A PARAMETRIC GEOMETRY MODELLING METHOD FOR GENERATION OF 3D UNSTRUCTURED GRID

МЕТОД ЗА ПАРАМЕТРИЧНО МОДЕЛИРАНЕ НА ГЕОМЕТРИЯ ЗА ПОСТРОЯВАНЕ НА НЕСТРУКТУРИРАНА ТРИИЗМЕРНА ИЗЧИСЛИТЕЛНА МРЕЖА

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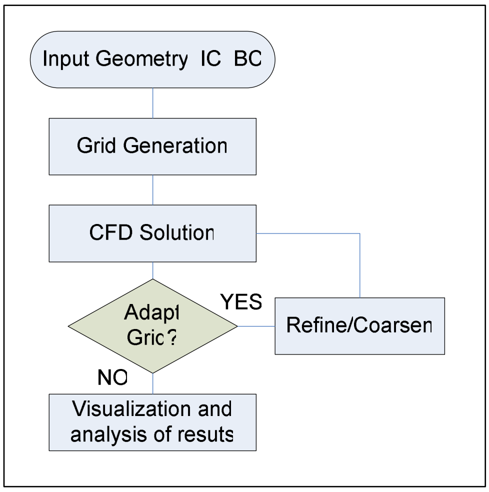
Abstract: *A method is proposed for parametric aircraft geometry representation to be used for unstructured tetrahedral computational grid generation in finite volume URANS based CFD solver. The geometric model is scripted in MATLAB/GAMBIT NSL providing an automated way to produce high-quality unstructured triangular surface mesh over wings of various geometry.*

KEYWORDS*: PARAMETRIC, AIRCRAFT, GEOMETRY GENERATION, FINITE VOLUME METHOD, UNSTRUCTURED GRID, CFD, TUBULENT FLOW, RANS, URANS.*

1. Introduction

The typical process of CFD modelling (Fig. 1) initiates with a definition of the input geometry commonly referred to as geometrical modelling. It serves as a basis for generation of the computational grid (spatial discretization) over which the governing equations are solved. Geometry definition is a critical part of the modelling process because of its direct influence on the quality of the numerical results. It is a time consuming process and requires significant amount of human input, which makes it very sensitive to human errors. A minor mistake or improper choice of parameter at this stage may easily compromise many hours of hard work at later stages of the project.

Fig. 1



In this paper, a method is presented for reduction of the human input during the geometry definition phase by introducing a parametric geometry representation of wing surfaces to be used with GAMBIT pre-processor and FLUENT Solver[1]

The idea for parameterization of aircraft components is not new. There are many existing parametric geometry models but most of them are highly specialized and bound to a specific CFD package, proprietary and not publicly available. Among these RAPID [6.1], Boeing's TRANAIR/CST [6.3] and OSCAR [6.2] should be mentioned. The choice of mathematical representation method for the aircraft geometry depends on the purpose of the model. In most cases parameterization is introduced for the purposes of aerodynamic optimization and therefore the set of describing parameters is kept to a minimum. Such models also rely on different geometrical parameters, the ones that are being optimized and therefore are not suitable for representation of arbitrary aircraft geometries. Although the above parametric models contain very useful ideas and solutions, none of them proved to be completely suitable for aerodynamic analysis of low-speed general aviation aircraft in GAMBIT and FLUENT solver. Therefore, a new, more versatile method had to be developed to produce suitable wing geometry and surface mesh for the wide variety of wings used in modern general aviation aircraft. Since the problem solved was analysis and not optimization, the set of parameters was chosen such that it represented the wing geometry as accurately as reasonable for analysis and the number of parameters is considerably larger than in the models used for optimization.

According to [6.4], desirable characteristics for any geometric representation technique include:

- Well behaved and produces smooth and realistic shapes
- Mathematically efficient and numerically stable process that is fast, accurate and consistent
- Requires relatively few variables to represent a large enough design space to contain optimum
- aerodynamic shapes for a variety of design conditions and constraints
- Allows specification of design parameters such as leading edge radius, boat-tail angle, airfoil closure.
- Provides easy control for designing and editing the shape of a curve
- Intuitive - Geometry algorithm should have an intuitive and geometric interpretation.

The proposed representation fulfils all of the above criteria.

2. Aircraft wing geometry representation

The model was designed with the idea to represent only the general geometrical features of the tested wings. Minor details of size smaller than the surface grid element size are omitted. The following parameters are used:

Table 1. Wing parameters

Parameter	**Type**	**Description**
Datum	x,y,z	Datum absolute position
Halfspan	%b_root	Wing half-span
Mid_sect	Integer	Number of mid sections
Airfoil_data	Array[Mid_sect+2]	Airfoil data

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[1] GAMBIT and FLUENT are registered trade marks of Fluent Inc., a division of Ansys Inc.

Incidence	Array[Mid_sect+2]	Section incidence
Taper	Array[Mid_sect+1]	Taper ratio
Sweep	Array[Mid_sect+2]	1/4 chord sweep, deg.
Dihedral	Array[Mid_sect+1]	1/4 chord dihedral, deg.

2.1. Datum

The datum point is set at the quarter-chord of the wing section on the symmetry plane (fig. 2). All distances are measured in [%root chord] from the datum.

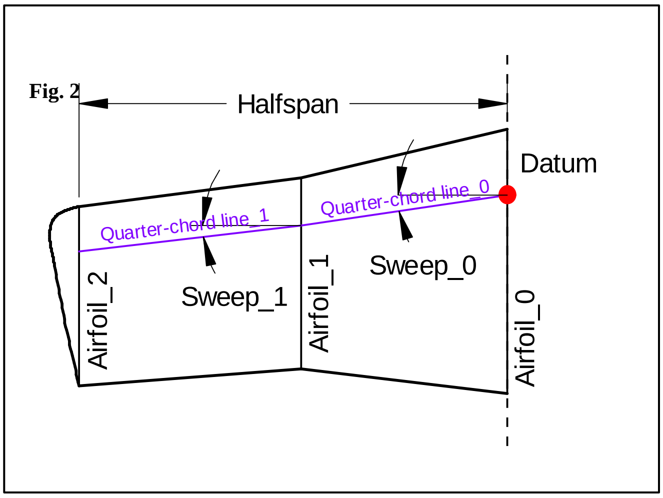


Fig. 2

2.2. Wing sections and airfoil data

The basic shape of the wing is formed by extrusion and interpolation between an unlimited number of wing sections. The minimum required for wing definition is root section and tip section. Most of the test cases required only 2 or 3 sections for proper representation of an aerodynamically clean configuration. The addition of a number of complementary sections allows modelling of different geometry anomalies such as ice formation of structural deformation.

The airfoil coordinates are extracted from text files with corresponding names e.g. Airfoil_data_0, Airfoil_data_1, Airfoil_data_2... Airfoil_data_n. The text file format is shown in Table 2

Table 2. Airfoil data

X	Y
0...100	0...100

The data is extracted from the files, scaled and directly used for modelling, so changes in relative thickness due to sweep and dihedral should be accounted for. The coordinates contained in common sources such as [6.6] and [6.7] are not matching upper and lower surface points and the number of points near the leading edge is not sufficient for a smooth surface. These problems are solved by defining a G0 (positional continuity) NURBS curve starting from and ending at the trailing edge [6.8].

2.3. Wing surface

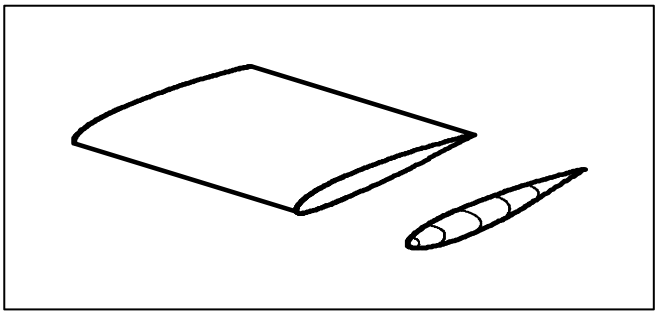
Wing surface is defined as two NURBS surfaces - the interpolated sections and the wing-tip surface. The two surfaces need to have matching nodes in order to produce a smooth "non-leaking" surface. (Fig. 3). That is achieved by using the same points for generation of tip section NURBS curve and the tip NURBS surface.

The tip surface is represented by generating a NURBS surface through a series of semi-ellipses. Each semi-ellipse is defined by three points - one on the upper surface of the tip section, one on the lower surface and one the tip contour surface. The following parameters are used:

Table 3. Wing tip parameters

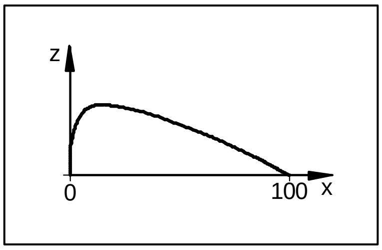
Parameter	**Type**	**Description**
Tip_contour	Array(x,z)	Contour curve data
Tip_dihedral	Real	Tip dihedral, deg

Fig. 3



Sample tip contour is shown on Fig. 4

Fig. 4



3. *Application*

The parametric representation is coded as a Matlab script generating a GAMBIT native journal file.

3.1. GAMBIT journal file

The following edges are produced:

Table 4. Edges

Edge	**Description**
Root_section	Root airfoil contour
Tip_section	Tip airfoil contour
Section_1..n	Mid sections
LE_1 ...LE_n	Leading edges
TE_1..TE_n	Trailing edges
Tip_contour	Tip contour

The following surfaces are produced:

Table 5. Surfaces

Edge	**Description**
Wing_srf	Wing surface
Tip_srf	Tip surface

3.2. Grid generation

Grid is generated by the script on each edge using successive ratio grading scheme with a size factor determined by the model scale. The size factor (SF) is entered manually and is different for each test case. Proper choice of SF ensures low element skew near the surface joints.

A triangular unstructured face mesh is generated over the edge nodes using GAMBIT's the built-in Delaunay triangulation algorithm. With the surface mesh ready the automatic part of the process ends. The mesh needs to be examined and later used as a starting point for generation of the volume mesh.

Results

Fig. 5 Surface mesh generation over the wing tip

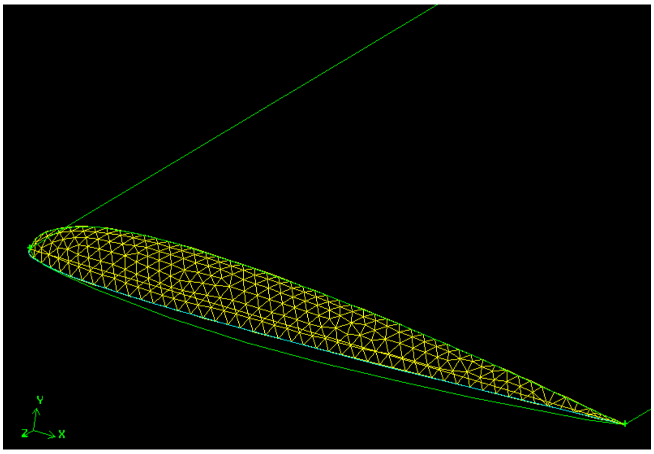


Fig. 6 Surface mesh generation over the wing

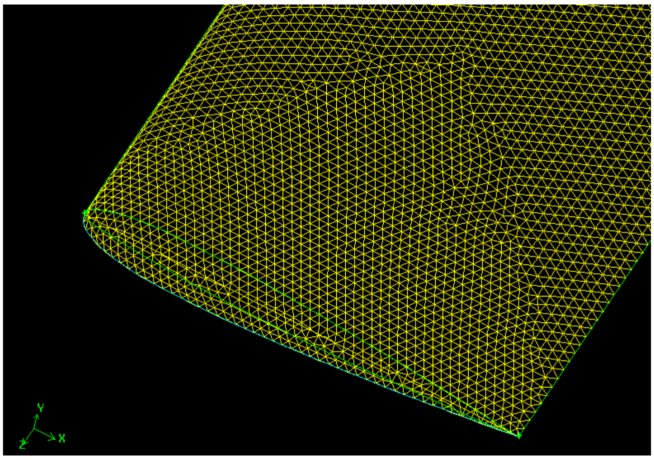
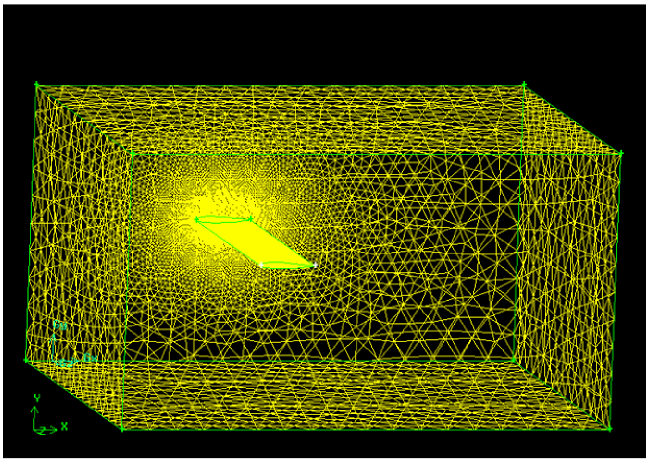


Fig. 7 Coarse volume mesh over the whole domain



4. *Summary*

The wing parameterization method presented is suitable for geometric modelling of wide variety of general aviation aircraft wings.

All surfaces are NURBS represented providing smooth and realistic geometry and allowing flexible choice of grid sizes while keeping a consistent high quality of the mesh.

The flexible multi-section data input allows representation of geometrical anomalies such as wing icing and structural deformations.

All parameters used are "physical" and they may be used for optimization problems.

The mesh produced is numerically efficient, with relatively low number of nodes and allows solution of unsteady viscous problems on a x86-based workstations

The model is scripted in MATLAB and GAMBIT native script and allows the user to incorporate new features relatively easy.

The reduced human input during the geometry definition phase reduces the risk of human error and introduces a more systematic approach to the modelling.

5. *References*

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