Amirkabir Journal of Mechanical Engineering

Amirkabir J. Mech. Eng., 50(1) (2018) 3-6
DOI: 10.22060/mej.2017.11668.5151

An Axiomatic Design approach to Reduce Repetition in Tail Conceptual Design Process

M. A. Shahi-Ashtiani, A. Alipour*

Aerospace Engineering Department, Malek Ashtar University of Technology, Tehran, Iran

ABSTRACT: From the perspective of synthesis, system design is comprised of conceptual, preliminary, and detailed design. Conceptual design is the first and most important phase of the system design that could influence the quality of the product. In general, conceptual design is iterative processes that tries to satisfy identified requirements. The outcome of the conceptual design phase is one or more concepts which does not necessarily accompany any detail. If the selected configuration could not satisfy the requirements, the designer should make changes in the decisions or may change the selected configuration completely. This activity makes the conceptual design process longer and increases the cost of the design process, as well. In addition, in the last decade, product design experienced fundamental changes in its concept from focusing on performance, function, and durability to sustainable design criteria such as being environmentally friendly, considering global warming, reducing energy consumption, and conducting end-of-product life cycle management such as reusing, recycling and remanufacturing. These conduct the designer to try to improve conceptual design process with the adoption of new methodologies. This article intends to use axiomatic design methodology for an innovative design, reduce repetition and satisfies most of the requirements in the conceptual design process.

Review History:

Received: 1 June 2016
Revised: 17 January 2017
Accepted: 5 March 2017
Available Online: 13 March 2017

Keywords:

Conceptual design
Iterative process
Customer needs
Axiomatic design
Quality function deployment

1- Introduction

Product design is an iterative, complex and decision-making process. It usually begins with the identification of a need, proceeds through a sequence of activities to seek an optimal solution to the problem, and ends with a detailed description of the product [1]. Generally, a design process consists of three phases: conceptual, preliminary, and detail design. Conceptual design is the first and most important phase of the system design and development process. As the name implies, the outcome of the conceptual design phase is a concept or configuration which does not necessarily accompany any detail [2].

Decisions made during conceptual design have a significant influence on the cost, performance, reliability, safety and environmental impact of a product. It has been estimated that design decisions account for more than 75% of the final product costs. It is, therefore, vital that designers have access to the right tools to support such design activities. In the early 1980s, researchers began to realize the impact of design decisions on downstream activities. As a result, different methodologies such as design for assembly, design for manufacturing and concurrent engineering, have been proposed [3].

In the last decade, product design experienced fundamental changes in its concept from focusing on performance, function, and durability to sustainable design criteria such as being environmentally friendly, considering global warming, reducing energy consumption, and conducting end-of-product life cycle management such as reusing, recycling and remanufacturing [4]. Usually, sustainable design criteria and traditional requirements of a product are at odds with each other. In fact, the reinforcement of sustainable design criteria limits the traditional requirements. Consequently, both sustainable and traditional factors should be balanced in the design process. This is because of the adoption of new theories and methodologies during this early phase of a product's life cycle to improve the quality of the final product. However, recent advances in system engineering fields and consequently improving new design methodology such as Axiomatic Design (AD), Multi-Disciplinary Design Optimization (MDO), etc. have now made it possible for designers to tackle some of the challenging issues in dealing with conceptual design activities. In this special issue, we have gathered together discussions on various aspects of AD influence on conceptual design problems such as reducing iterative in the design process and coupling between different Functional Requirements (FRs) by independent axiom and choosing the best configuration by information axiom

2- Tail Design by Using AD Approach

The aircraft tail design is a very complex design activity, an iterative process and must be repeated several times until the optimum aircraft tail configuration has been achieved. This repetition causes the design process to be longer and consequently more expensive. We try in this study to demonstrate the advantage of using AD to reduce the random search process for the best configuration, to minimize the iterative trial-and-error process, and finally to create a more suitable empennage for the airplane.

The AD algorithm is not limited to the product conceptualizing stage and is extended to include the detailed design and manufacturing process domain, as well [5].

Fig. 1 is shown to provide guidance to engineers seeking about AD place on the tail design process. According to this figure,

Corresponding author, E-mail: ar_alipour66@Mut.ac.ir

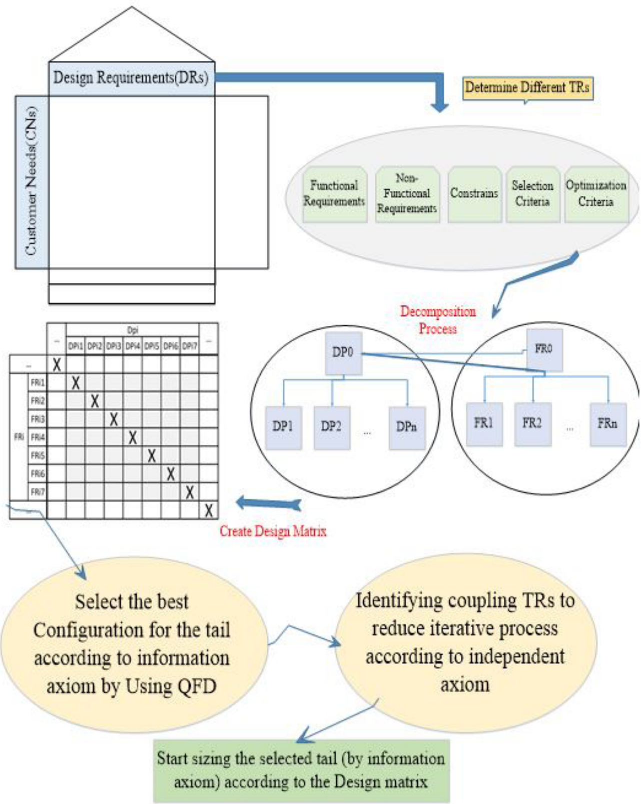

Figure 1. Guidance about AD place on the tail design process.

AD in tail design algorithm is applied in the beginning stage of the tail design. Generally, the definition and identification of the requirements is the basic and one of the most important design phase and this is the first application of AD approach in the design process.

Thus, the design process began by definition requirements with elicitation, collection, evaluation, translation, and organization of information about the desired artifact and its stakeholders and guidelines and instrument (such as Quality Function Deployment, QFD) that AD theory provides to facilitate this process. The determined Technical Requirements (TRs) lay the foundation for all of the next major steps in the AD process such as decomposition, the mapping between the design domains, the creation of design matrices, and the application of the design axioms [6].

Requirements in AD are usually defined by mapping the Customer Needs (CNs) to FRs and constraints (Cs). However, additional types of requirements, including Non-Functional Requirements (NFRs), Selection Criteria (SCs) and Optimization Criteria (OCs) are often needed [6]. In this article, TRs are divided into FRs, NFRs, Cs, SCs, and OCs.

3- Influence of AD Results on the Sizing of the Tail

The purpose of the tail is to provide the aircraft with a means of stability and control. As such, it is one of the most important components of the entire airplane. The aircraft designer must determine not only its size, location, and configuration, but also the type of controls it will feature. Before any stability and control analysis can begin, the designer must select the type of the tail configuration [7]. In this article, the conventional configuration is selected by using the second phase of QFD.

The concept of tail sizing refers to the process required to determine the size, shape, and position of the stabilizing surfaces [7].

All tail design parameters must be determined in the tail design process. The majority of the parameters are finalized through technical calculations, while a few parameters are decided via an engineering selection approach. There are a few other intermediate parameters such as downwash angle, side wash angle, and effective angle of attack that will be used to calculate some tail parameters. These are determined in the design process, but not employed in the manufacturing period [2].

The main goal of this article is not to design a new tail configuration but also the goal is to identify the influence of AD approach on the design process.

In the traditional design methods, if the considered tail configuration could not satisfy longitudinal and/or directional stability and controllability requirements, the designer should come back to the first step of the design process and repeat the design process. This iterative process influences the factors such as costs, design time, satisfying market demands, etc.

The author believes deeply that designers could reduce the tail iterative design process by using the Design Matrixes (DMs) that are obtained in the decomposition process of Axiomatic Design. For example, the designer could understand that there is a coupling between “To Satisfy longitudinal static stability requirements” and “To generate forces and moments to longitudinal trim according to FAR 23.161.c”. It means that the solution determined first could influence (negatively or positively) the second satisfaction. Therefore, when “The horizontal tail lift coefficient to satisfy trim requirement at cruise phase” has been calculated, the designer can study about the satisfaction of longitudinal static stability requirement. If this requirement satisfies suitably, the designer could continue the design process in the next step. It means that by using the result of AD approach, the designer can reduce iterative process. This can decrease the time and cost of the tail sizing.

In addition, selecting tail configuration by using the second axiom and second phase of QFD according to Cs, NFRs, SCs, and OCs, eliminates the probability of repeating design process due to bad tail configuration selection.

4- Conclusions

In this paper, the Axiomatic Design method was applied to the conceptual airplane tail design in order to derive a better configuration for the tail and reduce the iterative in the design process. The method is integrated with QFD that is a proven design methodology. This methodology is a well-known design method used to translate the voice of the customer to the designers. The “AD-QFD” integration method is a very suitable approach because of its ability to improve creativity, minimize the iterative process, and quickly optimize the best solution. In this paper, the author uses this integrated approach for mapping CNs into the FRs and their corresponding DPs to drive DM and identify coupling between different FRs according to the independent axiom, and to select the best configuration for the tail at the first step of the design process (according to the information axiom or second phase of QFD).

Ultimately, it is shown that using AD approach could help the designer to reduce the repetition in the tail conceptual design process. In the further study, a researcher could focus on the integrate QFD technique and information axiom to select tail configuration by using Ecological and sustainable criteria. To do that, they should model a QFD that estimates different solution information of every general DPs automatically.

References

[1] W. Hsu and I.M.Y.Woon, Current and Future Research in the Conceptual Design of Mechanical Products, *Computer Design*, 30 (1998) 377-389.

[2] M. H. Sadraey, *Aircraft design: A systems engineering approach*, 1st edition, Wiley Interscience, Place Published, 2013.

[3] B. Liu, Conceptual design: issues and challenges, *Computer Design*, 32 (2000) 849-850.

[4] A. Hosseinpour, *Integration of Axiomatic Design with Quality Function Deployment for Sustainable Modular Product Design*, M.SC Thesis in Department of Mechanical Engineering, University of Manitoba, Manitoba, 2013.

[5] B. S. El-haik, *Axiomatic Quality: Integrating Axiomatic Design with Six-Sigma, Reliability, and Quality Engineering*, 1st edition, A JOHN WILEY & SONS, Netherlands, 2005.

[6] Mary Kathryn Thompson, A Classification of Procedural Errors in the Definition of Functional Requirements in Axiomatic Design Theory, in: *7th International Conference on Axiomatic Design*(*ICAD*), (2013) 107-112.

[7] S. Gudmundsson, *General aviation aircraft design: applied methods and procedures*, 1st edition, University Elsvier, 2013.

Please cite this article using:

M. A. Shahi-Ashtiani and A. Alipour, An Axiomatic Design approach to Reduce Repetition in Tail Conceptual Design Process, *Amirkabir J. Mech. Eng.*, 50(1) (2018) 3-14.

DOI: 10.22060/mej.2017.11668.5151