DEVELOPMENT AND IMPLEMENTATION OF A MONITORING AND REAL-TIME MANAGEMENT SYSTEM IN FLEXIBLE MANUFACTURING

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Abstract. The paper presents the development and implementation of applications - software package for monitoring and real-time management of a flexible manufacturing line of cylindrical parts, serviced by an industrial logistic subsystem with feeding - transport - transfer and storage functions. The user can then monitor and control the entire system from the control monitor, shortcomings is noted in real time on each module of the process.

The applicative character of the research is to simulate the operation in a real physical system, designed and based on mathematical models of sizing and configuration, previously developed and the validation of simulation. The simulation revealed the behavioural properties of the flexible line and the evolution in real process. The developed applications -simulation programs, arose from the need to analyze and study the behaviour of a real system, in order to control and management in the future the system and will open new lines of research, with the cumulative effect of reducing the uncertainty that exists in flexible manufacturing.

Keywords: production systems, flexibility, modelling, simulation, management

1. Introduction

The production systems have been in recent years and are still subject to a process of profound transformation with increasing dynamics. The evolution in production systems was motivated by two key factors: productivity growth on one hand and diversification, discernible in the actual world, on the other hand. When striving to increase the degree of automation in the manufacture of small and medium series of products one has to provide a compromise between two conflicting goals: high flexibility and productivity of machinery. A solution to this compromise gives the concept of *Flexible Manufacturing System - FMS*, as the central element of integrated manufacturing system (*Computer Integrated Manufacturing - CIM*). As a result, a new concept appears in manufacturing, which includes integration of computer components and flexible manufacturing [1]. Nowadays, flexibility is an absolute prerequisite to manufacture, flexible manufacturing leading to the development of typological diversified products with reduced manufacturing cycles, competitive costs and responding to high quality requirements.

As mentioned in the literature [2, 3], flexible manufacturing is currently a dynamic research field, which absorbs a great research effort, because in the field of mechanical technologies the future is robotics, flexible automation, based on this technology regarded as a system.

It is found that flexible production systems are used for small / medium production volume in terms of economic efficiency, bringing the following advantages: flexibility, typological diversity, minimal time and cost of adaptation, simultaneous manufacturing of several types of random parts of the family respecting the pace of manufacturing, random entry of parts in the system, improved average pace of manufacturing, production organization in current flow by applying Lean principles, reduction of unfinished production and stocks, etc. These are the only advanced production systems that solve the contradiction between *flexibilities – adaptability – productivity* [4]. The effectiveness of FMS increases with the growth of flexibility and integrability, the management and monitoring with hierarchical network of computers and the application of constraints in continuous flow production.

In this context, the scientific research in this paper are directed towards the study of flexible manufacturing systems in the view of knowing their behaviour and performance as well, and if possible, even before the physical realization. Thus, after establishing on scientific based mathematical models for dimensioning and configuration [5] the simulation and validation was performed for the designed flexible manufacturing system.

The implementation is based on using a programming environment for the development of graphical applications in real-time control and management of flexible lines, served by an industrial logistics subsystem.

Engineering simulation is a tool that allows a better understanding of the complex issues that arise in the research, design and development of systems [6]. It allows a deeper analysis of the characteristics of the simulated system.

2. The simulation concept

Simulation study is important for understanding how the real system operates. In the process of mathematical modelling, system components are associated variables and parameters, some of which are known / controllable, called variables / input parameters, others are unknown / uncontrollable called variant / output parameters. The connections and interactions between system components or the system with the exterior can be transposed in mathematical model by functional relations (equations and / or inequalities).

In the mathematical model there is an objective function or more objective functions, linking various variables and that measure the system performance. The purpose of the model is to express uncontrollable variables of the model depending on controllable variables, so as to satisfy performance criteria, which means to solve the equations of the model and / or optimizing the performances of the system. Sometimes, however, the interdependencies between the components cannot be expressed by simple equations, but are described by logical conditions or procedures that can be solved only through the computer.

The mathematical model filled with such procedures becomes a simulation model. Where the simulation model is implemented on computer, based on values of controlled variables (internally generated by special algorithm routines) will produce values of uncontrollable variables and will choose the optimal decisions [7].

It follows that simulation model produces experiments on the system which is simulated and allows choosing those values of input variables and parameters that lead to the desired performance of the system. However, the simulation model is a necessary tool for the study of complex systems, such as flexible manufacturing system, where classical mathematical models are unable to capture the most varied and unexpected aspects of reality.

Unlike the mathematical models that have deductive character, solving them being performed by inference, simulation models have a procedural nature; their resolution is based on processing experiments within the model [3].

In contrast to the mathematical models (methods of optimization, linear programming, dynamic programming) technique for simulating the behaviour of the system does not guarantee that the best solution is optimal. It is, however, an effective research technique because it allows solving complex problems, impossible to study analytical (by mathematical optimization models), that raises real systems research, providing a feasible solution, even in complex systems [8].

2.1. Simulation software program

It was intended to use software, programming languages specific to design and simulation (Delphi, Visual C++, Catia, Cx Supervisor Developer, Ladder) and to develop new software, specialized applications in the design, management and monitoring of flexible manufacturing systems.

Some specialists consider Delphi as a version of RAD (Rapid Application Development) of Borland Pascal programming medium. One of the first things to be understand when working in a RAD medium refers to the fact that a RAD medium is a drawing up technology of solutions for several problems of informatics based on a series of concepts, components and protocols concerning their use.

Essential in simulation modelling, the logic element is set up by data structures convenient for the event's processing. The object oriented modelling outlook first introduces fundamental model categories by counting key model types of each category and, second, specifies the way of achieving programmed objects, starting from the real ones. The object oriented functional networks methodology was developed in view of incorporating all aspects concerning a system: structure, functionality and behaviour.

The model was also developed for permitting to the user a neat control on any level of a complex system, without losing any aimed aspect. It's also the case of the conceived flexible manufacturing system [5].

This modelling strategy supports graphical representations by visualization of the model. The structure of such a model is grounded on the concept according which any real system can be described as an informational part or an acting part.

Initial data needed in achieving a simulation model of FMS are:

- number and types of the system's working stations and of machine tools;
- number and types of conveyors and conveying speed; type of the used logistic sub-system industrial robots and their number; number of the systems stockers and their accumulating capacity;
- type of pieces, their technological route;
- duration of the processing cycle for each piece-type of each flexible manufacturing system model;
- number of items being simultaneously processed;
- volume of series of manufactured products.

2.2. Simulation validation

Figure 1 presents the experimental researches using a flexible system for round shafts real process.

The flexible production line designed and based on graphic-analytical sizing model that will achieve and validate simulation has the following functions:

- feeding with cylindrical parts;
- prior conveyor transport, up to the processing station;
- piece transfer to the position of processing;
- piece machining by drilling, with control over drilling depth;
- transfer of the workpiece on the conveyor;
- transporting the workpiece to the simulated cutting station;
- checking the dimensions of the workpiece by measuring with laser sensor in the control station, computer verification;
- sorting parts that do not have sizes in the prescribed tolerance;
- process simulation of turning of the cylindrical workpieces: automatic setting and driving the chuck rotating cylindrical blank;
- transporting of machined parts on a conveyor to a repository of finished parts.

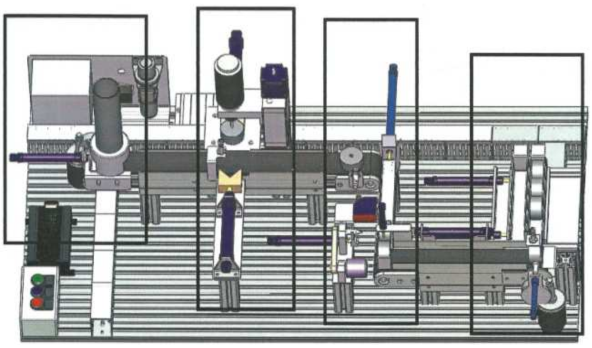

Figure 1. Real flexible system for validating simulation

By evaluating the flow of pieces on processing machines and stations and examining conflicts with regard to requirement of some limited resources, the system layout, selecting manner of equipment, as well as operating proceedings can be evaluated.

The program drawn up allows planning / programming and managing in real time the whole processing system.

Using the developed simulation models we studied: the influence of changes in the system structure on its behaviour, the influence of the initial conditions or parameters on the behaviour of the system. Thus, we could explore ongoing operations without interruption, new operating procedures, decision rules, information flows, flows of materials analyzed by system simulation.

3. Command and control of the designed FMS

The command function, monitoring, control and diagnostics of a FMS are carried by the information subsystem through informational flow that is transmitted in two ways: direct sense of control information and reverse, the information monitoring, control and diagnostics.

The automatic control function is performed using one or more programmable automatic (PA) in various configurations, centralized or distributed, or process computers working in real time or local units control (CNC equipment, PA systems for handling and transport, microcomputers for controlling automatic warehouses etc.).

Computer software provides overall system control information necessary for the processing and production customer (customer deposits parts and tools, command transmission system etc.). Information for achieving these sub-functions are obtained from the system using transducers, sensors, meters etc. and transmitted in reverse to the process computer or microcomputer PA local [9].

3.1. The presentation of the application

The implementation is based SCADA software using a graphical application development and management control line flexible served by the industrial logistics subsystem.

Through this application may be possible in real-time control and management of the entire manufacturing process, synchronized with functioning of the transport subsystem. Scheduling automated manufacturing processes on flexible line is performed by scheduling module SIEMENS AP.

Figure 2 is a block diagram of connecting the equipment to achieve real-time control applications.

The application of SCADA (Supervisory Control and Data Acquisition) in the OMRON developed by using Cx Supervisor- Developer Program allows the operator tracking, control and real-time verification and modification of operating parameters.

- PC: type application software running HMI (Human Machine Interface) developed and can be reconfigured depending on the objectives of teaching and research;
- PLC: application software runs sequential process management, environment Ladder developed and can be reconfigured depending on the teaching and research objectives.

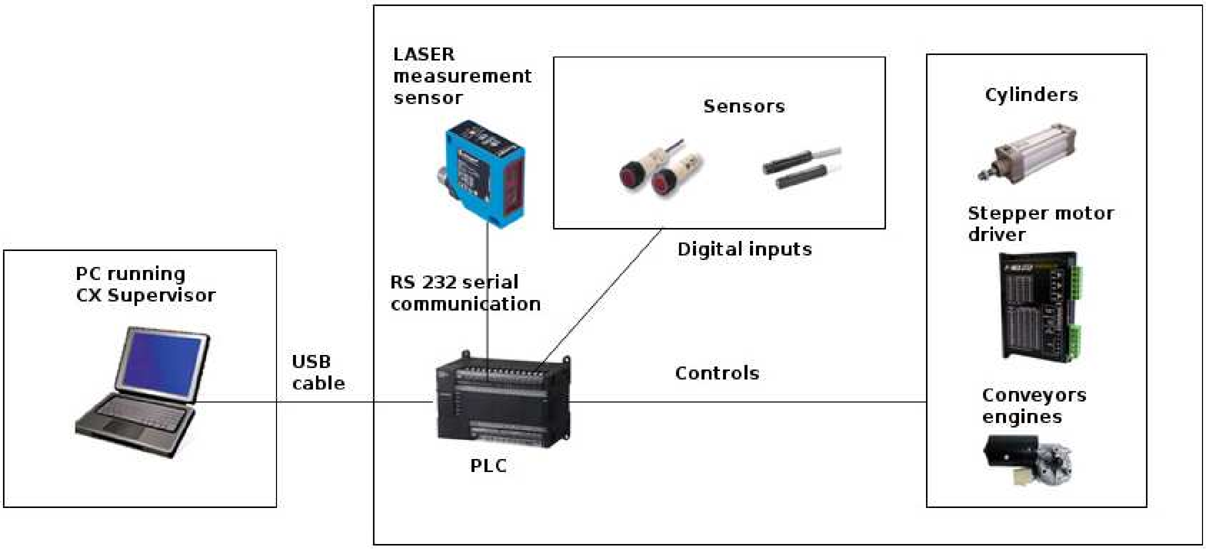

Figure 2. Block diagram of communication between management equipment used in flexible line

3.2. Ladder application development language

Programming PLC is made using diagrams Ladder (in English: scale - two vertical lines denoting power supply, and horizontal lines representing the control circuitry) (or "charts the contact"), which are nothing more than a symbolic representation of electrical circuits. Language Ladder has been developed to facilitate the creation of programs and to provide their easy maintenance. The components of the Ladder diagram and also the interpretation thereof represents an operating model the elements of a classic scheme with contacts.

The functional chart also called Grafcet (the graph functional of command stages - transition) is a graphical functional language designed order to specify the cycles and operating conditions of automated machinery. It allows drafting specifications of the machine then it helps to achieve and ultimately constitute an important aid in machine exploiting, debugging them, and any potential changes that may occur.

The process is broken down into stages which will be activated after another in a definite chronological order. Each stage can be associated with one or more actions.

These actions will not be effective, only when it is called active stage. A stage cannot be active as long as the previous stage itself is active and transition condition is verified. For example, in Figure 3 is presented a simple sequential action of a drilling machine performing a boring stroke and a return stroke [10]:

- The race drilling is done with two speeds: high speed until the drill reaches the piece and a low speed for advance the drill in material;
- The race of withdrawal is done at high speed;
- To start the shareholders there are of 'Start' button.

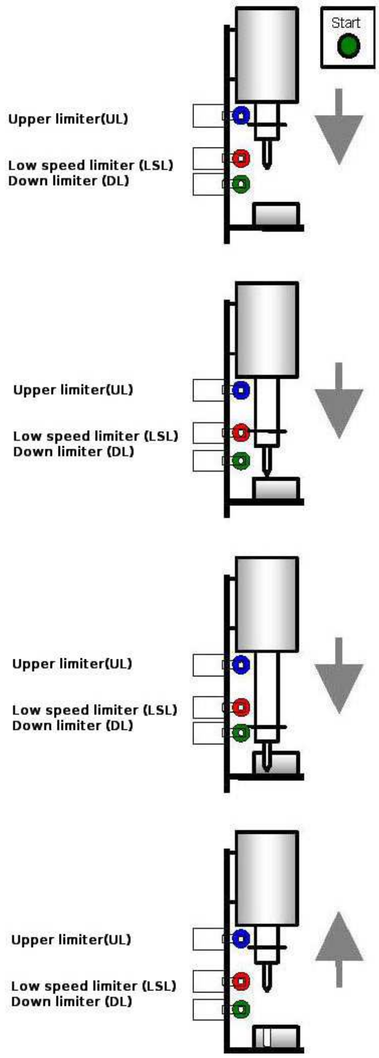

Figure 3. Sequential application [10]

System status is:
Step 1. Starting position (waiting)
Step 2. Start advance;
Step 3. Drilling;
Step 4. Withdraw the start position.

It builds Grafcet diagram associated of the process (Figure 4).

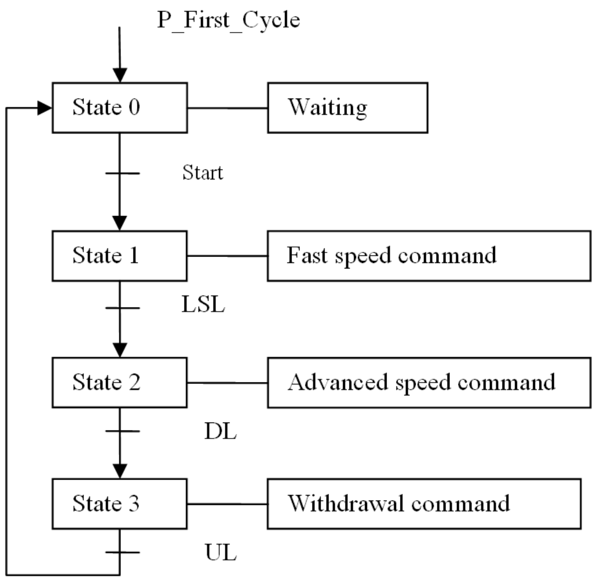

Figure 4. Diagram process associated Grafcet

The equations corresponding Grafcet scheme are:

$$\begin{aligned} State0 &= P_{First_{Cycle}} + State3 \cdot LSL + State0 \cdot \overline{State1} \\ State1 &= State0 \cdot Start + State1 \cdot \overline{State2} \\ State2 &= State1 \cdot LSL + State2 \cdot \overline{State3} \\ State3 &= State2 \cdot DL + State3 \cdot \overline{State0} \end{aligned} \quad (1)$$

Ladder program implementation requires:
- identify the variables used in the program (Figure 5);
- implementation of orders generated by state (Figure 6);
- implementation Grafcet equations (Figure 7).

Name	Data Type	Address / Value
start	BOOL	0.00
LS	BOOL	0.01
LVM	BOOL	0.02
LJ	BOOL	0.03
avans	BOOL	10.00
retragere	BOOL	10.01
v_mica	BOOL	10.02
starea0	BOOL	200.00
starea1	BOOL	200.01
starea2	BOOL	200.02
starea3	BOOL	200.03

Figure 5. The variables used in the program

Figure 6. Explaining orders

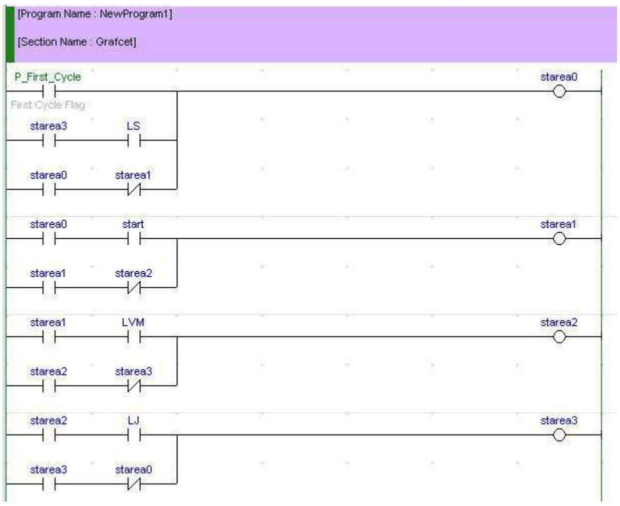

Figure 7. Implementation Grafcet equations

The components of the Ladder diagram and also the interpretation thereof represents an operating model of the elements of a classic scheme with contacts. The basic elements used for writing a program in Ladder language are: contacts, coils, timers and counters, function blocks (functions).

4. Conclusion

After the implementation of application monitoring and management in real-time, this research has made contributions to the development of a new flexible manufacturing structure capable of performing multiple tasks with the same equipment in various manufacturing processes.

The simulation revealed the behavioural properties of flexible lines and evolution under real process, the stages of production, which results in certain performance criteria characterizing physical process operation.

Validation of simulation models was achieved by simulating the actual physical applications on flexible modular system designed and manufactured on CNC machine tools, educational FMS and existing research infrastructure equipments. Model validation through simulation reflects the behaviour of the analyzed system.

This allows checking operations performed within the flexible line, operations are controlled by a control and monitoring algorithm. The method of synchronizing processing and logistics equipment developed and implement a management system whose structure can be adapted to significant changes in inputs / outputs allow ensuring of the continuous flow of production.

The concept of quality has been studied both in terms of quality of design and realization of the production system and in terms of product quality prototype made in the production process including steps, criteria and standardization enabling capability transfer and portability the whole project.

The researches will be also extended in the domain of flexible manufacturing systems management and control in real and virtual environment. Will be developed aspects concerning programming with the aid of FMS virtual reality and it will open new directions of research, having as cumulate effect the decrease of the uncertainty degree which exists in the domain of flexible production. Thus, will be generated useful results with impact in industrial reality, narrowing the gap between theory and practice.

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