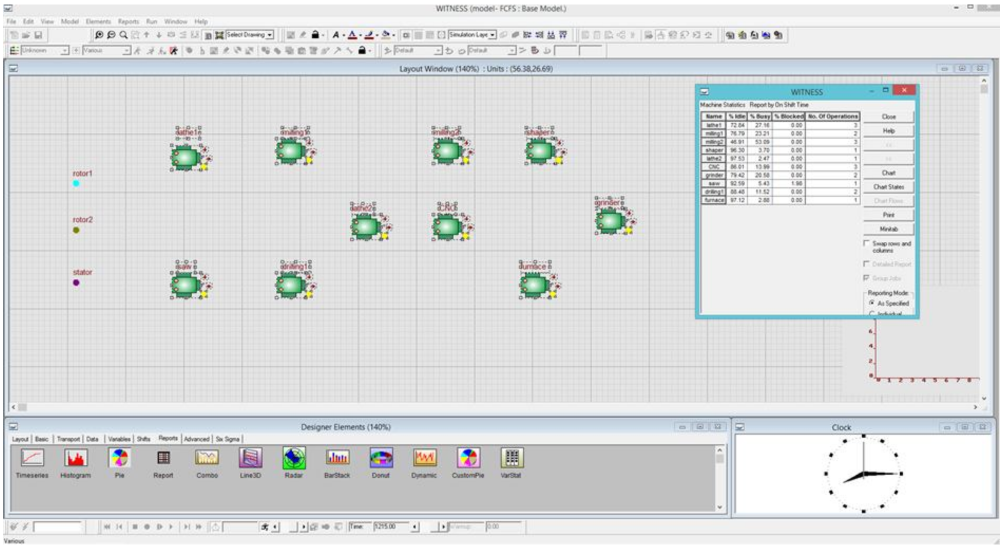


Fig. 4: Basic environment of simulation software Witness

rule 1.76%. It can be considered for negligible value considering to time 66 s. However, the greater number of parts production can complicate manufacturing. It is suitable prevent of this state and to use MS rule for optimization.

4 Conclusion

This article is focused on possibilities of planning and simulation software application for optimization of production operations. For the example, it was selected three parts which are produced on ten machines. It was used three dispatching rules MS, FCFS and SPT after the application of scheduling system Lekin. It is based on the best rule - MS with final time 1170s on the basis of presented results. It was ascertained that MS rule is not suitable for total weighted production time with using Lekin scheduling system. The most suitable is SPT rule which value is 35% from total weighted production time 3523 s of MS rule. MS rule was stated the best rule for busy state of machines after the simulation of material flow in Witness. In this rule, it is not blocking in operation “frame saw” and this brings the continuity of manufacturing process. It is possible to analyze impact of batch to creation of unacceptable states (blocking machines) for different dispatching rules in further research. Finally, it is made evident that the creation of the interconnection between simulation and planning software is very important for optimization of production. The creation of Gantt chart provides the basics for better realization of time structure simulation model. The interconnection of simulation and planning software reduces the production time up to 35%.

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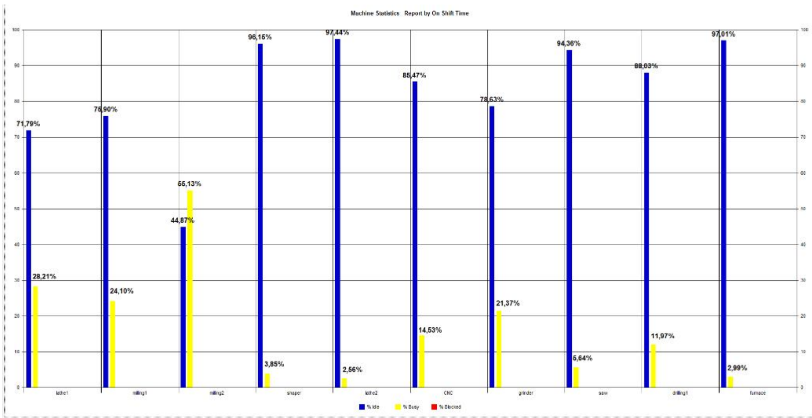
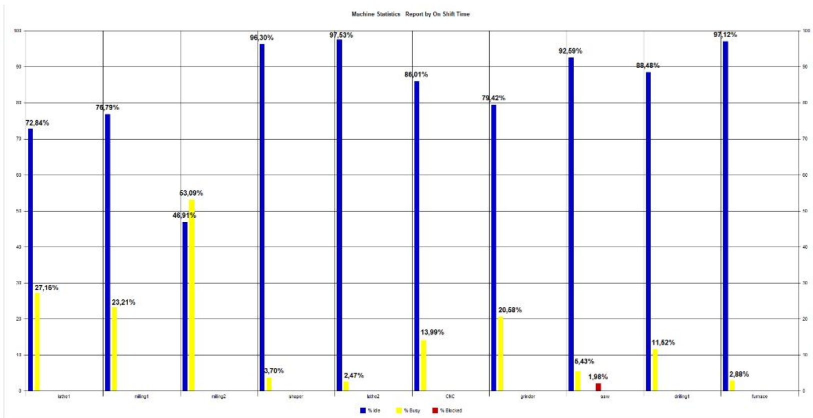
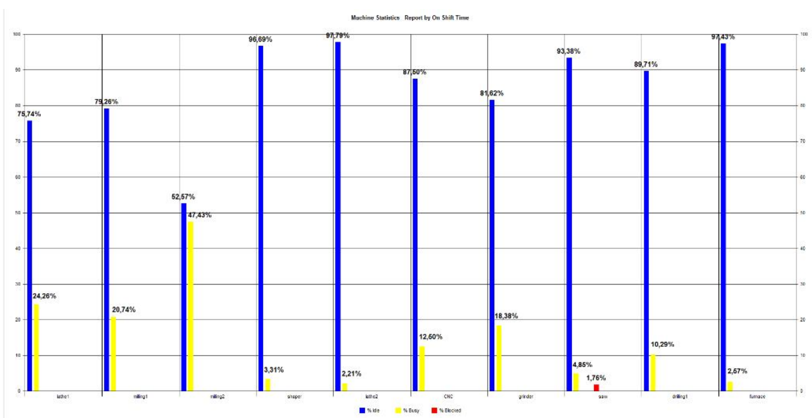


(a) MS



(b) FCFS



(c) SPT

Fig. 5: Statistics of machine for MS, FCFS, SPT rules (Witness)

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