USING SIMULATION APPROACH FOR DESIGNING OF ACID PICKLING LINES

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Presented paper deals with problems of discrete simulation within acid pickling lines. These types of lines are complicated mechanical systems required special algorithm for controlling. The paper discussed using of simulation approach both for projecting and controlling of acid pickling lines. Several experiments with the simulation model were performed to verify the production system design. In the paper are only mentioned simulation experiments which balance two alternatives; alternative with one crane, and alternative with two cranes. The key factor to be followed was the throughput (number of produced coils per hour) of pickling line in a steady state.

Keywords
Discrete Simulation, Acid Pickling Lines, Transport System, Production Rate

1. Introduction

At the present time the customer requires a quick reaction to his specific and particular demands on the part of producers. No competent estimations of characteristics for some future products are sufficient. There are claimed excellent qualities within offers namely by the presentation of designed production systems through a simulation modelling. Both for the end user and the designer of a production system it is important so that the simulation model by its behaviour approximates the most exact reality. Results of simulation experiments are then becoming confidential discussion groundwork among the designer, producer, and customer. Results from simulation models are presented to the customer both in a table and graphic form. The simulation animation serves to visual checks of the simulation accuracy, but in particular for responsible persons on the part of the customer – those who will determine on a realisation of brand-new projects.

The simulation modelling offers competitive advantages to design and production organisations. Mainly it brings the possibility to model not yet existing productions or to seek fault sources at some existing production. In this manner there can be obtained the survey on production process bottlenecks, the usage of transport units, the utilization of machines and equipment, the utilisation of staff, and likewise. The simulation software can be helpful at the staff training. The visualisation of the simulation can help to persons with a smaller technical imagination, but with relevant decision competences to be orientated in problems and to prevent risks.

The system simulation can be performed within a relatively short time. Its duration depends mainly on simulation specialist experiences and the knowledge of simulation processes. The simulation can achieve relatively exactly all possible hazards and weak points, which are not evident at first sight. Thus would be taken into account not only technical weak points but also economical ones. All investors evaluate the return of invested capital. The time optimisation of a production process can increase the production rate by tens of percents.

Approaches related to manufacturing system design using simulation studies include a lot of applications. Simulation of production capacity of a shock absorber assembly line was studied to propose a modification of the current line [Gujarathi 2004]. Redesign of an injector assembly and calibration production was discussed [Grimard 2005]. Research in analysing of concrete factors in a manufacturing system: the purpose of analysing some concrete factor of manufacturing system was to improve the current system. Roser, Nakano, and Tanaka [Roser 2001] studied a method for detecting the bottleneck in a manufacturing line. Duanmu and Taaffe [Duanmu 2007] attempted to improve throughput of a manufacturing line using a combination of tact time and simulation analysis. Simulation of robotic welding system was investigated to show the impact of system failures and delays on the output and cycle time [Williams 2002]. Man-machine ratios using simulation was studied to gain high resource utilization and output [Ong 2007].

2. Description of simulated system

Pickling lines are simulation objects. The topology of those lines can vary. According to the axis orientation of hook, which serves for manipulation with coils, can be distinguished the crosswise oriented system (the hook axis is perpendicular with regard to the production system axis), and the lengthwise oriented system. Manipulation manners with the hook can also bring some limitations: The crane on a lower position is not structurally limited in its horizontal movement or the crane on a lower position is structurally limited in its horizontal movement. The empty hook return can be accomplished out of the line or by means of the line crane. In the second case – if the line includes more cranes – then the return is carried out through a re-hanging point.

The number of transport units (cranes) is a further parameter, which must be set so that the throughput (production factor) would be assured. The simplest variant has one crane only, but the line can be designed with two or more cranes. Because the crane is expensive equipment then optimal crane number via the simulation brings considerable saving within investment costs. In case when more cranes are used then two different control strategies are possible according to the set of positions which are served: Each crane has own set of positions only (the sector which crane serves), or cranes can serve all positions.

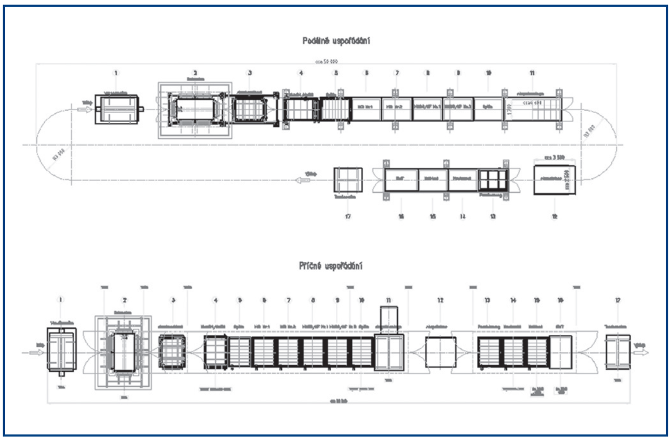

Figure 1. *Example of pickling line in two alternatives: Crosswise or lengthwise arrangement.*

The sequence of pickling line position engagements can be changed according to the flow of material. There are possible two variants – when position engagements are performed just in the material flow direction, or when position engagements are performed also against the material flow direction (manifold engaged positions). This fact considerably influences the preparation of simulation model, which implicates product flow control algorithms (the flow of pickled coils).

As to the technology two pickling technique can be applied – namely the cascade pickling at which all given positions must be engaged and simultaneously exposure durations cannot be summed, or summary pickling at which is sufficient to engaged one position and keep the summary exposure time (Figure 1).

After the deviation from a given pickling plans the three alternatives can be too distinguished: i. Without any deviation – that is the exposure cannot be exceeded; ii. The maximal deviation is defined – the exposure can be exceeded; iii. The maximal deviation is defined – the exposure can be exceeded only at some positions.

The pickling line configuration can be generally defined through the use of following parameters:

- The pickling line topology – the number of transport units TUn (the correct choice will be verified by a simulation), the number of transport hooks (the material is hung on the hook), the number and definition of technological posts (store, uploading, heating, pickling bath, rinsing bath, discharge, and likewise);
- The distance in horizontal direction (among positions);
- The distance in vertical direction (hook lift);
- The speed of travel;
- The speed of hoisting/lowering;
- The acceleration and deceleration of travel;
- The acceleration and deceleration of lift;
- The number of working positions;
- The pickling programme – that is entered by a technologist (the pickling programme is a sequence of positions to be engaged Sn for a chosen pickling programme):
  - According to the type of given technology – one or more pickling programmes;
  - The sequence of position (Si) engaging is defined for instance by the string: S1-S2-S4-S5-S6-S7-S9-S8-…;
  - The technologist determines material exposure durations within positions;
  - The technologist determines idle periods, for instance for draining away, uploading, discharging;
  - The tolerances within exposure periods.

During simulation studies these parameters are considered both as input parameters and subjects of simulating and optimising experiments.

3. Requirements for simulation model

The simulation model of the pickling line is to give answers mainly to following questions:

- With how many cranes can the production system be served?
- What is the production capacity of a given production system – Production Rate?
- What are the requirements as to the number of hooks within the production system?
- How will be cranes utilised?
- What is the maximal deviation from required exposure periods?

The simulation serves for operational characteristic verifications of production systems with a certain probability measure. During the design of production system there is necessary to correlate those three following requirements:

– Technologic;
– Technical;
– Economic.

The technologist enters the number of positions, exposure periods and eventually other limitations (time for dripping away, lowered speed during submerging, and likewise)

The designer enters dimensions, distances and standard speeds, and specifies technical limitations.

Investor and supplier evaluate production capacity, demands for the number of manipulating means (count of cranes, count of hooks).

In the model there is verified if the configuration of a designed transport system fulfils (with high probability) requirements, which were given to it. Simulation results are evaluated within the design team. The team either accepts results or will be looking for some solution (technologic, structural), which would improve parameters of the production system.

Output data from the simulation model of a pickling line, followed by the technologist, designer and investor are mainly as follows:

- Performance of production system – Production Rate;
- Demands as to the count of hooks;
- Demands as to the count of cranes;
- Usages of cranes;
- Maximal deviations from required exposure times.

Above-mentioned enumeration of input and output parameters cannot be naturally complete, but they can give some certain imagination what the simulating model would solve. The simulation versatility consists in the possibility to change any input parameters and then to process corresponding output parameters for them. Output parameters are then analysing, then they will be compared with end user's requirements, and also economical impacts of proposed technologic solutions are evaluated.

4. Simulation model of pickling line

From the previous elaboration large varieties of pickling line configurations can be derived. These varieties can be shown in quantities and arrangements of vats (baths), in means of transport numbers, in different algorithms for material flow control, and likewise. From such diversity naturally originates also different requirements with regard to the simulation model. To increase the affectivity of work during the preparation of simulation models, the more common methodology is preparing, which guides to preparation of more universal simulation models of pickling lines. It deals with a parametric model, which enables with smaller changes to create the simulation model for a concrete line. The general structure of some universal model is shown in the following example. (Figure 2).

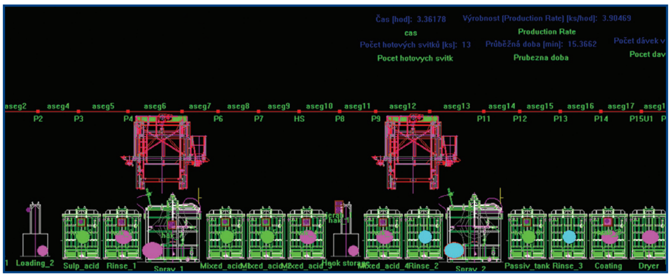

Figure 2. *Simulating model of pickling line*

The pickling line layout is derived from the proposal of line design that is elaborated in the Autocad environment. The line consists from individual vats according to the technological procedure. Vats are modelled as resources with capacity 1 (Figure 3). That means that they can handle in one moment only one coil. Resource is the entity (machine, operator, and likewise) allocated during operation and has the capacity of one load – 1 (one) coil. Loads allocate and release resources as per the technological procedure. For each resource (vat) we can define the initial setting (the state of the simulation experiment beginning), and the fault and servicing of resource. In case that faults are defined through the use of corresponding random functions then the stochastic simulation model would be created. Fault modelling problems will be discussed in another report.

Analogously to vats also input/output positions and re-hanging stations are defined as resources. To define hooks two approaches can be used. Either hooks are defined as single resources and com-

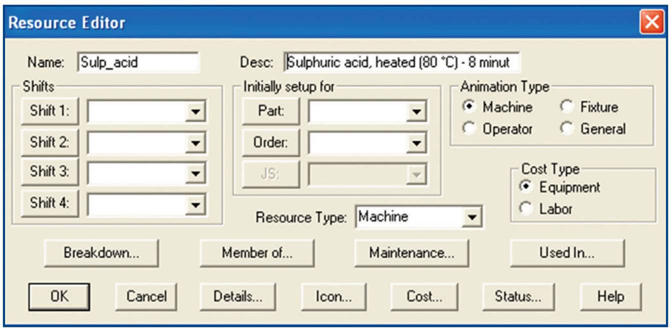

Figure 3. *Definition of vat as a component of resource type*

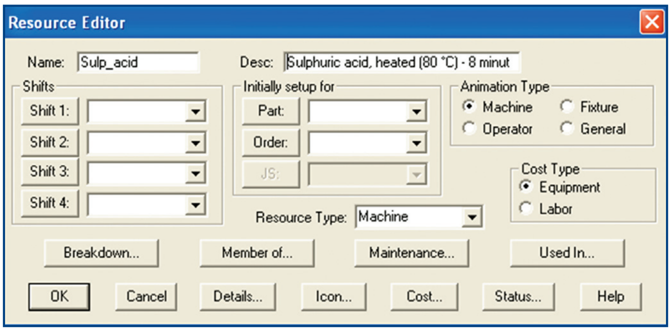

Figure 4. *Hooks defined as resource group*

bined to the group or hooks can be modelled by means of so called the multi-capacitive resource. In this presented simulation model the first possibility is used (Figure 4).

The crane track creates a transport system; one or more cranes are modelled by means of the use of modelling component AGV (Automated Guided Vehicle). The usage of sophisticated component for transport system of AGV type is evincible if the pickling line will be retaining two or more cranes. If during design proposals unambiguously only one crane was allocated then can be used the simpler transport component. But due to the fact that during simulating experiments the change of crane number is also required, so in this universal simulation model the AGV component is used.

The AGV system consists of transport segments and control points. Control points allocate each segment. At each segment the length, capacity, and velocity factor are defined. Control points define positions of individual vats, inputs/outputs to/from pickling line, transfer place, and likewise. In control points the decisions according to control algorithms of the transport system are performed. Hereinafter those following algorithms are defined:

- Sequence algorithms for load queue control – if the production load (coil) needs a resource (in that case a crane), which has been already allocated, then this load is placed into the queue according to the chosen algorithm;
- Algorithms for load (coil) selection from the queue of waiting loads – this algorithm will be activated after the resource has been freed and also can cause new creation of the load queue;
- Algorithms for crane selection – in case that pickling line retains more cranes the track of which are shared, then those algorithms are applied;
- Algorithms to control the crane behaviour during blockage, fault, or idleness.

From above we can see that control algorithms can influenced the behaviour of pickling line and its characteristics. The help of simulating experiments can find out suitable algorithms.

Other defined characteristics of transport system are the speed of crane with a load (it transports a coil), the speed of empty crane, and acceleration and likewise. Transport times are calculated by two methods: i. According to the length of segment, speed and acceleration; ii. Or according to the set of distances, speeds and accelerations. The choice of calculating method depends on what the simulation model will be used for. If the simulation model would be used for the design of pickling line when marketing purposes are expected, then the first method is more suitable. Besides others it enables better animation. The second method is quicker for data entry and calculation.

The technological procedure is modelled under the use of process plan. The process plan consists from individual process steps.

The technological procedure and the process plan are not identical, because the technological procedure is a subset of the process plan. In general the process plan describes the material flow (and also information and financial flow) through the production system. Due to that it contains besides the technology also control algorithms, bills of materials, and likewise. The example of generalised process plan is shown at the Figure 5.

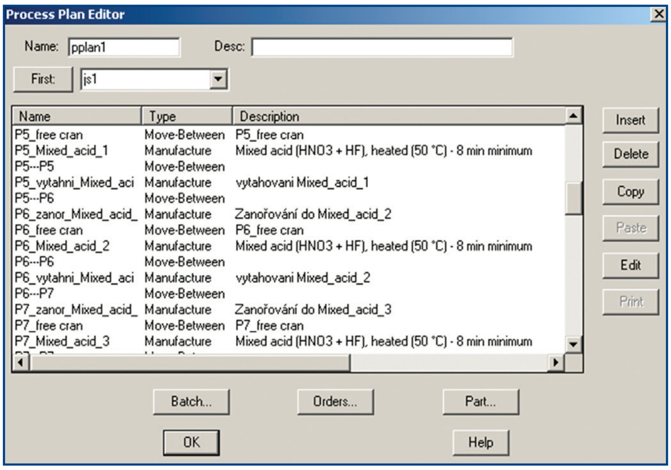

Figure 5. *Generalised process plan*

In the process plan two basic process job steps (beside others) are used: Manufacture and Move-Between. By means of the "Manufacture" process job step the manufacturing operations can be modelled – in case of pickling lines the coil submersing to vats. The process step "Move-Between" is used to model transport operations. Algorithms for allocation and releasing of resources are applied in both process steps.

The simulation model of technological process is processed within the development environment of licensed software FACTOR/AIM.

5. Results of simulation experiments

Several experiments with the simulation model were performed to verify the production system design. In the following description will be mentioned only simulation experiments which balance two alternatives; alternative with one crane, and alternative with two cranes. The key factor to be followed was the production rate (number of produced coils per hour) of pickling line in a steady state. In case that one crane is used the throughput is 6,716 pcs of coils per hour; when two cranes are used the throughput is already 9,061 pcs of coil per hour (Figure 6).

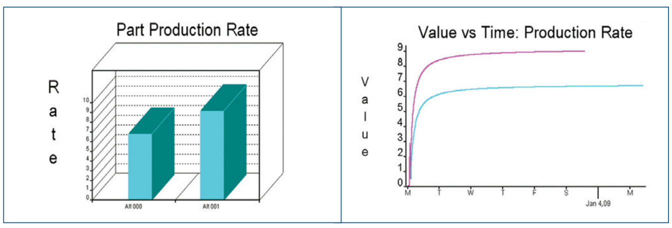

Figure 6. *Number of produced coils per hour*

The important factor the pickling line designs deals with is the resource utilization, for instance cranes or working stations as shows figure 7.

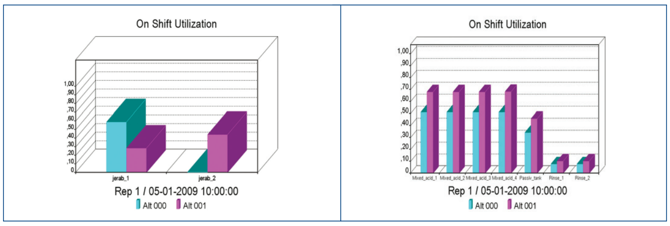

Figure 7. *Crane and working station utilisations in percents for both alternatives*

With the production throughput is also related the lead time when coils remain within the pickling line in a steady state (Figure 8).

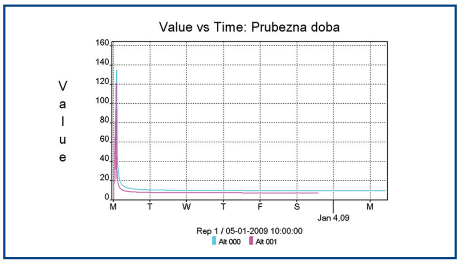

Figure 8. *Lead time*

To verify functions of the simulation model for analysis of pickling line operations, and to schedule the production, the Gantt's diagrams were generated (Figure 9).

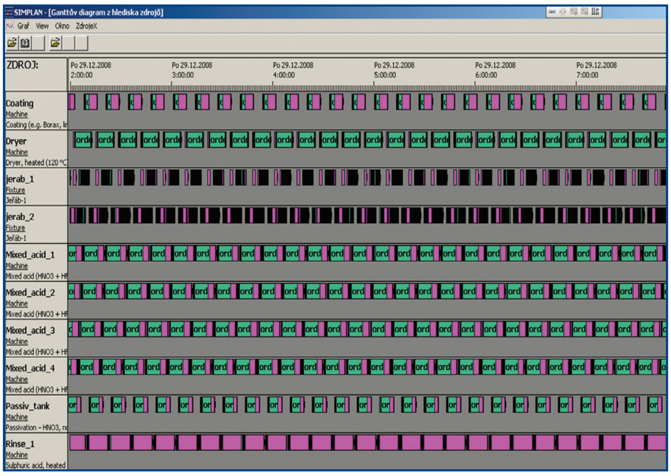

Figure 9. *Resoutce gantt charts*

6. Conclusion

The project benefits can be summoned to those following items:

– The demonstration of available technical parameters at the designed equipment;
– Savings at the equipment dimensioning and lower acquisition costs thereof (number of transport units, number of manipulation hooks, and others).

The simulation implementation to the production (on-line version) will be proven at the customer within following spheres:

– The overall material transport acceleration and thus the production increase;
– To reduce delays necessary to return the transport units to normal state (recovery after faults);
– To lover the number of wasted products.

From performed analyses can be expected the improvement within those economic parameters:

– The increase of work productivity within intervals 5–10 %;
– The working time rationalisations by o 5–10 %.

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