The Research on Aircraft Economic Design

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Abstract—Economics affordability like safety, reliability, maintainability, is the inherent attributes of aircraft. Total life cost is the main economic index for aircraft. Active economic design for aircraft shows cost as independent variable. And economic design should consider total cost throughout the product development including design, manufacture, use and maintenance. In the paper, the multilevel modular analysis model on total life cycle cost has been presented. The main dimension of aircraft economics design has been analyzed, including pneumatic design, composite materials design and oriented-maintenance design. Combination prediction model of life cycle cost for aircraft with fuzzy and uncertain information has been built. The aircraft economics design by collaborative optimization has been presented by multidisciplinary optimization. The aircraft integrated economics design has been discussed, including the framework and relevant technology of aircraft integrated design. The research result can also be used to other complex systems, such as weapon systems.

Keywords—aircraft economic design;complex system;cycle cost analysis;cost;model

I. INTRODUCTION

Economics (also called economic affordability) like safety, reliability, maintainability, is the inherent attributes of aircraft. Total life cost is the main economic index for aircraft. According to International Civil Aviation Organization the sort of aircraft competitive factors are economic, reliability, maintainability, passenger comfort, aircraft technical performance, customer service, financial support and aircraft series. Boeing forecasts the future of low fuel consumption of aircraft will win greater market [1]. From the history of development of world aviation industry, Boeing and Airbus aircraft will improve economics as an important means to enhance competitiveness.

In the economics design process, the basic goal is to reduce the life cycle cost, but for different customer group preferences are different, for the optimization of each component of the cost should also considered. In the design phase, aircraft life cycle cost can be decided more than 70% [2]. Therefore, how to strengthen the economics early in development of aircraft design, and runs through the whole life cycle of products, which has great significance.

The characteristics of aircraft economics design can be summarized as follows:

First, Active economic design for aircraft shows cost as an independent variable, instead of as a natural extension of other technical.

Second, economic design should consider total cost throughout the product development including design, manufacture, use and maintenance.

Third, economic design is closely related to the development of other design technology, such as pneumatic design, material technology, and mechanical processing ability.

Forth, technology and management should be integrated. That is to say, the development of economic design can be optimized by pneumatic, composite materials technology, as same as, also can be achieved by resources optimization and integration.

Fifth, at the beginning stage of the aircraft development, even the concept design phase, economics design influence is most obvious. But during this period, less data is characterized with subjective and uncertain information.

In this paper, combined with the characteristics of aircraft economics design, combined with the current research progress in aircraft economic design, there are four topics have been studied as follows. i. Aircraft economic design framework, which to solve aircraft economics theory and realization; ii. Economic design dimension analysis for aircraft, which can be used to improve aircraft economics methods; iii. Aircraft economic analysis, which is an important basis for aircraft design decision-making [3]; iv. Collaborative optimization and integration technology for aircraft economics design.

II. AIRCRAFT ECONOMIC DESIGN FRAMEWORK

The basic idea of aircraft economics design is to convert customer requirements and cost control to the design process. Using cost as an independent variable of aircraft design, cost systems Engineering (Costing System Engineering, CSE) in the total life should be applied [4]. Economics is closely related with the customer demand and market demand. The base of aircraft economics is to analyze the requirement of economics. Economics index should be allocated. Economics index and constraint should be abstracted.

The basic idea of aircraft economics design is from top to bottom. And the process is shown as Fig .1.

III. DIMENSION ANALYSIS OF AIRCRAFT ECONOMIC DESIGN

A. Aircraft economics design based on based on pneumatic technology

Pneumatic technology for improving aircraft

economics mainly applied advanced aerodynamic layout to reduce air resistance, enhancing the lift drag ratio and cruise efficiency, reduce fuel consumption, and thus greatly improve the aircraft economics. Shape optimization is the key of pneumatic technology for aircraft economics design. Through the advanced pneumatic technology can reduce fuel consumption ，at the same time, can also lead to an increase aircraft manufacturing cost, and increase the customer acquisition costs further. So, fuel consumption reduction and manufacturing cost increase should be balanced and optimized in the aircraft economics design by pneumatic technology.

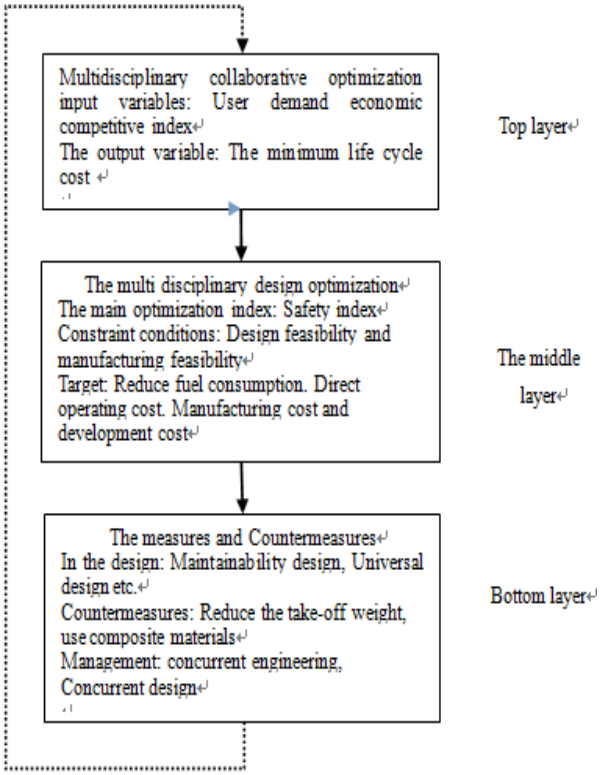

Figure 1. Aircraft economic design process

B. *Aircraft economics design based on composite materials*

The aircraft composite structure design, effectively reduce the structural weight up from 20% to 30%. If the other technical indexes are similar, carrying capacity can be improved. If the load is same, engine oil consumption can be reduce. Composite fatigue resistance and excellent corrosion resistance, improves the service life of aircraft structure, reduce the aircraft maintenance requirements [5]. Therefore, composite materials are widely used in reducing fuel consumption, reduce the maintenance cost and improve the aircraft utilization. Further, the total life cost can be reduced [6].

C. *Aircraft economics design based on Oriented-maintenance*

Maintenance costs can reach from 15% to 20% in the total life cost. Maintainability design is the effective cost control method, which significantly enhance the aircraft economics [7]. Design for maintenance(DFM) is the frontier design concept. DFM refers to meet user needs as the premise, by analyzing the characteristics of each stage of product life cycle, evaluating and balancing, improve the aircraft maintainability and related properties (reliability, security and testability, etc.) [8]. The main purpose of maintainability design is to reduce the plan maintenance and prolong the maintenance interval, reduce maintenance cost.

IV. AIRCRAFT ECODOMICS DESGIN BY COLLABORATIVE OPTIMIZATION TECHNOLOGY

The goal of aircraft economic design optimization is to realize lower total life cost with considering the customer needs and preferences. So, the aircraft economic design is a multidisciplinary collaborative optimization problem.

Multidisciplinary design optimization (MDO) technology emerged to reach the global optimum as possible in the design process of complex products. Some scholars have done introduced MDO technology in the field of aircraft design. The application is mostly used for performance optimization, only a little application have related with aircraft economics index, such as few involve minimum take-off weight. The definition of MDO is not unified, there are three definitions in AIAA MDO white paper [9]: i. MDO is a method of collaborative interaction mechanism by a fully explore and utilize the system to design complex system. ii. MDO refers that interaction analysis between different subjects or subsystems are necessary in the complex engineering design process.iii. If multiple factors in design affect all other elements, it is necessary to determine which factors should be changed and change degree. There are two difficulties, that is high computational complexity and organization of complex [10]. System decomposition is an important method to minimize the coupling between subsystems [11]. MDO decomposition algorithm is to translate system optimization problem to main problem and sub problem set by interaction degree between objective function.

Economic and other design parameters are the integral part of the customer demands. As same as, the complicated nonlinear relations are reflected. It is necessary to balance and optimize these users demand.

It should be mentioned that aircraft economic design process must not only address interactions between traditional aerospace disciplines (e.g. aerodynamics, structures, controls, propulsion), but should also account for “life cycle” disciplines (e.g. economics, reliability, manufacturability, safety, supportability, etc. These disciplines can bring a variety of uncertainties of differing natures to the design problem. It is the presence of uncertainty which demands the use of a probabilistic approach to design synthesis.

V. AIRCRAFT INTEGRATED ECONOMIC DESIGN

Aircraft integrated economic design technology is to choose and determine the layout and general design parameters under the constraint of customer demand. Cost is seen as independent variable and customer demand should be satisfied as possible by calculation, analysis and revision. In general, a lowest total life cost can be realized by satisfying different kinds of performance index under airworthiness constraint.

A. *The framework of aircraft integrated economics design*

To realize the aircraft integrated economic design, top economic design, auxiliary analysis and prediction system for economics design and economics expansion design should be in consideration.

The large aircraft top economic design is to determine the main economic indicators. Economic index should be balanced based on value concept.

Auxiliary analysis and prediction system for economics design is to analysis relevant data and predict cost under the specified economic index.

The economics expansion design reflects that aircraft economics depends not only on the aviation manufacturing sector, but also depends on the airline. So, economics expansion is necessary for increasing the airline profitability, which lays the foundation for the further open up the market. The feedback of expansion economics design can be used for sustainable aircraft economics optimization.

B. *The tecnology of aircraft integrated econimics design*

Integrated with the various economic design technology, the economic design technology can be further decomposed into overall economics design technology, means economics design technology, strategy economics design technology, strategy economics design technology, introduction economics and auxiliary economic analysis design technology. There is different strategy for different technology development.

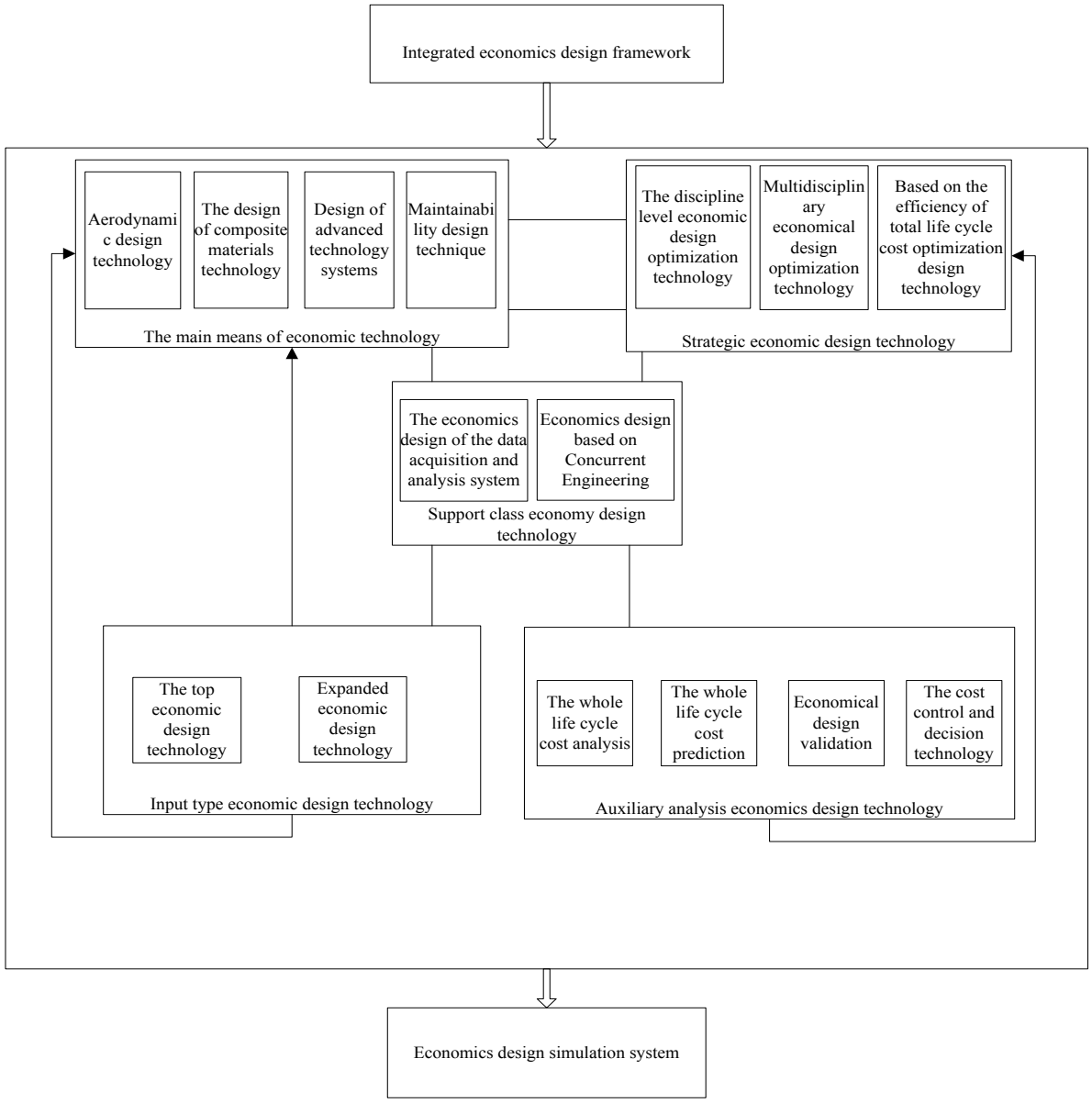

Figure 2. The framework and technology of aircraft integrated economics design

For the overall economics design technology, integrated economics design framework is the overall description and detailed explanation of strategy of economics technology development. So, the overall economics design should be started as earlier as possible. In the earlier aircraft design development, overall economics design should be emphasized.

Means economics design technology is directly related to the economic goal realization. But the means technology should be combining the development with other relevant technology development.

Strategic economics design technique is to achieve lowest total life cost based on the existing conditions. It is based on the disciplinary economics design, and the result will send feedback to the disciplinary design. The core of strategy economics design technology is how to establish the economics design model in accordance with the characteristics of the civil aircraft, and take the effective methods of solving complex system model.

Auxiliary economics analysis design technology is directly related with accuracy of aircraft design and optimization, which is the assistant decision tool for aircraft economics design. For auxiliary economic analysis design technology, the difficulty is how to deal with little data analysis and prediction technology. The development of auxiliary economics analysis technology development is affected by information technology and prediction technology development.

The framework and technology of aircraft integrated economics design are shown as Fig .2.

VI. CONCLUSION

The paper discusses the aircraft economics design. The main dimension of aircraft economics design has been analyzed, including pneumatic design, composite materials design and oriented-maintenance design. Aircraft economics design by collaborative optimization has been presented by multidisciplinary optimization. Aircraft integrated economics design has been discussed, including the framework and relevant technology of aircraft integrated design. In the future, aircraft economics design should be developed in the field as follows. i. Aircraft economics design using concurrent engineering; ii. Aircraft economics design using digital prototype technology; iii. Aircraft economics design by scare data and information. The aircraft economics design will be studied further.

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