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Modelling and Simulation with Arena of a Mechatronics System for Hydraulic Tubes Construction

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Abstract: - Today most modern manufacturing systems contain complex units, which are often difficult to model correctly. Therefore, it is desirable for simulation packages used in manufacturing to be flexible, and provide comprehensible modules. This research work presents a methodology of modelling and simulation of a manufacturing system using Arena software simulation tool, in order to deal efficiently with the production procedures and processes, and propose an appropriate system structure that will operate according to given specifications. The focus of the study is on manufacturing procedures taken place in the production of specific hydraulic units (tubes), for an industrial press machine, within an automatic mechatronics system.
The aim was to reduce capital requirements (e.g. machines, workers, etc.) and operating expenses, and ensure that the proposed mechatronic system design will operate as expected. As a result of the simulation models execution and the conclusions derived, the proposed manufacturing mechatronic system was further improved and the production procedures of the final product optimized.

Key-Words: Modelling, simulation, mechatronics system.

1 Introduction

The description of automatic manufacturing systems requires efficient design and development systems that allow the application of the design and quality assurance specifications [1], [2], among which an important role play modeling and simulation systems and methodologies [3], [4]. There are many simulation packages which are widely used to simulate manufacturing systems.
In this research work is presented the application and use of simulation models with Arena[1] in the description and study of an automatic production line of machine parts for an industrial press machine.
Initially are described the design specifications of the machine parts as well as the development procedures according to the required functionality and quality. Then, the creation of a model is presented, that describes the machine stations and manufacturing procedures taken place in the production of specific hydraulic units (tubes), based on Arena discrete modeling methods [5]. The model describes the relationships between the parameters of interest that play important role in the manufacturing of the specific hydraulic unit.
One of the general benefits, aiming to obtain from using simulation for manufacturing analyses, was to reduce capital requirements (e.g. machines, workers, etc.) and operating expenses, and ensure that the proposed mechatronic system design will operate as expected. All the information gathered from running the simulations, assisted further the understanding and improvement of the proposed system, particularly in certain issues, such as determination of the exact transportation facilities and of the optimal number of parallel-processing machines in the specified manufacturing system.

2 The Application Environment

The application platform is an industrial environment of a Machines Constructions Company in Volos, Greece [6]. The company is specialized into the design and manufacturing of a range of semi-automatic and automatic industrial machines for lime and concrete elements production, based on modern technology.
The research and experimental work described here, was carried out under company's innovative project for the implementation of new manufacturing

[1] Arena Version 3.01, Copyright © 1993-1997 Systems Modeling Corporation

techniques on machines production. The company's objectives are to keep high standards in production quality and maintain customers' creditability on machines operation.
The subject of the research is the application of modeling and simulation methodologies in the optimization of the manufacturing procedures of an automatic press machine component, a complex hydraulic unit, the schematic view and characteristics of which are given in Fig.1 and Table 1 respectively.

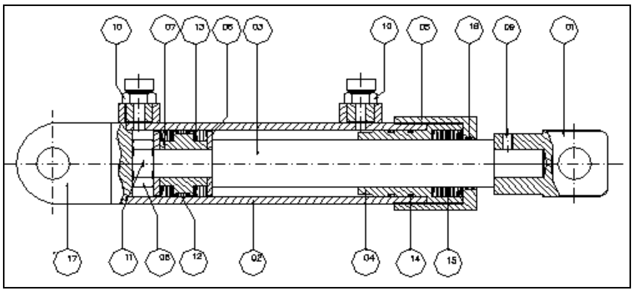

Fig.1: Schematic view of complex hydraulic unit.

Table 1: Hydraulic tube components.

Code	Part	Description
01	1	Movable edge - forward joint
02	1	Hydraulic tube
03	1	Vactro
04	1	Tube ring
05	1	External tube nut
06	1	Piston grommet
07	1	Piston
08	1	Vactro nut
…	…	…
14	2	O-ring
15	5	Gasket
16	1	Piston scraper
17	1	Backward stable joint

2.1 The mechatronics system

The mechatronics system under consideration in this study, is mainly consisted of the following five workstations: a milling machine that performs precise cutting on the actual vactro of the tube and piston winding, a drilling machine that drills certain part holes, a small press machine for tube stabilization, an IBM 7535 robot used for parts assembly, and finally a worker for some amendments and further improvements. The overall mechatronic system is supplied with hydraulic tube parts through a rotating (clockwise) conveyor belt. A schematic view, based on an Arena model description, is given in Fig.2.

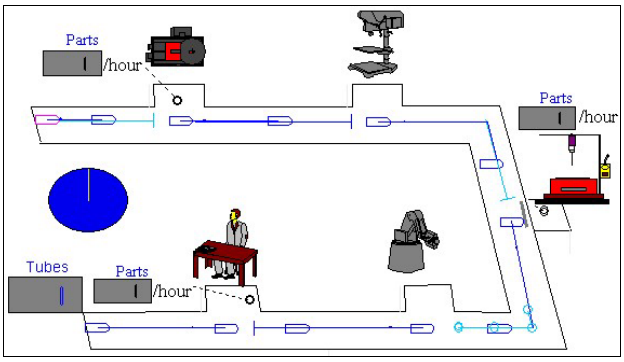

Fig.2: Arena model of the mechatronics system.

3 Modelling & Simulation with Arena

In order to evaluate and test the construction and production procedures prior to their actual implementation, a simulation model was build using Arena, based on the given structure of the above mechatronics system. In Arena a model is specified as a structure of modules (e.g. arrival, departure, servers, etc.), each of which corresponds to specific objects, e.g. workstations, machines, processes, etc.
In this case, a model was build using the types of variables that correspond to basic parameters of the complex hydraulic unit construction procedures, such as initial values of parts positions, sensors state, machines status, parts stages, machines utilization, production rate, etc.
A brief summary of the system's overall operation is provided as stages shown below.

ST_0: Initial conditions of machine states
ST_A: State of milling machine
ST_B: State of drilling machine
ST_C: State of press machine
ST_D: State of robot manipulator
ST_E: State of worker
Ma: Variable of ST_A (busy-starved)
Mb: Variable of ST_B (busy-starved)
Mc: Variable of ST_C (busy-starved)
Md: Variable of ST_D (busy-starved)

The equations that describe the machines states of the system are given by the following relationships:

$$ST\_A = (ST\_A + ST\_C \cdot Ma) \cdot ST\_A \cdot Ma \quad (1)$$

$$ST\_B = (ST\_B + ST\_A \cdot Ma) \cdot ST\_B \cdot Mb \quad (2)$$

$$ST\_C = (ST\_C + ST\_B \cdot Mb) \cdot ST\_C \cdot Mc \quad (3)$$

$$ST\_D = (ST\_D + ST\_C \cdot Mb) \cdot ST\_D \cdot Md \quad (4)$$

A small part of the Arena simulation model design is shown in Fig.3.

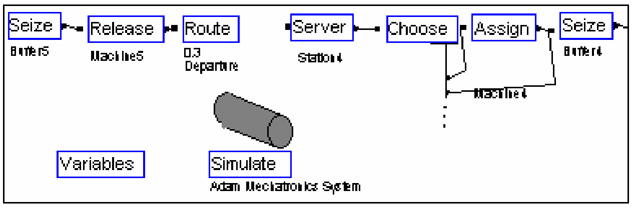

Fig.3: Arena model design of the mechatronics system.

A prototype model was created and executed (Fig.4), in order to specify the structure of the appropriate production procedure that reflects the functional requirements for the mechatronics system.

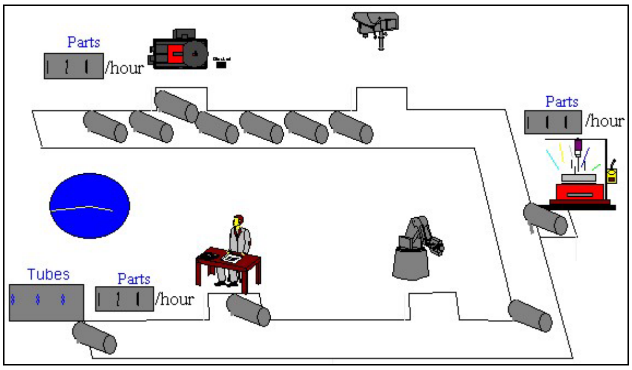

Fig.4: Arena Simulation model.

A small part of Arena's internal language (SIMAN) that describes part of the above simulation model (press machine operation and status) is given below:
Model statements for module: *small press machine*

```
40$     STATION, Station4;
404$    TRACE, -1,"-Arrived to Station4\n":;
367$    DELAY: 0.;
411$    TRACE, -1,"-Waiting for Machine4\n":;
328$    QUEUE, Machine4_Q;
329$    SEIZE, 1: Machine4,1;
438$    BRANCH, 1:
439$    MOVE:Machine4,Station4;
426$    TRACE,-1,"-Releasing resource\n":;
351$    RELEASE: Buffer3,1;
448$    DELAY: 0.0;
330$    DELAY:60/Mach4Rate;
395$    DELAY: 0.;
339$    ASSIGN: Picture=Stage5;
```

The above code was in general generated automatically, however, further modifications have been carried out, in order to achieve the required model functionality.

4 Application Results

There are several measures of performance obtained from this simulation study of the manufacturing system, such as: throughput, times parts spend in queues, work-in-process, queue sizes, utilization of machines and personnel (proportions of time a machine is busy, or broken, or starved -waiting for parts), etc. Below are given some of the case study's analysis results that were produced using statistical analysis methods embedded in Arena simulation environment for the anticipation and the achievement of the final system specifications for implementation purposes.

The conclusions that have been derived from the simulation results, aim at the optimisation of the manufacturing system and the production procedures of the final product.

A small part of Arena simulation results report obtained is shown below:

TALLY VARIABLES

Identifier	Average	Min	Max	Observed
Time In System	10.521	4.190	44.590	245
Hourly Throughput	75.666	51.000	96.000	3

DISCRETE-CHANGE VARIABLES

Identifier	Average	Min	Max	FinalValue
Buffer4 Avail	4.0000	4.0000	4.0000	4.0000
Buffer3 Avail	4.0000	4.0000	4.0000	4.0000
Buffer2 Avail	4.0000	4.0000	4.0000	4.0000
Buffer1 Avail	4.0000	4.0000	4.0000	4.0000
# in Worker_Q	.81714	.00000	4.0000	.00000
# in Robot_Q	.73683	.00000	4.0000	4.0000
# in Press_Q	2.5038	.00000	4.0000	4.0000
# in Drill_Q	3.4172	.00000	4.0000	4.0000
# in Mill_Q	1.9954	.00000	2.0000	2.0000

COUNTERS

Identifier	Count	Limit
Jobs This Hour	18	Infinite

FREQUENCIES

Identifier	Category	No	AvgTime	Percent
STATE(Mill)	Starved	1	.30100	0.15
	Busy	218	.59633	65.00
	Blocked	218	.31972	34.85
STATE(Drill)	Starved	1	1.1010	0.55
	Busy	100	1.3909	69.55
	Failed	3	6.7661	10.15
	Blocked	100	.39510	19.75
STATE(Press)	Starved	4	3.9453	7.89
	Busy	6	25.000	75.00
	Failed	1	4.2409	2.12
	Blocked	2	14.988	14.99
STATE(Robot)	Starved	223	.14072	15.69
	Busy	225	.59394	66.82
	Failed	1	6.4158	3.21
	Blocked	2	14.283	14.28
STATE(Worker)	Starved	215	.21316	22.91
	Busy	216	.56713	61.25
	Failed	2	15.835	15.84

The analysis and processing of the above simulation results, in many points have reconfirmed that the proposed manufacturing system for the production of the specified complex hydraulic unit, after certain modifications is finally acceptable and reliable. In addition, described some of the essential requirements which the company must keep, in order to ensure the quality of the production.
The environment provides also and graphical representations of the important parameters of interest. An example of such a graphical representation, e.g. for drill machine status during the execution of simulation, is shown in Fig.5.

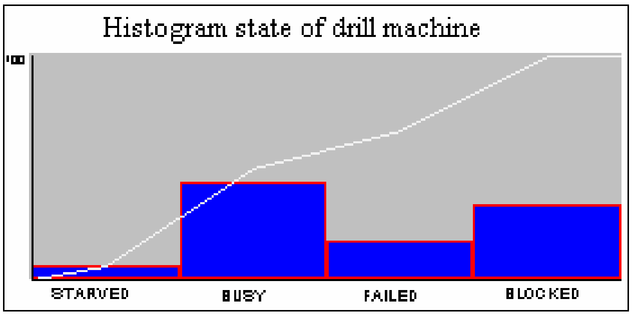

Fig.5: Graphical representations of Arena model's simulation.

5 Conclusion

This research work presents a methodology of modelling and simulation of a manufacturing system using Arena software simulation tool, in order to deal efficiently with the production procedures and processes, and propose an efficient system structure that will operate according to the defined specifications.
Based on the results obtained from the simulation, the proposed manufacturing mechatronic system was further improved and the production procedures of the final product optimized. As a result, capital requirements and operating expenses, during the actual system implementation, were reduced, while at the same time was ensured that the proposed mechatronic system design will operate as expected.

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