INGEGRAF

XVI CONGRESO INTERNACIONAL
DE INGENIERÍA GRÁFICA

CAD MODELLING AND VIRTUAL SIMULATION OF AN AIRCRAFT DOOR MECHANISM

E. Pezzuti, G. Piscopo, A. Ubertini, P.P. Valentini, L. Vita

University of Tor Vergata
Department of Mechanical Engineering
Via del Politecnico, 1
00133 – Roma, Italy
e.mail: valentini@ing.uniroma2.it

RESUMEN

En este trabajo los autores explican una metodología para reconstruir un mecanismo de una puerta de un avión y para simular el su funcionamento. Computer Aided Simulation (Digital Mock-up) es el solo modo para evaluar completamente todas la prestaciones, el montaje, las posibles interferencias y la sensibilidad a los errores mecánicos de un aparado mecanico muy complicado. In este caso el aparato esta formado de varios cientos de partes funcionales y de diferentes mecanismos que interracionan simultáneamente durante la abertura de la puerta. El movimiento de la puerta es espacial y muy complicado da evaluar sin una simulación 3D. La simulación dinámica del movimiento ha sido realizada por medio de las técnicas multibody; de esta manera ha sido posible evaluar todas las fuerzas y las reacciónes en cada juntura y estudiar la dinámica del sistema entero. La metodología desarrollada emplea un programa totalmente paramétrico y permite de introducir las variables específicas para simular los errores mecánicos y de montaje para evaluar suos efecto en el movimiento de la puerta.

Palabras clave: Simulación 3D, digital mock-up, puerta de un avión.

ABSTRACT

In this paper the authors explain a methodology to reconstruct a mechanism of an aircraft door and simulate its functioning. Due to its complexity the computer aided simulation (Digital Mock-up) is the only way to evaluate the performances, to check the assembly procedure, to find out possible interferences, and to study the sensitivity of each component to mechanical errors. The complete assembly is made of hundreds of functional parts. Moreover, the whole system is composed of several different mechanisms which interact together during the door opening procedure. All these mechanisms have to work precisely and in cooperation, and the motion of the door is spatial and quite difficult to understand without a three dimensional simulation. The dynamic simulation of the motion has been performed by means of multibody techniques, so it has been possible to evaluate the reaction forces on each joint and characterize the dynamic behaviour of the whole system. The proposed methodology is based on a fully parametric CAD program and it allows to introduce specific variables to simulate mechanical errors in manufacturing or assembling in order to assess their effect on the motion of the door.

Key words: CAD modelling, virtual simulation, aircraft door

1. Introduction

All mechanical devices are the product of a creative mind. In many cases just watching the functioning of one of them gives the sensation of something magical. It happens in a particular way when the mechanics is very complex and the movement is made of many sub-movements and all the mechanisms are driven by a single operation automatically.
One of this fascinating device is the opening system of an aircraft door. In the US patent n° 3791073 there is the description of one of them proposed by the Boeing Company in 1974 (BAKER, 1974). As it clearly appears the simple drawings and descriptions do not offer a complete explanation of the device. To fill this gap and to have a complete understanding of the functioning of each part and the way they interact together, a more accurate analysis is needed. Moreover the simple description and even accurate drawings are not sufficient to figure out the actual movement and the way to improve reliability, performances or just verifying the current ones. In this case only a virtual simulation in three dimension can improve the comprehension and can also be a valid support for the designer.
The investigated device is mounted on the aircraft fuselage (LIMITI, 2003) with tilting angle w.r.t. the vertical plane. For this reason the mechanism designed to open the door has to perform a rotation of the hinge line first and then a rotation around it. The advantages of this solution are that the door does not require do be opened inward (this avoid possible interferences) and when it opens it allows a full admittance. The opening mechanism is a good solution also for the assembly of gaskins (a continuous boundary loop can be mounted around the door frame) and for the aircraft pressurization.

2. Description of the mechanism

The entire assembly (depicted in Figure 1) is made of hundreds functional parts (excluding pins and bolts). Moreover the mechanism is composed of several sub mechanisms (ZADRO, 2004): there is the unlocking mechanism which operates at the beginning of the opening; the cam mechanism which drives the door upward to disengage the blocking pins; the ten bar mechanism (made of two different four bars linkages connected together) which drives the door outward and align the hinges line vertically in order to allow the final rotation till the fully opened configuration is reached.
The unlocking mechanism (see Figure 2) which allows the door to start moving, can be driven by two levers (one inside the aircraft, one outside the aircraft) connected together by means of a simple gear train. So when one lever is pushed up, the other one opens too. The shaft of the inside lever is connected to two pins (one of each side of the door) which engage the groove of planar cams. During the opening the rotation

of the lever makes the pin move inside the groove and so the door is pushed upward and outward. At the same time a spherical four bars linkage moved by the same lever shaft disengages the locking pin at the top of the door frame.
Then while the door is opening following the profile of the cam (called “main cam” in Figure 2), the upward movement of the door guides two pins each side out of two other planar cams (supporting blocks, as shown in Figure 2). These cams support the entire weight of the door and make the opening quite simple.

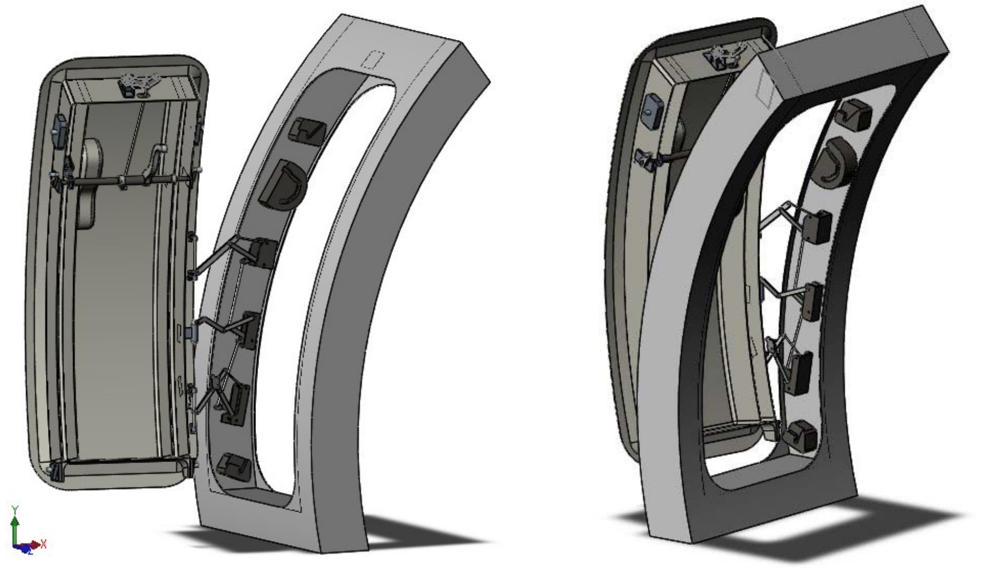

Figure 1: The complete assembly of door opening mechanisms in two different views

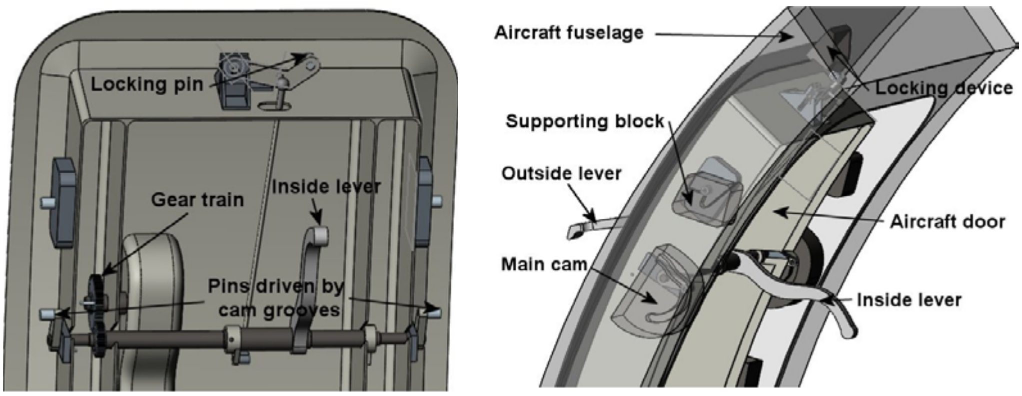

Figure 2: Unlocking mechanism

When the two pins arrive at the end of the cam grooves the motion of the door is governed by two four bars linkages connected together to form a ten bar mechanism. This one pushes the door outward till the vertical alignment of the hinges line is reached.

This movement causes the door also to rotate to assume a vertical position. Till the end of this phase the door can not be fully opened because the rotation around the main joints is allowed only when the axes of all the hinges is vertical. In this configuration the blocking system (see Figure 3) constraints one of the link and suppress the unique degree-of-freedom of the ten bar mechanism. When the door is completely pushed outward the pin is no more in contact with the lateral plate and the blocking arm engages the groove in the other link. At the same time the blocking lever comes in contact with the lower ring to support the weight of the entire door. When the ten bar linkage stops, the central hinge allows the door to rotate till the end of opening process.

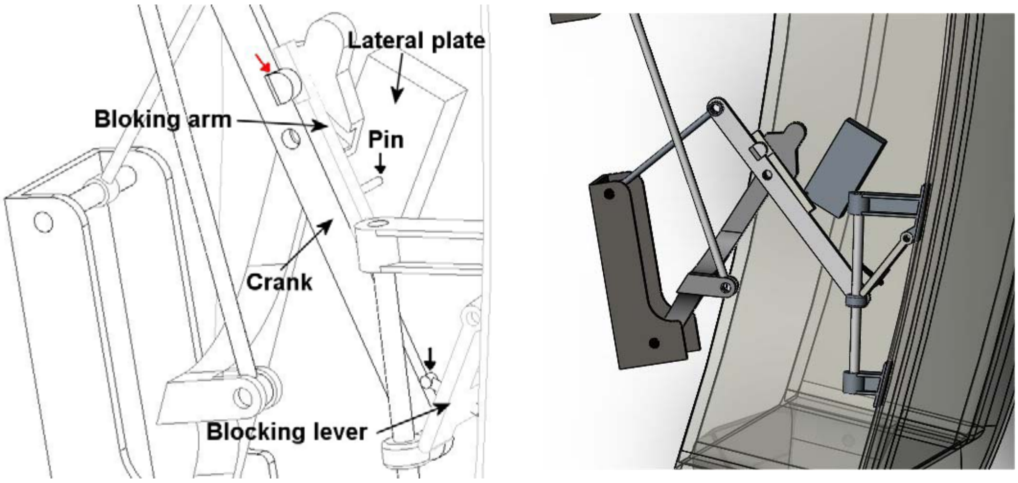

Figure 3: Detailed drawing of the ten bar blocking system

The opening phases can be summarized in the following steps (which are also depicted in Figure 4):

1. The operator acts on one of the opening lever, pushing it up;
2. At the same time, the blocking system is disengaged, and the door can be pushed upward and outward following precise cam profiles;
3. When the ends of the cam profiles are reached, the door movement is prescribed by the ten bar linkage which aligns the axes of the hinges vertically;
4. When the axes of the hinges have been aligned along a vertical axis, the blocking mechanisms stops the door (and it prevents also unwanted closure for passengers' and assistants' safety). Now the door is allowed to rotate around the hinges till the fully opened position is reached.

3. CAD reconstruction and multibody simulation

Each component of the full assembly has been modelled as a part using a fully parametric CAD program.

A particular attention has been dedicated to the synthesis and generation of cam profile (DI BENEDETTO et al., 1993). In fact the inaccurate design of the path of the groove may lead to critical configuration and make the opening of the door impossible or possible only exerting a very high force. Moreover the wrong synthesis may lead to some interferences between the door and the main frame during the upward and outward motion. In fact the first movements are very critical to disengage the door from the fuselage frame.

The CAD parametrization of the control points of the path using statistical variables is useful to perform a manufacturing errors sensitivity. For this purpose the results have been compared to those obtained by means of rules of synthesis typical of kinematics and it can be said that the cam in the middle of the frame plays a very important role and it has to be manufactured with precision to avoid critical configuration or position with improper pressure angles.

Also the two four bar mechanisms (which are connected to form a ten bar linkage) have to be design carefully. They both have the property to reproduce a straight line trajectory of a point on the connecting rod, so they can be designed according to Chebishev theory (KRAUS, 1955).

The parts have been assembled in the same CAD program using simple relation of insertion, mating surfaces, and inclination. Contact forces between pins and cam have been added and dynamic analysis (according to multibody dynamics technique in HAUG, 1989) has been performed simulating the action of a flight assistant on the lever with a simple force.

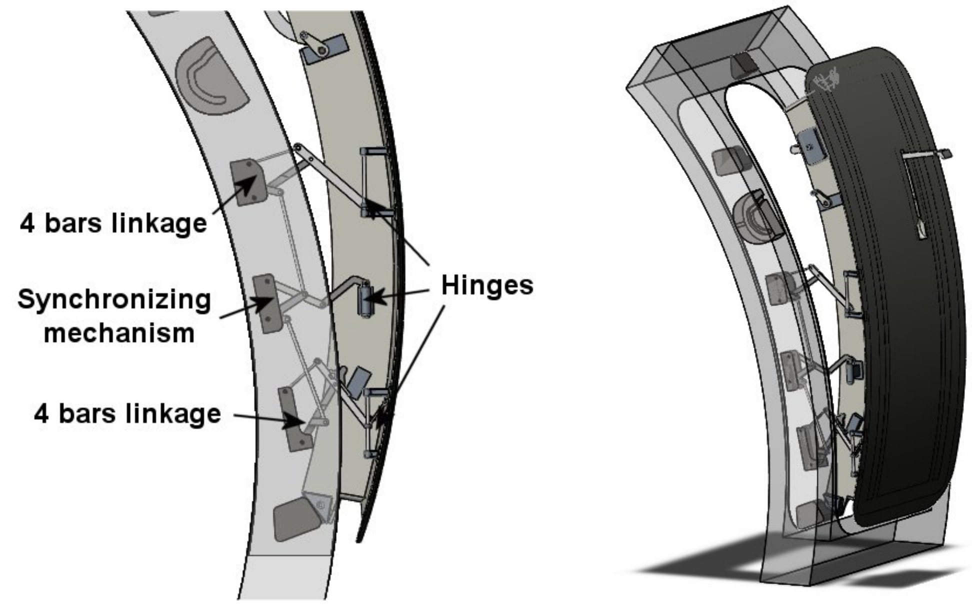

Figure 4: The ten bars mechanism drives the door till the hinges axis is vertical

The simulation has given useful information about the minimal value of opening forces and the time needed to complete the whole operation. It was also possible to esteem loads acting on every part (see an example of contact forces in Figure 6). Possible interferences have been also checked and avoided.

4. Conclusions

The virtual three dimensional simulation of complex mechanisms is the only way to study their complete movement. It also makes possible to improve the feature of the mechanical devices checking and the way they interact with the rest of the structure and the surrounding environment. The studied system is a very fascinating mechanism designed to perform the opening of an aircraft door. This device is a fully mechanical assembly without electrical or electro-mechanic components.

The CAD modelling has shown its importance in order to study the influence of manufacturing tolerance or mounting errors on global performances. Moreover, the multibody simulation is a powerful tool to understand the complex movement of the door, check possible interferences, verify the interaction among all the sub mechanisms and sub structures and have an assessment of the forces which the joints have to support. This virtual simulation can avoid the manufacturing of physical prototypes and test rigs saving money and time to setup expensive tests for different solutions.

Moreover, the graphical output (i.e. movies, pictures) can be used for didactical purpose, for enriching assembly instruction, for training expert personnel, and also for reverse engineering purposes.

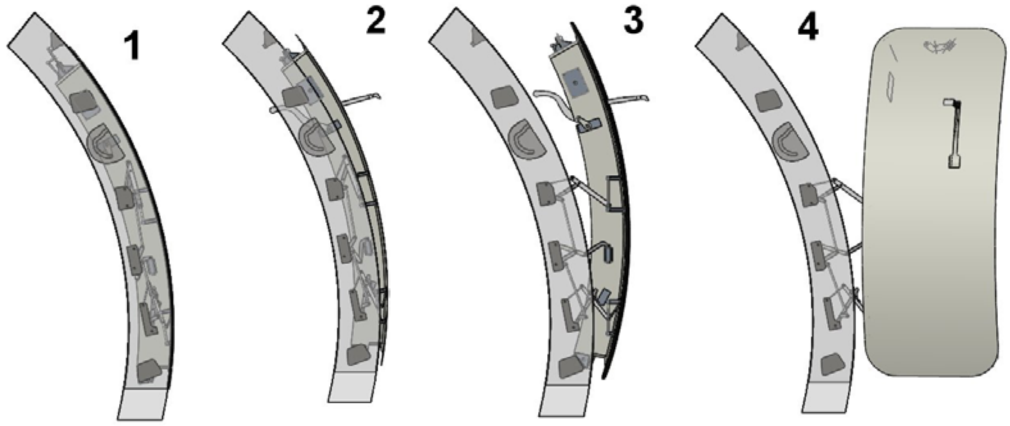

Figure 5: Opening phases of the aircraft door

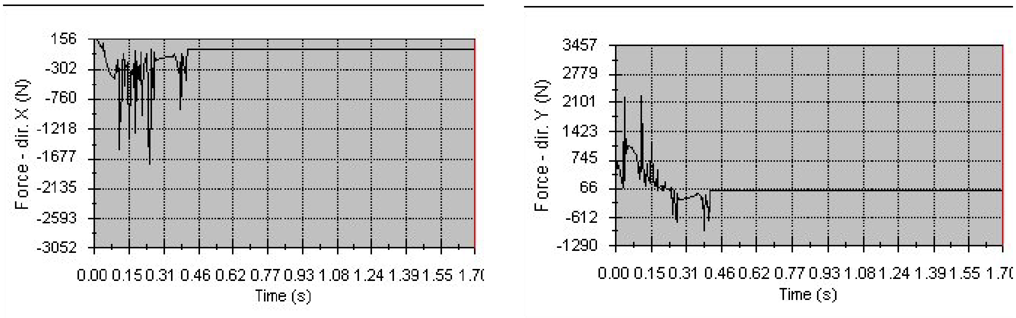

Figure 6: Examples of computed contact forces between pin and cam groove

Acknowledgments

The authors wish to acknowledge Ing. Michele Zadro for his help in collecting information about the mechanism.

References

BAKER, I.G. (1974), *Aircraft door with moving hinge line*, US Patent n°3791073

DI BENEDETTO, A., PENNESTRÌ, E. (1993), *Introduzione alla cinematica dei meccanismi, Casa editrice ambrosiana*, Milano, Italia, Vol. 1 (in italian).

HAUG, E. J.(1989) *Computer-Aided Kinematics and Dinamics of Mechanical Systems*, Allyn and Bacon, vol. I, pp.48-104.

KRAUS, R. (1955) *Geradführungen durch das Glenkviereck*, Düsseldorf, Verein Deutche Ingenieur (in german).

LIMITI, M. (2003) *Progetto di meccanismi per porte di aeromobili*, First Level Thesis in Mechanical Engineering, University of Rome Tor Vergata, a.y. 2002-2003 (in italian)

PENNESTRÌ, E. (2002) *Dinamica Tecnica e Computazionale*, Casa Editrice Ambrosiana, Vol. 2.

ZADRO, M. (2004) *Progetto di meccanismi che regolano il movimento di porte di aeromobili*, Degree Thesis in Mechanical Engineering, University of Rome Tor Vergata, a.y. 2002-2003 (in italian)