URBAN AND ARCHITECTURAL DESIGN | VIRTUAL PROTOTYPES AND REAL PRODUCTS | WATER ENGINEERING | AEROSPACE ENGINEERING | ARCHITECTURAL COMPOSITION | ARCHITECTURE, URBAN DESIGN, CONSERVATION OF HOUSING AND LANDSCAPE | BIOENGINEERING | BUILDING ENGINEERING | DESIGN AND TECHNOLOGIES FOR CULTURAL HERITAGES | ELECTRICAL ENGINEERING | ENERGY | GEOMATICS AND INFRASTRUCTURES | INDUSTRIAL CHEMISTRY AND CHEMICAL ENGINEERING | INDUSTRIAL DESIGN AND MULTIMEDIA COMMUNICATION | INFORMATION TECHNOLOGY | INTERIOR DESIGN | MANAGEMENT, ECONOMICS AND INDUSTRIAL ENGINEERING | **MANUFACTURING AND PRODUCTION SYSTEMS** | MATERIALS ENGINEERING | MATHEMATICAL MODELS AND METHODS IN ENGINEERING | MECHANICAL SYSTEMS ENGINEERING | PHYSICS | PRESERVATION OF ARCHITECTURAL HERITAGE | PROGRAMMING, MAINTENANCE, REHABILITATION OF THE BUILDING AND URBAN SYSTEMS | RADIATION SCIENCE AND TECHNOLOGY | ROTARY WING AIRCRAFT | SANITARY - ENVIRONMENTAL ENGINEERING | STRUCTURAL SEISMIC AND GEOTECHNICAL ENGINEERING | TECHNOLOGY AND DESIGN FOR ENVIRONMENTAL QUALITY IN BUILDINGS AND URBAN CONTEXT | TERRITORIAL DESIGN AND GOVERNEMENT |

PhD Yearbook | 2010

DOCTORAL PROGRAM IN MANUFACTURING AND PRODUCTION SYSTEMS

Chair:
Prof. Bianca Maria Colosimo

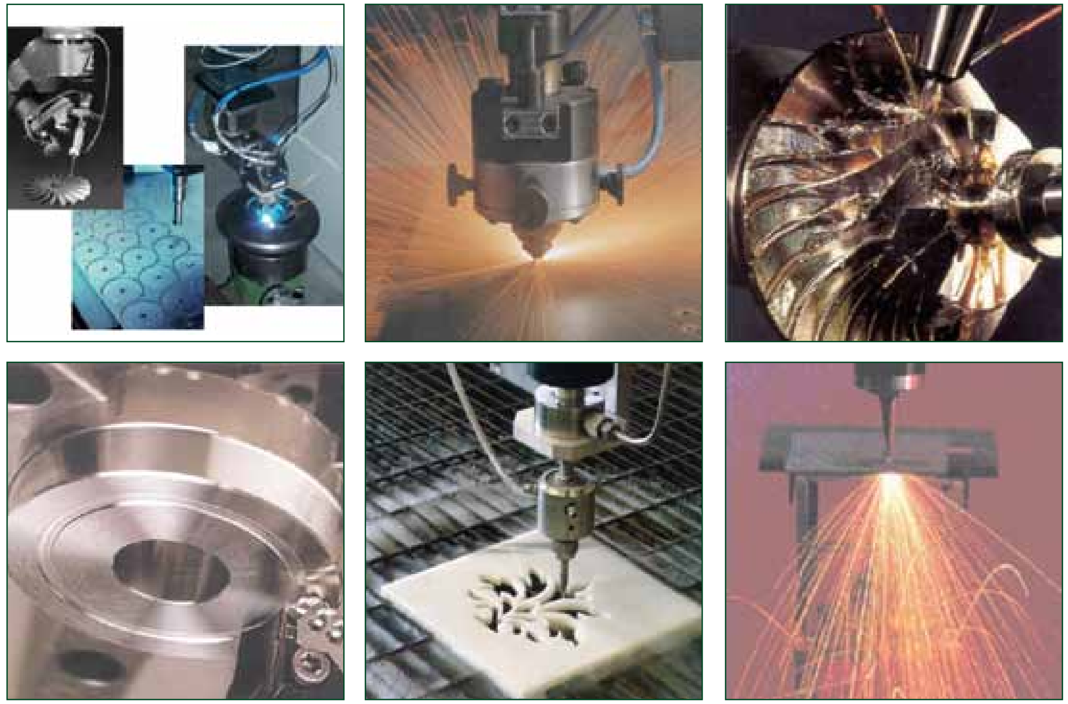
Manufacturing is a leading sector of the European economy since European Manufacturing is a dominant force in international trade. As an example, the EU's share of total global manufacturing trade was 18% in 2004, while the US had 12% and Japan 8%." (Manu*future* Strategic research Agenda – September 2006 – European Commission).
In some key sectors such as machine-tool, robot, and automation industry, Italy has even achieved a global leadership, accounting for about 10% of the total export (acting as the third in the world) and Lombardia is playing a dominant role, hosting 48.2% of the Italian companies (Report 2005 of the *Association of Italian Manufacturers of Machine Tools, Robots, Automation Systems – Ucimu)*.
In this competitive scenario, Politecnico di Milano has the fundamental role of providing people with specific training in Manufacturing and Production Systems engineering, by strengthening their research skills in the industrial and academic context. Therefore, the PhD programme in Manufacturing and Production Systems focuses on the optimal transformation of raw materials into final products, addressing all the issues related with the introduction, usage, and evolution of technologies and production systems, during the entire product life cycle.

1.

Career Profiles

The professional skills acquired in the degree program give the competence for managing and solving problems related with product and/or service realization. In particular, issues of continuous improvement and integration of all the activities ranging from conception to realization are emphasized.
A Ph.D. in Manufacturing and Production Systems acquires her/his knowledge through the activities of study, research, lab experience, development in cooperation with industries, foreign institutions and international research groups. Using her/his background, the PhD candidate will be able to blend the exactness of scientific knowledge with the ability to deal with practical industrial problems. The outlined skills are of great interest to industrial companies devoted to: i) continuous improvement of technologies and processes; ii) strong integration of product-process-system design; iii) complete product lifecycle management; iv) optimal design of production, logistic and service systems.
In this view, a Ph.D. in Manufacturing and Production systems can eventually aim at prestigious positions at national and international level within industrial companies, consulting companies, universities and research institutions.

2.

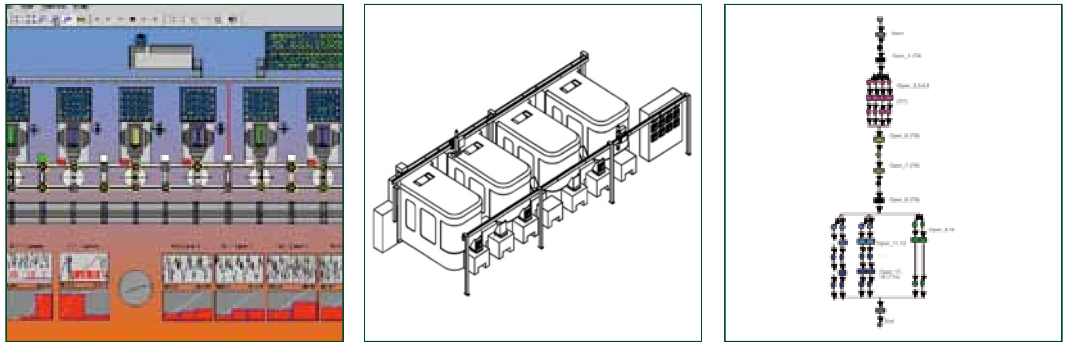


3. Manufacturing Processes

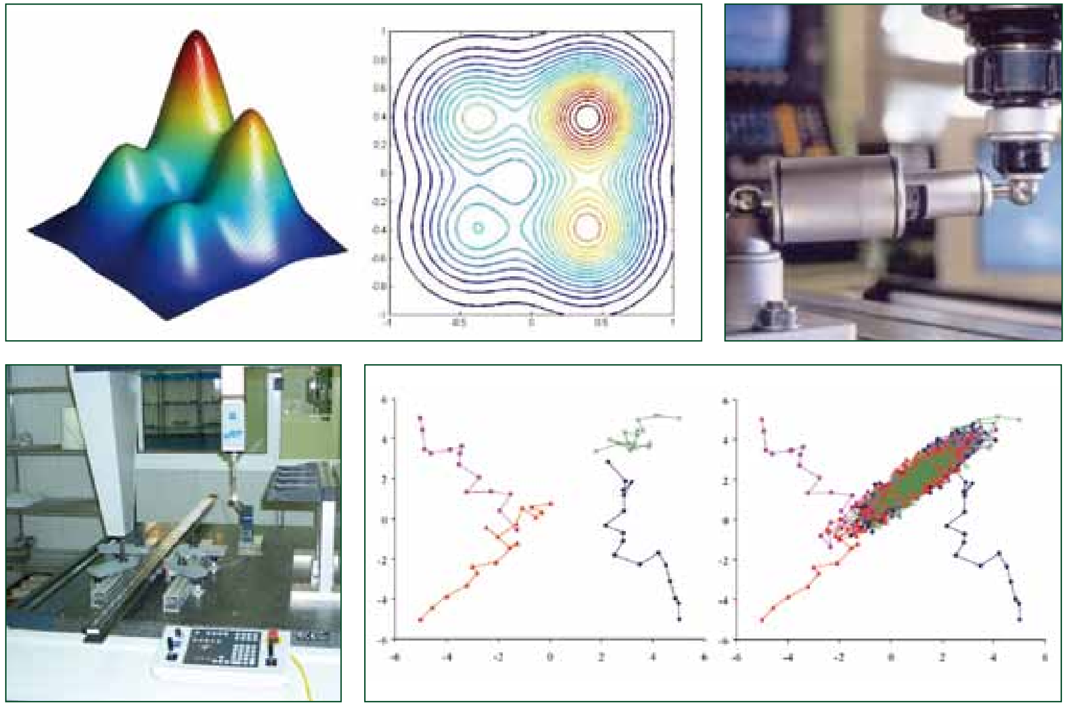
Main Themes

Ph.D. activities can specifically focus on one of the following topics:

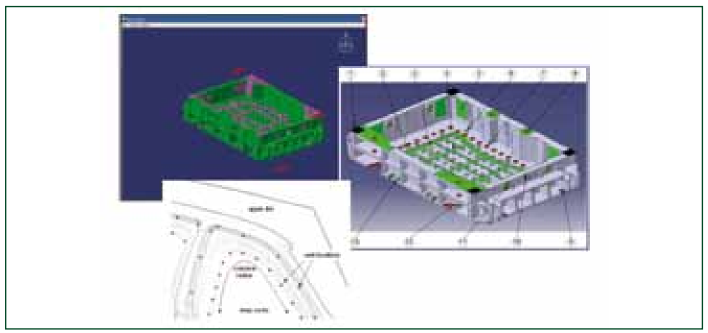
- *Manufacturing Processes (fig.3):* This research area is aimed at studying both conventional and innovative manufacturing processes. The study can specifically deal with: developing new processes for innovative applications or for innovative materials; evaluating the application constraints of new and existing manufacturing processes; performing economic optimization of the process performances, investigating on the relationship between process parameters



4. Production Systems



5. Quality



6. Product Lifecycle Management

and process results. The research area is therefore very wide, with activities ranging from basic to industrial research.

- *Production Systems (fig.4):* The research activities carried out in this area are concerned with the design and management of integrated production systems. The research activities encompass innovative and traditional system architectures
in different sectors (machine tools manufacturing, production of mechanical components, services). Studies and research activities are based on real cases and underline the deep relations amongst products, processes and production systems.
- *Quality in Manufacturing (fig.5)*: Quality has a relevant role in the new competitive scenario in which European manufacturing is pushed toward high-value products. Research activities in this area focus on studying and developing new approaches, methods and tools for quality management, process monitoring, control and optimization and metrological issues (design and verification of geometric product specifications).
- *Product Lifecycle Management (PLM) (fig.6)*: This area provides the methodologies and tools related to computer-based product lifecycle management, with emphasis on the automation and integration of product design and process planning. Relevance is also given to the impact of process design on production-system design, both at single-plant level and at network-enterprise level.

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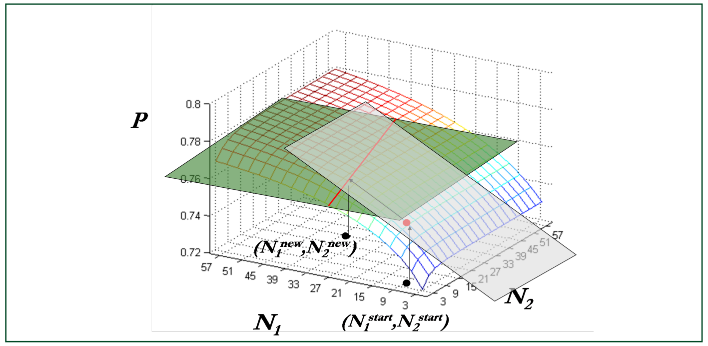
AN ANALYTICAL METHOD FOR THE OPTIMAL DESIGN OF ASYNCHRONOUS TRANSFER LINES

Daniela Borgh

Production system design is a critical task for manager and engineers. In this phase a lot of decisions that will influence the competitiveness of firms in the medium and long period have to be taken. Design includes the choice of the type and the number of resources to be utilized, taking into account strategic and production objectives and logistic and economic constraints.
The production system design process usually consists in two main steps: first, a small number of system alternatives are selected among a wide range of options, then the characteristics of these systems are more deeply investigated in order to individuate the most suitable solution.
Once identified the objective, decision makers should select the driving parameters that mostly impact on the objectives and try to find the values of those parameters that maximize/minimize the required objective. At this point usually some suitable alternatives are selected and discussed, they are often revised several times, and eventually the decision makers come to a solution. The capacity of generating valid alternatives to be discussed is very important at this point. In the earlier phase of system design, the selection of alternatives has to be as quick as possible in order to limit the effort dedicated to the study of unpromising solutions. Analytical methods are particularly useful for this scope: they are fast and have sufficient precision to make a first analysis of production system performance. The motivation of this thesis is to provide an analytical methodology which helps in making fast the phase of alternatives generation.
The manufacturing lines under consideration are composed by *K* machines in which machining and/or assembly operation are performed, separated by *K-1* inter-operational buffers, each with finite capacity, N_i. Each machine has a deterministic processing rate that may differ from one station to the others. Machines can undergo different failure modes; each failure mode is identified by a failure and a repair rate that are the inverse of, respectively, the Mean Time To Failure and Mean Time To Repair. Failure and repair times are assumed to follow exponential distributions and failures are assumed to be operation dependent.
Buffer allocation is one of the most important decisions to be taken during this activity. Increasing buffer capacities increase the average production rate of the system, because the average time each machine is idle for other workstations' disruptions is reduced.
On the other side, large buffer capacities imply increasing work in progress and average flow time and their cost have an high impact on the total investment cost. For these reasons, buffer capacities should be chosen in order to satisfy production objectives and economic constraints derived from the production policy of the firm. The problem of the optimal buffer capacity allocation in production systems has been extensively addressed in literature; the proposed techniques are based on the different existing methodologies for production system performance evaluation.
The buffer allocation problem is usually considered a combinatorial problem, in which the number of alternatives to be compared rapidly increase with the number of stations composing the system; consequently, a lot of different techniques with the aim of efficiently explore the feasible region exists. Buffer allocation techniques based on analytical models for performance evaluation are usually gradient-based methods, for which a large number of evaluation are needed in order to estimate the gradient vector of system throughput depending on buffer capacities. Since for production lines composed of more than



1. Algorithm Scheme

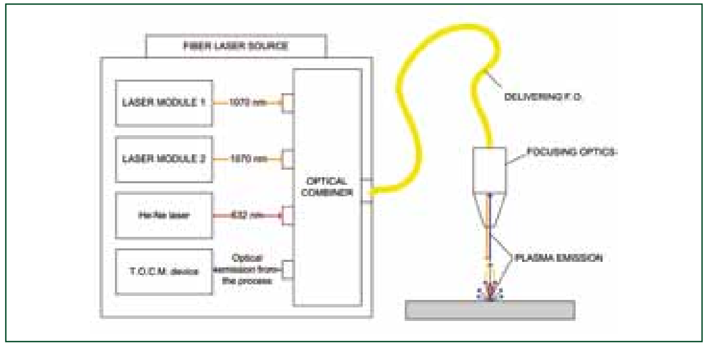
two stations and one buffer a direct analytical relation among system parameters and performance does not exist, gradient has to be estimated by using finite difference and therefore by varying buffer capacities one at a time and applying the existing algorithms to evaluate performance.
Since usually analytical methods are time-consuming, and computational time increases when the number of stations gets higher, gradient-based methods are not very efficient.
We propose here a different method for buffer capacity allocation in asynchronous transfer lines formed by a generic number of stations, each one having multiple failure modes. The main innovation of the method is that the algorithm applied for searching the optimal requires only one long-line evaluation for each step, independently from the length of the line. Moreover, the algorithm statement is enough general to be applied also to production systems with more complex layouts like assembly/disassembly systems, architecture including merge and split of material flow and multi-product systems. On the other side, the need for first order Taylor approximating equations to hold requires a better formulation of the approximate analytical method the performance evaluation of asynchronous lines.
The main idea underlying the design method proposed in this thesis is to exploit the information given by the equations used to evaluate the performance of the system in the initial configuration point to evaluate the characteristics of the throughput function with respect to any design parameter, through a technique that we will refer to as the tangent hyperplane methodology.
The approximate analytical method we use to solve the line consists in a system of equations solved by applying an iterative algorithm. Once this set of equations has been solved, for a generic set of parameters we know that all of them are satisfied at the same time, therefore also their first order Taylor approximations simultaneously hold in that point. If we are able to build a system of equations composed of the linear version of those used to evaluate the performance of the system, we have a linear system whose variables are the variations of design parameters and performance indicators and whose coefficients are the partial derivatives of the original equations taken with respect of each design variable (both design parameters and performance indicators).
By applying an iterative search algorithm we can find the minimum number of buffer spaces and their distribution among the line in order to obtain a desired level of throughput *P* (see Fig.1).

The thesis reports an analysis of the international state of the art has been carried out, in relation to the problem of the production system design, details on the optimization method based on the tangent hyperplane methodology and the solution to the buffer allocation problem.
The accuracy of the tangent hyperplane equations is tested in comparison with the simulation approach.
Conclusive considerations on the presented work are given, and a series of possible applications of the tangent hyperplane methodology are proposed and discussed.

THROUGH OPTICAL COMBINER OF FIBER LASER WELDING PROCESSES

Daniele Colombo

For less than five years a new family of laser source, called Fiber Lasers (FL), has been available on the market.
It is capable of generating a high-power laser beam that can easily be focused on significantly smaller areas (at least ten times smaller) than traditional laser sources, allowing for higher brightness. Unlimited laser powers, high beam quality and high reliability are only some of the key features of FL sources that are defining new edges to the laser process performances.
Thanks to these new features, FL sources have spread rapidly in the market and predictions about their future expansion are extremely positive. However, existing laser systems are not suitable for integrating FL sources and complete innovation is required to integrate and fully exploit the potential offered by high brightness lasers. Furthermore new process configuration and performance are now being developed for FL applications. However, to allow a wide penetration of high brightness in everyday manufacturing further studies and development are still needed.
In this background, a common trend that could lead to a faster characterization of high brightness processes and to a deep industrialization is the development and implementation of system and process sensors.
The natural evolution of laser systems is in fact towards highly automated systems equipped with high-quality process sensors. In particular, process sensor development will take the direction of process monitoring, aimed at improving the quality of the finished product.
The final target is obviously towards real-time processing control, with the system "learning" the process in order to maintain the quality of the processed parts.
Process monitoring of FL processes will so play a strategic role in future years both in academic and in industrial fields.
In the first case, application of monitoring devices and techniques will help to deeply understand all the aspects related to FL processes.
As for the industrial application, process monitoring will warrant a fast and reliable on-line evaluation of process performances and of the overall quality of the manufactured parts.
Among all the FL processes in the multi-kilowatt range, a relevant role will be played in the future years by cutting and welding applications.
Cutting process will benefice of high brightness for its high cutting speed and performances. Thus, its actual limitations – such as the focus shift or the cutting quality at high speed or in presence of high thicknesses – could bond its full exploitation.
As for welding, high brightness is now replacing other traditional fusion bonding processes in the production of complex parts for key-markets, among which we can mention aerospace and automotive applications. However, a deeper comprehension and optimization of the related welding phenomena are still missing.
Development and application of monitoring strategies can thus promote FL applications in the afore-cited markets leading to process optimization and control, mainly in welding applications were complex process dynamics are often present.
According to these considerations, the main objective of the thesis work was the development and the characterization of a new configuration for process monitoring designed to perfectly match the characteristics of FL sources in the multi-kilowatt range.
As shown in Figure 1, this new configuration is based on process monitoring directly from inside the optical combiner of the FL source, thus allowing its easy installation on almost all the FL sources used for welding and cutting applications.
This solution, called Trough Optical Combiner Monitoring (TOCM), shows some interesting advantages. The main are the easy and non intrusive installation of the device in the laser system and the increased stiffness of the device because none of its parts needs to be near the welding process being inside the laser source.
Through Optical Combiner Monitoring (TOCM) allows process monitoring by the evaluation of the optical radiation emitted from the process area. Because of the TOCM configuration, monitoring techniques of the optical radiation with spatial resolution are not possible. Thus, only Optical Emission Spectroscopy (OES) or Optical Emission Monitoring (OEM) approaches can be used.
In the thesis work, attention was focused mainly towards TOCM of FL welding applications (FLW).
First of all, a prototype of a FL source - IPG YLR 1000 - was enabled for TOCM at SITEC, laboratory for laser applications of the Mechanical Dept., PoliMi (Figure 2).
Then OES and OEM approaches were used for TOCM of FLW processes.
By OES a deep characterization of FLW process was obtained and furthermore, indications for the following design of a TOC device for OEM were obtained.
Finally, tests on welding case studies proved that the designed TOC device for OEM is able to identify common welding defects thus allowing the foreseen of future application also in other FL applications, such as drilling, cutting and cladding.



1. Scheme of the Through Optical Combiner Monitoring configuration

2. IPG YLR – 1000 FL source used for TOCM characterization at PoliMi

PERFORMANCE ANALYSIS OF TRANSFER LINES WITH GENERAL PROCESSING TIME AND GENERAL REPAIR TIME

Francesca Simone

The global competitive pressure urges industries to become costumer oriented. The entrance if new competitors, coming from the east, in the global market has affected strongly the conditions of the manufacturing sector. The increasing frequency of new products introduction, their shortening of the life-cycle, the products demand variability and mix, are the main factors observed in the last fifteen years. The effort of the most important companies to survive in the market has been directed toward flexibility through all the organization. This capacity of the companies of rapidly adapting to the market changes has been analyzed in literature with the name of "changeability" that impacts at all company levels. At a production system level, "reconfigurability" is defined as the ability of reactively changing volume and product mix, with low costs and time, by integrating new production and transportation modules. Therefore, if the market is changing frequently, a lot of reconfigurations of the system can be necessary in a very short period. Each reconfiguration of the system requires the evaluation of a large number of possible system configurations and a comparison between the feasible solutions. Especially in these cases, system designer needs methods and tools for supporting the analysis of the performance of different system configurations. These tools have to be rapid, accurate, applicable to a large set of real system architecture and effective in the sense that may help the designer in the identification of the key factors that mainly impact on the performance of the system. Analytical methods are able to synthesize the main behaviour of complex systems in a few related variables, most of the time implicitly, by dynamic equations. Their capacity to understand relations among several system variables through equations, is very important in the configuration/reconfiguration phase. It allows to select the change drivers that have higher impact on system performance, and to vary them, in line with system requirements and costs constraints. Moreover, they are very fast in evaluating the performance of a system and generally they provide accurate results. However, they are mathematical models, therefore it is often necessary to introduce restrictive assumptions for simplifying the mathematical treatment of the model that reduce its applicability. In the last decade, much effort has been dedicated to enlarge the set of real systems and production management policies which can be analyzed by approximate analytical methods. However, it is still a big challenge to analyze real systems with analytical techniques given the fact that some basic assumptions of these methods are rarely satisfied in the reality.

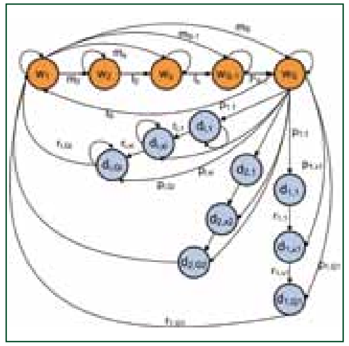
This thesis work focuses on one of the most critical assumptions of the available methods.

An analytical method for evaluating the performance of systems in which machines can fail in multiple modes, can be repaired with general time and can work with general processing time is proposed. Indeed, while analyzing real production systems with analytical technique, one of the main difficulties is to capture the real behaviour of the system in the adopted system model and to verify the commonly used assumptions. The present thesis proposes for the first time a decomposition method for evaluating the performance of systems in which machines can fail in different modes, for each failure, general repair time and general processing time are considered and modelled through phase-type (PH) distribution.

In order to develop a tool able to analyze a greater and greater set of real systems the exact analytical solution of the two machine one buffer (part storage) system and the following approximate analytical model to extend the analysis to multi-stage system was presented. In the two machine system analysis, the behaviour of each machine of manufacturing flow line is represented through a Markov chain. There are several factors which motivate the use of stochastic modelling for manufacturing flow lines. The machine breakdowns deeply affect the performance of the system since it may cause the interruption of flow. Processing time at a machine, load/unload of parts, tool breakdowns, scraps, etc. are other factors that can be taken into account by stochastic models.

An exact analytical model, based on the solution of the whole two machine system Markov chain was presented. In particular a closed form solution was found. In this way it is possible to evaluate performance measures of manufacturing two line system characterized by multiple failure mode machines, and general distributions of processing and repair time. Afterwards an algorithm based on decomposition technique was developed to extend the evaluation of productive performance measures to multi-stage lines.

The decomposition technique is based on the idea to decompose the all transfer line in a series of two machine system in which the first machine represents the portion of line upstream the buffer which is considered and the second machine represents the portion of line downstream the same buffer. Numerical results demonstrate that this new method is able to model sources of variability which are not captured from the available methods in literature.



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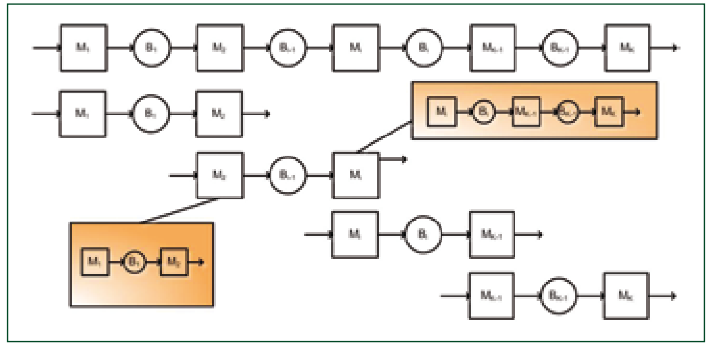

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