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MODELING, SIMULATION AND OPTIMIZATION OF PROCESS PLANNING

Abstract: Designing of production systems from the standpoint of necessary resources for carrying out the production process for many years present an important set of engineering tasks. In the scope of design of production systems, in addition to design of process planning, it is necessary to make the determination of normative parameters, by which the effectiveness of the production process will achieve a high level. This is possible using application of the software system Tecnomatix Plant Simulation. This software system implementation is one step closer to the automation design of process planning, by modeling and simulation of technological processes. In this paper it process planning was a modeled and simulated in concrete conditions, applying this program system, in 2D and 3D environment and also determining optimal parameters of production.

Key words: Tecnomatix Plant Simulation, Design, Modeling, Simulation.

1. INTRODUCTION

Designing of production systems from the standpoint of necessary resources for carrying out the production process for many years present an important set of engineering tasks. This process is determined by a number of influential factors of different degrees of intensity, direction and effect direction. In terms of growing competition the procedures of optimization of process planning are gaining in importance.

Process planning in metal manufacturing industry has variety of characteristic solutions in all its phases, i.e. operations. These characteristics were caused by the input data, which are encompassed with drawings and volume of production, the available technological equipment and raw materials, as also techno-economic conditions and subjective commitment of technologists.

In general, process planning variants of making a certain product are arising as a result of conventional design from technologist or application of automated systems design.

No matter which way of design is used, each adopted variant of the process planning is a logical set of appropriate technology development operations, whose solutions depend as from solutions of previous operations, as from solutions of the following operations.

Thus, the j-th variant of the process planning of production can be represented as a set of corresponding operations, i.e.:

\[(TP)_j = \{o_{j1}, o_{j2}, o_{j3}, \ldots, o_{jp}\} \quad (1)\]

where letter \(p\) is the number of manufacturing operations, for the observed variations of the process planning.

Within the design of the manufacturing process planning, in addition to designing technologies of production, it is necessary to make the determination of norms (standards of time, materials, areas, etc.), by which the effectiveness of the production process will achieve a high level. During this, the most important role has work needs norms of production systems that are closely related to the time of production and quantity of products (parts).

To achieve high performance of the production systems, it is necessary to optimize process planning. Optimization in most cases is performed by applying some of the known methods and it taking into account the processing time, hold time, off time, preliminary-final time, set-up time, extra time and etc.

This paper contains presentation of computational system Tecnomatix Plant Simulation, which allows one step closer towards automation design processes of production, by modeling and simulation of process planning.

2. SIMULATION OF PROCESS PLANNING

The aim of the simulation is to achieve results that can be transferred into the real world. In addition, the simulation defines the preparation, execution and evaluation of carefully targeted experiments in a projected simulating model. Simulation of process planning is executed using the following steps:

- Assessment and collection of data from real production processes, which are necessary for designing simulation models,
- Determination of simulation studies goals and creation of simulation models in accordance with defined goals,
- Running experiments to perform the simulation, in context of simulating model. This gives a certain number of results, such as: how often the machines in the state of failure, how often are blocked, setting of machine, process times, utilization of the machines, etc.,
- Interpretation of simulation data.

In the process of defining tasks and goals of the
simulation studies, usually we need to ask the following questions:

- What kind of bandwidth and the output can be expected?
- What is the optimal number of resources (machines, workers, tools)?
- Where buffer zones are required?
- What is the optimal size of buffer zones?
- What optimal number of working pieces can be processed?
- What strategies are most appropriate for the task?
- How to combine and interact some or all of these factors to produce different results?

After all that, it is necessary to decide on the scope of simulation: only process plan or other areas of production (receiving, storage, delivery, etc.).

Developing a simulation model is cyclic and evaluation process. The simulation is executed on the first or initial model, and then with its improvement and enhancement, model becomes operational to provide optimum results after completion of the process simulation. Finally, after several cycles of improvement and enhancement, optimum simulation model is reached. Thus defined optimal simulation model represents a real process plan in the production system, for which is necessary to conduct needed research and analysis.

In general, the process simulation technology is applied in cases:

- where new production system is planning,
- for improving the existing production system and
- for introducing a plan that is defined in practice.

3. OVERVIEW OF PROGRAM SYSTEM TECNOMATIX PLANT SIMULATION

Tecnomatix Plant Simulation is a software system which is designed for modeling, simulation and optimization of manufacturing process planning. Optimization of manufacturing process planning using this software system is based on time-oriented simulation and event-oriented simulation.

Time-oriented simulation takes into account a wide range of different types of production time, while event-oriented simulation takes into account only these points in time which events have an impact, within the simulation model.

Modeling of technological processes and the creation of simulation models of real production processes by applying the system Tecnomatix Plan Simulation can be performed in 2D and 3D environments.

Modeling in 2D environment, shown in Figure 1, is applied to complex optimization problems, related primarily to the time balancing the technological process, i.e. analysis of the production process from the point of time (production times, extra and additional times, a preliminary-final time, cycles production, etc.).

Modeling in 3D, shown in Figure 2, is primarily used for monitoring the distribution of technological systems and devices, which is necessary to spatially arrange in the appropriate production system.

Fig 1. Modeling of process planning in 2D environment

Fig 2. Modeling of process planning in 3D environment

Modeling in 2D and 3D environments is possible to connect, so when model in 3D environment is being created, model in the 2D environment was generated automatically.

The course of creating simulation models is carried out as follows:

- Generation of the 2D or 3D models of appropriate technological systems, devices, methods of transport material, inputs, outputs, etc. from the database of mentioned technological units,
- Development of spatial distribution of selected technological units and their adjustment to the conditions related to real production processes,
- Connecting the appropriate technological units in the production line. Thus defined product lines represent the actual product flows, which occur in the appropriate production system,
- Setting of parameters for each of the selected technology unit, which is a part of appropriate production flows. Data which are being entered in this step, should correspond as much as possible to the values of the real production process,
- Defining the appropriate objects, in the form of diagrams, tables, histogram, etc., which have the function of monitoring and presenting the results of simulations of the production process,
- Modeling of the production process and its setting in order to create conditions for the execution of
process simulation, i.e. testing of the simulation model,
- If the designer is not satisfied with the results of model simulations, he/she correct the input parameters until he/she get a model that gives satisfactory simulation results.

Capabilities of the system Tecnomatix Plan Simulation from the aspect of objects and methods of simulation are reflected through the simulation and modeling of:
- Process plan with a number of different strategies of production,
- Production process using the process planning,
- Condition: in malfunction, in work, in pause, etc.,
- Participants in the work and tasks they perform,
- Working shifts systems,
- Transportation systems etc.

4. APPLICATION OF PROGRAM SYSTEM TECNOMATIX PLANT SIMULATION

4.1 Process plan model

Application of the program system Tecnomatix Plan Simulation in this paper is shown on the model of process plan for production and assembly of crankshafts for production of motor saws. The production process in the specific situation involves making a three parts of crankshafts: one half of the magnet, one half clutch and piston rod.

Following data was used as input parameters for process of simulation and modeling using program system Tecnomatix Plan Simulation: the manufacturing process plan for parts of crankshafts (sequence of operations, production time, extra time, list of machines) and the number of pieces crankshafts annually.

4.2 Process plan simulation

Simulation of manufacturing process plan and assembly for crankshafts using the system Tecnomatix Plan Simulation in 2D environment consists of several steps:
- Defining the spatial model and generation of individual processes, which represent the operations in the production process from the process plan,
- Defining the distance between the individual technological systems in order to effectuate the simulation time which is lost during transportation of parts prior to the following operations,
- Linking individual processes in the flows of materials processing according to designed process plan,
- Defining the required time for individual processes,
- Defining the methods and rules of the transition work pieces during processing of materials,
- Defining objects for monitoring and recording the results of simulations
- Performing initial process simulation,
- Analysis of the results of simulation,
- Modification of simulation models and
- Performing the final process simulation.

Simulation of manufacturing and assembly process plan for crankshafts by the system Tecnomatix Plan Simulation in 2D environment is shown in Fig. 3.

Fig. 3. Segment from simulation model shown in 2D

After designing satisfactory model of the manufacturing and assembly process plan for crankshafts in the 2D environment, it is being made a modeling of process plan in 3D environment. The purpose of modeling the 3D environment is primarily to determine the spatial layout of machinery and equipment in the production plant.

Fig. 4. Simulation model shown in 3D

By placing the machines and devices in precise defined locations in the production plant in 3D environment it is determined the precise distance between the machines that affect optimization for earlier designed models.

Fig. 5. Simulation model located in the corresponding production plant
Simulation model and production plant of the manufacturing and assembly process plan for crankshafts by the system Tecnomatix Plan Simulation in 3D is shown in Figure 4 and Figure 5. This model is founded on the basis of previous information on the number, layout and positions of the necessary technological systems and equipment.

4.3 Simulation results

Improving the simulation model is performed through initial process simulation and analysis of simulation results. In the model after the analysis of results, bottlenecks of production are being identified and accumulation of working pieces of precisely defined operations of the process plan. Efficiency of machines performing the initial process of simulation, i.e. before performing the optimization process, is unsatisfactory as shown in Figure 6.

![Fig. 6 Efficiency of machines before optimization](image)

After analysis of influential factors, process optimization of process plan was performed, where goal is set as a function of high efficiency machines and minimum time duration of the cycle of production, while the limits were defined by the process plan. Resolving the above-mentioned shortcomings, introduction of buffer zones and increasing the number of machines, it was achieved a significantly shorter production cycle time. For example batch of 100 pieces of crankshafts, saving time in manufacturing process after the simulation was about 40%. After completion of design and simulation of process plan in the 3D environment, it was determined the exact location of machines and devices in the spatial layout of production facilities. Based on this information manufacturing cycle is reduced by 5% as a result of savings in time in transport parts between machines.

Based on the layout and location of machines and devices, it was designed a preliminary solution for production plant with the appropriate characteristics (departments, roads, entrances, exits, etc.).

Within results from execution of simulation of process plan, cycle times were generated for the appropriate size of batch parts and percentage utilization of machines in the manufacturing process. According to optimal designed simulation model, for the case of simulation of process plan and for the batch of 100 pieces crankshafts, the percentage utilization of machines is shown in Figure 7.

![Fig. 7 Efficiency of machine after the optimization](image)

5. CONCLUSION

Process plan modeling and simulation allows creating of models that represent adequate production processes, which generates the following benefits:

- Improving the productivity of existing production systems,
- Reduce investment in planning new production facility and capacity,
- Reduce inventory and flow time,
- Optimization of production systems dimensions, including backup size,
- Reducing investment risk through early proof of production concept,
- Maximizes utilization of productive resources,
- Improvement in design and layout of production line and machines.

In the example, final result of performing simulations showed data related to the duration of the manufacturing cycle, utilization of resources, as well as the required dimensions of the production plant that meet the set requirements from process plan.

6. LITERATURE


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