ICAS 2016
30th Congress of the International Council of the Aeronautical Sciences
DCC, Daejeon, Korea ; September 25-30, 2016

STUDY ON THE SYSTEM INTEGRATION FOR MULTI-ELEMENT AIRFOIL AERODYNAMIC ANALYSIS

DOWOO NAM*, JONGYUN LEE*, BYOUNGSOO KIM*
***Dept. of Aerospace Engineering, Chungnam National University**

Keywords: *eMEGA, ModelCenter, lift-to-drag ratio, multi-element airfoil*

Abstract

This paper describes our research efforts on the system integration of aerodynamic design for multi-element airfoils and application for parametric study of relative positioning to study effects of airfoil's relative position. Furthermore, this paper demonstrates how the integrated system can be used to find out aerodynamically efficient arrangement of airfoils through parametric study. System integration is processed with ModelCenter, and grid generation with eMEGA. And aerodynamic analysis is accomplished by using ANSYS fluent.

1 Introduction

Airfoils have been developed and researched actively for better aerodynamic performance; however, it cannot avoid definite limitation of performance as a single element. Hence, the concept of using multi-element airfoil is a natural choice for production of higher lift.

Higher aerodynamic performance is required in fatal reason; safety, especially in landing or taking-off. Another reason would be efficiency in flight. Better performance results in a lower cost.

In common, multi-element airfoils for higher performance are called slat and flap. As fig. 1 shows, slat is an airfoil which is located in front of the main airfoil. Flowing through slat, air flow is deflected toward the main airfoil, and this enables flow separation to be delayed. Airfoils behind the main airfoil are called flaps. Flaps increase effective chord-length of main airfoil, and could be available to get steeper descent angle with lower velocity. Also, Fig. 2 shows increase of maximum lift coefficient by flaps, and extension of stall angle by slats.

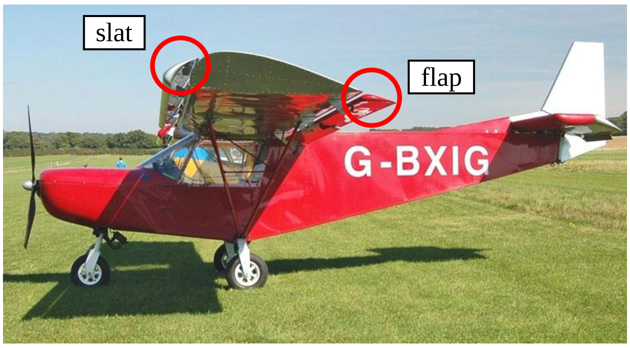

Fig. 1 Slat and flap in an actual plane

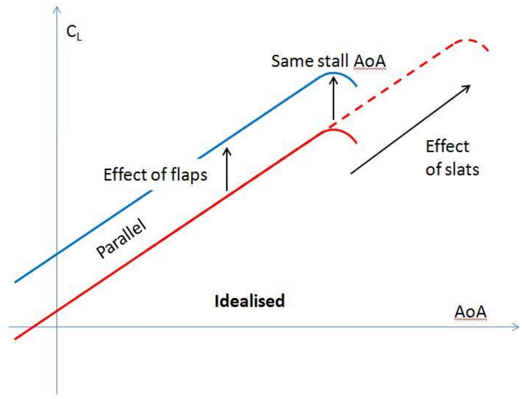

Fig. 2 Effects of slat and flap

2 Research summaries

Aerodynamic performance of multi-element airfoils is very sensitively affected by even small changes in relative positions among those airfoils. As shown if Fig. 3, this research tries to integrate geometric definition, grid generation, and analyzing aerodynamic characteristics to study effects of relative arrangement of high-lift devices. Commercial program such as ANSYS fluent, is used for aerodynamic characteristics, and in-house code, eMEGA, is used as a pre-processor. And ModelCenter is used for integration of the whole process.

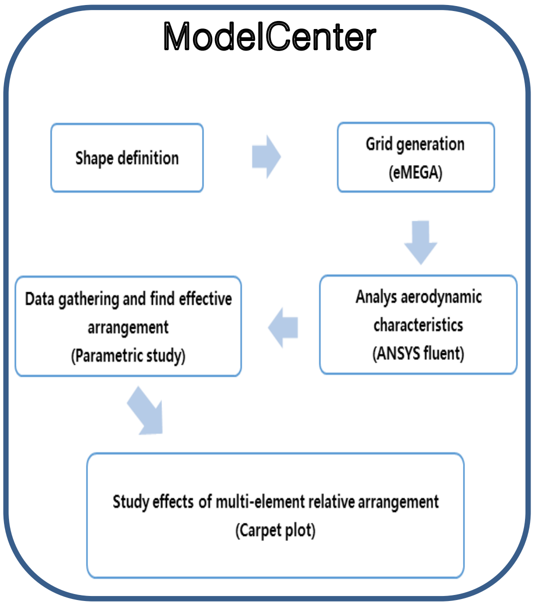

Fig. 3 Process diagram

3 Analyzing method

3.1 System integration

3.1.1 ModelCenter

ModelCenter increases productivity by enabling users to execute in less time and resources. ModelCenter is known as one of very powerful and popular tools for multi-disciplinary optimization which can integrate any number of modules written in various computer languages.

3.1.2 Integrated system

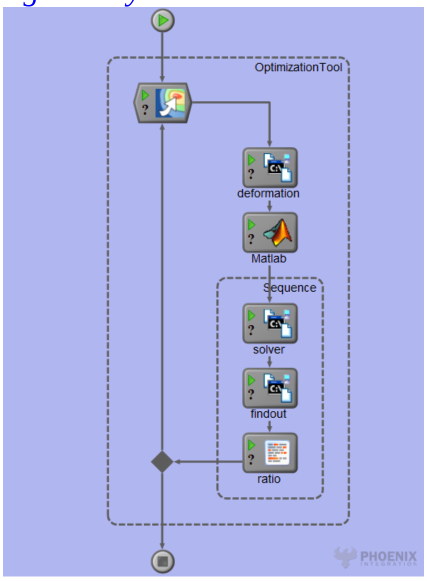

Fig. 4 Integrated system by ModelCenter

System including grid generation, aerodynamic analysis and optimization was built by using ModelCenter. Grid generation is done in "deformation", "Matlab" shows how airfoils are arranged by changing position parameters graphically. "Solver" works for analysis of aerodynamic characteristics, and "ratio" is for lift-to-drag ratio calculation out of coefficients from "findout" component.

3.2 Geometric definition

There are many ways to define slats and flaps geometrically, but in this research, multi-element airfoils including slat and flap are geometrically defined by separating the original airfoil into 3 pieces as shown in Fig. 5. NASA GAW 1 is chosen as a base airfoil which is from NASA report, due to having difficulties to define separating lines. Slat is translated along the x and y-axis after being rotated with its own leading edge as the center of rotation. Flap and main airfoil are transformed in a similar way.

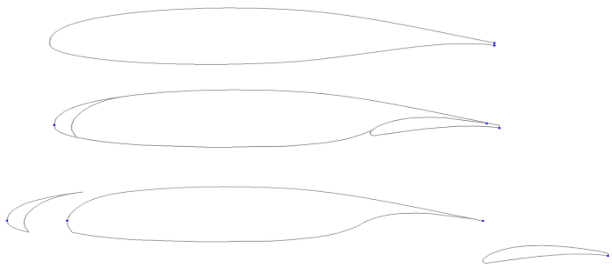

Fig. 5 Geometric definition

3.3 Grid generation and deformation

3.3.1 eMEGA

General-purpose grid generation program, eMEGA (in-house code which is developed in author's laboratory, CFDL, Dept. of Aerospace Eng., C.N.U.) is used for multi-block grid generation. The current version of eMEGA has been updated so that mesh deformation can be dealt with, and this version was used for iterative mesh deformation following changes of position parameters accompanying re-arrangement of multi-element airfoils.

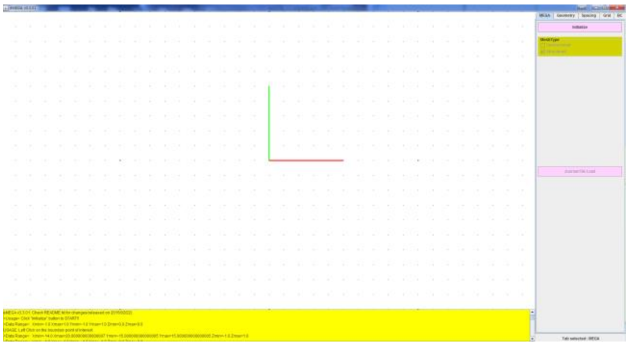

Fig. 6 Interface of eMEGA program

3.3.2 Deformation

For deformation, Delaunay triangulation method is applied.

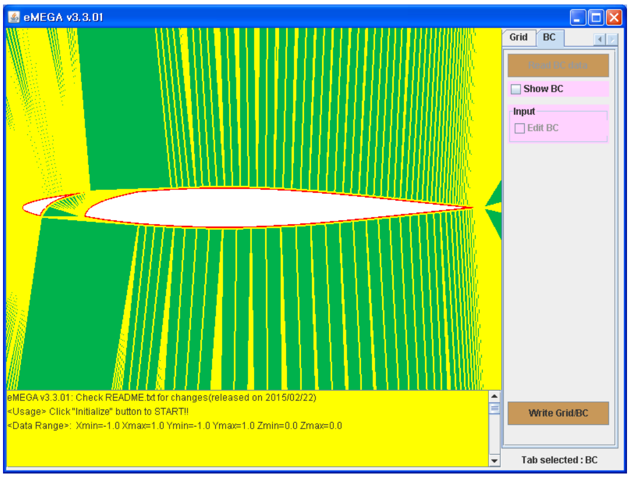

Fig. 7 Delaunay triangulation at eMEGA

3.3.3 Deformation limitations for this research

Flaps or slats could be translated with no limit, but in this research translation is constrained and limited because of grid quality issue and/or negative volume issue. This issues are due to deformation method; deform the mesh from base grid as slat or flap is translated linearly or rotationally.

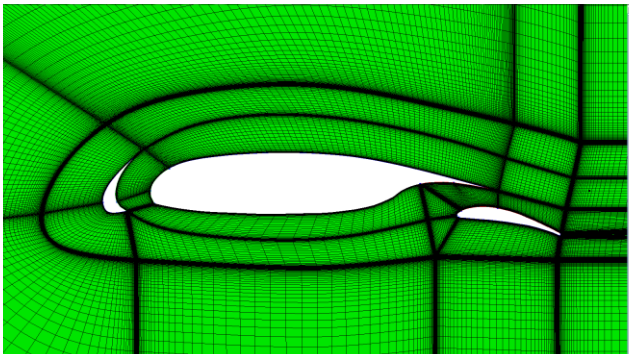

Fig. 8 Base grid for this research

3.4 Flow condition and aerodynamic analysis

3.4.1 Flow conditions

Usually flaps or slats are deployed for landing or taking-off. In this research flow conditions relevant to this flight status are used, as shown in Table 1.

Table 1 Flow conditions

Re	Flow type	AOA	Steadiness
3,400,000	turbulent flow (k-omega SST)	10°	steady

3.4.2 Aerodynamic analysis

Aerodynamic analysis is accomplished by ANSYS fluent macro (Text User Interface) to be integrated by ModelCenter.

3.5 Optimization

3.5.1 Definition of effective position

This research uses lift-to-drag ratio as the measure for effectiveness of relative position of multi-element airfoils.

3.5.2 Optimization methods and examples

This research contains several optimization methods as follow.

- The first process of optimization on this research is D.O.E (Design of experiments) including "Design explorer orthogonal array (D.E.O.A.)" and "Latin hypercubes (L.H.S)" methods. Orthogonal array has biggest coverage in minimum experiments which is biggest advantages for saving resources. And Latin hyper cube is stratified sampling without replacement, this has high reliability samples.

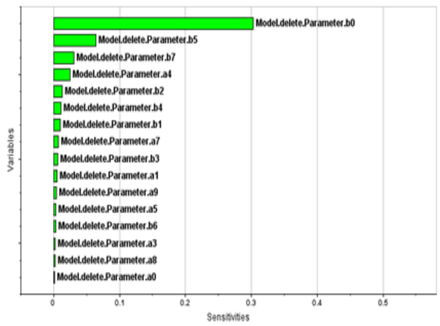

Fig. 9 Sample of parameter sensibility analysis

- Sensitive parameter analysis is the second step. Each translation or rotation parameters are checked for effects of aerodynamic results by D.E.O.A and L.H.S.s
- The last step is checking effective relative position by drawing carpetplot. Two of most sensitive parameters from the second step would be each of x-axis and y-axis and result of lift-to-drag ratio would be z-axis.

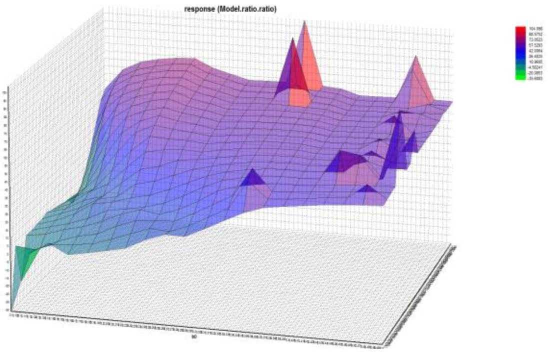

Fig. 10 Sample of effective relative positioning exploration by 3D carpetplot

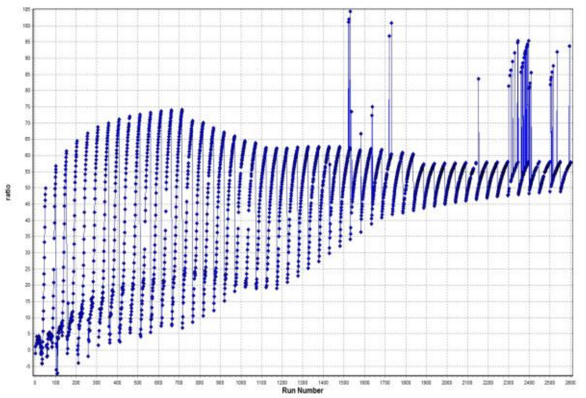

Fig. 11 Sample of distribution chart of lift-to-drag ratio by calculation run number

4 Conclusions

This paper demonstrates system integration of aerodynamic design for multi-element airfoils and searched effected relative positioning of high-lift airfoils through several optimization methods. eMEGA is used for grid generation and mesh deformation by re-arrangement of multi-element airfoils by parameters. Aerodynamic analysis is accomplished by ANSYS fluent, ModelCenter integrates whole process. This research could help in reducing analysis resources and costs for development. Furthermore, this would be a fundamental research for analyzing aerodynamics of multi-element airfoils and optimizing high-lift devices.

5 References

[1] Braden J, Whipkey R, Jones G and Lily D. *Experimental study of the separating confluent boundary-layer volume II- experimental data.* NASA, 1983

6 Contact Author Email Address

aero1130@gmail.com

Copyright Statement