Simulation Aspects on the Design of Automated Manufacturing Systems

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Abstract: Economic aspects applied to automated manufacturing systems behavior are crucial and may be considered since the design of those systems. Modeling languages, software tools and analysis techniques are, thus, key issues for achieving the proposed goals for obtaining optimized systems, in order to reducing production time consuming and, consequently, reducing production cost by reducing effective production time cycle during normal (and possible failure) behavior of those systems. In this paper it is presented an approach that intends to reduce the time cycle consuming of automated manufacturing systems - since the specification and design steps - by using, together, the Simulation analysis technique, the modeling language Modelica and the Simulation environment software DYMOLA. Using a case study, there are presented models for the controller behavior, for the plant behavior and also for the closed loop controller-plant behavior. The impact of Simulation tasks in obtaining an optimized behavior is discussed and all the considered aspects are extrapolated for automated manufacturing systems of the same kind.

Keywords: Automated Manufacturing Systems, Simulation, Plant Modeling, Controller Modeling, Dependable Controllers.

1. INTRODUCTION

The design of automated manufacturing systems requires three fundamental aspects when it is intended the reduction of production costs and, consequently, the reduction of the manufacturing time cycle: the controller design, the plant design and optimization of the closed-loop global system controller/plant (exhaustive study of the process and desired product).

The fundamentals of planning an industrial process in a numerically controlled environment lie with the control and quality of operation planning and that planning time represents 50 to 80 percent of the global process time for single parts or small batches (Ahlquist, 2002). It becomes more critical for complex situations and new manufacturing technologies tend to extend the time further. Process planning has been defined by Alting as a function within the manufacturing environment which deals with the selection of manufacturing processes and parameters to be used to create the final product (Alting and Zhang, 1989).

Investigations by Younis showed that an efficient CAPP system could result in reduction of the manufacturing costs by up to 30% and would also reduce the manufacturing cycle and the total engineering time by up to 50% (Younis and Wahab, 1997). Hence, the focus has been on process planning as the task of the determination of manufacturing processes, which for instance can determine whether or not a product should be manufactured through a defined operation (ISO, 2004).

In this paper it is presented a methodology for design automated manufacturing systems with modeling of controller, plant and interaction between them in order to reduce the manufacturing time cycle. For accomplish this goal it is used the Simulation technique (Baresi et al., 2000) (Baresi et al., 2002), the Modelica modeling language (Fritzson et al. 1998) (Elmqvist et al. 1999) (Fritzson and Bunus, 2002) and Dymola software (Dymola, 2010). The Modelica language and its associated support technologies have achieved considerable success through the development of specific libraries and allows modeling the plant, even considering simulation of different kind of systems technologies (hydraulic, pneumatic, HAVAC, electrical,…) and also the modeling the controller using the Stategraph library (Otter et al., 2005).

Modelica supports both high level modeling by composition and detailed library component modeling by equations. Models of standard components are typically available in model libraries. Using a graphical model editor, a model can be defined by drawing a composition diagram (also called schematics).

With the use of this approach it is possible to simulate the desired behavior, the possible failure behavior for the system - because it is developed a global model of the system (controller model, plant model and respective closed-loop behavior) – and, finally, to study and define the conditions that will allow to reduce considerably the manufacturing time cycle, fixing some process parameters and allowing the changing of other process parameters.

The consideration of the Controller Modeling, the Plant Modeling and also the interaction (controller-plant) model, can make Simulation tasks more realistic and more conclusive (Dymola, 2010) (AS, 2010) (Mosterman, 2002) (Baresi, 2002).

To accomplish our goals, in this work, the paper is organized as follows. In Section 1, it is presented the challenge proposed to achieve in this work. Section 2 presents a general presentation of the case study involving a tank filling/emptying system. Further, in section 3, it is presented the methodology to obtain the plant model, namely the conditions of functioning and the definitions of the different stages, parameters and variables considered in this task (mathematical modeling). Section 4 is exclusively dedicated to the closed-loop (controller + plant) system modeling, using the modeling language Modelica. Section 5 presents and discusses the obtained results on simulation performed with Modelica Language, considering the desired behavior and, also, optimization of the manufacturing time cycle. Finally, in Section 6, the main conclusions and future work are presented.

2. CASE STUDY DISCRIPTION

The case study that is proposed as base for this work is inspired on the benchmark system proposed by (Kowalewski et al., 2001).

Figure 1 illustrates an example of an evaporator system, which consists of two tanks, where an aqueous solution suffers transformations. In the first tank that solution should acquire a certain concentration through the heating of the solution using an electrical resistance (H1) which provokes the steam formation.

Associated to the tank1 (tank1) a exists a condenser (C) responsible for the condensation of the steam that however it was formed. The cooling, in that condenser, it is done through the circulation of a cooling liquid (whose flow is measured by sensor FIS) that passes through the cooling circuit (if open the valve V13).

Associate to the tank1 there are a group of sensors: level sensors (maximum (LIS1) and minimum (LII1)), temperature sensor (acceptable maximum (TIS1)); sensor of conductivity (QIS) that is to indicate the intended concentration; they also exist several actuators: filling valve of the tank1 (V12), drain valve (V16) and emptying valve (V15), that it is also the filling valve of the tank2.

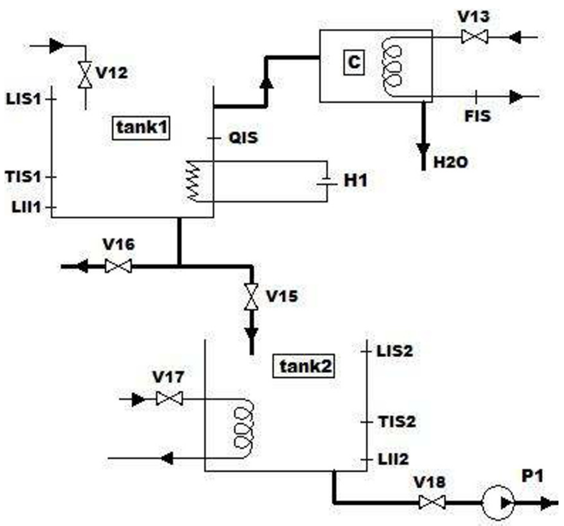

Fig. 1. Scheme of the entire evaporator system

In the normal operation mode, the system works as follows.

The tank1 should be previously filled to its superior level with an aqueous solution by opening valve V12. When the tank1 is full, the heating system is switch on and also, in simultaneous, the cooling system of the condenser by opening valve V13. When it is formed steam, this condenses in the condenser C. When the concentration desired in the tank1 is reached, there are switch off the heating system and the cooling system of the condenser. Continuously the solution flows from tank1 into tank2, and it must be guaranteed that the tank2 is empty.

The transfer of the solution to the tank2 is for a powder-processing operation that is not, here, described. For that powder-processing operation, there is necessary to heat the solution to avoid possible crystallization, and for that there are two approaches: it can heat until the temperature sensor of the tank2 indicates that the desired temperature was reached; or it can heat up for a certain time. Finally, the tank2 is emptied by the pump P1, if the valve V18 be opened.

On the other hand, in the possible failure operation mode, the system works as follows.

A possible failure scenario of the system happens when the cooling fluid flow in the condenser be to low (detected by sensor FIS). This implicates the increase of pressure and temperature in condenser C and tank1, if the heating system keep switch on (solution steam). It is necessary to guarantee that the pressure in the condenser C doesn't exceed a maximum value to avoid its explosion. For that, it should be guaranteed that the heating in the tank1 is switch off before the open of the safety valve (V16).

For this situation of failure operation, it should switch off the resistance H1 the more quickly possible, but tends in account that the solution doesn't crystallize, then that we are before a critical time. To switch off the resistance H1 they are considered two possibilities: through a time after sensor FIS to have detected reduced flow; or through the sensor of temperature TIS1 (due to the pressure and temperature are parameters that are directly related).

There are evidences that should be guaranteed, as for instance that the tanks should never overflow. After the failure situation occurs, all of the valves should be immediately closed.

2.1 - Controller Specification

In order to guarantee the desired behavior, the controller specification was developed according to IEC 60848 SFC specification.

The input and output variables of the controller which controls the process in closed-loop are presented and described in Table 1.

The SFC specification of the controller behavior (normal and failure modes) is presented in figures 2 and 3.