Dynamic Analysis of Manufacturing Systems

Wanlong Wang[1], Jerry Y. H. Fuh[1], Yongnian Yan[2],
1. Department of Mechanical & Production Engineering
National University of Singapore
10 Kent Ridge Crescent, Singapore 119260
2. Department of Mechanical Engineering
Tsinghua University, Beijing 100084, P. R. China

ABSTRACT

Manufacturing systems has been an important area in the studies of manufacturing science and technology, especially manufacturing systems design, modeling, analysis and implementation. However, most researches only focus on one or few aspects of manufacturing systems, e.g. on manufacturing processes or management. Besides, these researches are also lack of dynamic analysis by using static methods only. Thus, the present researches on manufacturing systems are not comprehensive and profound. In this paper, some new concepts and methods to manufacturing systems study are proposed by using evolutionary and life cycle theories. As we know, manufacturing systems are changing with the time under the market environment. The paper demonstrates the basic dynamic properties of manufacturing systems, such as elements of manufacturing systems, mutation and reorganization, market selection, life cycle, etc., and the relationship between evolutionary and life cycle theories.

Introduction

Manufacturing systems are the most important production systems in society. Modern development on manufacturing science and technology has greatly avanced the quality of the human life. Manufacturing systems decide the competitiveness of a country in the world wide market. The history of the industrial revolution has proved that manufacturing industry is the key industry in a country. But manufacturing industry is mainly composed of a variety of manufacturing systems.

Since Industry Revolution, the researches on manufacturing science and technology can be categorized into two parts: technology and management. Later on, engineering and management disciplines are developed separately. For the engineering researches, every individual manufacturing type involved its independent discipline, such as mechanical engineering for mechanical industry, electrical engineering for electrical industry. For management, there are also complete disciplines formed, such as management theory, organization and behavior, quality control, production management and so on. The two big disciplines are developing independently for more than one century. Since the development of modern communication and transportation, the globe is becoming closer and forming a unified marketplace, and thus the competition is more and more intensive. In such case, manufacturing systems must optimally combine management and technology to strive in the competition. From 1970's, many researchers have tried to study the manufacturing systems as a whole. For example, Harrington [1] published "Computer Integrated Manufacturing" in 1973, he first proposed the integrated information concept in manufacturing researches. Hitami [2] published "Manufacturing System Engineering" and proposed the concepts of

manufacturing system engineering. In the last decade, manufacturing systems researches have achieved a great progress.

The present studies on manufacturing systems fully show the trends of combining management and technology. Since the proposal of Computer Integrated Manufacturing (CIM), there are also many other manufacturing systems theories proposed, such as Lean Production [3] and Agile Manufacturing [4]. In all these theories, the key points are laid on the combinations of management and technology. From the contents of these theories, it is not found that all these theories are not comprehensive enough and profound to reflect the complexities of manufacturing systems. For example, in CIM theory, one of the initial points is that the whole procedure of manufacturing process essentially is the procedure of collection, transmission, processing and transferring of information. The essence of the manufacturing process is the combination of the information process and physical process. Besides these defects, the methods used in present manufacturing systems theories are mainly static, not dynamic. Static methods are good for the initial study of a new subject. It has some complete methods to analyze new things. But it is limited in recognizing the development and change of the things. In this paper, a new methodology will be used to analyze the properties of manufacturing systems by means of system science and dynamic methods.

Manufacturing Systems

From system point of view, manufacturing systems can be divided into two categories: the narrow sense and broad sense [5]. For the narrow sense, manufacturing systems define as the organic integration of three fundamental elements, namely manpower, tool and material. These elements form the basic structures of the manufacturing systems. Of course, this is viewed from the structural points. From the procedural points of view, manufacturing systems are composed of serial procedures of design, process planning, machining, assembly, diagnostics and monitoring.

It is noted that information is the coupling of the three elements. It is the symbols of the objective, state and behavior of manufacturing systems. It is very important to manufacturing systems, but not for the element of manufacturing systems. There is no usage of information if it is not combined with these three elements.

From the broad sense, besides the above contents of the narrow sense, manufacturing systems also include the market requirements, sale and post service. For traditional studies of the narrow sense of manufacturing systems, the technology researches are mainly focused on procedural properties, such as design, process planning, assembly, diagnostics and monitoring. The management studies are mainly on the structural properties, such as decision, management, organization and behavior, quality control, etc. Form the global view of point, manufacturing systems should combine the two aspects of the structural and procedural properties. Hence the studies on manufacturing systems should realize the unifications of structural and procedural research, and management and technology research.

From the dynamic point of view, manufacturing systems are also change with the time. An advanced manufacturing system at present is not necessarily advanced in the future. This is because that the marketplace is changing with time and same as the technology, and the management is also changing as time goes along. The integration of these components are also changing with the time. Traditionally, the studies on manufacturing systems are mainly focused on the static analyses of manufacturing systems, without considering dynamic properties. This

is why that it is quite difficult to evaluate the feasibility of the existing manufacturing systems in the future or predict the development trend. Thus, the manufacturing systems researches should realize the unification of the static and dynamic analyses.

This paper will employ the system science and dynamic methods to study the macro-dynamic behaviors of manufacturing systems. It is also called dynamic analysis of manufacturing systems. The main contents include the evolutionary theory and the life cycle theory. The evolutionary theory studies the processes of manufacturing systems evolving from the lower status to higher status, the main scopes are to study the evolving manufacturing environment, style, power and behavior. The life cycle theory is mainly to study the life cycle phenomenon of the manufacturing systems.

The Evolutionary Theory of Manufacturing Systems

Manufacturing systems are changing with time. They are always developing from simpler to more complex, and from a lower status to high status. This phenomenon is quite similar to that of biotic livings. This is why the evolutionary method is used to study the dynamic properties of manufacturing systems. The fundamental objectives of manufacturing systems are to earn profit through producing products and make the systems grow up. Hence the internal driving forces to develop manufacturing systems are the desire to make profits. On the other hand, products are sold in the market and the new required products are also determined by the market information. A manufacturing system must struggle with others so as to live in the market, thus the external driving forces to make manufacturing systems developed is the market competition. The market consists of the evolutionary environment. The evolutionary style is the combination of inner and outer factors, namely mutation and re-organization of the fundamental elements and the natural market selection.

Mutation means the great change or creation of the elements. For example, the emergence of new materials results in the generation of new manufacturing systems. The replacement of the traditional machines to NC machines has greatly advanced the machining technology. Generally, all the great changes or creations of the elements will promote the development of manufacturing systems.

Re-organization means the change or adjustment of the relationships among the three elements. These changes may result in the changes of the manufacturing systems structures, and further cause the changes of the natures and behaviors of manufacturing systems. These will promote the development of manufacturing systems. For example, when lean production patterns are adopted in manufacturing systems, the technological state is still not improved. The only change is the re-organization, but manufacturing systems have been developed.

To express the existing opportunity of a manufacturing system, the fit degree is used. Fit degree is defined as the relative fitting degree of a manufacturing system to the demands of the marketplace. It can be used to conduct the quantitative studies of the manufacturing systems.

In market selection, the most effective competition is faced to the limited market. In generally, the growth of manufacturing systems are faster than that of the market. This reminds us that the number of manufacturing systems built will be more than that of existing ones.

It is necessary to point out that on one hand the evolution of manufacturing systems is similar to that of the biotic livings, on the other hand, there are also big differences existing. On the

similar aspects, both are competition for existence, and realized by the environment selection. On the different aspects, the biotic livings are natural systems, the evolution is the passively adaptive process to the natural environment. The generation of a new species is a random process. But manufacturing systems are man-made systems, the mutation and re-organization of the elements are realized with certain initiatives and motives. And for the accumulation and propagation of human knowledge and techniques, the evolving speed of the manufacturing systems is much faster than that of the biotic livings.

The Life Cycle Theory of Manufacturing Systems

The life cycle theory means to study the whole process, i.e. generation, growth, maturity and elimination of manufacturing systems. Only based on this life cycle mechanism can manufacturing systems evolve from lower to higher. The life cycle is originated from the mutual interactions of market selection, mutation and re-organization of the elements.

Generation means that a new embryonic form which is quite different from its original state because of the mutation or re-combination of the element of manufacturing systems. It indicates the beginning of a new generation.

Growth means transition from generation to maturity. Maturity indicates that stable and complete organization, technology and management structures of a manufacturing system have been formed. Elimination means that manufacturing systems are eliminated through market selection or competition.

The studies to the life cycles of manufacturing systems will be helpful to recognize the historical stages of the manufacturing systems and grip the right moment to make full use of manufacturing systems to earn profits as much as possible and make them evolve to a high status.

Conclusion

The dynamic properties of manufacturing systems are discussed in this paper by using system science, evolutionary and life cycle methods. These new concepts give more comprehensive and profound thinkings to manufacturing systems. It will be useful to conduct the dynamic analysis of manufacturing systems compared to the traditional static analysis.

Reference

1. H. Hitami, "Manufacturing Systems Engineering", Taylor & Francis Ltd, London, 1979.
2. R. Arabham, and W. Shrensker, "Computer Integrated Manufacturing", Computer Integrated Manufacturing Series, Society of Manufacturing Engineers, Deaborn, MI, 1986
3. G. Yang, "Lean Production -- the Targets of the Modern Production" (Chinese), China Mechanical Engineering, Vol. 4, No. 2, pp32-34, 1993.
4. P. Vijaykumar, and P. Ronald, "Agile manufacturing: economical survival for the future", Industrial Engineering, Vol. 26, No. 2, pp46-49.
5. W. L. Wang, "Studies on unified manufacturing theory and rapid prototyping technology", Ph.D. Dissertation, Department of Mechanical Engineering, Tsinghua University, P. R. China, 1995.