Optimization of Time Structures in Manufacturing Management by using Scheduling Software Lekin

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***Abstract* – In each manufacturing plant it is one of the basic requirements to produce the largest quantity of products in the shortest time and at the lowest price. In performance of these requirements used are diverse modern methods, technologies and software which ensure the efficiency improvement of manufacturing, costs minimization, production time minimization etc. Presented article is focused on time structures optimization of real manufacturing process of engineering component by using scheduling software Lekin. It is based on theoretical scientific knowledge on which is afterwards found the optimal layout of the manufacturing process in practice. The optimal layout it created by construction and analysis of Gantt charts in scheduling software Lekin with minimum production time condition.**

***Keywords* – Scheduling, Time structures, Production process, Lekin.**

1. Introduction

Scheduling is one of the basic elements of success in each manufacturing plant and it is a tool for ensuring long – term market stability [6]. It contributes to market value growth ensuring of manufacturing plant and to determination of targets and their application to particular levels of the manufacturing management [4].

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Planning process is possible to approach as systematic determination of means and measures to achieve the predetermined target in concrete time. This process is composed of following steps sequence [1]:

- formulation of targets,
- analysis of manufacturing plant surrounding,
- selection of activity for target ensuring,
- checking of plan fulfilment.

Planning has substantial importance in each manufacturing plant. The mission of planning is not only creation of estimates, future development in the fields of cost, revenue, financial, money flows and funding but also narrowing potential problem positions, optimization and finding opportunities [2][9]. It is necessary to respect the following rules for quality and purposeful planning [7]:

- *completeness* – all relevant tasks have to be included in theplan,
- *unambiguity* – all of suppositions have to be realized,
- *continuity* – planning must not be used as occasional and separate tool,
- *flexibility* – it is necessary to plan alternative targets and measures associated with it for different development,
- *economy* – usability and conclusions of the plan have to be in economic relation to the costs of its making,
- *plan comparison and reality* – it is realised instantly after termination of monitored period.

The word SMART is created from five English words which shortly describe the characteristics of determined targets. Includes the following words [11]:

- **S**pecific – requirement for maximum definiteness of required targets,
- **M**easurable – requirement for measurability of required targets, the ability of their consideration during whole planning period,
- **A**chievable – requirement for suitability of assigned tasks which are necessary to achieve required targets,
- **R**ealistic – requirement for realistic result – required targets,
- **T**ime – requirement for determination of deadline for performance of required targets.

In the field of planning it is possible to apply several kinds of methods which are focused on identification and determination of task sequences [10]:

- *Network diagrams* - enable presentation time sequence and mutual linkages.
- *Influential diagrams* – the construction of influential diagrams is similar to network diagrams.
- *Key events diagrams* – are compiled list of activities with graphically represented time consecutiveness and mutual interconnection. These diagrams are suitable to apply for planning of complicated manufacturing operations. They are suitable to apply for organization of actions for example – introduction of new product, preparation for scientific conference etc.
- *Gantt charts* – enable arrangement of activities according to progress and time sequence. They follow tasks order and their deadline.

2. Gantt chart as a graphical tool of time structures representation in manufacturing planning process

Gantt chart is kind of line segment diagram which is possible to apply in various fields of human activities but primarily in the field of manufacturing planning and designing. Its structure consists of coordinate system (time axis) and line segments which present always some activity running in time – in timeline direction. Vertical axis presents the titles of activities and horizontal axis presents relevant time intervals. Gantt charts offer relatively good ratio – quantity of information per unit area. These diagrams give information about sequence of elements in the manufacturing process.

The base of purpose for which are used for it is possible to categorize the Gantt charts following [5]:

1) *Diagrams of machines using* – these diagrams are used for determination of size and causes of machine idles (these causes are marked with capital letter, for example M – it can mean the reason of idle – lack of materials). This lost time and its causes are precondition for receiving measures in manufacturing which direct the manufacturing to efficiency using of machines in the future.
2) *Diagrams of labour force using* – these diagrams are used for comparison real performance with standard performance and they are used for cause determination of standards non-fulfillment (these causes are marked with capital letter, for example B – machine breakdown). Recorded data are used for suggesting of method solution. The solution target is prevention of mistakes and increase productivity of employees.
3) *Diagrams of work plan* – these diagrams are used for assignment activities for machines and employees. The main task is to increase the efficiency of employees and machines. Diagram distributes the orders in accordance with fulfillment of deadlines
4) *Diagrams of work reserve* – these diagrams are used for illustration of the total work reserve at the moment.
5) *Diagrams of work procedure* – these diagrams are used for monitoring of continuous progress of tasks fulfillment. This kind of diagrams record the state of planning tasks and signalize delay, advance or accord with plan. Data from this kind of diagrams illustrate realistic relation between plan and reality.

Gantt chart is also possible to be understood as technique of time limits list expression taking into length of continuous time.Particular steps are depicted as time-proportional frameworks which are linked together with very marked important nodes in a network. This type of chart is the central visualization tool of the manufacturing process and an important communication tool in planning, too.

One of the graphical tools which provide fast and simple creation of Gantt charts is scheduling software Lekin. This software was developed at New York University and is useful in education and development. It is constructed on dispatching rules and simple heuristic methods. It has possibility to add the defined algorithm from user [3].

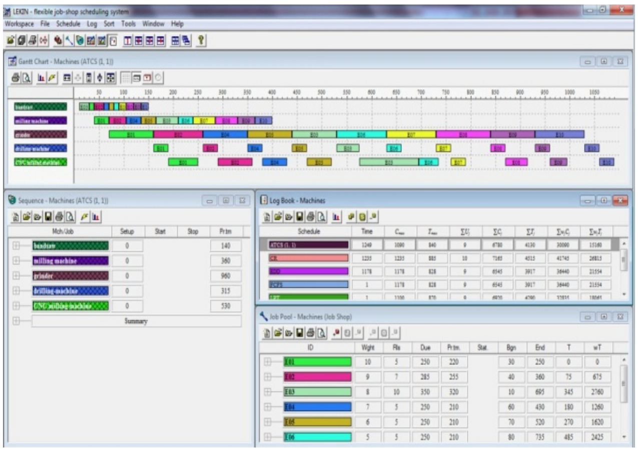


Figure 1.Working environment of scheduling software Lekin

It is possible to use created (by user) heuristic methods and it is possible to use external files with standardized input and output parameters in this scheduling software, too. It enables to test new algorithms in interactive environment and it facilitates comparison of different methods. The next table presents the list of dispatching rules and scheduling heuristics which the scheduling software offers.

Table 1.Overview of dispatching rules and scheduling heuristics

Dispatching rules	Scheduling heuristics
Earliest Due Date (EDD)	Bottleneck Heuristic
Minimum Slack (MS)	
Longest Processing Time (LPT)	The Shifting Bottleneck/sum wT
Shortest Processing Time (SPT)	
Weighted Shortest Processing Time (WSPT)	The Shifting Bottleneck/Tmax
First Come First Serve (FCFS)	
Apparent Tardiness Cost With Setups (ATCS)	Heuristics for local searching
Critical Ratio (CR)	

3. Optimization of time structures by scheduling software Lekin in practice

Optimization of time structures is described by manufacturing of engineering component which is manufactured in five different machines (band saw, milling machine, grinder, drilling machine and CNC milling machine). For this optimization model, it is manufactured ten different kinds of this component which are called E01 – E10. The following table presents input data which are necessary to realization of subsequent optimization.

Table 2. Input data

Components	Production time [s]					Weight [-]	Release Date [s]	Due Date [s]
	Band-saw	milling machine	grinder	drilling machine	CNC milling machine			
E 01	10	30	90	30	60	10	5	250
E 02	20	35	100	30	70	9	7	285
E 03	20	45	90	45	120	8	10	350
E 04	10	30	90	30	50	7	5	250
E 05	10	30	90	30	50	6	5	250
E 06	10	30	100	30	40	5	5	250
E 07	15	45	100	30	30	4	5	250
E 08	15	45	110	30	45	3	7	285
E 09	15	35	90	30	35	2	3	230
E 10	15	35	100	30	30	1	5	250

After assignment the input data into the scheduling software Lekin it was applied 8 dispatching rules (Table 1.). On the basis of production time minimization, the most suitable possibility is using WSPT dispatching rule in given condition. [14] The value of total production time is the shortest (1 065 s). Contrarily, the least suitable is using the CR dispatching rule for which the production time is the longest (1 235 s). In the following table (Table 3.) is presented the graphical structure of optimizing manufacturing process for CR and WSPT dispatching rules.

Dispatching rule Critical Ratio (CR) is focused on the preference of jobs that must be done to keep shipping on schedule. Of the same, it is possible to characterize this rule as the way of urgency of any order compared to the other orders for the same facility. Mathematical notation of the rule is following [12]:

$$C_r = \frac{D_d - T_d}{L_t} \tag{1}$$

, where:
D_d – due date,
T_d – today´s date,
L_t – lead time remaining.

After the application of this rule, the first component which goes into the manufacturing process is E03. The total production time is 1235 s and this part has delay 895s in the manufacturing process.

Dispatching rules WSPT optimized total priority time and all of the manufactured components are scheduling so that was preserved validity of equation [12]:

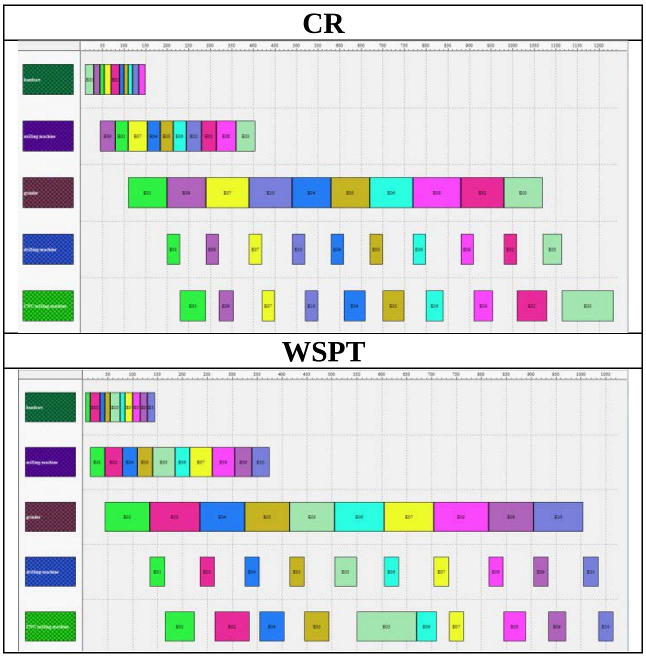
$$\frac{p_1}{w_1} \leq \frac{p_2}{w_2} \leq \ldots \leq \frac{p_n}{w_n} \tag{2}$$

where:
p – Period [s],
w – Weight [-].

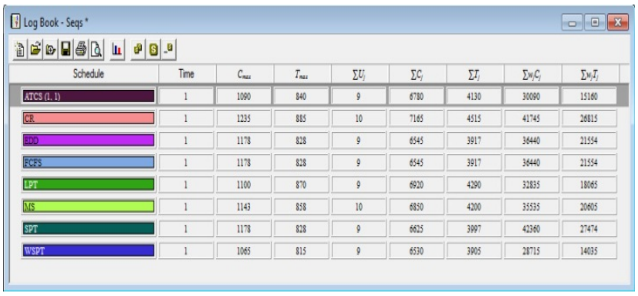
The first component which goes into manufacturing process is E01 when applying the WSPT dispatching rule. The total production time is 225 s and it shows that this manufacturing has any delay. The last component which goes into manufacturing process is E10 after the WSPT optimization. The total production time of it is 210 s and it shows that this manufacturing has any delay, too.

The production time intervals of other rules (Table 1.) are between WSPT and CR rules. They are not registered deviations from the most suitable rule however the order of components machining is different.

Table 3.Graphical structure of optimizing manufacturing process by Gantt charts – CR and WSPT dispatching rules



The next figure presents summary results after the application predefined dispatching rules. They are important and decisive the next values C_{max}, T_{max} and $\sum U_i$ from all of presented values. The first value (C_{max}) interprets total time in second which is necessary to components manufacturing after the defining input data. The second value (T_{max}) informs about the maximum possible breach of due date in seconds. The third determinative value ($\sum U_i$) is number of all components which have idle during the manufacturing.



Schedule	Time	C_{max}	T_{max}	$\sum U_j$	$\sum C_j$	$\sum T_j$	$\sum w_j C_j$	$\sum w_j T_j$
ATCS (1, 1)	1	1090	840	9	6780	4130	30090	15160
CR	1	1235	885	10	7165	4515	41745	26815
EDD	1	1178	828	9	6545	3917	36440	21554
FCFS	1	1178	828	9	6545	3917	36440	21554
LPT	1	1100	870	9	6920	4290	32835	18065
MS	1	1143	858	10	6850	4200	35535	20605
SPT	1	1178	828	9	6625	3997	42360	27474
WSPT	1	1065	815	9	6530	3905	28715	14035

Figure 2.Optimized values of production time after the dispatching rules using scheduling software Lekin

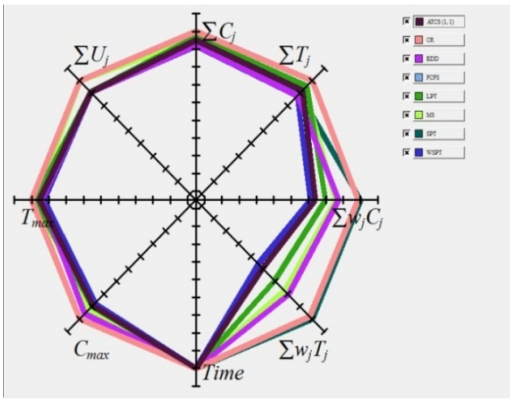


Figure 3.Graphical comparison of optimized production time for dispatching

4. Conclusion

The main of each manufacturing plant is effort to increase efficiency, speed and reliability. It is important that all of the activities which manufacturing plant performed were subordinate to systematic management and scheduling. [8][13]. Presented article described one of the ways to efficiently, fast and without burdening financial cots optimize the manufacturing process from the point of view of time. Manufacturing process was optimized by scheduling software Lekin which with simple and fast method. This scheduling software is usedfor manufacturing planning in project management. Lekin provides optimal user interface and it includes 8 scheduling heuristics (dispatching rules – methods). It enables efficient scheduling of material flows which result in improvement of production and management in company. After the application of dispatching rules it was determined as the most suitable WSPT rule given the predefined requirements. Application of this rule was the total production time reduced by 170 s to which the percentage is 13.77 %. As part of further researches it can be realised the impact of production costs to optimization changes which were realised by application of dispatching rules of scheduling software Lekin.

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