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Application of MBSE in Aero-engine Structural Parameter Calculating System

Yanxin Che
AECC Shenyang Engine Research Institute, Shenyang 100015, China

Abstract

Due to the high development complexity of the aero-engine structural parameter calculation system (hereinafter referred to as the parameter calculation system), the traditional document-based system engineering method can not fully meet the development of the parameter calculation system, so the model-based system engineering method is introduced into the development of aero-engine structural parameters calculation system. In order to improve R&D efficiency, reduce R&D cost and shorten the R&D cycle, the requirements are fully analyzed in the concept stage of the project, and the software tools are used for modeling, simulation and design analysis to verify and confirm the requirements. By applying the model-based system engineering (MBSE) method in a certain aero-engine structural parameter calculation system, the necessity and feasibility of applying the model-based system engineering (MBSE) theory to the development of aero-engine structural parameter calculation system are proved.

Keywords: MBSE, areo-engine, structural parameter

1. Overview

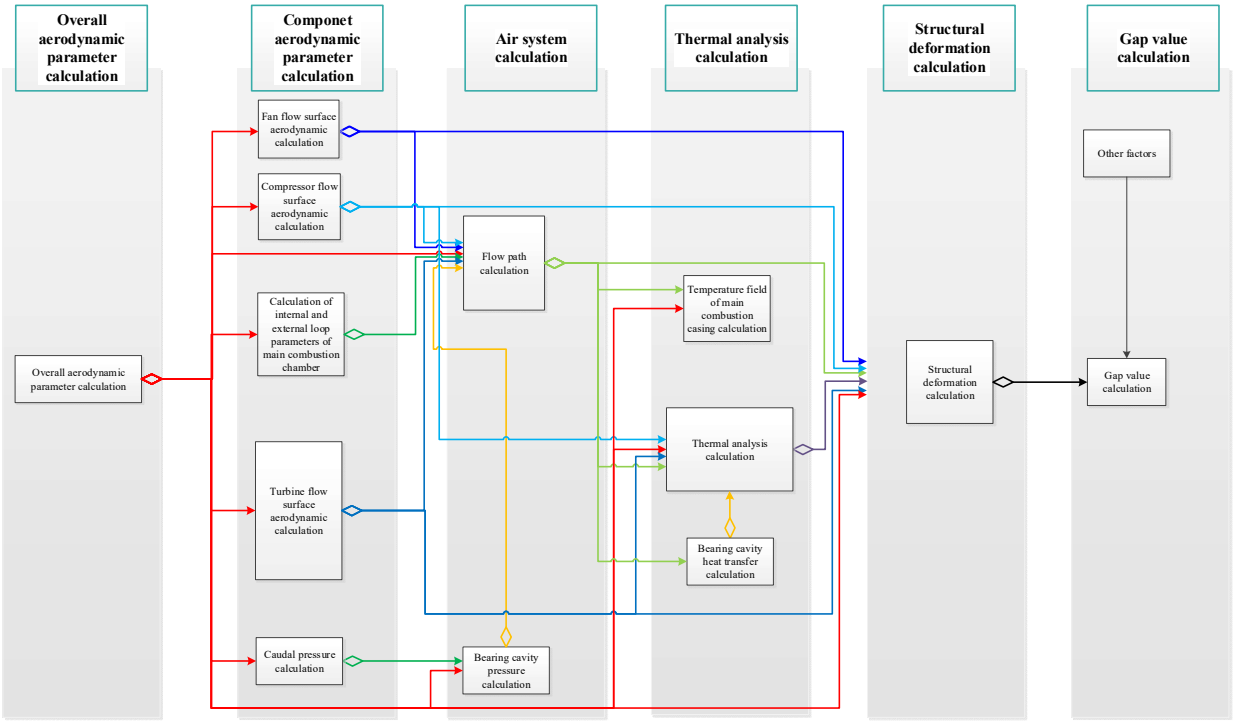

Figure 1 – Calculating process of some parameters of aero-engine general structure.

The calculation of structural parameters of related components or components in Aero-engine design process is a calculation process with a long iteration period, involving a large number of computing personnel and a large amount of calculation data (as shown in Figure 1). Currently, there are some problems, such as irregular calculation process, lack of management of calculation

resources, low efficiency of data flow and low efficiency of department collaboration. In order to improve the aero-engine R&D capability, standardize the calculation process, improve the accuracy and reliability of parameter calculation, shorten the calculation cycle and reduce the calculation cost, the aero-engine structural parameter calculation system (hereinafter referred to as parameter calculation system) is designed and developed.

The structure of the aero-engine structural parameter calculation system is complex. The traditional document-based R&D process can not fully meet the needs of the development of the parametric computing system. Often, due to the insufficient analysis of the early requirements of the project, the system solution can not meet the overall demand, which requires the project to be completed. A lot of improvement work was restarted, which eventually led to an extended development cycle. The introduction of model-based system engineering methodology can well solve the problem of insufficient demand analysis, and through the use of tools for modeling and simulation, to fully analyze, verify and confirm the requirements in the design phase, effectively avoid unnecessary Rework, improve design quality, reduce research and development costs, and shorten the development cycle.

2. Theoretical model

Traditional Text Based System Engineering (TSE) uses a variety of text documents to construct the system architecture. The output of TSE is a series of natural language-based, text-based documents, With the development of information technology, the document of system engineering have evolved from past paper methods to electronic processing methods, and all parties to read information from the document is still a line-by-line scanning method. There has been no fundamental change in the understanding of the contents of documents by the relevant parties. That is to say, TSE does not actually make full use of the advancement and achievements of information technology. Therefore, traditional system engineering is document-centric system engineering.

In 2007, the International Society of Systems Engineering (INCOSE) gave the definition of model-based systems engineering in the Vision of System Engineering 2020. Model Based System Engineering (MBSE) is an official recognition of the application of modeling methods in systems engineering activities, to enable modeling methods to support activities such as requirements, design, analysis, validation and validation. These activities begin at the conceptual design stage and continue throughout design, development and beyond. All life cycle stages. From the definition of MBSE, it can be seen that modeling is the process of building a model using a modeling language and modeling tools and simulation is the implementation and execution of the model. Model is the basic method for us to think about problems and the basis of thinking in design work. The key technologies involved in model-based systems engineering development methods are system architecture design, multi-physics domain modeling, integrated simulation computing environment, model and data management.

This paper focuses on MBSE, forms the DOORS requirement model of computing system and Rhapsody requirement analysis model, functional analysis model, design synthesis model and merge model. It shows through practice that the introduction of MBSE in system development can improve the reusability of system development, improve design quality, reduce R&D cost and shorten R&D cycle.

3. Traditional research and development process of aeroengine structural parameter calculation system

The traditional R & D process of aeroengine structural parameter calculation system is: in the overall scheme design stage, the document based system engineering method is adopted, which mainly depends on the development experience and ability of the designer. The traditional R & D process of aeroengine structural parameter calculation system is shown in Figure 2.

4. Application of MBSE in the development of aeroengine structural parameter calculation system

4.1 Introduction of MBSE methodology into R & D process

MBSE is a system engineering method based on demand driven and model-based. The R & D process is shown in Figure 3.

It can be seen from the flow chart in Figure 3 that after the introduction of MBSE methodology into the development process of aeroengine structural parameter calculation system engineering, the

traditional document based development process is transformed into a demand driven system engineering method. Through early modeling and simulation, the traceability of design and requirements is ensured, and the system requirements are fully verified and confirmed at the early design stage, By using this method, when the requirements change, it can also make a top-down rapid response, conduct a comprehensive change impact analysis, and ensure the continuous traceability of the design and requirements.

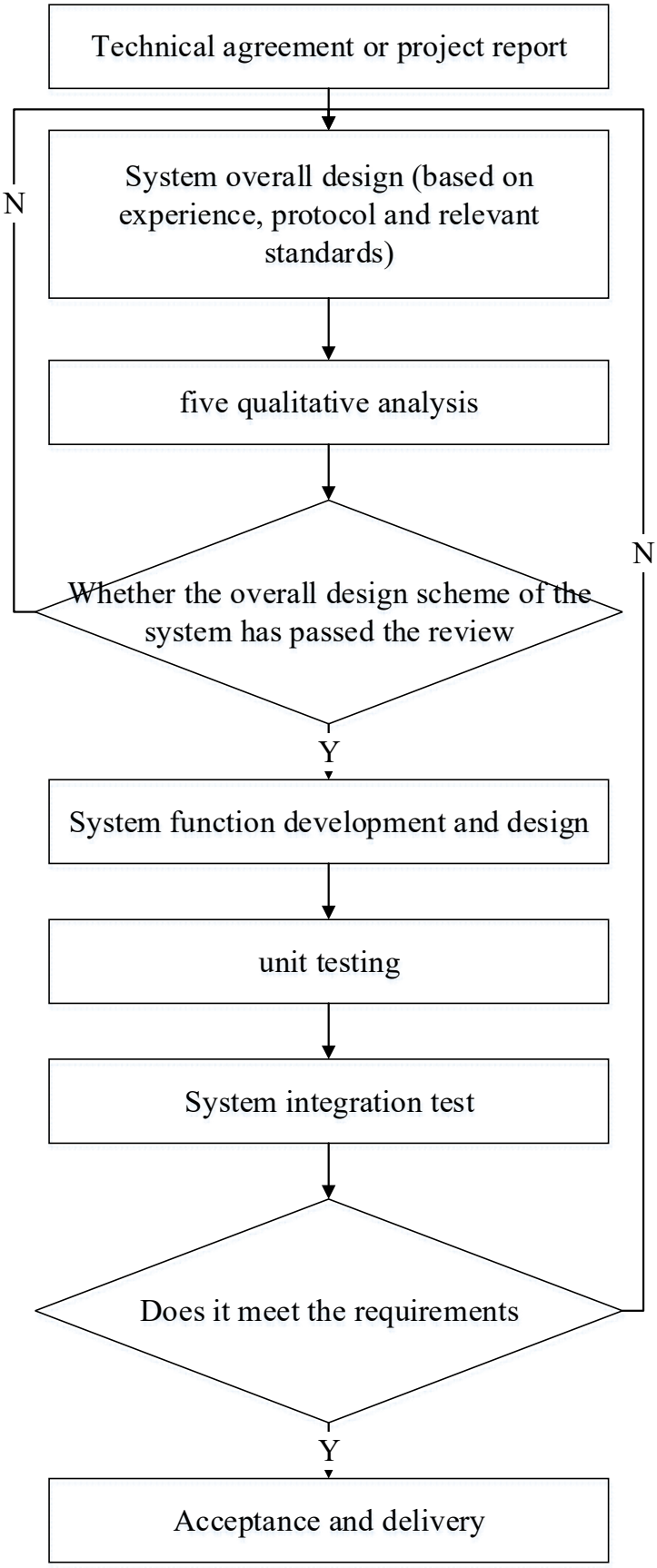

Figure 2 – Traditional research and development process of aeroengine structural parameter calculation system.

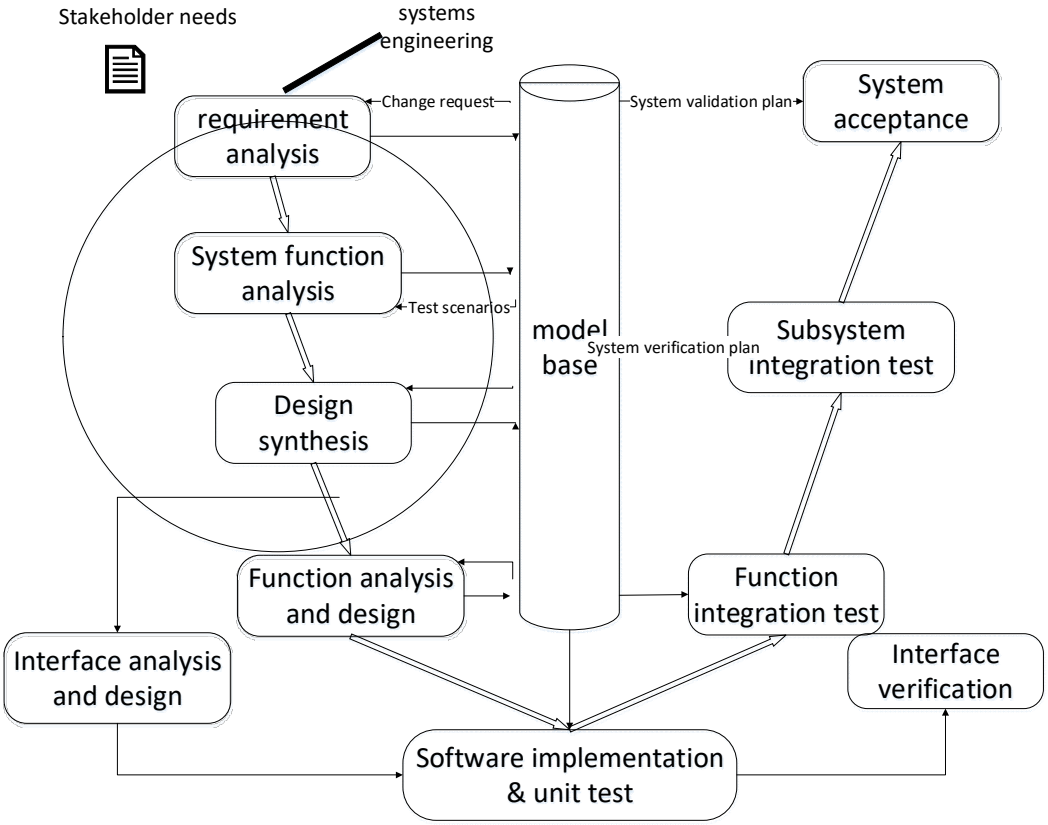

Figure 3 – Research and development process of MBSE methodology.

4.2 Application of mbse in pilot project of aeroengine structural parameter calculation system

In order to better compare the advantages and disadvantages between the model-based system engineering method and the traditional system engineering method, the pilot practice of the model-based system engineering method of an aeroengine structural parameter calculation system was carried out.

When the model-based system engineering is applied in a pilot project of aeroengine structural parameter calculation system, the requirement sorting of aeroengine structure parameter calculation system is completed under the requirements management tool DOORS, and the work in the model engineering stage is completed under Rhapsody; The modeling and analysis of the function requirements of aeroengine structural parameter calculation system is completed under Rhapsody. The modeling process is Harmony Se and the modeling language is the standard modeling language SysML.

4.2.1 Demand analysis

The research and development of aeroengine structural parameter calculation system adopts mbse method. Firstly, the system requirements are analyzed under the requirements management tool DOORS. According to the signed technical agreement, specific requirements of model, accumulated experience and relevant industry standards, the functional requirements and non functional requirements (including performance requirements, physical requirements and "six" requirements) of the system are sorted out, Form entry-based requirements, and conduct internal audit of team members and peer experts to ensure that the meaning of requirements is complete, explicit, clear, unambiguous and verifiable.

The sorted itemized requirements are introduced into the modeling tool Rhapsody. According to the functions of the system, the literal requirements are transformed into the requirements expressed by use cases, and the tracking relationship between the requirements and use cases is established. At this time, the use case model is a functional model, and the non functional requirements are tracked to the related use cases at the same time, It not only ensures the integrity of requirements, but also

facilitates the transfer of non functional requirements to the next level team at the same time.

4.2.2 System function analysis

After completing the requirement analysis, the system function analysis is started. With Rhapsody, the aeroengine structural parameter calculation system is regarded as a black box, the overall function of the system is sorted and designed, the function flow of each system use case is analyzed, and the functional, interface and other requirements are expressed as a clear description of the system function, Then, the interaction between the aero-engine structural parameter calculation system and other systems is identified, and the complete description of the system state behavior is completed through the black box activity diagram, sequence diagram, 1BD diagram (internal block diagram) and state diagram.

4.2.3 Design synthesis

In the design and synthesis of aeroengine structural parameter calculation system, the aeroengine structural parameter calculation system is regarded as a white box under the Rhapsody. Based on the comprehensive consideration of all system functions, the system architecture is analyzed and designed. The system is divided into components, that is, BDD diagram (block definition diagram) is formed, Then, based on the unified architecture, each use case is decomposed and allocated according to components (the process is similar to the black box of system function analysis). Finally, the formed use case models are combined to form the full function model of the system, and the comprehensive verification of the system is completed through the implementation of the model.

In addition to the function logic analysis and design of aeroengine structural parameter calculation system by Rhapsody, other tools (such as fluent, fensap, cards, mechanical, etc.) can be used to simulate and analyze the design scheme at the system level and component level, so as to find out the defects or weak links in the design as soon as possible and form the optimal scheme of the system after correction, Then it decomposes and forms the component level task book (including executable model, interface control document, etc.) to be delivered to the component level R & D team.

4.3 Form results

After the pilot practice of model-based system engineering of aeroengine structural parameter calculation system, the requirement model library of aeroengine structural parameter calculation system is formed under doors, the requirement analysis model library, the function analysis model library, the design integrated model library and the combined model library are formed under Rhapsody tool, As well as RBE (requirements based Engineering) information architecture, RBE process, RPE (rational publish engine) template of development plan report and enterprise standard "requirements writing specification" and "system modeling specification" which are suitable for the research and development of aeroengine structural parameter calculation system.

5. Comparison of two R & D processes

Through the model-based system engineering pilot practice, the advantages and disadvantages of traditional document based R & D process and model-based system engineering R & D process are compared by selecting a certain aeroengine structural parameter calculation system project. The comparison results of the two kinds of R & D processes are shown in Table 1.

Serial number	Comparator	traditional R & D process	MBSE R & D process
1	requirement analysis	nothing	Through the requirements management tool DOORS to sort out and manage the requirements
2	design basis	It is mainly based on the agreement and the experience of designers	Demand based
3	Modeling and simulation tools	nothing	Rhapsody Fluent Mechanical FENSAP Icepak FEXO CARMES SIWave ANSYS
4	Requirements, design verification	After the development of functional modules, functional	The system comprehensive verification of virtual objects in

		verification is carried out, and then system integration verification is completed	the concept stage through model
5	Form results	The document edited under word is filed as paper document	The requirement model and modeling model are stored in the computer server
6	Guidance for subsequent projects	Content scattered, difficult to find, poor guidance	It is easy to find and borrow, and has strong guidance

Table1 Comparison between traditional R & D process and MBSE R & D process

From the comparison in Table 1, it can be seen that the traditional R & D process is based on documents, and the main tool is Word. It is difficult to guarantee the consistency and traceability of requirements and design. Moreover, due to the lack of early verification means, reusable information cannot be provided when the system changes or evolves. The model-based system engineering process can solve the difficulties that the traditional document based R & D process cannot overcome, It focuses on the early verification of requirements and system architecture. In the concept stage, it verifies the requirements and design and the comprehensive verification of the system through the virtual object model. When the requirements change, it can quickly carry out the change impact analysis through the model, and can provide reusable requirements and design information for the continuous improvement of the system.

6. Concluding remarks

Through the pilot work of model-based system engineering of aeroengine structural parameter calculation system, the DOORS demand model of the computing system, Rhapsody demand analysis model, function analysis model, design synthesis model and combination model are formed. Through practice, MBSE can be introduced into the system research and development, which can improve the reusability of the system research and development and improve the design quality, Reduce R & D cost and shorten R & D cycle.

References

[1] Jamshidi M. System of Systems Engineering: Innovations for the 21st Century. Wiley & Sons , 2009.

[2] Dennis M B. The Engineering Design of Systems: Models and Methods. A. John Wiley & Sons Inc., 2009.

[3] B. H. Rao, K. Padmaja, P. Gurulingam. A Brief View of Model Based Systems Engineering Methodologies. International Journal of Engineering Trends and Technology, Vol. 4, No. 8, pp 3266-3271,2013.

[4] Fisher J. Model-based Systems Engineering: a New Paradigm. INCOSE Insight, Vol. 1, No. 3, pp 3-16,1998.

[5] Ramos A L, Ferreira J V, BarcelÓ J. Model-based systems engineering: An emerging approach for modem systems[J]. IEEE Transactions on Systems, Man, and Cybernetics, Part C: Applications and Reviews, Vol. 42, No. 1, pp 101-111, 2012.

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