Geometrical modelling of UAV using parametric CAx systems

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ABSTRACT

Selected problems of CAx systems usage in design and preparation of UAV are presented in this paper. The issues which have the influence on the applying of these systems in practice are described. Some of the helpful rules of part and assembly modelling in parametric CAD system as well as reverse engineering approach for UAV components are outlined.

1 INTRODUCTION

Computer aided engineering CAx techniques (CAD, CAM, CAE etc.) are becoming more and more significant in the process of design, production and introduction of a new product onto market. They reduce considerably the time-period of introduction of a product's release version for sale. This leads directly to lower costs of a new product design and testing its prototypes with the help of virtual 3D models as well as quicker introduction of the final version of a product. Development of modern CNC techniques as well as Reverse Engineering and Rapid Prototyping techniques requires application of CAx tools.

One of the main aims of modern CAx educations is learning the possibilities and methodologies of parametric modelling concept. Nowadays, the feature based 3D modelling is the standard of mechanical design. Today study of CAx systems and CAx engineering applications is an integral part of product design, manufacturing and development in various branches of industry [1], [2], also in the UAV field.

2 ADVANTAGES OF CAX IN UAV BRANCH

2.1 Why CAx?

Nowadays advantages of CAx systems usages are unquestionable. In aviation branch are using both high level CAD/CAM/CAE integrated systems (e.g. CATIA) as well as CAx systems based on more popular and much cheaper middle level CAD software.

Present CAx systems called „middle level" (for example: SolidWorks, SolidEdge, TFlex, Alibre Design, BricsCAD) are based on the main parametric solid-surface geometry modeller and work in 3 environments: „Part", „Assembly" and „Drawing" [3].

Definition of the mission assumptions and requirements before beginning of design process is the most important issue. Next, in many ways, we can determine type and scale of airframe (e.g.: classical system, flying wing, delta plane, canard). Then geometrical properties of basis vehicle components (shape of wing, tail, fuselage) are described. After that the mass-balance is estimated, diverse analyses using CAE tools are carried out as well as optimization and integration of structural body with the other parts of the aircraft (i.e. navigation, propulsion systems, payloads etc.) are performed.

2.2 CAx applications in UAV

There are many areas of CAx application in multidisciplinary UAV design process:

- conceptual phase 3D model;
- mass properties modelling (e.g.: selection of materials and technologies, CG, moments of inertia);
- modular design;
- KBE (Knowledge Based Engineering) design;
- CFD/FEM Structural, Thermal, Modal analyses;
- mission-based optimisation;
- real prototypes making using Rapid Prototyping (RP);
- flow visualization, wind tunnel testing using RP objects;
- experimental structural validation (CAD model using to fast machining of real component on CNC machine or for example mould preparation for composite elements performing);
- assembly integration studies (both virtual as and real – RP or CNC making)
- Reverse Engineering techniques using for various UAV component (3D scanning, point cloud objects processing);
- fast cooperation by presentation UAV conception in any phase of project using standard and special (e.g.: Adobe 3D PDF, eDrawing, 3DVIA Composer) file format, the Internet publication, Virtual Reality, etc. (Figure 1).

Generally, the above applications of CAx systems allow time and costs saving while implementing of the new UAV product.

2.3 Conceptual and multidisciplinary design

The aircraft geometrical configuration can be changed during the design process. We should find the best version from the permissible set of solutions. In many cases of UAV design a conceptual approach is used [4].

The design space is large and multidimensional, there are multiple and often highly multimodal objectives and constraints, these depending not only on the design variables, but often on each other as well. Multidisciplinary Design Optimization studies can be conducted at different levels of

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detail, depending on the chosen trade-off between the size of the design space and the fidelity of the analysis [5], [6].

In many cases special multidisciplinary optimisation engine was developed to design the vehicle, taking into account altitude, range, efficiency, payload, propulsion, aerodynamic characteristics, etc. [7] – [12].

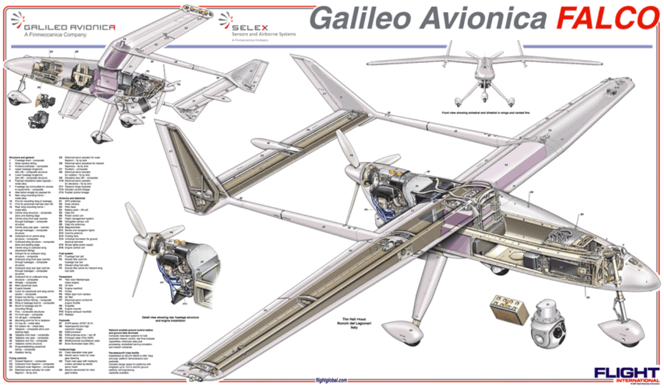

Figure 1: Cutaway view of UAV "FALCO" produced by the Galileo Avionica company (Italy) [13]

3 CAx FOR PRACTICE

3.1 Implementation of 3D parametric CAD systems

Because a 3D model provides much more detail, designers and engineers can communicate product information and visualize complex parts and assemblies more clearly. Since 3D model data can be transferred to analysis and validation tools and used for CAM as well, it increases the accuracy of results and saves time by eliminating the need to re-create data. Many 3D modeling programs offer features that increase productivity by automating aspects of the design process, for example, by enabling the reuse of existing designs or the quick creation of part families [14].

For companies that adopt 3D, these capabilities translate into valuable benefits. The main goal is to reduce the time needed to get new products to market. Other objectives include meeting consumer demand for new products, improving product performance, enhancing product quality, and addressing increasingly complex customer requests. In many cases, companies are driven to 3D just to keep up with the competition.

3.2 Progression of requirements in CAx branch

Modern engineering education should be directed for quickly varied needs and requirements of industry, among other things in mechanical engineering. This can be realized by many ways, i.e. as follows [15]:

- collaboration with industry in aspects of their expectations and skills of new, modern generations of engineers;
- recognition of requirements in particular branches of industry from graduate of engineering fields;
- development in education institutions of new technology of product design and manufacturing;
- probing at the start and the end of CAx student's education process and their understanding and skills of design terminology, meaning, methodology;
- work out by CAx specialists the general rules of design process in engineering education allowing rapid development of CAx techniques for.

3.3 Development trends of CAD systems

Development of CAD systems, in principal measure, is directed on following issues [3]:

- advanced surface modelling tools (surface styling, tools for surface continuity analysis, free-form surfaces modelling);
- functional modelling (consideration of functional aspects of CAD model by designer – not for determine of features sequence in design-history tree, e.g. SolidWorks Intelligent Feature Technology (SWIFT) introduced in SolidWorks 2007 and systematically evolving);
- design based on KBE (Knowledge-Based Engineering);
- development of expert tools e.g. for detecting and solving problems in sketches, dimensions and features on the part level or mates on the assembly level;
- development of specialised tools for converting existing 2D drawings to 3D models (2D to 3D);
- possibility of publication and presentation of product as a virtual 3D model (e.g. Adobe 3D PDF format, eDrawing, virtual reality VR, Internet 3D presentation formats, advanced rendering and animation);
- trends to consolidation tools for scanning and processing „point clouds" with popular CAD systems (e.g. add-in tool „ScanTo3D" from SolidWorks 2007 and its collaboration with commercial „NextEngine" scanner).

3.4 Professional trainings

Trainings of designers and engineers using CAx tools should be a continuous process. The following reasons should be take into consideration in industrial practice [16]:

- nowadays, new software versions bring absolutely innovative modelling techniques and tools, therefore, among other reasons, it takes too much time for an intermediate user to master all the novelties;
- employers now realise that professional training courses organised by authorised units for designer help them use their potential more fully;
- employers costs of designers participation in training courses, workshops and conferences will very quickly pay dozens of times;
- at present, lack of progress in CAx techniques means passive retardation and unavoidable decrease in a company's competitive ability;
- software distributors offer trainings in primary and advanced scope and specialised tools (e.g. what new in new version, 2D drawings, tools for mould, sheet metal, weldments, surface modelling, piping and electrical system, API, CAM, CAE, PDM, dedicated training for the particular company, ect.);
- possibility of individual training based on materials available in particular CAD system www portals.

4 GENERAL RULES OF PARTS AND ASSEMBLIES MODELLING IN PARAMETRIC CAD SYSTEMS

Practical using of geometrical design methods should be directed to increase the knowledge of advanced part and assembly modelling [17].

A geometrical model is the main common feature characteristic of engineering computer tools irrespective of the CAx system being used. Therefore, it is fundamental to identify correctly and effectively the geometrical features of a virtual 3D model. The method of geometry modelling in CAD systems functioning on the basis of the structure of defining a 3D model features, which is also called History-Based CAD, is essential. It is mainly connected with a CAD designer getting to know the philosophy of defining „intelligent” and „elastic” models [18]. One should consider design guidelines, which give the information about the sequence of the features used and dependence between them. Current research in cognitive science leads to the conclusion that 3D solid modelling CAD knowledge should be reconceptualised to include three types of knowledge: declarative command knowledge, specific procedural command knowledge and strategic knowledge [19].

The following attributes combine to give an efficient and robust part model with the proper design intent [20]:

- correct part orientation in 3D space;
- optimum model origin;
- correct sketch plane selection for base feature sketch;
- correct base feature;
- appropriate use of symmetry planes;
- simple sketch geometry;
- correct sketch relations;
- fully defined sketch geometry;
- correct feature sequence;
- proper parent-child feature relations;
- correct feature defining;
- correct feature duplication;
- correct part design intent.

Generally, in the case of part modelling, the aim is to define a body, which is a solid body in most cases, in the final stage of geometrical modelling determining. However, there are many methods of generating the ultimate CAD model. The majority of contemporary parametric CAD systems have a possibility of multibody modelling. All performances carried out on separated objects in part file can be called „multibody techniques” [21].

Modelling of assemblies in parametric CAD systems is an important stage in the process of virtual design and testing any devices consisting of at least two functionally separate elements called assembly components. Assemblies are dealt with in practically every field of engineering. In the mechanical branch, the naming of assembly can vary and mostly depends on their application, size or mobility [22].

Generally, a assembly model is a collection of parts saved in one file. Modern parametric systems of surface – solid modelling offer a separate area for defining assemblies and special tools and techniques of assembly design. Components of assemblies can be separate parts or other assemblies which are functional subgroups of a bigger assembly. A subassembly can be put into the main assembly as a rigid or flexible one. The addition of a component to a assembly creates a link between the assembly and the component. When the program opens the assembly, it finds the component’s file to show it in the assembly [23].

The subject of assemblies modelling in CAD systems is very wide and is not going to be considered in detail in the present work.

The main principles of assembly modelling having influence on effective and robust virtual model:

- advisable division of devise on structure with many levels of sub-assemblies resulting mainly from functionality particular subsets;
- adequate choice of first component in space of pre-defined planes in assembly environment (e.g.: frame, mount, casing, etc.);
- skillful use of component patterns (e.g.: patterns based on a feature);
- using standards available from a libraries;
- imposing a mates resulted from mobility character (taking away the degrees of freedom)
- non-defining useless mates (e.g.: in connecting elements)
- using of assembly configuration;
- appropriate use of mobility sub-assemblies in main assembly in flexible or rigid mode;
- proper work with “large assemblies” (there are three suppression states for assembly components: in fully resolved, lightweight, suppressed).

5 REVERSE ENGINEERING APPROACH FOR UAV COMPONENTS

5.1 *Principal information*

There are many components of various geometric forms in UAV structure. The shapes are often described by free-form surfaces, for example: blades of propeller or turbine, elements of fuselage and aerofoil, fairings of engine or landing gear, wing tip and others. The use of reverse engineering techniques for conversion of an existing physical object to virtual model makes easier the procedures of design process and in this way accelerate the construction and technologies preparation process [24]. In some cases components from “large” aviation can be used for collection geometrical information and its processing according to UAS requirement, e.g. in developing process of new aerial vehicles.

The virtual reconstruction of real object from various contact or non-contact measurement methods is a very hard problem, not completely solved and problematic in case of incomplete, noisy and sparse data. The goal is always to find a way to create a computer model of an object which best fits the reality [25].

Reverse engineering (RE) approach allows also evaluating of geometric changes which take place in operation process in comparison with geometric characteristics of the object being tested before its introduction to the running. A current trend in reverse engineering is the use of feature-based models and methodology [26]. In the case of measurement of object with

3D complex form it is required the object to be digitized, i.e. the object's surface to be scanned. For this aim the coordinates measurement techniques or non-contact measurement methods (e.g. 3D laser scanning) is used.

In this case the geometric data of the object are obtained as a collection of coordinates of measured points (mostly unorganized) called usually as „point cloud". After the virtual CAD model creation of real element, it could be analysed and modified as common editable 3D the surface or solid model. Reverse engineering procedures allows fast correcting of shape and improvement of functionality, ergonomic and esthetical qualities of the element. It is widely used in numerous applications, such as tools, moulds and press tolls manufacturing or reconstruction, medical diagnosis or else 3D work of art reproduction were it is necessary to collect the data of a indefinite surfaces representation. Generally RE has wide range of applications in various branches. We can used reverse engineering techniques to reconstruct, preserve and collect information for the future or make it available for the public access (e.g. by internet network) of wide range of technical, anatomic or artistic existing things.

Measured data could be used for the generation of CAD model of analysed real object. Using such virtual model it is possible, for instance, to evaluate the geometric changes of various objects being operated or to generate CNC code with the aim of manufacturing analogous product or fast performing real things using Rapid Prototyping systems.

5.2 Practical application

For example the reverse modelling process was used to mapping and reconstruction the geometric characteristics of element with free-form surfaces such as propeller of PPG (powered paraglide) drive [27]. The basic approach in reverse modelling process in middle range standard parametric 3D modeller such as SolidWorks system was performed. The digitizing process was performed on the coordinate measuring machine (CMM) (Figure 2). Using surface-solid modelling tools the virtual solid models of propeller were created. They are based on 3D curves preparing from point cloud (Figure 3) as a sectional profiles separately for top and down of propeller (Figure 4).

Figure 2: PPG propeller on CMM table

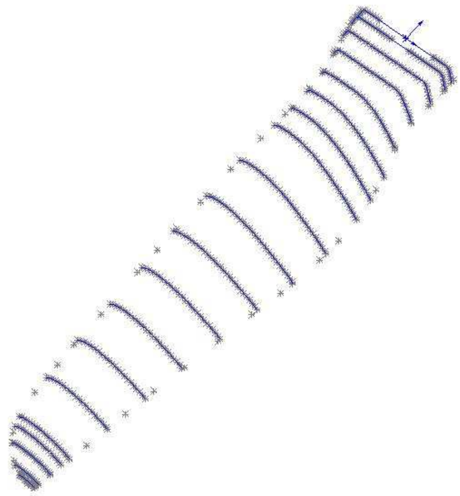

Figure 3: View of 3D curves

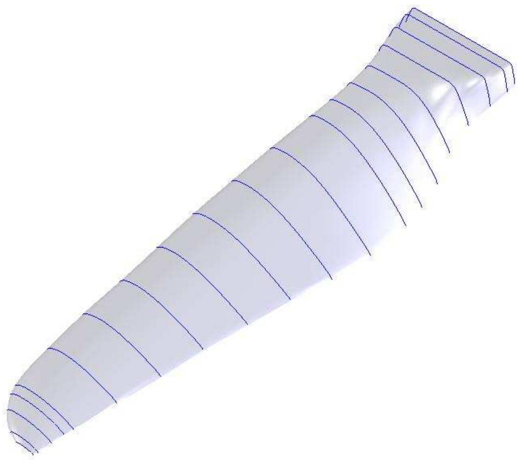

Figure 4: View of surface body equivalent to top surface of propeller

In next step CAM code for scaled-down solid model of upper and lower half mould (Figure 5) for laminating technology, based on 3D feature-based model, was prepared. Finally CNC machining on 3-axis miller were realized.

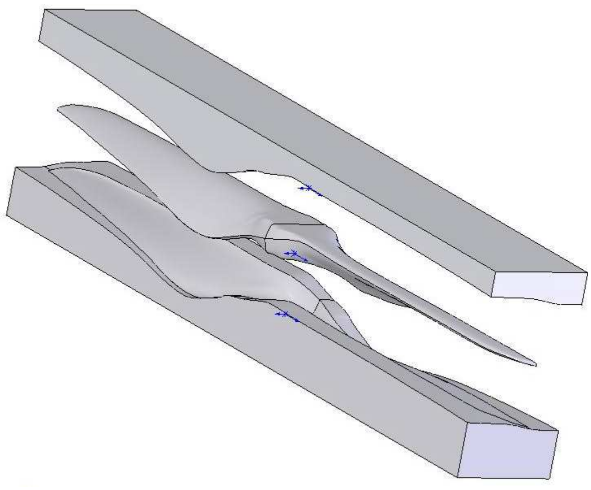

Figure 5: Solid bodies of: propeller, the core and the cavity of mould

Other examples of Reverse Engineering application were described in author's previous papers [28], [29].

6 CONCLUSION

The design process using CAx tools is a basic approach aimed to obtain better UAV product. Advanced part-assembly geometrical modelling methods, parallel with proper aerodynamic, structure, modal and other analyses loop should give robust and efficient base for manufacturing of real UAV prototype. Modern and fast manufacturing technologies can be used to receive components for reality simulations, for example wind tunnel or mechanical tests.

Designers should strive for integration works in common environment. Nowadays flexible CAx systems, based on popular parametric CAD modeler, permit to carry out of many tasks in design process (e.g. use of CFD and structural, modal FEA at the earliest stages of design). For example we can use SolidWorks Simulation (to SW 2008 version called as Cosmos) package tools for wide scope virtual simulations.

Issues connected with the application of CAx tools and modern techniques Reverse Engineering and Rapid Prototyping lead to a quicker introduction of a product onto the market.

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