Doctoral Dissertation Abstract

Title: Optimisation of small aircraft parameters in the preliminary phase of a design project

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An elaboration of a future aircraft design concept has become increasingly complex due to changes of the basic criteria for evaluating emerging solutions. In the past, the basic performance characteristics of an airplane were the only selection criteria. Today, more and more emphasis is placed on factors such as impact on the environment, cost-effectiveness, or comfort of travel.

The thesis presents a method to optimise parameters of a small aircraft and to be used in the initial phase of a design project taking into account the requirements of aviation safety imposed by the European Union certification specifications CS-23 and a requirement of aircraft competitiveness within the total transport system.

The basic design decisions regarding a future aircraft, including the selection of basic parameters are taken in the initial phase of a project (a definition of requirements, a conceptual design, a preliminary design). It means that most of the decisions concerning a future aircraft, including decisions significantly affecting aircraft competitiveness, for both, a manufacturer and an operator, are taken before the stage of a technical design. However, in this phase of a project, it is extremely difficult to evaluate achieving project goals due to the imprecision of requirements and design parameters, lack of knowledge of any ongoing interactions among parameters and uncertainty of analysis and calculations. A solution to this dilemma is to increase knowledge of the early stages of a design process.

The method is based on a mathematical model of aircraft and the multidisciplinary design optimisation (MDO) and the method covers the basic areas of aircraft design: aerodynamics, aircraft structure, performance and expected operating costs.

First, I determined the basic requirements for future aircraft by defining project goals accompanied by a set of basic design parameters. I select these basic parameters to define a configuration, that corresponds most accurately to the goals.

The objective function was defined as the value of the direct operating costs per 1 passenger-kilometre. Evolutionary algorithm was applied to solve the optimization problem.

The competitiveness requirements were formulated basing on a concept of the Small Air Transport system (SATs). The SATs vision was developed by the consortium within the projects of the 6th and the 7th Framework Programme of the European Union. The SATs is based on a fleet of small aircraft and rotorcraft equipped with 4 to 19 seats, and operating within an integrated and intelligent transport management system, at small airports and aerodromes. The SATs conclusion underlines significance of a fleet of turboprop aircraft.

The first stage of my study was to analyse the current state of the art in three thematic areas: the small aircraft transportation theory, the design process at the stage of concept development and preliminary design, and the modelling, computer simulation and numerical optimisation methods.

I used the analysis results to formulate a mathematical model of aircraft. It consists of four modules: a mass model, a performance model, a direct operating costs model and an optimisation algorithm.

My next step was elaboration of the simulation model and the simulation program. The simulation model was elaborated using Mathcad software. The basic aim of the simulation model was to validate the structure of the mathematical model, the completeness of data and algorithms.

I coded the simulation program in the Visual Studio environment using C++ programming language.

Then, I carried out the optimisation of design parameters of the 9-seater and the 19-seater as an example of this method application. I compared the optimisation results of my method with the results obtained using the minimisation of the engine power method.

Moreover, I analyse the sensitivity of the objective function with respect to selected parameters of the aircraft. The results facilitate choosing the most significant variables responsible for operational costs.

The thesis includes conclusions from modelling and analysis, and the recommendations leading to improve the competitiveness of small aircraft.

Keywords: small aircraft, small air transport system, preliminary design, multidisciplinary design optimisation, direct operating costs, evolutionary algorithms