DEVELOPMENT OF THE "SYNAMEC" A DESIGN TOOL FOR AERONAUTICAL MECHANISMS APPLIED TO LEADING EDGE DEVICES

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Abstract

This paper present the development and use of the SYNAMEC design methodology applied to the design of leading-edge mechanisms, this methodology allows designers and engineers to create new mechanisms in 2 dimensions by using a simplified and automated design process.

1 General Introduction

The design of mechanisms in aircraft has not changed for many years, as engineers and designers often rely on their experience and the trial and error method before designing a mechanism which satisfies its objectives. There is no commercial software or product that can generate such things at the moment on the market. This leads to limited innovation in the design of mechanisms in aeronautical applications. Many companies choose to use an 'old' geometry or system and adapt it to their needs. Many mechanisms have been used many times and proved to be reliable, with predictable maintenance costs. Moreover the time to develop new kinds of mechanism has cost implications, and, the final result may not always be achieved with the required accuracy. Current methods, however, do not ease the development of innovative design but an automated design methodology could be used to investigate many more configurations. This should enable the investigation of more efficient designs. SYNAMEC is such a system, which is being developed by a consortium, including Cranfield University.

The design of leading edge device has been chosen for the demonstration of the development and use of the SYNAMEC tool. The minimal amount of space available (within the airfoil) and the very precise deployment trajectory definition make it the perfect example for the demonstration of how to use this new tool.

2 Methodology

The classic methodology of designing mechanisms comprises many steps from the initial concept to the final working prototype. The importance of the SYNAMEC tool is to reduce the number of steps as well as the time spent on each one of them.
The use of CAD systems can help to reduce the time to design a new prototype, but CAD systems do not include modules which can find new types of mechanism on their own. The best tools or software available on the market are optimization programs which can be linked to a parameterized CAD model to find solutions that are more accurate for some objective functions defined by the designer. The solutions available to the designer from SYNAMEC can produce new configurations or geometries. The user only has to define the required objective trajectory and the main fixation points for the mechanism to be designed. The SYNAMEC tool then finds a possible geometry for the proposed case.

This tool allows progression from the initial requirements to the preliminary design by performing the "type synthesis" work for the designer. Type synthesis is the creation of a new kinematic chain [1], or in other word a new topology for the mechanism. This is the creation of new elements (bars and joints) joined together to make a new kind of mechanism.

However, it is possible for the designer to try to find other kinds of topology by changing some parameters, such as the fixing point position, or even to define a slightly different objective function.

The typical design methodology, which is an automated process for SYNAMEC, is the following:

Level 1: the Type Synthesis with the creation of kinematics chain for a new mechanism

Level 2: The Dimensional synthesis aims to find optimal values for the positions of each point and the length of each bar.

Level 3: The Detailed design aims to find a final shape for all the components as well as introducing material properties for a structural analysis.

3 Case studies / Validation

In order to demonstrate the use of the SYNAMEC methodology it is necessary to have a case study. The design of a leading edge mechanism for a regional aircraft was chosen to demonstrate the capacities of such a tool. Each step of the design will be explained for this case.

3.1 Initial requirements

The initial requirements were given by an aerodynamic study; this study gave the first elements of the design process.

The airfoil profile was known and also the deployment path to be followed by any moving parts such as the leading and trailing edges (fig. 1 and 2). The path, or trajectory, for these devices was very precise and some additional objectives had to be fulfilled. For example it was imperative to have the top part of the leading edge to be sealed with the airfoil at any position during deployment.

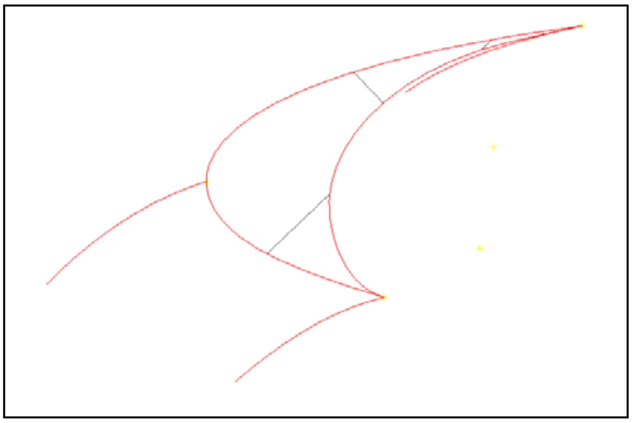

Fig. 1. Leading Edge Airfoil And Trajectories

The wing box was defined next. The positions of the main items (spar and ribs) in the wing box were given as an approximation (% of the chord and span). This structure was to be used to fix the mechanism to the wing, the position of the "strong points" or fixation points were likely to be fitted to the front spar of the wing.

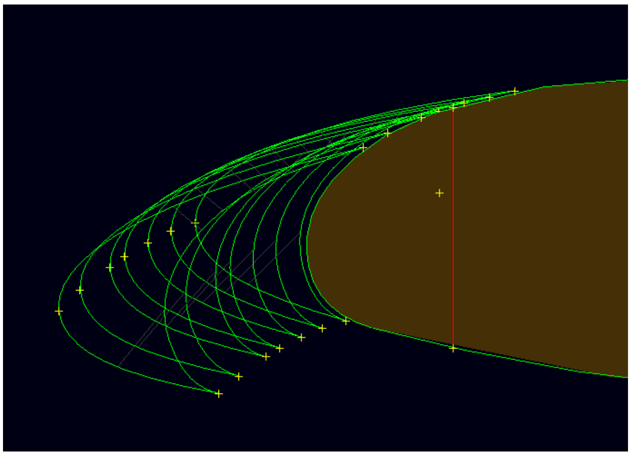

Fig. 2. Leading Edge Airfoil Position And Wing Box Structure Position.

3.2 Initial designs

After the aerodynamic requirements and the major structural element positions were known, it was then possible to get the available space or "work envelope" where the designer had to fit the mechanism. This is generally where the problems start for the design of leading edge mechanisms, since the available space to fit the mechanism is small.

The first objective to be achieved was the deployment of the mechanism following the trajectory of the frontal point of the leading edge.

The main requirements for this case were the trajectory of deployment and the position of the fixing point (fig. 3). The main fixing point on the wing box will be the position of the actuator (rotation) and the second fixing point was created by the designer to see what kind of solution could be found.

At this stage of the design, the trajectory was defined by a prescribed displacement of the frontal point of the leading edge corresponding to 3 points of the deployment trajectory (initial position –intermediate position – fully deployed position). At the present time, the SYNAMEC system can only handle cases with a 3 passing-point trajectory. It is planned for the future to improve this to a full trajectory description.

The actuation range was also defined and the angle of rotation chosen by the designer was changed several times before finding a new solution. This changed the solution provided by the SYNAMEC tool.

Any of the above parameters (actuation range - fixing point positions – passing point position) have a huge influence on the solution given for the type synthesis.

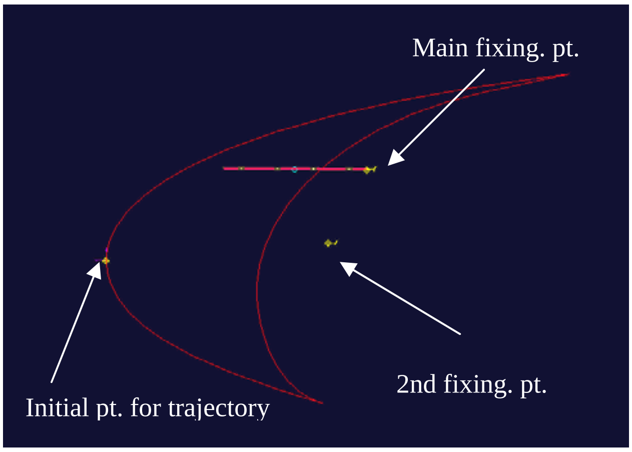

Fig. 3. Initial Data Set For Type Synthesis

After the initial set of data had been created for the type synthesis it was possible to launch the SYNAMEC tool in order to find a new type synthesis (or "geometry") for the leading edge mechanism.

The first solution found by the SYNAMEC software was a mechanism composed of 2 bars and a triangular element (3 points), as seen on figure 4. Each joint was defined by the junction of the new bar elements. The mechanism at this stage only looked for the deployment trajectory of the middle point of the leading edge and ignored the other trajectories (top and bottom path). The SYNAMEC tool automatically changed the position of the bar initially created because the program found an optimum position for the geometry of the mechanism and the position of each point, given the range of motion. In fact this means that the designer only has to worry about the range of motion of the actuation system and not the initial position of the bar on which the actuator acts on. A more detailed optimization could be carried on after but the proposed solution was already of good quality.

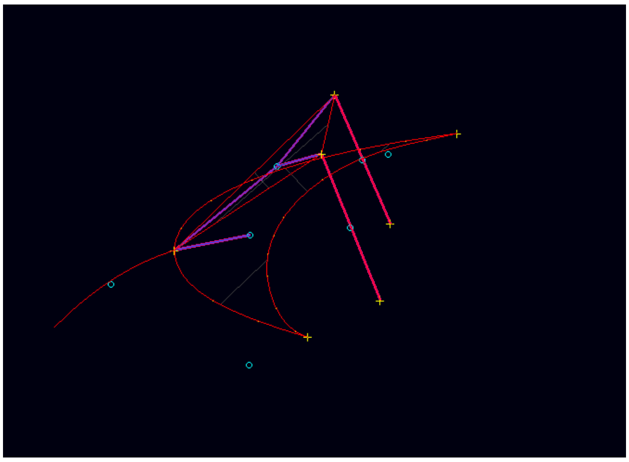

Fig. 4. First Solution For The Type Synthesis

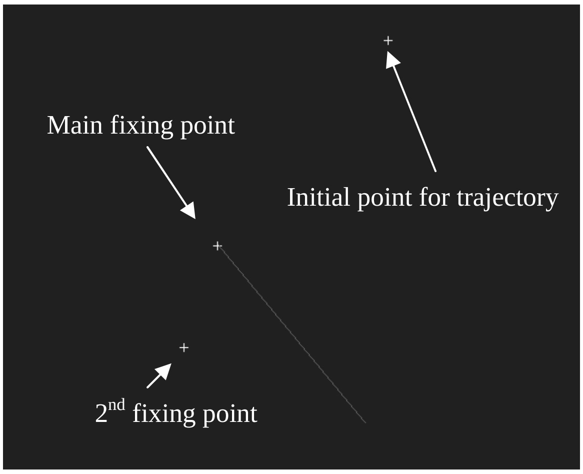

Fig. 5. Set of Data For The Second Type Synthesis Solution

As seen on figure 4 the mechanism to deploy the leading edge was located partially outside the airfoil. This will not satisfy the aerodynamic requirements, since any parts protruding from the airfoil will create additional drag and significantly decrease the aircraft performance.
Moreover the top and bottom trajectories were undefined for this first simulation and were not met.

3.3 Second design

For the second step it was decided to change the primary objective, as the middle trajectory was used before. It was then decided to use the top trajectory. This will normally give a mechanism which deploys and be sealed at all times. It was also hoped that the new mechanism would stay in the airfoil profile to retain aerodynamic performance.

Changing the objective did not change the way the work was done. A new set of data had to be created for the new case, even as it was very similar to the first case. The point which differed in the data was the definition of the trajectory which this time was based on three points from the top trajectory (fig. 5).

After the second set of data was created it was possible to launch the program again to find a new type synthesis complying this time with the top trajectory (fig. 6).

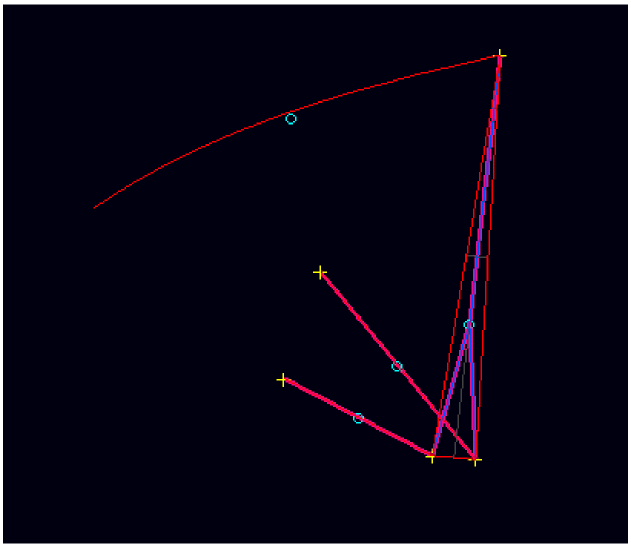

Fig. 6. Second Solution For The Type Synthesis With The New Objective

The new mechanism was automatically created with new elements (bar, face, joints).without any work from the designer. This solution was nearly perfect in terms of following the top trajectory.

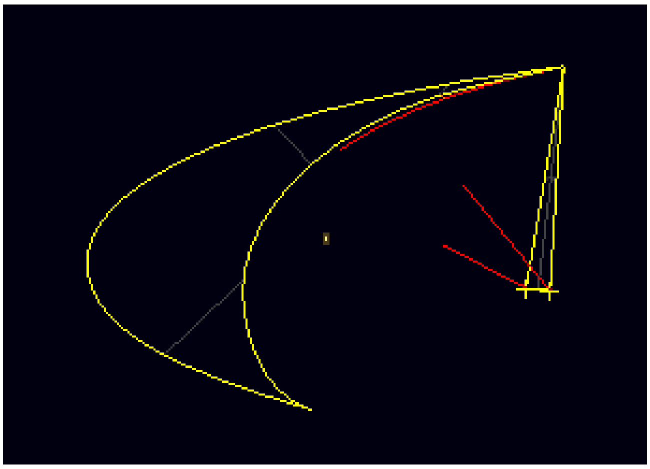

Fig. 7. Second Solution (With Leading Edge Profile)

The only drawback of this solution (fig. 7), so far, was that the mechanism was now placed within the wing box, which is a problem but this is less of a problem than for current paired track - slat track schemes.
The leading edge follows now the profile of the airfoil and is near to the perfect trajectory. The deployment of the leading edge is now nearly perfect and complies fully with the objective used for the second design solution. As seen on the following pictures (fig.8 and fig.9) the different positions during deployment for the leading edge using the mechanism created earlier.

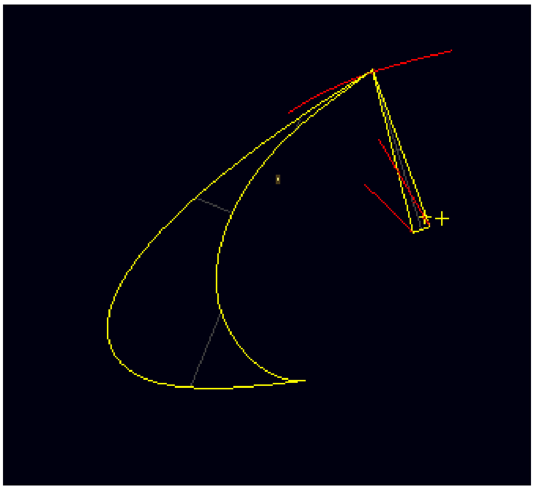

Fig. 8: Second Solution (Middle Position)

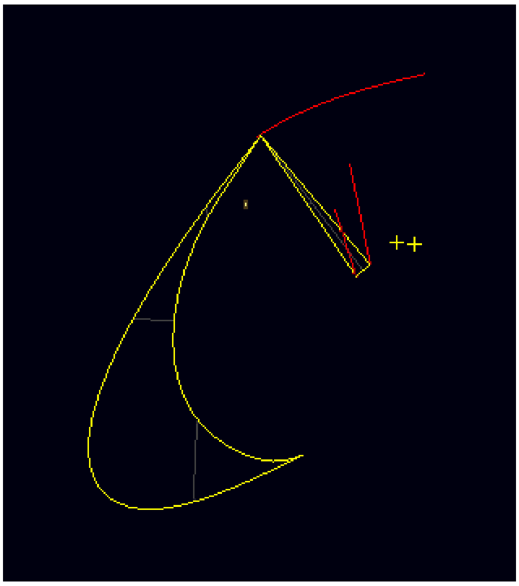

Fig. 9. Second Solution (Fully Deployed)

3.4 Other case Studies

Following the same process, Cranfield University and Alenia Aeronautica (Italy) have worked on other kinds of aeronautical applications for the design of mechanism using the SYNAMEC tool.
Cranfield University worked on wing trailing edge flap applications and managed to design new types of mechanisms. Two new trailing edge mechanisms have been designed, one of them would have fairings and the other solution would be a mechanism which is all included within the airfoil profile. These trailing edge designs joined to the study case on the leading edge are part of the on going research on variable camber at Cranfield University [2].
Alenia Aeronautica has worked on the design of a novel landing gear mechanism, with some success.
Both parties carried out some optimization work on their respective case studies in order to get a more accurate deployment trajectory, or a simpler mechanism type.

4 Conclusions

It has been demonstrated that the use of a novel tool such as SYNAMEC will help, in the near future, designers and engineers to save many design cycles. The trial and error method can be augmented or replaced by a more automated process. This automated process can only be supported by computer programs able to compute physical representation of automatically produced designs but human intervention is currently needed to guide the process.

The research and testing work carried on this new tool has proved to be very useful, and the whole process seems to be much quicker than before in the production of preliminary designs.

There is much more work required to cover other mechanism types, such as roller/track systems, and to extend from two-dimensional to three-dimensional mechanisms.

References

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