Process of establishing design requirements and selecting alternative configurations for conceptual design of a VLA

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Abstract In this study, a process for establishing design requirements and selecting alternative configurations for the conceptual phase of aircraft design has been proposed. The proposed process uses system-engineering-based requirement-analysis techniques such as objective tree, analytic hierarchy process, and quality function deployment to establish logical and quantitative standards. Moreover, in order to perform a logical selection of alternative aircraft configurations, it uses advanced decision-making methods such as morphological matrix and technique for order preference by similarity to the ideal solution. In addition, a preliminary sizing tool has been developed to check the feasibility of the established performance requirements and to evaluate the flight performance of the selected configurations. The present process has been applied for a two-seater very light aircraft (VLA), resulting in a set of tentative design requirements and two families of VLA configurations: a high-wing configuration and a low-wing configuration. The performance requirements include two mission requirements for the flight range and the endurance by reflecting the customer requirements. The flight performances of the two configuration families were evaluated using the sizing tool developed and the low-wing configuration with conventional tails was selected as the best baseline configuration for the VLA.

1. Introduction

The life-cycle of an aircraft is divided into the following phases: concept studies on customer requirements, conceptual design, preliminary design, detailed design and development, production, operation and maintenance, decommissioning.
and recycling. The conceptual design phase includes several important tasks such as the design requirement analysis, the feasibility study of development, the demand forecasting and market analysis, the conceptual aircraft configuration design and subsystem definition, and the establishment of initial planning for aircraft development. Accordingly the conceptual design phase is most influential in the aircraft life-cycle. Although relatively small investments are necessary during the conceptual design phase, large efforts should be made since 70–90% of a design is defined in this phase. Therefore, development of a logical and efficient conceptual design method will be of great importance. In the conventional conceptual design approaches, the process of selecting the best configuration typically employs a trial and error method based on the experience of a designer. This increases the development time and cost due to the large number of design iterations.

Efficient conceptual design requires a series of well-organized processes that enable designers to make logical and objective decisions on an aircraft design. Many methodologies that can be applied to such processes have been presented in the field of industrial engineering, but there have been very few developments and applications of the methodologies in the conceptual design phase of aerospace engineering. Mavris et al. successfully established an objective and efficient design process. They excluded a designer’s subjective judgment from their proposed aircraft conceptual design process, which includes concept establishment, selection of alternative configurations, and an assessment process. Park improved Mavris’ design process for optimum alternative configurations that reflect user requirements. Yoon presented an optimum baseline aircraft configuration selection process using a decision-making model that considers both airworthiness certification regulations and user requirements during the conceptual design phase.

In this study, a systematic design requirement analysis, which is an early stage of the aircraft conceptual design phase, is conducted to produce the design requirements considering user requirements, marketability, and certification regulations. Moreover, a baseline configuration design process is established to suggest objective and reasonable baseline configurations that satisfy the resulting design requirements. For aircraft design purposes, we have strived to make a logical flow in order to select the design requirements and baseline configurations. In addition, the internal data of the process were consistently managed to reflect the design requirements properly. A two-seater very light aircraft (VLA) was selected for the present study because it is anticipated that two-seater VLAs will be in demand as aero leisure sports are becoming popular domestically and globally.

For the requirement analysis, the voices of users, designers, and clients were collected through a survey of various groups of people including VLA pilots, students and faculty in aerospace engineering, and aviation company engineers. The proposed process of selecting baseline configurations used the quantitative requirements analysis methods (see Fig. 1). It also used initial sizing and a performance analysis respectively to generate the baseline aircraft configurations and to evaluate whether they satisfy the mission and performance requirements.

2. Building model

2.1. Brainstorming

The systematic method proposed in this paper uses a series of decision-making models to address the design requirements and the design alternatives in a more logical, objective, and quantitative manner. In this section, the decision-making models used in the present method are briefly described.

2.2. Affinity diagram

This method is a long-term human intellectual activity to organize data by grouping the data into groups based on natural relationships. The term “affinity diagram” was devised by Jiro Kawakita in the 1960s and has been used as a business tool to organize ideas and data. The method allows a large number of ideas stemming from brainstorming to be sorted into groups for review and analysis.

2.3. Tree diagram

The tree diagram is a graphical method that lays out a hierarchical structure of objectives and measures systematically to find the most appropriate measures in order to achieve the goals. In general, this method is used for spreading out the subordinate goals of the primary goal or for breaking down a large-scale project into progressively smaller feasible tasks.

2.4. Analytic hierarchy process

A psychology and mathematics based method, the analytic hierarchy process (AHP), is a multi-criteria decision-making (MCDM) method for making decisions about complicated problems rationally and efficiently. The AHP was developed by Satty in the 1970s based on the fact that the brain uses a

![Fig. 1 Quantitative requirements analysis methods.](image-url)
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