PRELIMINARY DESIGN OF AIRCRAFT USING FREEWARE XFLR5

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Abstract: Preliminary CAD design or CAD drafting is a design stage that involves the creation of digital sketches with the help of specialized software tools that define the basic geometric shape and dimensions of an aircraft, digital sketches that can underpin the detailed design approaches of the aircraft's constructive elements. The paper presents both a general theoretical approach about CAD tools and an analysis of the realization stages of a series of 3D aircraft concepts using freeware tools. Initial geometric definition can cover CAD design requirements for parametric initial levels with relevant and useful numerical data export functions for possible software post-processing steps.

Keywords: aerodynamic concept, CAD design, XFLR5, educational software

Simboluri și acronime:

ACAD	*Architectural CAD*	*CAD*	*Computer Aided Design*
CECAD	*Civil Engineering CAD*	*CFD*	*Computational Fluid Dynamics*
CNC	*Computer Numerical Control machines*	*EASA*	*European Union Aviation Aafety*
FAA	*Federal Aviation Administration*	*FEA*	*Finite Element Analysis*
FOSS	*Free and Open-Source Software*	*MCAD*	*Mechanical CAD*
RCAA	*Romanian Civil Aeronautical Autority*	*XFLR*	*X Foil Low Reynolds*

1. INTRODUCTION

Preliminary CAD design is a design stage that involves the creation of digital sketches with the help of specialized software tools that define the shape and basic geometric dimensions of an aircraft, digital sketches that can underpin the detailed design approaches of the aircraft's constructive elements.

Digital CAD tools (exclusively with CAD functions or with built-in modules) are used in all industrial and creative fields depending on the accuracy and compatibility of the generated files, thus we can highlight two relevant classes: freeware tools and commercial tools.

CAD software tools can be classified into:

- by functionality: 2D CAD, as examples Autocad LT, LibreCAD; 3D CAD, as examples Solidworks, Blender, FreeCAD; parametric modeling, as examples Solidworks, Inventor; direct modeling, as examples: Rhino 3D, Meshmixer; [1, 2, 3]
- according to the field of application: mechanical CAD (MCAD), as examples Solidworks, Inventor; architectural CAD (ACAD), as examples ArchiCAD; civil engineering CAD (CECAD), as examples AutoCAD Civil 3D; CAD product design, as examples Fusion 360, Onshape; [2, 4, 5]

- according to the purchase price: commercial software, as examples CATIA, Solidworks; free and open-source software (FOSS), such as Blender, FreeCAD, TinkerCAD, OpenSCAD; educational software, such as AutoCAD Student version, Solidworks Student Edition; [1]

- according to operating facilities: file compatibility (import and export files), ease of use (for beginner and/or expert users); system requirements (hardware specifications).

2.THEORETICAL

2.1. Design stages

Designing an aircraft is a multidisciplinary process that involves a series of logical steps, as follows (see Fig. 1 and 2):

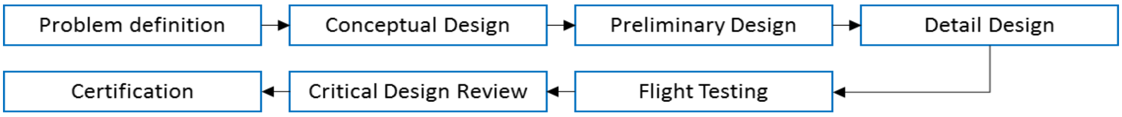

FIG. 1 Stage of aircraft design

- *the stage of the requirements* (geometrical, structural and performance characteristics);

- *the development stage of the aircraft concept* with the evaluation of design options through aerodynamic CFD, structural and propulsion system simulations (preliminary sketches and 3D models);

- *the detailed design stage* (detailed 3D models of the constructive components, FEA analyzes regarding deformation and vibration values);

- *the design stage of the aircraft production* (manufacturing and assembly drawings of the component elements, files for CNC machine tools);

-*test stage and validation through virtual tests* of aerodynamics and propulsion system (CFD simulations, FEA with data collection and identification of critical cases);

- *the documentation stage* by creating detailed technical documentation regarding the design, manufacture and maintenance of the aircraft (manuals for operation, maintenance and regulatory requirements);

- *certification stage,* to obtain certification from the certification entities (RCAA, EASA or FAA), demonstrate the aircraft's compliance regarding performance and safety in operation and exploitation and obtain commercial and/or military operating approvals.

2.2.About preliminary concept CAD design

Preliminary CAD design aims to: conceptualize the design through visual representations, explore options by testing different configurations, communicate the project by sharing project ideas, and establish relevant parameter values (geometry, shapes, and parameter interdependencies), see Fig. 3.

The principles of preliminary CAD design focus on: clarity of concept, accuracy of design, flexibility of concept, and efficiency in using CAD tools within the time resource provided. [6, 7, 8]

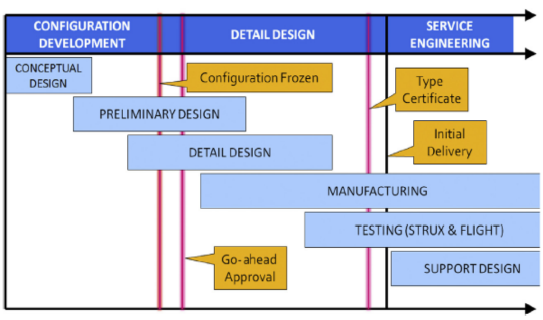

FIG. 2 Stage of aircraft design, [6]

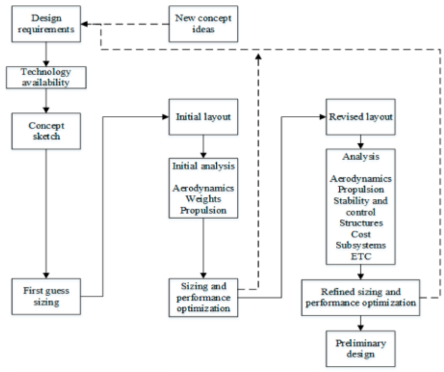

FIG. 3 Stage of aircraft design, [7]

2.3.XFLR5 software versus CAD design software

We can question whether XFLR5 is a CAD design software tool, no it is not, (see table 1) because:

- it is an analysis tool for airfoils, fixed bearing surfaces and bodies of revolution;

- this is focused on numerical simulation/evaluations of aerodynamic performance (aerodynamic forces and moments, stability and centering values);

- although it offers limited geometric parameterization functions it does not offer detailed 3D modeling capabilities specific to a 3D CAD tool. So the limitations of XFLR5 for 3D CAD design approaches, are:

- limited geometric parameterization functions (complex shapes);

- focusing on aerodynamic analyses, no material properties, detailed structures can be used for structural stress and vibration analyses.

However, XFLR5 can be used in the preliminary design process (iteration and rapid analysis) under the following aspects:

- 2D and 3D geometries can be defined with a limited degree of resolution;

- CAD geometries can be imported into the aerodynamic analysis process;

-analyzed and possibly refined/optimized CAD geometries can be exported.

Table 1. Key diference XFLR5 vs CAD software

Feature	CAD Software	XFLR5
Focus	Creating detailed 3D models	Analyzing aerodynamic performance
Functionality	Modeling geometry, defining materials, assemblies	Defining wing parameters, simulating airflow
Output	3D models, engineering drawings	Aerodynamic results, performance data
Other	Lowcost, easy learning	Learning time, cost expensive

For the effective use of XFLR5, it is recommended to study both the theoretical basis on the principles of aerodynamics and the study of the software user guide (tutorials and movies) to familiarize yourself with the GUI interface and the analysis tools that ultimately lead to the exploration and design analysis of the resulting aerodynamic effects. [9, 10, 11, 12]

3.PRELIMINARY CAD GEOMETRICAL MODELS

3.1.Objectives and stages

The objective is focused on creating a preliminary CAD model that fits the requirements imposed by a UAV with the characteristics noted in table 2.

Table 2. UAV features

Characteristics	Value	Characteristics	Value
Class	miniUAV	Span	max. 2.2 m
Aerodynamic concept	clasic monoplan	Fuselaj	fusiform

The realization steps are: setting up the working XFLR5 project (units of measurement, viewing conditions); defining the 2D geometry of airfoils (generated or imported geometry); defining the 3D wing and tail geometry; defining the 3D fuselage geometry; defining the full 3D UAV geometry and optimizing the 2D/3D geometry according to the requirements.

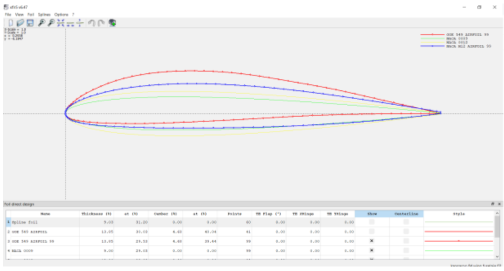

FIG. 4 2D airfoils design, [9]

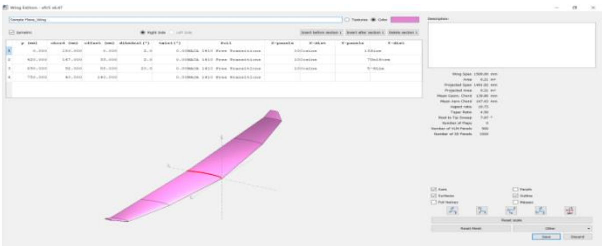

FIG. 5 3D wing design, [9]

The concept stage involves defining the geometry of the 2D aerodynamic profile (Fig. 4), 3D wing (Fig. 5), 3D wings (Fig. 6), 3D fuselage (Fig. 7).

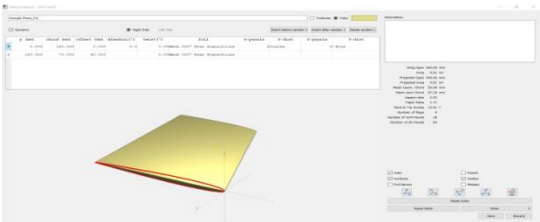

FIG. 6 2D tail design, [9]

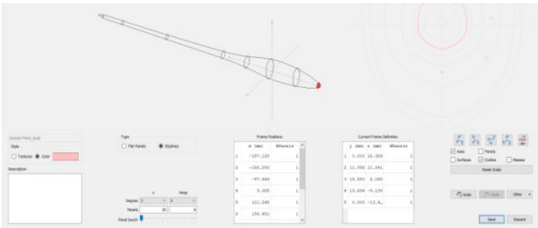

FIG. 7 3D body design, [9]

3.2.Rezults and connex stages

The initial requirements are highlighted by the 3D geometric result in Fig.8.

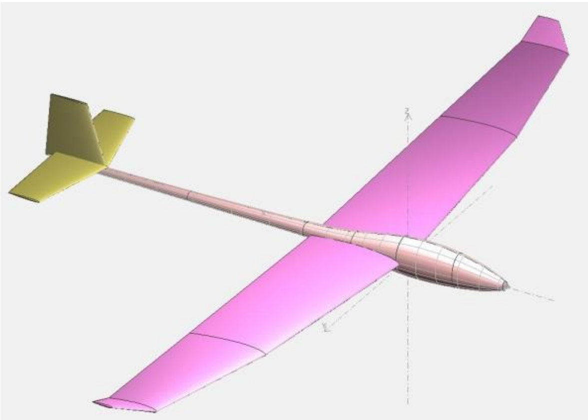

FIG. 8 UAV 3D model , [9]

The results obtained by XFLR5 geometric parameterization can be used for in situ aerodynamic and stability analyzes or for geometric post-processing with other software tools, examples of the obtained other geometries are shown in Fig. 9.

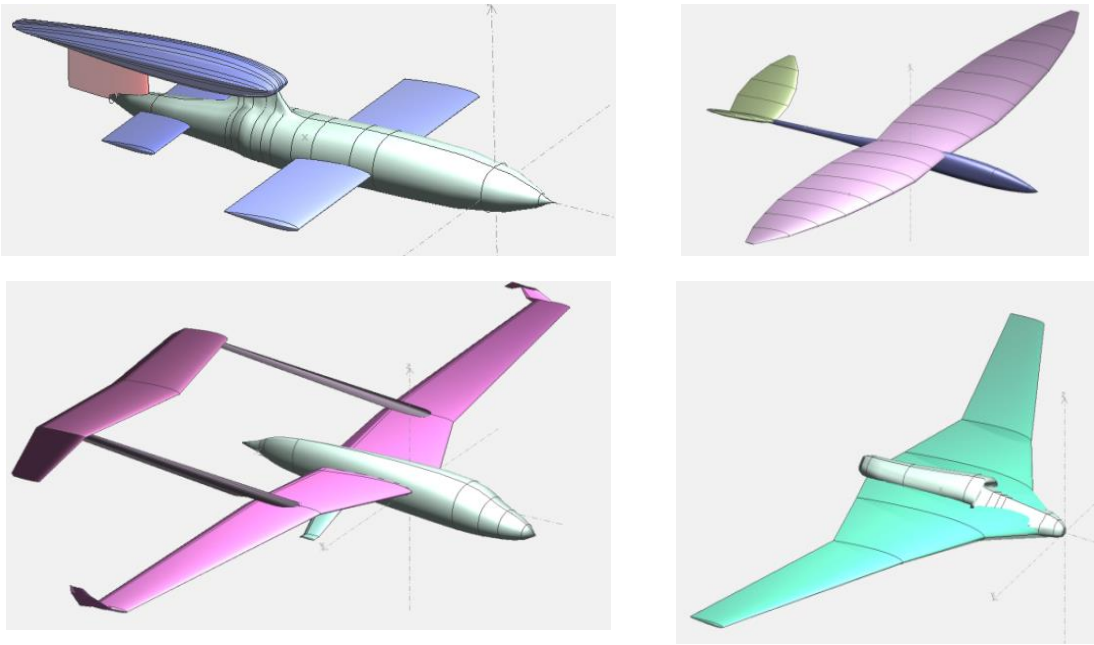

FIG. 9 3D models concept, [9, 10]

The related steps offered by XFLR5 focus on the possibilities of using the geometries obtained with the export functions: *.xml, *.avl files for numerical processing or *.stl files for making 3D printed models. [9, 10, 11]

CONCLUSIONS

The use of software tools in the educational field determines multidisciplinary approaches focused on an imposed theme with implications on the results and the time required to obtain knowledge.

XFLR5 is a potential educational software tool for the aerospace field by studying the forces and moments acting on a 2D/3D geometry, the software-based approach allows learners to interactively visualize and analyze aerodynamic principles. XFLR5 provides a series of geometric parameterization and aerodynamic parameter visualization tools (diagrams, graphs) that facilitate experimentation and create an interactive environment for learning through simulation through design and critical comparative analysis. XFLR5 is recommended to be used in conjunction with traditional teaching methods, it is an additional tool and does not constitute a theoretical basis on its own.

Future research directions are focused on the use of XFLR5 on complex comparative analyzes applied to a family of aerodynamic geometries to highlight the implications of changing geometric parameters on the local and global performance of an aircraft.

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