

RAPID GEOMETRY DEFINITION FOR MULTIDISCIPLINARY DESIGN AND ANALYSIS OF AN AIRCRAFT

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Abstract. Conceptual and preliminary design level of aircraft design is searching for an easy, flexible and efficient way of computational geometry definition. Accelerating the process of geometry definition is the basic step for acceleration of all computations. It also enables optimization, where changes of numerical model are made automatically according to the optimization algorithms. The geometry definition has to be robust, free from errors and stay feasible.

Keywords: geometry definition, multidisciplinary, design, analysis

Introduction

Number of efforts are taken worldwide, by well known institutions to realize this claim. European project SimSAC [1] from year 2006 concentrated on enhancement of conceptual design and early preliminary design processes by introducing integrated environment CEASIOM [2] for multidisciplinary analysis, with special attention to aircraft stability and control characteristics. The software package is capable of multidisciplinary analysis on different levels of fidelity, including: geometry and mesh generation, mass model definition, FEM analysis, aerodynamic analysis and stability and control analysis.

New approach of software generation also has to guarantee it's flexibility and robustness in future development and maintenance. On Virginia Polytechnic, basis of special common language Aircraft Design Markup Language (ADML) [3] for aircraft design were set. The basic concept utilizes main concepts and features of common markup language XML. Markup coding languages are easily extensible allowing for great flexibility of future development and maintenance of tools for aircraft design. They do not provide ready data structures, but rather flexible rules to define the structures, utilizing concept of classes, encapsulation, polymorphism and so on. The language is human readable, allowing for interaction in substandard cases directly on the code to create innovative aircraft configurations and solutions like joining configuration. These languages offer also standard procedures of data consistency checking to avoid basic data errors. The difference between ADML and XML is that the basic structures, common in aerospace computations field of science, are already provided. This allows for fast definition of computational cases and efficient management of data. Similar efforts were taken by DLR institute to define platform of common information sharing between different faculties in the institute. The faculties have detailed knowledge about the science disciplines they are involved in and basic about other aerospace disciplines, but all have to share same data when designing an aircraft. DLR created the Common Parametric Aircraft Configuration Schema language CPACS [4, 5, 6] also based on main XML language features.

The main effort in defining ADML language was taken bottom-up in defining powerful constructs for functions and abstract mathematical objects, with unconventional aircraft configurations in mind, while CPACS concentrated on the way top-down for entire aircraft definition to single data objects like point lists and can only currently handle traditional aircraft designs.

Joining the main stream concepts of SimSAC project, ADML and CPACS languages, at Warsaw University of Technology in the department of Aircraft Design we established concept of tools for Multidisciplinary Aircraft Design and Optimization MADO [7]. MADO package contains a group of programs: OptoM for multidisciplinary optimization, SDSA for nonlinear dynamic stability and control analysis and Panukl [8] for pre-processing, aerodynamic analysis, data export for SDSA [9] and CalculiX/Abaqus FEM software [10] and post-processing. The core assumptions of the concept are:

- User friendly interface with errors warning
- Less complexity with maximum efficiency of computational cases definition
- New concepts of advanced geometry definition for fast geometry definition
- Easy and automated data exchange for multidisciplinary analysis and optimization
- Enabling creation of innovative aircraft configurations
- Flexibility of the future development and maintenance of the software tools

1. Geometry definition environment

One of the most pleasant things to do in MADO package is efficient and error free computational geometry definition in Graphical User Interface (GUI) called Ms2editor (Fig. 1). There is also possibility to define the geometry in plain text, but this is not recommended since GUI suggests options to choose and provides error checking. The tool is very powerful and flexible in use.

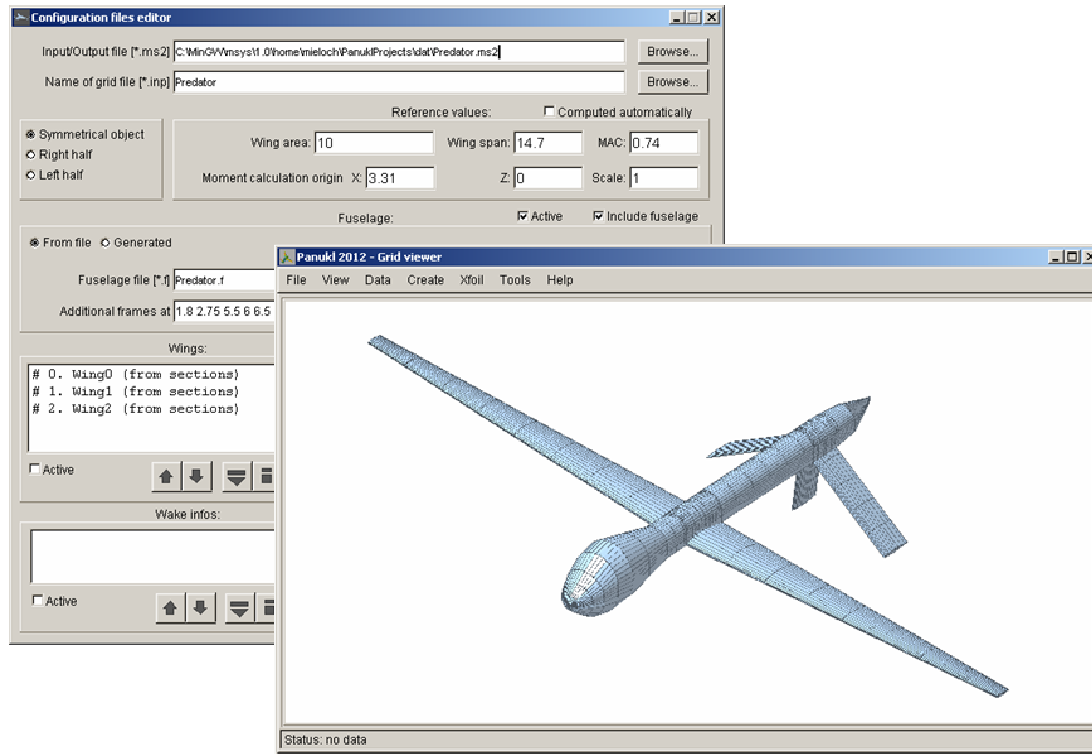


Fig. 1 GUI of MS2editor (Panukl pre-processor).

2. New concepts in geometry definition

We introduce a new concept of building the geometry by modular wing definition. Previously wings were built using separately defined sections containing airfoil coordinates properly placed in three dimensional space. This way of building wing geometry is easy when dealing with fairly simple geometry, for example trapeze wing plan form, but becomes very inefficient when wing geometry contains more complicated three dimensional forms like smooth winglets with arcs or joined wings. Building geometry using modular wing concept is similar to building with different blocks (line, arc, etc.) added to one another. The advantages are that a group of cross sections are defined at once, with less parameters to set, guarantee of geometry connection is satisfied, smooth geometry with tangency condition of arcs and linear parts of the wing can be achieved.

To visualize it better, example definition of wing with winglet is presented (Fig. 2). The basic geometry consists of horizontal linear part, arc at the joint of the main wing and winglet, which is vertical linear part. The arc module automatically computes tangency constrain to the main wing module. Setting the same angles for arc ending and winglet module will provide tangency for the arc-winglet joint (Fig. 2a). Few adjustments can still be made. To add fuselage, the first panel of the planar module of the wing can be made bigger to fit the fuselage. Nonlinear paneling distribution is improved chord wise and span wise. If the wing should have minimum induced drag, option "Optimize for minimum induced drag" enables it (Munk law [11] is used to calculate optimum chord distribution assuming constant design lift coefficient and defined reference area) - Fig. 2b. Airfoils position in the chord wise direction is set in the end (Fig. 2c). The definition of the wing geometry requires setting only a few parameters. Building wings with modules is easy, fast and flexible.

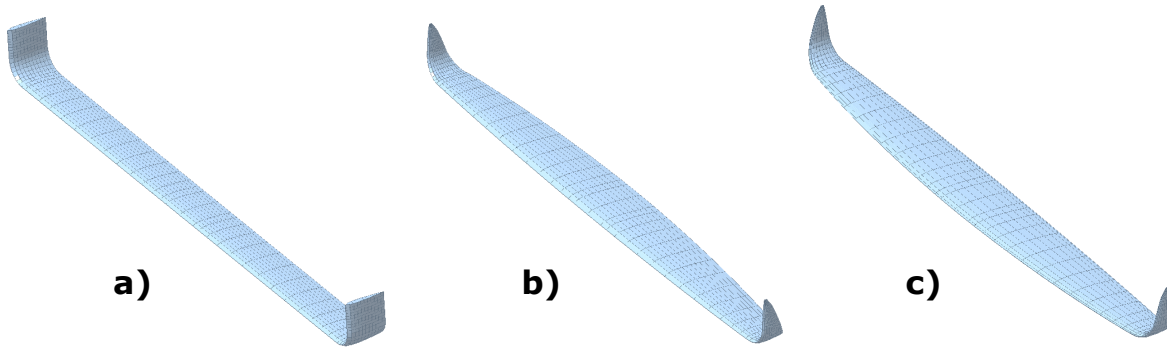


Fig. 2 Modular wing geometry with winglets.

Definition of fuselage is also very easy with help of Ms2editor widgets. The concept of definition of fuselage is shown on Fig. 3a. The shape of a fuselage is defined by main contours (up contour, side contour and down contour). Paneling along longitudinal axis of the fuselage is set by projection of panels from super ellipse [12] on the spine. Finally convexity distribution of fuselage upper and lower quarters along longitudinal axis is defined. The convexity idea is shown on Fig. 3b. Grid with wing and fuselage defined is shown on Fig. 4. Different convexity on the upper and lower parts of the fuselage is emphasized.

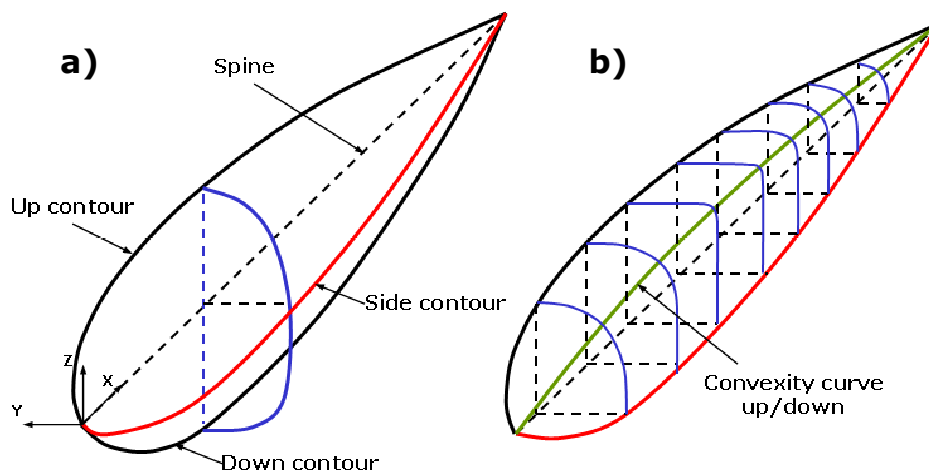


Fig. 3 Concept of fuselage definition.

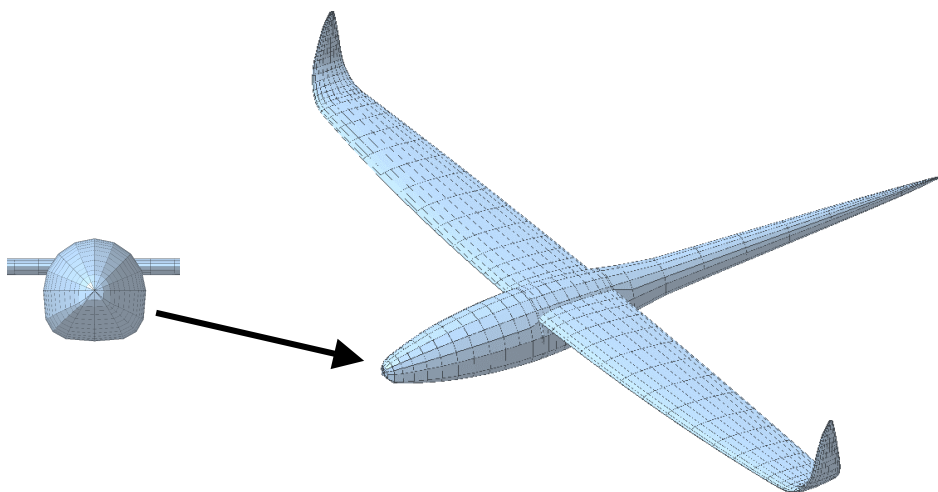


Fig. 4 Grid with different convexity of upper and lower fuselage quarters.

It is also possible to define nacelles with only few parameters (Fig. 5). Profiles for the nacelle can be inverted, which will create accelerating or decelerating effect. Convexity factors of the nacelle make it easy to create nacelles with very different forms Fig. 6.

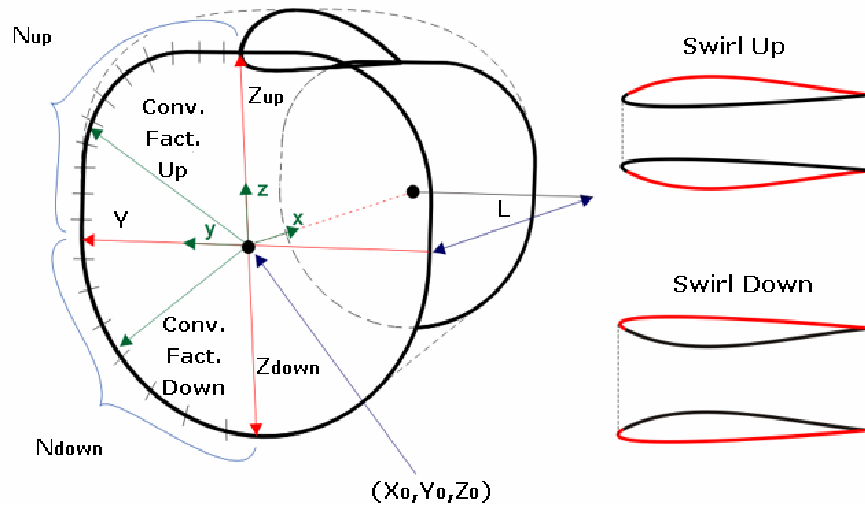


Fig. 5 Nacelle parameters.

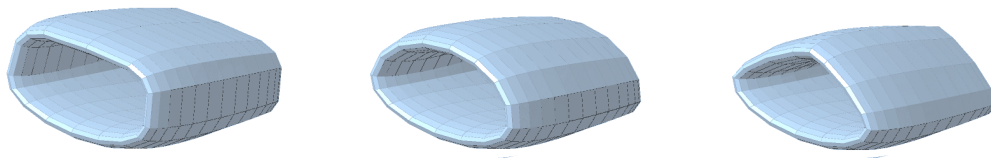


Fig. 6 Examples of nacelles with different “Conv. Fact.”.

MADO environment for geometry creation offers even more unique and innovative concepts. Examples of generated grids, containing sophisticated geometry are shown on Fig. 7, 8, 9.

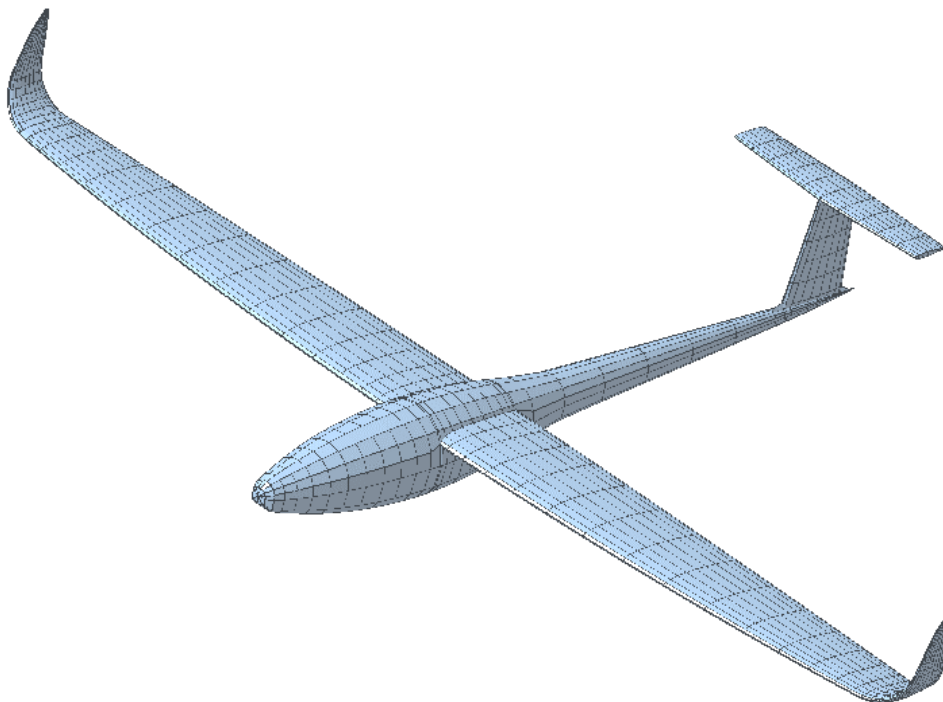


Fig. 7 Advanced glider grid.

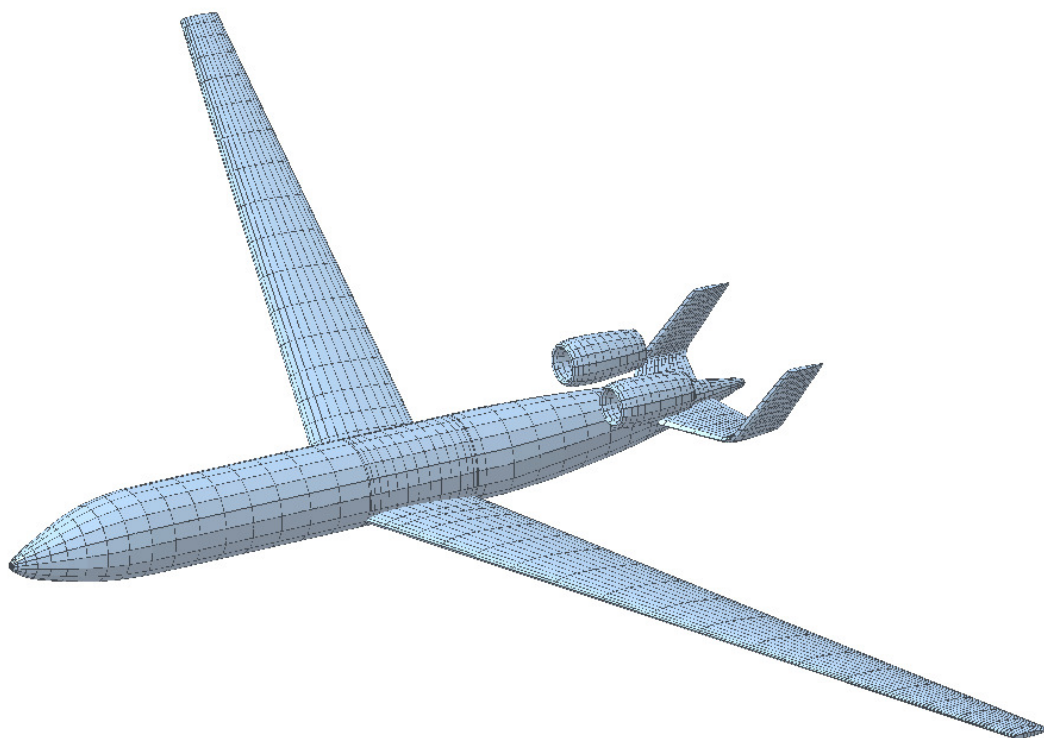


Fig. 8 Grid of innovative transport aircraft.

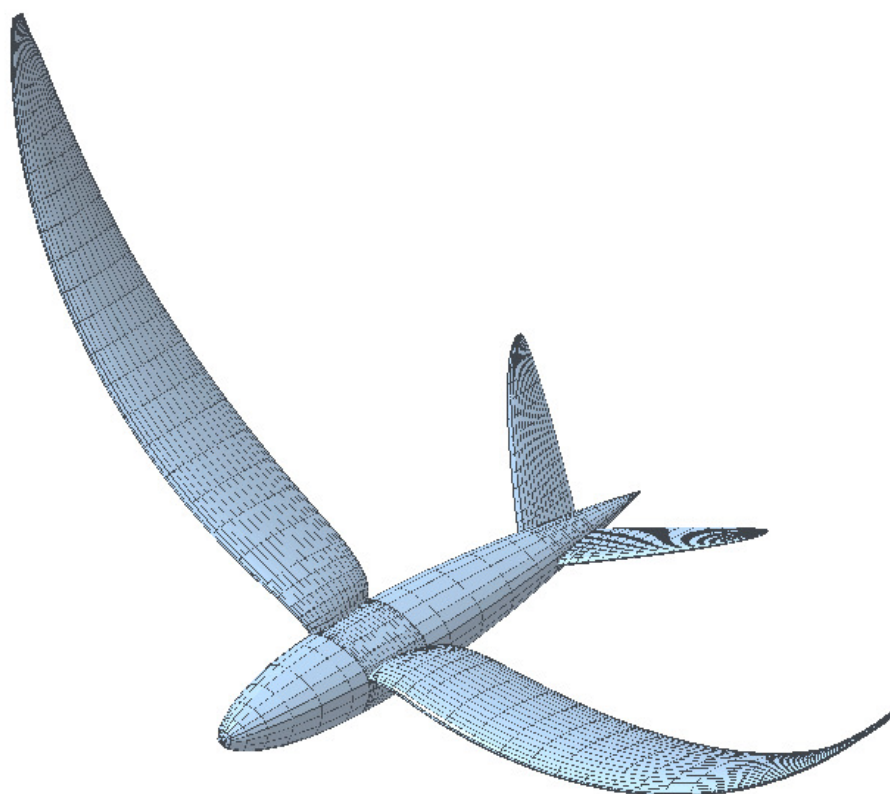


Fig. 9 Fantastic airplane benchmark for geometry generation tools.

3. Geometry for optimization

Tools for grid definition allow for easy preparation of associative geometry for optimization. Geometry parameters can be changed manually in the Ms2editor GUI, or changed by numerical optimization variables. An example of hard to define geometry used for optimization of a novel aircraft in a joinwing configuration is shown on Fig. 10. For the optimization Monte Carlo algorithm was used. The objective function was aircraft aerodynamic efficiency with constrain on equality of gravity and lift forces. In this optimization case fifteen geometry optimization variables were used. This was the preliminary stage of optimization and work on the project is still ongoing.

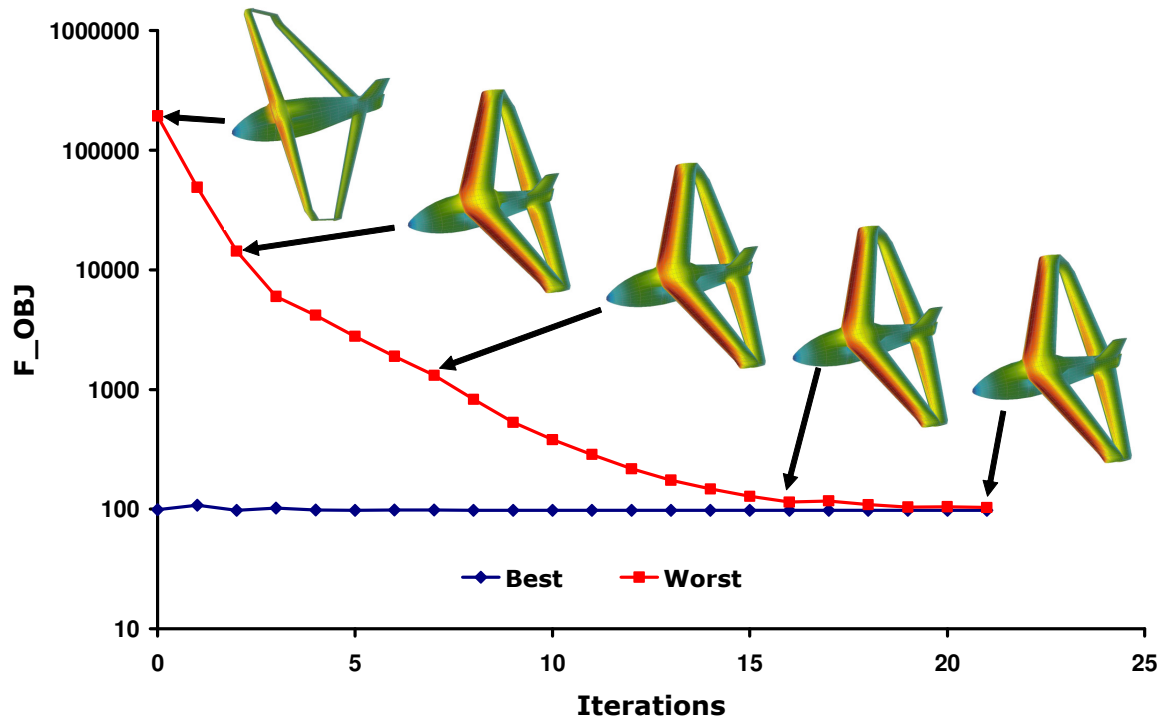


Fig. 10 Optimization of joinwing aircraft geometry.

4. XML file format exchange

To satisfy condition of exchanging geometry data between software tools, XML standard was used. It allows for data structuring, connection with existing standards (i.e. CPACS) and in consequence for easy extension of software functionality, development and maintenance. Storing data definition of an aircraft in a single file prevents of information loss during data exchange. Textual file format of XML makes it human readable and easy to modify by user. Moreover, due to structural form of the XML documents, different applications can use different parts of whole schema without knowledge about the rest of the schema. Besides this, it is possible to check document consistency without analyzing particular data using appropriate XSD schema. This approach saves developers' time.

Conclusions

Package of tools for rapid geometry definition for multidisciplinary design and analysis of an aircraft contains many innovative concepts. Software provides easy and error-free way of geometry definition. The concept proves to be efficient, fast and flexible.

Acknowledgments

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