7th INTERNATIONAL MULTIDISCIPLINARY CONFERENCE
Baia Mare, Romania, May 17-18, 2007
ISSN-1224-3264

IDENTIFYING AND IMPROVING OF PRODUCTION CONSTRAINTS IN THE MANUFACTURING LINE

Dariusz Plinta, PhD. B.Eng.
University of Bielsko-Biała, Department of Industrial Engineering
2 Willowa Street, 43-309 Bielsko-Biała, Poland
dplinta@ath.bielsko.pl

Abstract: *The paper presents practical application of the modelling and simulation method in identifying and improving of production processes according to principles and stages of the theory of constraints. The particular stages of the mentioned theory are illustrated by the practical example of analysis of the crankshafts' manufacturing line. By means of simulation it is possible to check different variants of possible ways of workplaces improvements and to choose the best for realization.*
Key words: *modelling and simulation, theory of constraints*

1. INTRODUCTION

Several stages of development of the computer simulation method can be determined. They are connected with development of programming languages and development of data processing techniques. This development caused that the method of modelling and computer simulation has been wider used. Presently many simulation systems are available on the market from the simplest created on the basis of mathematical models, to the most complex, with environment for creating animation, 3D graphics, virtual reality and the possibility for integration with the company data bases.

Simulation systems such as ARENA offer a comprehensive set of advanced solutions designed to analyse processes realized in production enterprises [3, 4, 6]. The range of applications covers the whole manufacturing process, from designing and planning to assembly of final products. Typical scenarios include:

- documenting, visualizing, and demonstrating the dynamics of a process with animation,
- predicting system performance based on key metrics such as costs, throughput, cycle times, and utilizations,
- identifying process bottlenecks such as queue build ups and over-utilization of resources,
- planning staff, equipment, or material requirements.

With simulation software, we can:

- model our processes to define, document, and communicate,
- simulate the future performance of our system to understand complex relationships and identify opportunities for improvement,
- visualize our operations with dynamic animation graphics,
- analyze how our system will perform in its “as-is” configuration and under a myriad of possible “to-be” alternatives so that we can confidently choose the best way to run our business.

In next chapters, there is presented the analyse of manufacturing line according to the theory of constraints, application process which illustrate how we can model, simulate, visualize, and analyze manufacturing processes with simulation software.

2. THEORY OF CONSTRAINTS (TOC)

2.1. Modelling and simulation in theory of constraints

The Theory of Constrains (TOC) is a philosophy of management, which directs main attention on a bottle-neck of production system, that is the part which decides about efficiency of the whole system. Improvement of the bottle-neck gives the largest progress in the process of company development [1, 2, 7].

A large majority of people from high and medium management try to increase the efficiency only in chosen fragments of the production process, especially in their own departments. They do not look at the whole production system. The basis of such approach often is an assumption, that if every unit of the system is improved, then the efficiency of the whole enterprise will increase too. Such assumption does not take into account connections between particular departments and particular production processes. The improvement of particular sections very often does not lead to improvement of company efficiency. The optimum of the system is not a sum of local optimums. The improvement of efficiency in one part of the organization does not guarantee the improvement of the whole.

According to the theory of constraints all systems have “the weak link”, which is the constraint and which determines the efficiency of the whole organization. Strengthening of other links, beyond the weakest, will not strengthen the chain of processes.

The modelling and simulation method is a perfect tool which enables to find this weak link. It is often this workplace, which is maximally loaded and before which comes into being the largest queue of pieces waiting on processing. The bottleneck of a production system is possible to find by analysing of information included in the report from simulation, and also by observation of animation from computer simulation.

With help of simulation it is possible to realize next activities leading to the system improvement and connected with the Theory of Constraints – checking possibilities of the bottleneck from the point of view of maximum utilization, checking possibilities for his strengthening, adaptation of the supply and manufacturing schedule to the possibilities of the bottleneck [5].

2.2. Process of changes in the theory of constraints

Production process is the chain of activities, which are realized on mutually related resources and only several units (constraints) in this system have influence on the achieved result. Understanding this dependence makes it possible to find solution even for very complicated problems.

Improvement of the production system should be realized in a cyclic way in the 5 following stages [1, 2, 7]:

1. identifying the constraint (bottleneck) of the system,
2. maximum exploitation of the present possibilities of the bottleneck,
3. subordination of all to the maximum utilization (exploitation) of the bottleneck,
4. elevation of the bottleneck possibility (throughput),
5. return to stage 1.

On every stage, it is possible to use simulation, for example to identify the system limitation, to check the present bottleneck possibilities and to plan properly uncritical tasks practically.

In next chapter of this paper, there is presented an example of the realized project according to above-mentioned stages.

3. EXAMPLE OF THE PRODUCTION LINE IMPROVEMENT

3.1. Characterization of the analysed production system and the aim of research

The main goal of the conducted analysis was to increase volume of production in the crankshafts' manufacturing line. The analyzed line works in 3-shift system and 6 days per week, what excludes possibilities for increasing efficiency by introduction of additional shift or extra hours.

The aim of research was the analyse of tools exchange and material flow between the store and workplaces in the crankshafts manufacturing line and also looking for new solutions permitting improvement of the analyzed production system. The domain of study covers the flow of material between workplaces taking into account breaks caused by setup of working units. Different models in the ARENA system were prepared, whose aim was the imitation of the real system functioning and checking the proposed improvements. First variant of the simulation model encloses all operations realized in the analyzed production line. The goal of this simulation was to find a bottleneck, it means this workplace, which should be improved first. Next variants include activities realized in the bottleneck in detail defined. Different ways for setup realization were defined – different number of workers, different range and way of work organization. Presentation of the achieved results was prepared on the basis on reports from simulation. The most essential parameters of the analyzed systems were separated and by changes of their values the best solution was looked for. This activity is a typical example of realization of the fourth step in TOC – elevation of the bottleneck possibility.

3.2. Identifying the constraint

After modelling of the crankshaft manufacturing line (fig.1) and simulation of weekly production, in reports we found information about duty of workplaces, about size of queues before workplaces and the achieved volume of production. It made possible to identify the bottle-neck. This simulation was conducted in ARENA software packet.

The bottleneck of the analysed production system is the machining centre for 14^{th} operation characterized by the largest duty and the largest time and number of waiting pieces in the queue – fig.2. This operation has the longest operation time and also the longest setup time.

3.3. Maximum exploitation of the present possibilities of turning machines

To enlarge the efficiency of machining centre some organizational changes were proposed. The creation of conditions for continuous production in this workplace was the effect of these changes. In the bottleneck always will work at least one operator. The machining centre will be supported additionally by the operator from neighbouring workplaces.

The above mentioned changes were introduced into the second simulation model. From the conducted simulation the following conclusions were drawn:

– duty of all workplaces of the analysed production line grew – average by about 2%. The bottleneck was loaded almost by 100%;
– the volume of production grew similarly - from 18200 to 18600 pieces per week (by about 2%).

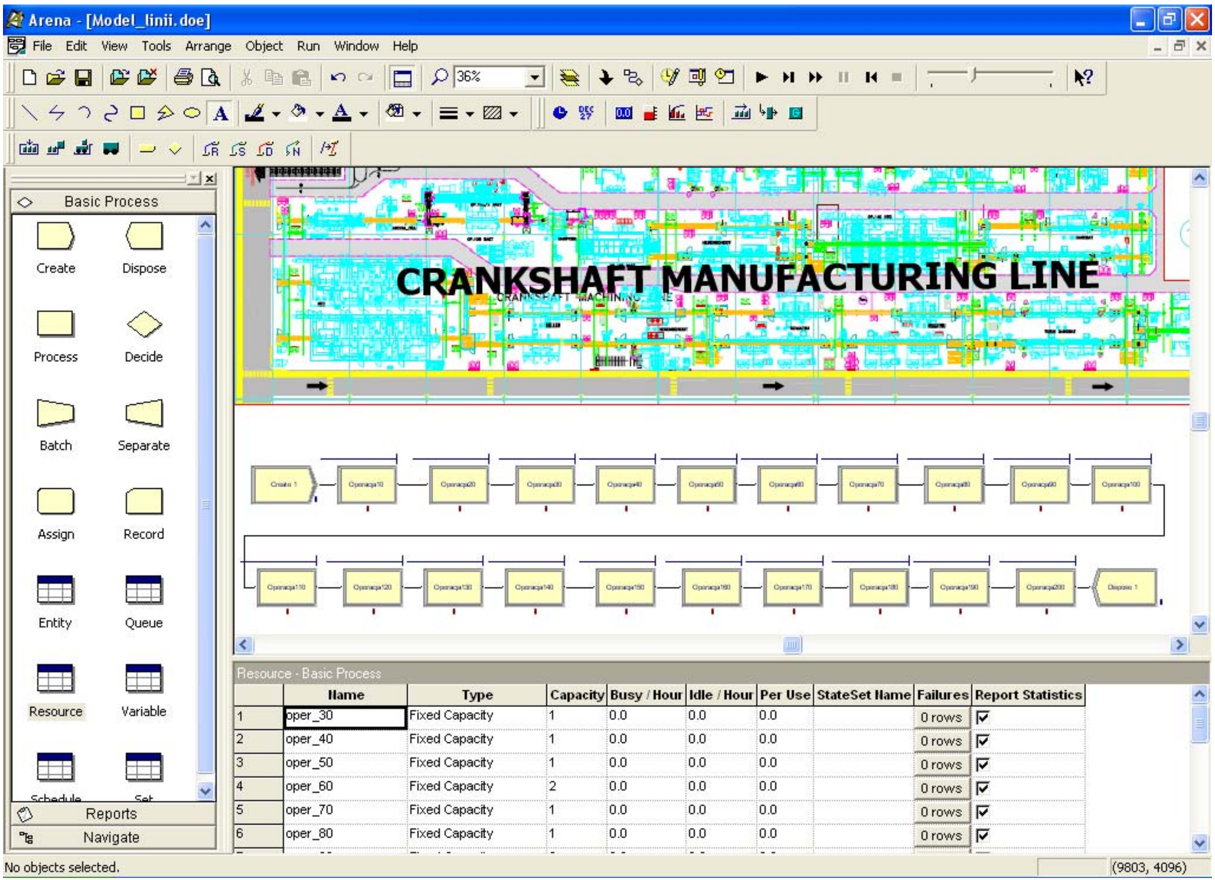

Fig.1. *Simulation model of the crankshaft manufacturing line (Arena software)*

3.4. Subordination of all to exploitation of the bottleneck

This principle was realized by the proper scheduling of production orders. In the first simulation the size of batches of material was established on the level of 20000 parts per week. As it turned out from simulation, we are not able to process such quantity of material. In effect, this guided to enlarging queues before machining centre (bottleneck). On the basis of results from the simulation, there was established that 18600 pieces will be the suitable size of weekly batch of production. With such level of production the average weekly size of the queue before bottle-neck will be constant.

Replications: 1 Time Units: Hours

Queue

Time

Waiting Time	Average	Half Width	Minimum Value	Maximum Value
Process 140.Queue	8.3518	(Correlated)	0.00	17.4297
Process 10R.Queue	0.5428	(Insufficient)	0.4232	0.9061
Process 11R_1.Queue	0.6434	(Insufficient)	0.5212	1.0084
Process 11R_2.Queue	0.3289	(Insufficient)	0.00523676	0.7882
Process 13L.Queue	0.1243	(Insufficient)	0.1025	0.1655
Process 13R.Queue	0.3860	(Insufficient)	0.06180565	0.8451
Process 14R.Queue	0.8390	(Insufficient)	0.7746	1.0691
Process 16L.Queue	0.1927	(Insufficient)	0.1884	0.1974
Process 16R_1.Queue	0.8891	(Insufficient)	0.8267	1.1167
Process 16R_2.Queue	1.0234	(Insufficient)	0.9616	1.2510
Process 4L_1.Queue	0.00549558	(Insufficient)	0.00511336	0.00586370
Process 4L_2.Queue	0.05493961	(Insufficient)	0.05319113	0.05869136
Process 4R.Queue	0.2032	(Insufficient)	0.1361	0.3424
Process 5L.Queue	0.07152477	(Insufficient)	0.04990562	0.1131
Process 5R.Queue	0.3458	(Insufficient)	0.2777	0.4862
Process 7R.Queue	0.4751	(Insufficient)	0.4230	0.6223
Process 8R.Queue	0.6187	(Insufficient)	0.5672	0.7631

Fig.2. *Part of simulation report*

3. 5. Elevation of the bottleneck throughput

The efficiency of the machining centre should be enlarged by purchase of a new machine. This solution was rejected due to too large costs of investment. The next proposed solution was the modernization, which makes it possible to achieve shorter setup time.

Some organization changes connected with tool exchange were proposed, whose aim was to shorten the time of machine standstill during setup.

In the analyzed workplace there are 15 machining units, which are prepared for working in different cycles – exchange of tools after different quantity of worked parts. The setup of any working unit requires stopping of whole line and it often causes standstills. It was the main reason to establish the same cycle for all units (to minimize quantity of standstills).

With regard on large differentiation of tools and their costs, simultaneous setup of all units is not possible. Several solutions were proposed, which are modelled and checked by computer simulation - fig.3.

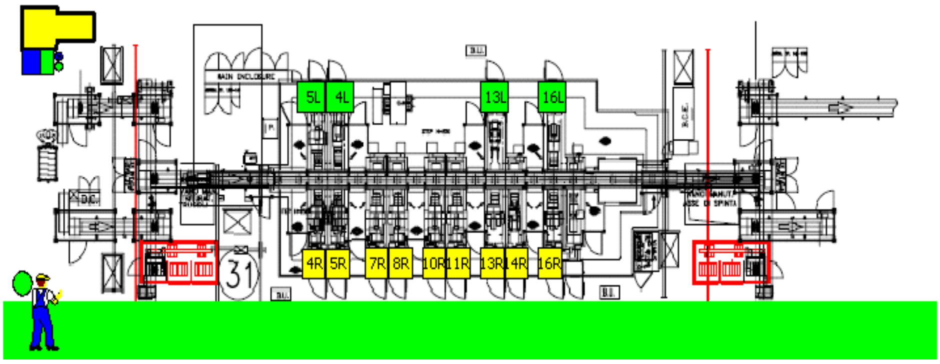

Fig.3. *Simulation model of the exchange of tools in machining centre*

The most important variants are:

V1 - present state (one worker sets up all production units in machining centre),

V2 - second worker's employment (one worker sets up from left side, and second from right side),

V3 - engagement of two workers (both workers set up units from left and right side in dependence on need),

V4 - new schedule for setup (the change of setup cycles and grouping tools for minimize quantity of standstills).

Results from simulation were used to compare the proposed variants. The best variant from the point of view of production volume was variant number 3 - fig.4. The achieved results can be the basis for planning of tool services.

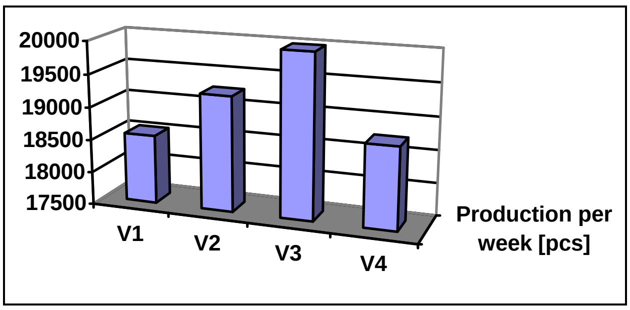

Fig.4. *Example of results from simulation*

The achieved volume of production carries out almost 20 000 pieces per week. The duty of workplaces was increased on the average by about 6%. The duty of the analyzed machining centre carries out 98%, what means that we should return to the beginning of the analysis, which is to improving a new constraint of the analysed production system.

4. CONCLUSIONS

If it turns out that another workplace after improvement (realization of changes in the production system) will be the bottleneck, we should go back to the stage 1. In the last stage of the presented analysis it turned out, that the other machine became the bottleneck and this workplace should be strengthened in the next step of improvements. Thanks to the simulation, after any change we see its influence on the constraint and also on the other elements of the analysed system.

In the described analysis, there were presented only chosen examples of simulation variants. In practice, there are more variants. They are more detailed and they take into account more aspects of the analysed production systems.

Next conclusion is that the modelling permits to represent the real system and to find these elements, which are essential from the point of the analysed problem (the setup of machine units). Besides, there exists the possibility for unrestricted interference into the system without the risk of causing irreversible losses. Therefore, this method gives us a huge possibilities connected with searching for solutions improving the work of logistic systems in enterprises.

5. REFERENCES

[1] Goldratt E. M.: Critical chain. Gower 1997.

[2] Goldratt E. M., Cox J.: The Goal. Gower 1997.

[3] Gregor M., Haluškova M., Hromada J., Košturiak J., Matuszek J.: Simulation of Manufacturing System. Politechnika Łódzka Filia w Bielsku-Białej, Bielsko-Biała 1998.

[4] Matuszek J., Košturiak J., Gregor M., Chal J., Krišťak J.: Lean Company. Wydawnictwo Akademii Techniczno-Humanistycznej, Bielsko-Biała 2003.

[5] Plinta D., Matuszek P.: Constrains management in production systems with utilization the computer simulation. AUTOMATION 2005 - konferencja naukowo-techniczna automatyzacja – nowości i perspektywy, PIAP, Warszawa 2005.

[6] Training materials for ARENA software.

[7] www.eligoldratt.com