

Computer Aided Design Analysis of Aircraft Wing Using Cad Software



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Abstract:

Introduction Computer-Aided Design (CAD) has wide applicability in the design and development process of an aircraft[1,3]. CAD is the use of computer software and systems to design and create 2-D and 3-D virtual models, the benefits of which are increasing rapidly, ranging from shape visualization to its analysis, machining, layout designing and considerable cost reduction. Availability of CAD models reduce the experimentation considerably and aid in quick changes to design with initial estimates hence reducing the design and development cycle[2,4]. Creating drawings, preparing reports of assembly and part drawings, preparing bill of materials, etc. become much easier and faster with the use of CAD systems aircraft design is a complex and multi-disciplinary process that involves a large number of disciplines and expertise in aerodynamics, structures, propulsion, flight controls and systems amongst others. During the initial conceptual phase of an aircraft design process, a large number of alternative aircraft configurations are studied and analyzed. Feasibility studies for different concepts and designs are carried out and the goal is to come up with a design concept that is able to best achieve the design objectives. One of the crucial studies in any aircraft design process is the conceptual design study of an aircraft wing.

Concept for Wing Spars:

As far as the wing spars are concerned, the wing spar position will be defined by “point values on curve” along the root and tip of the tip of the wing. The point values on curve will range between 0 and 1. 0

means that the spar position will start at the leading edge while, means that the spar position will start at the trailing edge. There are two approaches for the construction of wing spars inside the wing model. One is that the spars run continuously throughout the wing across all the wing panels while the other is that the wing spars are placed along each wing panel separately and then they are joined together to each other. In either approach, it is important that it is not possible for two spars to intersect each other in any way. Furthermore, it is important that, all new spar positions along the root and the tip of the wing should be modified based on the position of the old spars. The wing spars will have a thickness associated with them, however, this thickness should not protrude inside the thickness of the wing panel skin.

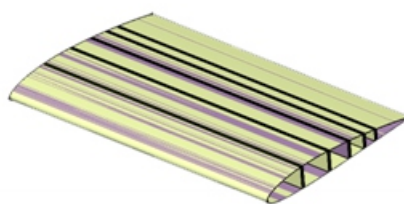


Figure 9: Wing spars inside the generic wing model

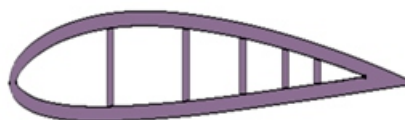


Figure 10: Wing Spars Thickness should not protrude inside wing panel skin thickness

Concept for Wing Ribs:

Similar to the case of the spars, the wing rib positions will be defined by “point values on curve” along the span of the wing (front and aft curve of the wing). For the surface model, the rib will be placed perpendicularly or an angle and will just be composed of surfaces, while, for the case of solid model, it is important that the ribs are divided based on the number of spars present in the generic wing model. For example, if there is one spar present in the wing, the wing rib should be divided into two. If there are two spars present in the geometry, the rib is divided into three and so on. It is also important that no ribs should intersect each other. Similar to the case of spars, the ribs will have a thickness associated with them. It is important that the rib thickness doesn't protrude the spar thickness neither should it protrude the wing thickness associated with the skin of the wing panels.

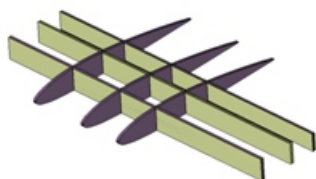


Figure 11: Division of wing ribs based on the number of spars in generic wing model

Wing Panels Mesh:

A Surface mesh is generated for the wing panels which are linked to a “join wing” surface in the Wing Panel model geometrical set. As the number or size/shape of the wing panels are changed, the “join wing” surface is updated. As this surface is connected with the surface mesh for the wing panels, this ensures that when the mesh is updated, it takes into account any and all changes made to wing panel geometry. In order to ensure that the nodes of the mesh elements between wings and ribs as well as wing and spars are properly connected, an intersection lines are defined between “Wing Join and Ribs Join” and between “Wing Join and Spars Join” surfaces. The growth of the wing panels now take place from these intersection lines, thus ensuring that the nodes between wing panels, ribs and spars are reconnected properly to each other. As an example of the wing panel mesh is shown in the figure below,

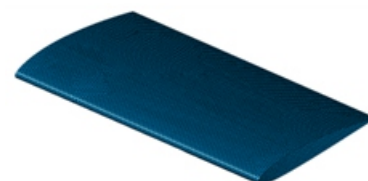


Figure 22: Wing Panel mesh with parabolic triangular finite elements

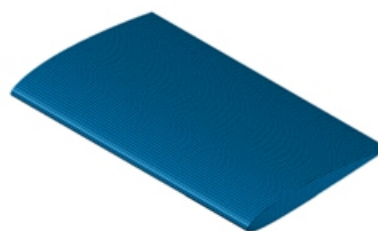


Figure 23: Wing Panel mesh with parabolic quadrangle finite elements

The quality of the mesh can be checked by using a dedicated mesh quality tool available in CATIA “Advanced Structural Analysis” module. The tool shows the quality of mesh in terms of a color palette. A green color for the mesh indicates that a mesh is of good quality while, a red color shows that the mesh is of bad quality. Interim colors between the green and the red shows that the mesh is of intermediate quality. Meshing tools available in CATIA V5 CAD software can be used for altering the mesh nodes if some elements nodes are found to be of bad quality or at uneven or high angles. As an example, for checking the quality of the mesh, the mesh quality tool is used on the above wing panel as shown in the figure below,



Figure 24: Quality of the mesh on the wing panel (green color shows mesh elements are of good quality)

Wing Spars Mesh:

A surface mesh is generated for the spars of the wing which is linked to a “join spar” surface in the Spars geometrical set in the aircraft model. As the number, position or the thickness of the spars is changed, the “join spar” surface is updated automatically.

This ensures that the current geometrical information for the spars is available for the mesh and when the spar mesh is updated, the mesh is generated for the current geometry. Intersection lines between “Spars and Ribs” are also defined.

They ensure that the mesh growth for the spars takes place in such a manner that the nodes of the mesh between the Ribs and the spars are properly connected to each other.

An intersection line between “Wing Panel and Spars” was already defined in the wing panel mesh so that the mesh elements between wing panels and ribs are already properly connected to each other. As an example, a surface mesh for the wing spars (which in this case are 4) is shown in the figure below,



Figure 25: Wing Spars mesh with parabolic triangular finite elements

As an example of the mesh connection between spars and the ribs the following figure is shown which shows that the mesh elements nodes between the wing spars and the wing ribs are properly connected to each other.



Figure 26: Mesh connectivity between FE mesh of wing spars and FE mesh of wing ribs

The quality of the mesh can be checked by using the dedicated mesh quality tool that is available in CATIA V5 software. Elements in the green color show that the mesh elements are of good quality.

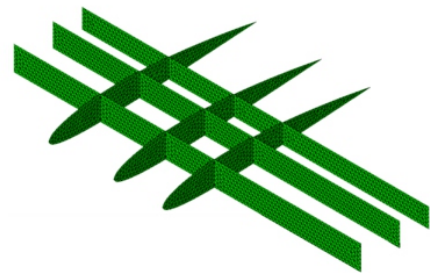


Figure 27: Quality of FE Mesh on wing spars

Compound Delta Wing:

A compound delta wing is a type of delta wing planform, which has two sweep angles. In a compound delta wing, the inner sweep angle is larger or steeper, while, in the outer sweep angle is smaller.

11.1.1.7.4 Ogival Delta Wing

An Ogival delta wing is a type of delta wing planform, where the leading edge of the wing blends smoothly from the root to the tip, typically resembling a “wine-glass” shape. This type of delta wing planform is seen on Concorde SST aircraft. Some other types of wing planform are,

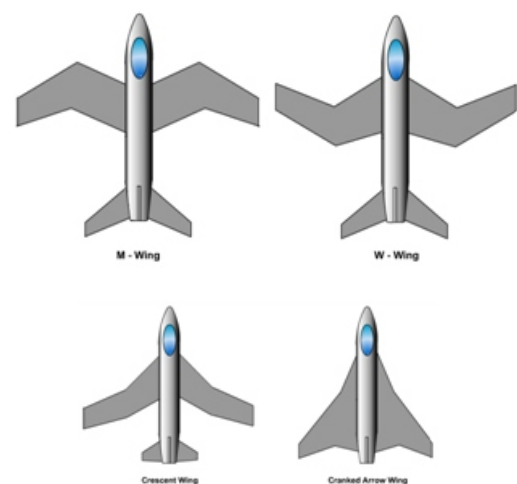


Figure 34: Different Types of Wing Planform

11.1.1.8 Crescent Wing

The crescent wing is a type of aircraft wing planform where, the outer section of the wing has a smaller sweep angle than the inner section of the wing.

11.1.1.9 Cranked Arrow Wing

The cranked arrow wing is a type of aircraft wing planform which has two distinct sweep angles at the leading edge of the wing. This type of planform is similar to the compound delta planform, however, in the cranked arrow wing, the trailing edge of the wing is kinked inwards. This type of configuration can be seen on the General Dynamics F-16XL aircraft.

11.1.1.10 M-Wing

The M-wing is a type of wing planform which is in the shape of the alphabet (M). In this type of wing planform, the inner section of the wing sweeps forward while, the outer section of the wing sweeps backward.

11.1.1.11 W-Wing

The W-wing is a type of wing planform which is in the shape of the alphabet (W). In this type of wing planform, the inner section of the wing sweeps backward while, the outer section of the wing sweeps forward.

11.1.2 Wing Planform based on Wing Sweep

When the sweep of the wing is changed, different types of wing planform can be achieved some of which are shown in the figure below,

Generic Aircraft Wing Model Parameters

12.1.1 Root Airfoil

The root airfoil defines the shape of the root of the wing panel. The Root airfoil is a drop-down string parameter which can be selected from a list. As, an example, the root airfoil could be “NACA 2412”. When any airfoil is selected from the list, the geometry changes automatically to reflect this change for the new airfoil.

12.1.2 Tip Airfoil

The tip airfoil defines the shape of the tip of the wing panel. The tip airfoil is a drop-down string parameter which can select from a list.

As an example, if the tip airfoil selected from the list is the “NACA 2415” airfoil, then the geometry of the tip of the airfoil changes automatically to reflect this change. Furthermore, since the tip and the root chord of each successive wing panel are attached together, so when the tip airfoil of for example, first wing panel is changed, the root airfoil of the second wing panel changes automatically to match the tip airfoil of the first wing panel. This ensures that all the wing panels are geometrically connected with each other.

12.1.3 Wing Panel Span

The wing panel span parameter defines the span of the wing panel from the root to the tip. Changing the wing panel span will either increase or decrease the span of the wing. Furthermore, the projected area of the wing panel are also updated continuously, if any or all changes are done to the wing panel span, root chord or tip chord etc.

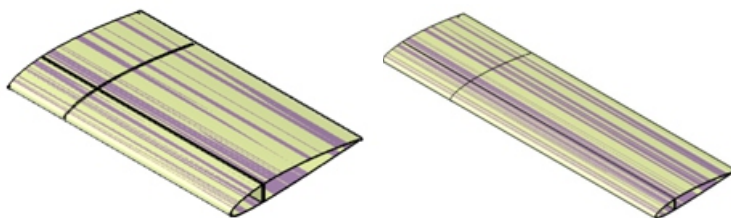


Figure 42: Increasing wing panel span from 5 to 10 meters

12.1.4 Root Airfoil Chord:

The root airfoil chord parameter changes the chord length of the root of the wing panel. As, the root airfoil chord is changed, the airfoil of the root of the trapezoidal wing panel is sized accordingly.

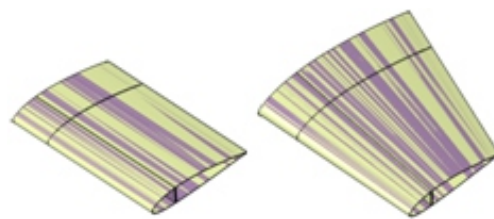


Figure 43: Increasing Root Airfoil Chord from 3 to 5 meters

Tables of comparison between PC with VB Scripting and KP Approach

13.1.1 Test # 1: Time to Instantiate wing panels

A comparison between the times to instantiate wing panels in both approaches is shown in the table below,

<i>Number of Wing Panels</i>	<i>Knowledge Pattern Approach</i>	<i>Power Copy with VB Scripting Approach</i>
3	11.9 sec	45.2 sec
5	16.4 sec	1m 45 sec
10	37.8 sec	6m 50 sec

Table 2: Time to Instantiate wing panels between the two approaches

13.1.2 Test # 2: Time to delete wing panels

A comparison between the times to delete the wing panels in both approaches is shown in the table below,

<i>Number of Wing Panels</i>	<i>Knowledge Pattern Approach</i>	<i>Power Copy with VB Scripting Approach</i>
3 to 1	2.8 sec	57.2 sec
5 to 1	4.1 sec	2m 5 sec
10 to 1	6.9 sec	6m 37 sec

Table 3: Time to delete wing panels between the two approaches

Conclusions:

The following conclusions are made regarding the master thesis work,

1. Both the knowledge pattern approach and the powercopy with VBA scripting approach can be used successfully in creating a generic wing model as shown in this thesis work.

2. If the time for modification, update and deletion of the geometry of the generic model is critical, then the knowledge pattern model is superior to the powercopy with VBA scripting model. The knowledge pattern based generic model was faster in all the tests compared to the powercopy with VBA scripting based generic model.

3. Not all features and tools in CATIA can be accessed by the knowledge pattern, whereas, a large number of features and tools can be accessed using VBA.

4. Not all geometrical entities of the generic model are accessible in the knowledge pattern based model while, all the geometrical entities of the generic model are accessible in the powercopy with VBA scripting based generic model.

5. The amount of code required to be written for the knowledge pattern based generic model is significantly smaller than the powercopy with VBA scripting based model.

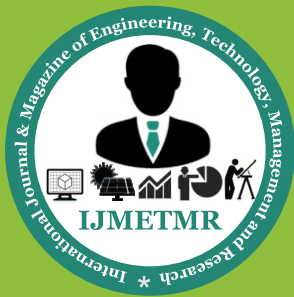
6. Debugging and error checking is much easier in powercopy with VBA scripting than in the knowledge pattern due to the availability of the debugging tools in VBA environment.

7. The generic aircraft wing model that is developed can be very effective and useful in the aircraft conceptual design process and can result in cost savings associated with the design process of aircrafts.

8. Automatic finite element mesh generation and modification is possible as shown in this thesis work.

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