<https://doi.org/10.52810/TC.2021.100025>

Application and Development of Electronic Computers in Aero Engine Design and Manufacture

Zhe Luo

College of Information Engineering, Shaanxi Institute of International Trade & Commerce, Xi'an 712046, Shaanxi, China

* Corresponding author

Manuscript submitted 9 May 2021; Accepted 11 May 2021; Published 17 May 2021

Academic Editor: Jinchao Chen

Abstract: This paper has introduced the development of CAD and CAM at home and abroad, especially the application in aero engine; The development goal, implementation steps and assumption of computer system configuration of CAD / CAM technology for aero engine in China are put forward combined with the current situation of CAD / CAM technology in China.

Index Terms: Aero Engine Design and Manufacture, Electronic Computers.

1. Preface

The rapid development of computer technology has greatly promoted the development of world economy and technology, CAD closely related to computer technology, computer aided manufacturing technology (CAD / CAM) for industrial modernization, especially the development of aviation industry to open up a new path[1]. Using electronic computer to design engine can realize the optimization design of engine with short time and low cost. It is unrealistic to develop engines with high thrust-weight ratio if we do not use advanced computer technology and only rely on traditional old methods. It is necessary to have computer system and enough engineering workstation, rich system software, application software and software tools beyond the computing ability. The most important point is to cultivate a high-level technical team. It can be asserted that computer technology has and will have a more profound impact on the design and manufacturing technology of aero engine and the performance of products[2].

2. The development of CAD / CAM technology and its application in engine industry

With the development of international economy, CAD / CAM technology is also developing. In 1950s, The world's first CAD team was born at MIT in the United States, which used TSS (Time Sharing System) to do research work; From 1960s to 1970s, CAD / CAM technology entered the practical stage in advanced industrial countries. For example, General Electric Company and Pratt & Whitney Company have applied CAD / CAM technology to the design and manufacture of aero engine. In the early 1980s, CAD / CAM entered a period of diversification and popularization[3]. The hardware used is computer / minicomputer / engineering workstation. There are plenty of microcomputers and software with strong generality; In the middle of 1980s, the integrated system was used. It is a highly integrated production system which uses all functions of computer control design and production activities. This system is an integrated system of human, equipment, material, capital and information with the help of computer. Looking forward to the 1990s, the world economy will enter a period of greater restructuring [4]. Accordingly, FMS will enter the popularization period. This system can produce many kinds of products in time according to the requirements, and the product varieties are easy to replace,

which can greatly reduce the cost and improve the product quality. Meanwhile, the idea, technology and method of knowledge engineering will be introduced into CAD. The traditional CAD system will be developed into AI-CAD, and CIMS will also get faster development and application[5].

CAD / CAE / CAT / CAM integrated system technology has accumulated a lot of system composition and use experience, and has become mature. Some famous aviation industry companies have invested heavily in the application of this technology. Boeing’s computer services company, for example, used \$600 million of computer systems for CAD / CAM in 1985; In 1988, GE Company invested about US \$1.3 billion in engine engineering development, a large part of which was used in computer engineering software development, and 20% of the investment in equipment was used in computer hardware. Tab. 1 the CAD / CAM profiles of several major foreign engine companies. Fig. 1 shows the total investment situation in the world CAD market.

In China, CAD / CAM technology of the Ministry of Aeronautics and Astronautics is in a leading position, which mainly refers to the CAD / CAM of the aircraft industry. Due to various reasons known in history, the development

of CAD / CAM in engine industry is slow. The project determined in Shenyang meeting in October 1982 failed to be carried out due to investment difficulties, and it did not start until 1987. In terms of software and hardware environment, the engine industry is also backward. The hardware is a low-grade VAX machine, the application software is not matched, the technical personnel are short, and the funds are difficult. In the face of this situation, the enthusiasm of the existing personnel has been brought into full play, and the whole staff has made concerted efforts to

Tab. 1 CAD / CAM profile of three major

Company name	Software personel	Equipment condition		Integrated system	Application
		Hardware	Software		
<div>GE (USA Evendale)</div>	2000	CRAYX-MP 48 1set IBM3090-400E 2set VAXB600 15set VAXII 785 10set Honeywell 6000 Workstation 300+set All kinds of terminals 4000 set IBM4341, 4381 batch	NASTRAN PATRAN ABAQUS IDEAS INGRES CALMA system Document management system APT4 Proprietary software GDSS MRP	in progress CIMS system work	CAD CAE CAT CAPP MIS CAM MRP
<div>PW (USA HARTFORD)</div>	800	CRAY II 2 set IBM3090 7 set IBM4341 and IBM4381 one batch VAX equipment one batch Workstation 200+ set All kinds of terminals 1000+ set	NASTRAN ABQCS DBMS MARC AD2000 ANVIL5000 CADFEED APT14 ASKA	GDS (General Design System) In progress CIMS	The same as above
<div>RR(England)</div>		Since 1987,£ 25 million was invested to purchase workstations			Shorten the develoment cycle by two years

achieve certain achievements. From 1983 to November 1988, Institute 608 of the Ministry of Aeronautics and Astronautics successfully developed the five coordinate computer aided manufacturing (TI-CAMSNC) system of titanium alloy integral centrifugal impeller, which was equipped with interface with the centrifugal impeller CAD system and realized the integration of CAD / CAM. This technology was the first-developed in China and reached the international level in the 1980s. The Institute 606 of the Ministry of Aeronautics and Astronautics has integrated the famous finite element analysis system with CAD system, which provides an important means for component design and whole machine design.

3. General goal of computer system in engine industry

At present, our country is rectifying and deepening the reform of the economic system, making the economy face other areas, and our economic and technological development will be greatly affected by the international economic restructuring. Therefore, in formulating the strategic objectives of China's aero engine industry, we should combine the national conditions with the worldwide technological development to carry out "overall planning, based on their own, digestion and application, innovation and development", give full play to the power of factories, institutes and colleges, complete a CAD / CAM integrated system together, and meet the needs of large engine and small engine development.

3.1 Change ideas and adapt to development

In recent years, when people are concerned about FA (Factory Automation), they have noticed great changes in the meaning and scope of FA itself. In the future international economic competition and cooperation, enterprises and institutions must pay attention to the requirements of the market and produce an appropriate amount of products with high quality and suitable price. The mode of production should not only consider mass production, but also consider small batch and multi variety production mode or multi variety and variable batch production mode. How to adapt to this requirement? First of all, in terms of management, it is necessary to carry out continuous and comprehensive scientific management. In terms of strategic decision-making, it is necessary to realize OA (Office Automation), strengthen management, make full use of resources, make all undertakings full of vitality and competitiveness, and improve their social status; In terms of technology, in order to transition from batch production technology (Automation Technology) to small batch, multi variety production technology or variable batch production

technology, the technical department is required to do the following:

- Maintain the advanced nature of design technology
- Ensure the new products put into the market
- Ensure continuous improvement of QCD (quality / cost / delivery)

3.2 Objectives

In the long run and the process of research, design and production, it is undoubtedly correct to implement the principle of giving consideration to both the army and the people. To this end, in the use of computer technology, we must achieve universal use, combine general and private use, integrate practicality and advanced nature, and achieve continuous development in utility. General purpose is conducive to meeting the needs of various environments, technical cooperation and the adaptation of multiple production modes.

To sum up, the overall goal of China's aero engine development is to basically establish such a technical system; It can adapt to the changes of the times and environment, and complete the development and production tasks of small batch, multi variety, short cycle, low cost and high quality products. This goal will be basically achieved by 2000, and it is implemented in three stages: Build the rudiment of integrated environment, and establish the primary CAD / CAE system in the Seventh Five-Year Plan. Focus on solving the structure of the total system, integrate the management system and the engineering system, and initially build an intermediate CAD system running on two to three levels of network in the Eighth Five-Year Plan. At the same time, vigorously develop the CAM of typical parts and tooling. The possibility of integration with CAM in the future should be considered when establishing intermediate CAD system. At the same time, a AI-CAD is introduced to build an advanced CAD / CAM integrated system to solve CAM in the Ninth Five-Year Plan. After achieving this goal, the level of computer aided design and manufacturing technology of aero engine in our country can reach the level in 1980s in the world.

3.3 Computer system configuration of engine industry

3.3.1 Basic requirements of computer configuration

The Engine Corporation of the Ministry of Aeronautics and Astronautics of China is mainly responsible for the development and production of large and medium-sized engines such as WP7, WPS. WP13 and Qianxian aircraft power equipment, WZ8, WJ9 and WJ5A-1 small engine development, production and modification tasks, advanced compressor, combustion chamber and turbine

three core components and core engine preresearch tasks, as well as digital electronic tuning, structural integrity, computer-aided design and other research tasks.

In order to accomplish these tasks, there are five main requirements for computer configuration:

a. In the aspect of CAD. In order to build an intermediate level aero engine CAD system, the computer system is required to be able to undertake the system set of engine CAE and CAD, scheduling operation, data transmission and database operation management; It can carry out large-scale scientific calculation of fluid mechanics, solid mechanics, combustion and dynamic simulation at high speed; It can realize the generation of space grid, flow field, concentration field, stress field and temperature field before and after numerical simulation; It can realize the geometric modeling, geometric interference display, simulation assembly and decomposition, drawing and database construction of complex structure.

In the aspect of CAM. Realize the NC machining of main engine parts; The computer system is required to connect with CAD system; Build programming software; Realize the tool path display and simulated cutting of 2-axis and multi axis NC machining; Connect with NC machining equipment to realize NC machining of main parts.

b. In the aspect of computer aided tooling design. Build CAD system and integration of tool, clamp, quantity and mould for engine parts manufacturing; Realize the geometric modeling, geometric interference display, simulation assembly and decomposition of complex structure and engineering drawing; Carry out scheduling operation, data transmission and operation management.

c. In the aspect of computer aided test and detection. Basically realize the automatic acquisition, processing and process control of test data. Require the computer system to be able to complete comprehensive processing and analysis of the altitude simulated test cell, high speed data acquisition of ground test rig and large and medium test equipment, dynamic data acquisition, real time display of test data, dynamic analog display metering, detection and test results.

d. In the aspect of computer aided management. Carry out the computer management of engine development and production process. Require that the computer system can continuously provide the corresponding computer-aided management environment support with the improvement of the management level of each link in the engine development and production process.

3.3.2 Preliminary opinions on computer configuration

Carry out the overall planning, step-by-step implementation, according to the concept of computer

network construction, and arrangement of computer configuration

There are different types and levels of requirements for computer systems in the engine industry and various factories. It is not reasonable in technology to use a single model to meet various needs. However, it will lead to the situation that design and production technology and hardware and software resources cannot be shared and coordinated in the industry without planning and control. Therefore, it is necessary to strengthen the industry management, and implement overall planning and step-by-step implementation.

In the computer development planning of engine industry, a preliminary idea of configuring computers according to the concept of computer network construction in the industry, as well as three-level computer network in scientific research institutes are put forward to establish computer aided design system. Super minicomputers and workstations are equipped in the factory to carry out the application research of computer aided manufacturing of key parts, and super minicomputers and microcomputers are equipped in all factories to carry out computer aided management.

The three-level network refers to the configuration of computers according to the three-level structure of high-speed computer level, general-purpose computer level and engineering workstation (including microcomputer). Computers at different levels undertake different main tasks to meet the multi-functional requirements in the development and production of models. Three level network is the basic mode of computer configuration in engine industry. Each plant will be equipped with one, two or three-level computer network according to its own task requirements and condition allocation of technological transformation

The assumption of the selection scheme are:

Small supercomputer is to be selected for high speed computer, and the main technical indexes are as follows: The computing speed is 100-300 million floating point operations/s, the memory capacity is 500-1000 megabytes, and the external memory capacity is 50-100 gigabytes

The main technical specifications of general purpose computer are as follows: The computing speed is 10-20 million instructions/s, the memory capacity is 128-256 megabytes, and the external memory capacity is 50-100 gigabytes.

The main technical indexes of engineering workstation are as follows: The calculation speed is 5-5 million instructions/s, memory capacity of 4-128 megabytes, external memory capacity of 50-100 gigabytes.

4. CADISEN overview

According to the design characteristics of vortex jet, vortex fan and vortex shaft, propeller, CADISEN will include a set of software modules for engine design, analysis, engineering drawing and other tasks, and realize data exchange among design system, subsystems and modules[6].

CADISEN system is composed of CASSEN (engine engineering analysis software system) and CISEN (engine integrated environment). CASSEN concentrates all the engineering analysis and design modules needed in the process of engine design. The control function provided by CISEN system establishes the operation interface between the user and CASSEN in two ways: menu and programming language. By using CISEN geometry system, the function of geometric design, engineering drawing and other drawing of parts can be realized by CASSEN. The general finite element analysis system can be used to analyze complex structures. The data generation and conversion program provided by CISEN will realize the data exchange between the database, UF file and each block. The executive control system is an integrated interactive design system composed of CASSEN, large graphics software, database system and general finite element analysis system. The relationship between systems in CADISEN can be shown in Fig. 2 as follows:

4.1 Function overview of CISEN system

CISEN system is the core of the integration for Aero engine CAD with intelligent architecture, which is the completely modular software. With standard user interface and unified interface of external system, the engineering analysis system is easy to integrate. With perfect software engineering environment and standard programming language, it shall be separated from

hardware equipment as far as possible. It has distributed processing function, adapts to multi-level network computer configuration, adopts database technology, and has data sharing function. The system consists of hardware environment, basic software, geometry system,

front and back processing, general finite element program, general external interface and so on,

4.2 Function overview of CASSEN system

CASSEN system is an integrated design system for basic cover aeroengine design process with the characteristics of the multi-function, multi-purpose and human-computer interaction of standardization, graphics, optimization and integration, which can complete the design of various engines and embody two characteristics of vortex jet, vortex fan and vortex shaft, propeller. It consists of 13 design systems such as engine general system and 12 databases such as original standard engine database[7]. The main functions are:

- A. It has the coordination function of matching aircraft and engine
- B. It can meet the requirements of users and complete the screening of overall performance parameters under matching conditions
- C. It can complete the design analysis of the whole and each part
- D. Under the support of the integrated environment, each design system can run independently and can be used in parallel
- E. With the support of geometric modeling system, it can complete the design of components, proofing drawings of components, engineering drawings of components and some axonometric drawings, and provide relevant documents for production and processing
- F. With the support of general finite element program, the structural analysis of parts can be completed
- G. It has the reverse design function of the whole, parts and components
- H. It has applicable pre and post processing function
- I. It has 12 kinds of engineering databases. It can realize data sharing and has the function of querying relevant data
- J. It has the function of human-computer interaction

5. AI and CAD

Combined AI with DB, it can not only improve the intelligence of DB, but also can be used in knowledge management. It is a major technical topic to introduce AI technology in CADISEN in a planned way. The CAD technology we use today can only support engineers in the detailed design stage and later stages, and there is nothing to do in the conceptual design and outline design stage. This is because the current CAD systems are limited to algorithmic or deterministic problems[8]. As we all know, engine conceptual design and outline design is the core stage and

foundation of the design process. The working mode of traditional CAD system is man-machine dialogue, which lacks the ability of synthesis, reasoning and selection[9]. It is not easy to spread and expand the scope of application. In the process of aero engine design, two kinds of problems are usually solved. One kind of problem is analyzable, and its goal can be expressed in a special form; The other kind of problems belongs to synthesis type, whose goal can only be described in the form of characteristic or behavior. In order to solve these problems, it must be above the program layer, because the computer implementation process is represented below the program layer. Therefore, the introduction of knowledge expert database (KES) can help people realize the same problem solving process interactively through the established model on the computer. Through the analysis of aero engine design process, it is of great significance to extend the idea, method and technology of knowledge engineering to CAD.

6. CAM

Because our country aero engine enterprise is weak in computer technology, during the Eighth Five-Year Plan period, the research on CAM has not been carried out in a large scope like CAD, and is still in the stage of laying the foundation. At present, we have carried out the research of auxiliary tooling design, 2-5 axis NC programming, integral impeller CAD / CAM and other topics. In the future, we will take these aspects as the starting point, master CAM technology, cultivate talents, gradually expand the scope of research, and apply the research results to some parts of NC machining. In addition, through the opportunity of cooperating with foreign countries in the production of trunk line power, the application and development of MRPH (production resource management system) will be carried out to improve the management quality of the factory[10]. During the Eighth Five Year Plan period, combined with the cooperation of trunk power and model development, the development of CAM technology in the industry will be systematically carried out in the appropriate period, with emphasis on the auxiliary manufacturing of some parts. During the Ninth Five Year Plan period, the work of networking and integrated manufacturing system will be considered.

References

- [1] Chen guiyang. Research on computer aided test technology of Aeroengine [J]. *Journal of Aerospace Power*, 1999, 14 (004): 417-420.
- [2] Rolls-Royce. The jet engine [M]. England: Aerospace Group. 1996:2.
- [3] Fang changde. Development of Civil Passenger Plane engine [J]. *Civil aviation economy and technology*. 1995.5.
- [4] Fang changde. Development prospect of Aeroengine [J]. *Aircraft Engine*, 2004 (03): 1-5.
- [5] Zhang shaoji. Development and Prospect of Aeroengine control system [J]. *Journal of Aerospace Power*, 2004 (03): 375-382.
- [6] Chen junba. CADISEN system introduction [J]. *Aviation computing technology*, 1993 (04): 107-112.
- [7] Tang hailong, Zhang jin. Research on object oriented programming method for aeroengine performance simulation [J]. *Journal of Aerospace Power*, 1999 (04): 421-424.
- [8] Zhang weiguan. CAD/CAM help aviation manufacturing industry [J]. *Metalworking (cold working)*. 2011 (03): 12-15.
- [9] Zhou keping. Application of computer CAD technology in engineering design [J]. *Silicon Valley*, 2015, 12 (3): 119-120.
- [10] Guo wenyou. The viewpoint of CAD/CAPP/CAM for Aeroengine design [J]. *Aviation technology*, 1999 (02): 10-12.