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[1]Implementation of discrete event simulation on a manufacturing system optimization.

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Abstract: The complexity of enterprise systems, the increasing needs for advanced collaboration among various systems within one institution or among many collaborating parties, and the velocity of organizational, policy, structural and market changes, presents nowadays challenges for the research community to develop more flexible and reliable technologies. Many real world manufacturing systems are too complex to be modeled analytically. Simulation based optimization is a very actual topic in discrete-event systems simulation. The paper deals with the problem of simulation based optimization of a manufacturing system. A model of a real manufacturing system that allows simulation of the system behavior at varying parameters is presented. The manufacturing system is modeled as a discrete event system with the purpose to a optimize job schedule.

Keywords: simulation-based optimization, discrete-event simulation, knowledge representation

1 INTRODUCTION

Simulation historically was not an optimization technique. Based on the improvement of heuristic optimization techniques (genetic algorithms, simulated annealing, tabu search, etc.) and development of computational hardware (faster PCs), simulation of a very large number of production systems´ configuration can be performed. The goal of the optimization is to find a set of parameter values that leads to an optimal, or near optimal solution. The paper is focused on job scheduling in manufacturing systems. Traditional approach to handle scheduling problems in manufacturing systems assumes a static environment. Unfortunately real world manufacturing systems presents highly dynamic systems with many unpredictable changes. Manufacturing systems are dynamic in nature and are subject to various disruptions, referred to as real-time events, which can change system status and affect its performance. Viera et al. (2003) classifies real time events that cause environmental changes, into two categories:

- resource related events (machine fails, defective materials, human related fails, etc.), and
- job related events (new order arrival, changes of job priorities, changes of deadlines, changes of job processing times, etc.).

That is why a dynamic scheduling is preferred for real world manufacturing scheduling. With reference to (Mehta and Uzsoy, 1999; Vieira et al., 2000a, 2003; Aytug et al., 2005; Leus and Herroelen, 2005), dynamic scheduling is defined in the following categories:

- completely reactive scheduling,
- predictive-reactive scheduling,

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- robust predictive reactive scheduling, and
- robust pro-active scheduling.

Dynamic scheduling always is connected with a new schedule generation as a reaction to the changes of environment. Dynamic scheduling can be decomposed into a set of static problems, and classical scheduling approaches can be applied to handle these problems. Dynamic scheduling can apply all classical approaches, like dispatching rules, heuristics, meta heuristics (tabu search, simulated annealing, genetic algorithms, etc.), artificial intelligence, and multiagent systems. Depending on the time when re-scheduling is required, there are several rules for re-scheduling used – *periodical rescheduling*, when the rescheduling is required in regular time intervals, *event driven rescheduling*, and also *hybrid approach*, when schedules are created regularly, but in case of an urgent event arrival, the schedule is created immediately. All these rules can be applied using simulation of manufacturing process, which enables to simulate some kind of events and prepare some scheduling options prior an event arrival.

A case study of a real manufacturing system is presented in this paper. A plastic foil recycling line and its model is described in section 2 and 3. Some simulation results are given in section 4.

2 A PRODUCTION SYSTEM DESCRIPTION

In this section we describe a real manufacturing system and an optimization problem in this system. The goal is focused on research and development of new approaches to optimize control and job scheduling of applied research on plastic recycling manufacturing system in the field of unconventional methods of control with the main attention on a specific manufacturing line for recycling-based polymerization.

The manufacturing system consists of several parts. Waste plastics are processed on *a granulate line*. The polymerization process of waste plastics leads to production of different color granulates (“wet way” production). The granulates serve as a base material for further processing on *a blowing line*. There LDPE (low density polyethylene) film of desired shape, thickness, width and color is produced using granulates and other input additives. The blowing line consists of four different types of extruders, which vary in basic characteristcs (e.g. electricity power consumption, shape, thickness, and width of produced films). The produced foil is reeled into rolls of defined maximum weight. The maximum weight of rolls depends on the type of extruder. Consequently the LDPE film is welded, punched and scrolled to desired size and this way a diversity of waste bags are produced on *a scroll line*. There are two different scroll line types available in the manufacturing system. A block diagram of the manufacturing system is depicted in figure 1.

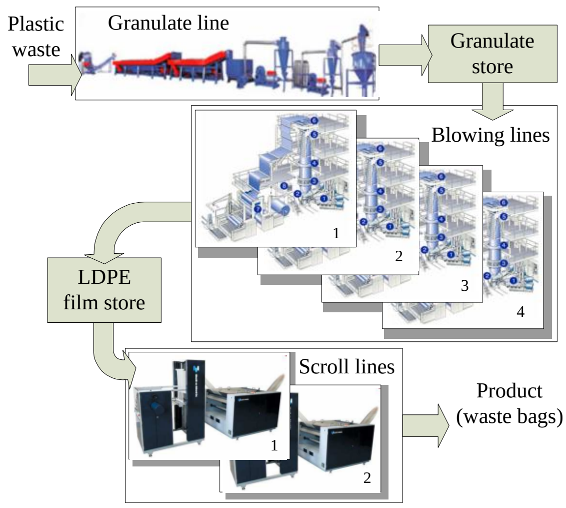


Fig. 1: A block diagram of a plastic foil recycling line

The goal of the production system optimization is to create a uniform clue to simplification of the job schedule. By creating of the convenient criterion we can figure with (Zelenka, 2010):

- material loss minimization by color change (the sequence of colors to be change affect the amount of waste material by the change and that way also the cost of the change),
- material loss minimization by parameters change (material loss is increasing when the changes are made during LDPE foil production without interruption),
- downtime minimization,
- production time minimization (by dividing one order to two or more machines),
- power consumption minimization.

3 A DES MODEL OF A PLASTIC FOIL RECYCLING LINE

Discrete event systems (DES) formalism is widely used for modeling of production lines, e.g. assembly lines. With some limitations it can be successfully used also to model continuous production lines, as e.g. a soft plastics recycling line.
Discrete event simulation is controlled by a set of discrete events. The characterization of these events is crucial for application of DES framework for simulation of the production process.

A model of the granulate line created using SimEvent toolbox of MATLAB is depicted on fig. 2.

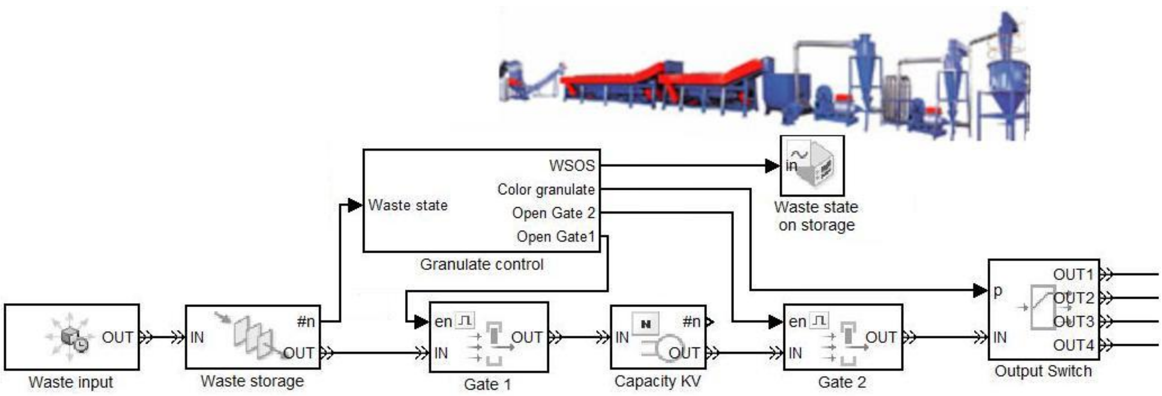


Figure 2: A model of the granulate line.

The main part of the model is an entity generator - "Waste input". Each time unit an entity is generated. The entity contains information weight of delivered plastic waste. A block "Waste storage" is represented as a FIFO queue. The function of the Waste storage is to ensure that plastics are not fed faster than it is processed. Gate 1, Gate 2 and Capacity KV server ensure that the number of entities will not be higher than the granulate line capacity. The Output Switch transports entities to the next FIFO queues. All of these blocks are controlled by the Granulate Control block, which ensures a transport of entities from the server to FIFO queues intended for granulation. A blowing line and a scroll line model (see figure 3) can be created similarly. Input and output switches ensure transport of entities from FIFO queue of granulate from which the LDPE film will be produced.

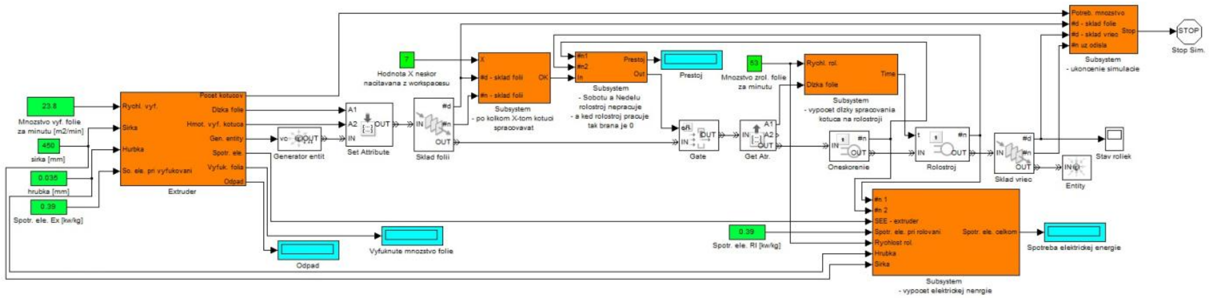


Figure 3: An example of blowing line and scroll line model

The Control block generates events that enable transition of entities through the model and ensure correct run of the manufacturing system simulation. The generated entity represents a produced roll of LDPE foil with desired weight, width, and shape. The roll is then processed on the scroll line. The model represents also material flow among the lines. The model enables to set the number of rolls that must be produced by the blowing line before the scroll line starts processing of the rolls. The more detailed model of the blowing line is depicted in figure 4.

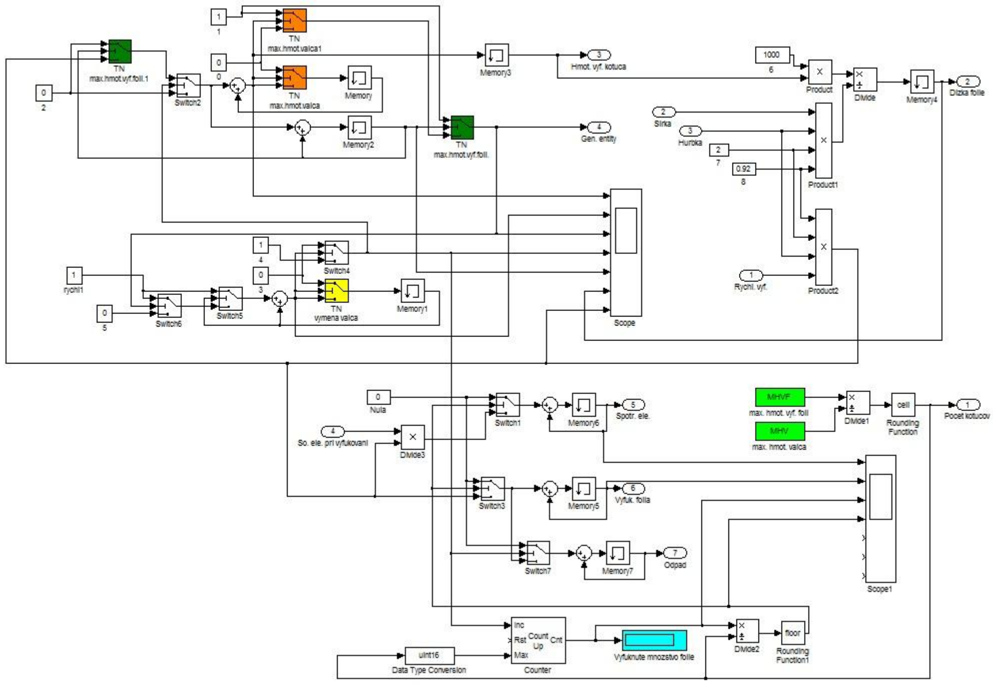


Figure 4: The blowing line model

The scroll lines do not work on weekends. It was necessary to consider also non working days (weekend, holidays, etc.) as inputs for the simulation. The control block for this type of downtimes is depicted in figure 5.

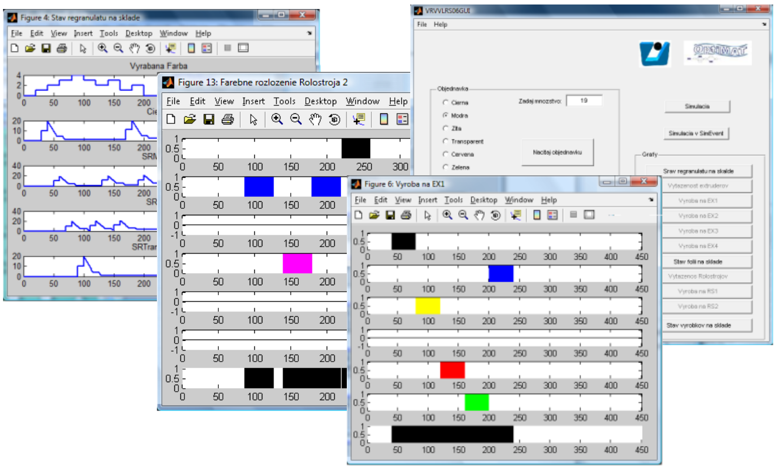


Figure 5: A control block for time schedule considering non working days.

The input information (customer orders) is loaded through a graphical user interface - GUI (figure 6). The following information can be set through GUI:

- all information from orders (order number, desired color, size, thickness, shape of bags, roll quantity, number of bags on rolls, delivery time, etc.),
- the blowing line or scroll line parameters,
- non working days (holidays, weekends)

The input information from orders is not compatible with required information for simulation. Some of this information must be converted into parameters that are specific for the production lines (e.g. it is necessary to know the conversion rate between the weight of film and the weight of granulate).

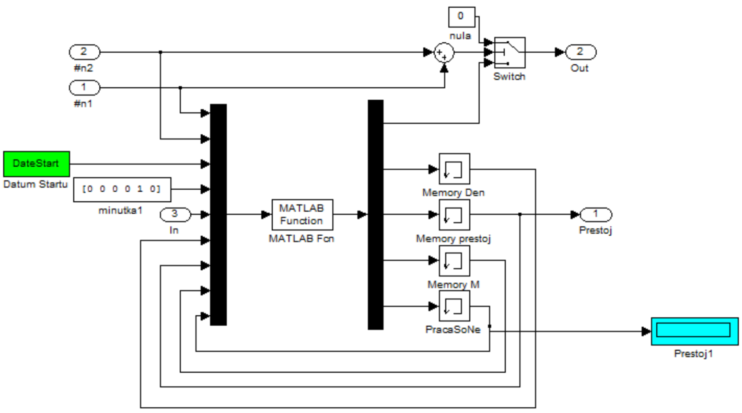


Figure 6: An example of a graphical user interface

Another input information that are required for simulation are thickness and wideness of LDPE foil, demanded amount of foil, average power consumption, and the maximum weight of a roll for each of the extruders. The simulation is finished after the last roll of the foil is processed on the scroll line. The output of the simulation is information about overall power consumption, downtimes and material waste during simulation.

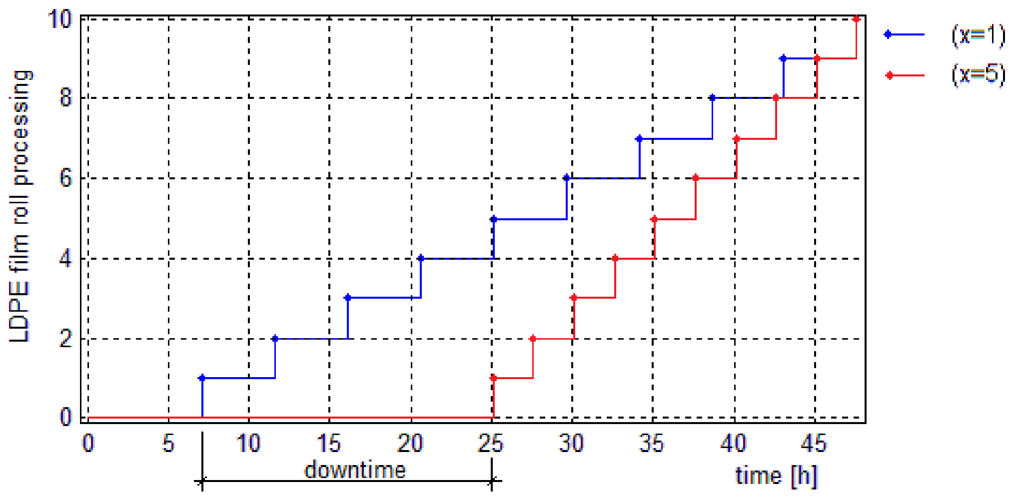
The simulation enables to examine the results with changing parameters. A manager can see how the changes affect production results and then he can choose the most appropriate schedule. In addition, a function that defines the managers´ preferences, can be formulated and the system then can offer the preferred schedules.

4 EXAMPLE OF SIMULATION RESULTS

An example of simulation results is given in figure 7. There are compared two ways of LDPE film processing:

- the LDPE film roll is processed on the scroll line immediately after being produced by the blowing line. When the processing time of the scroll line is less than the production time of the blowing line, the scroll line must wait for the production of film roll. (blue line)
- the processing of the LDPE film starts after production of the xth film roll on the blowing line. (see red line in figure 7 for x=5)

The results of this simulation are summarized in the table. For example, when the scroll line starts to process the roll film after fifth produced film roll, then the production time is reduced to eighteen hours and the roll film processing finishes at the same time as with the first way of production.



T_{RS1}	TD_{RS1}	x	T_{RS2}	TD_{RS2}	Δ_{DT}	Δ_{DF}
...	...	...	...	...	...	...
43,0 h	47,5 h	5	25,0 h	47,5 h	18,0h	0h
...	...	...	...	...	...	...
43,0 h	47,5 h	10	25,0 h	70,0 h	18,0h	-22,5h

Figure 7: An example of simulation results – two ways of LDPE film processing

5 CONLUSION

The task of manufacturing system simulation is to analyze the system behavior and to create a model, which will represent the behavior of the system. With this model created we can easily find the answer to the question, which would be hard without simulation. The possibility of the model created by SimEvents interconnected with the state diagram created by Stateflow toolbox, makes the Matlab software tools stronger for modeling of discrete event systems.

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