Optimal Analysis of Structures by Large Wing Panel Using FEM

Byeong-Sam Kim, and Kyeongwoo Park

***Abstract*—In this study, induced structural optimization is performed to compare the trade-off between wing weight and induced drag for wing panel extensions, construction wing panel and winglets. The aerostructural optimization problem consists of parameters with strength condition, and two maneuver conditions used residual stresses in panel production. The results of kinematic motion analysis presented a homogenization based theory for 3D beams and 3D shells for wing panel. This theory uses a kinematic description of the beam based on normalized displacement moments. The displacement of the wing is a significant design consideration as large deflections lead to large stresses and increased fatigue of components cause of residual stresses. The stresses in the wing panel are small compared to the yield stress of aluminum alloy. This study, described the implementation of a large wing panel, aerostructural analysis and structural parameters optimization framework that couples a three-dimensional panel method.

***Keywords*—Wing panel, Aerostructural optimization, FEM, Structural analysis.

I. Introduction

THE structure of the aircraft's wing has been modeled using FEM analysis plates to model all structural elements, ribs, spars, skin, slats and flaperons. The aerofoil shape was constructed with nodes spaced appropriately to capture stress gradients. share of air flight control device wing aileron. Kinematic motion analysis program by Sim Designer acting on each joint of panel force and torque aileron requirements for information corresponding to the conditions that were identified, based to identify the characteristics of each part and the structural basis of this analysis using ABAQUS 6.5 model was developed separately by each working on structural analysis, structural characteristics and performance and forecasts were performed. In addition, components of the safety margin for hydraulic components were confirmed by checking the structural safety. In the generic fighter of aileron example discussed in this paper, linear models will be used. This is not a requisite, but for the analysis based on non-linear models, more detailed information and motion algorithm. The linear actuators of mechanism can be either hydraulic rams or electric spindle devices. The aileron actuator motion-bases generally utilize a mechanism known's as the Stwart Platform or "hexapod", which was originally proposed for a base-frame, six actuator legs in Fig. 1. This method can be applied to both the gravitational forces and the aerodynamic load and gravitational forces categories. The positioning of the links and joints are not changed within the analysis, because of the nature of the design synthesis performed on the mechanism. By changing the lengths of members or moving the links or joints, the desired motion for morphing the wing may no longer be achievable [1]..

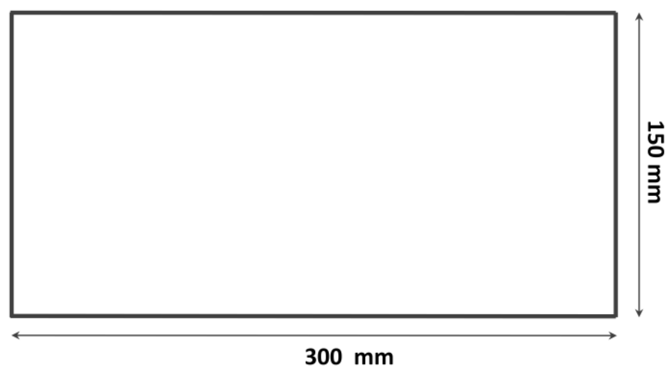


Fig. 1 Large Wing Panel base model

II. Structural Analysis

A. *Base model Analysis*

Wing Aileron's structural analysis model can be divided into three. The piston rod, bellcrank, stroke is these three different parts. The results of kinematic motion analysis were used for the structural analysis based on data that the load applied to each part. The statics pressure range because it contains the maximum pressure in the range of a maximum pressure of 3000psi was the result of applying the data. Case 1 and Case 2 also occurs in the value of the force and torque limit value because they are included within the scope of Case 2 is a TEU 24 ° TED 16 ° and in the context of structural analysis was carried out in Fig. 2.

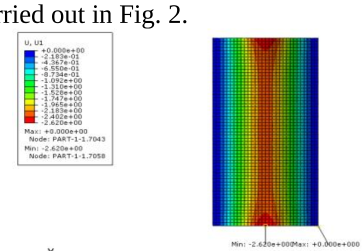


Fig. 2 Base model with 15mm- sppeed-30 mm/s for verification

Manuscript received March 20, 2014.

Byeong Sam Kim is with the Automotive Engineering Department, Hoseo University, Asan 336-795, KOREA (phone: +82-41-540-5814; fax: +82-41-540- 5818; e-mail: kbs@ hoseo.edu).

Kyeonwooi Park_is with the Mechanical Engineering Department, Hoseo University, Asan, 336-795, Korea (e-mail:kpark@hoseo.edu).

B. Mechanism Analysis model

Wing system as shown in the 3D model is composed of the larger piston, bell crank, clevis, stroke and flap. By using kinematic motion system analysis, all of the above free design variable and constraints can be combined to yield the most architecture aileron actuator of the four major parts. This is part of joint connecting the four joint. For simplified system analysis, in this point unnecessary pin were also removed [2].

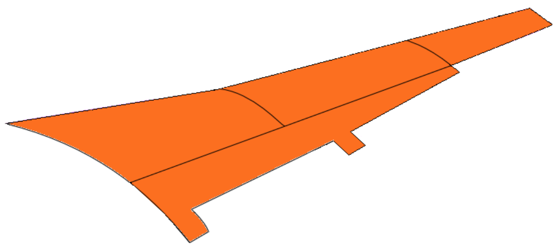


Fig. 3 Wing panel composition and peeing parameters

In the generic fighter of aileron example discussed in this paper, linear models will be used. This is not a requisite, but for the analysis based on non-linear models, more detailed information and motion algorithm in Fig. 2. The linear actuators of mechanism can be either hydraulic rams or electric spindle devices. The aileron actuator motion-bases generally utilise a mechanism known's as the Stwart Platform or "hexapod", which was originally proposed for a base-frame, six actuator legs (the jacks). This method can be applied to both the gravitational forces and the aerodynamic load and gravitational forces categories [3].

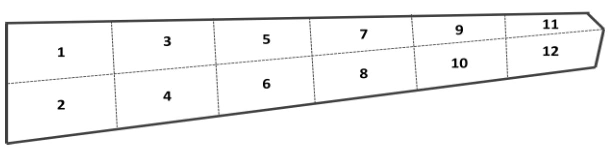


Fig. 4 Wing Panel for analysis model and joint mechanism

The positioning of the links and joints are not changed within the analysis, because of the nature of the design synthesis performed on the mechanism in Fig. 4. By changing the lengths of members or moving the links or joints, the desired motion for morphing the wing may no longer be achievable. Aileron's system as shown in the 3D model is composed of the larger piston, bell crank, clevis, stroke and flap in Fig. 3. By using kinematic motion system analysis, all of the above free design variable and constraints can be combined to yield the most architecture aileron actuator of the four major parts. This is part of joint connecting the four joint. For simplified system analysis, in this point unnecessary pin were also removed. This method can be applied to both the gravitational forces and the aerodynamic load and gravitational forces categories for aileron mechanism. Aileron mechanism have moved up the wing when the maximum angle of 19 ° (TEU 19 °), went down to below 11 ° (TED 11 °) at Case1 and when the wings moved up 24 ° (TEU 24 °) , went down to below 16 ° (TED 16 °) Case 2 a time were compared. The rated pressure of the pressure piston (rated pressure) 2775psi, the maximum pressure 3000psi applied when compared in each case. The motion analysis represented a Sim Design@ and, Adams@' program. See Table I.

TABLE I
KINEMATIC ANALYSIS IN EACH CASE

Case	Aileron Angle	Pressure (psi)
Case1	TEU 19°	2775
		3000
	TED 11°	2775
		3000
Case2	TEU 24°	2775
		3000
	TED 16°	2775
		3000

C. Structural Analysis

Wing panel structural analysis model can be divided into 12 pieces forming process. The results of kinematic motion analysis were used for the structural analysis based on data that the load applied to each part. The statics pressure range because it contains the maximum pressure in the range of a maximum pressure of 3000psi was the result of applying the data. Case 1 and Case 2 also occurs in the value of the force and torque limit value because they are included within the scope of Case 2 is a TEU 24 ° TED 16 ° and in the context of structural analysis was carried out. The pressure of piston can be used the maximum pressure 3000psi. Each model defines a material density as well as linear, elastic isotropic values of modulus of elasticity, and Poisson's ratio. As with the real constants sets, the first tentative designs are modelled after the second generation model [4], [5]. The materials property include stainless steel (AMS5862 15-5PH) was applied, element type the Tetra mesh (C3D4) were used for ABAQUS 5.7@.

TABLE I
THE RESULT OF KINEMATIC MOTION ANALYSIS WITH SIMDESINER

Joint	Pressure (psi)	TED 11°		TEU 19°	
		Force (N)	Torque (in-lb)	Force (N)	Torque (in-lb)
Piston & Bell crank	2775	37936	2929.2	37936	2929.2
	3000	41012	3166.8	41012	3166.8
Bell crank & Clevis	2775	54983	8222.8	67412	11340.4
	3000	59441	8889.8	72878	12260.6
Bell crank & Stroke	2775	37926	3141.5	49128	4068.0
	3000	41001	3396.3	53112	4397.9
Stroke & Flap	2775	37926	2900.3	49128	3791.8
	3000	41001	3135.4	53112	4099.2

The main design consideration for this study is to reduce the amount of ther-mal load on the structure which ultimately causes bending at the joints and supports and shear stresses in the core. Assigning different plate properties to each structure type differentiated them from one another. Dimensions of wing skins, ribs, spars and flanges can all be manipulated independently. This has enabled us to optimize the wing, finding the strongest and lightest combination of component thicknesses. For the purpose of forming a cylindrical shape on 76× 76× 3mm samples with a curvature radius of 600mm in Fig. 5.

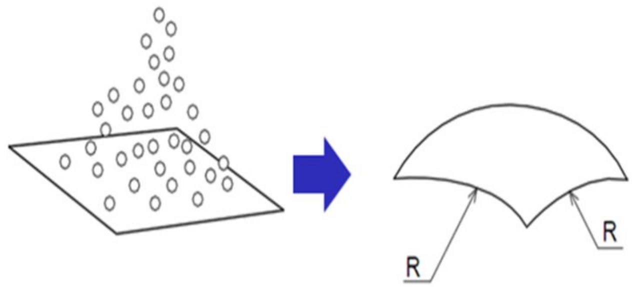


Fig. 5 Forming method wing panel for analysis

III. Result Of FE Analysis

A. *Results of FE Structural Analysis*

Table II shows the result of FE analysis in each part. The results of margin of safety for bellcrank (TED 16°) and (TED 24°) with this final design are 0.434 and 0.429 when the load is estimated to be insufficient to withstand. Bell crank joint connection with the piston rod in the most stress and displacement results showed values of the angle did not differ significantly [6]. The stroke is associated with the bellcrank joint was the most stress and displacement. However, the resulting values were different angle, TEU 24 ° at a TED 16 ° greater than the stress and displacement angles seen representing the larger part that the recipient can know the load is greater. The stroke, but also belong within the range of margin of safety is sufficient to withstand the loads are evaluated. When applied to the piston displacement amount 3000psi maximum pressure 0.105mm, Von-Mises Stresses in wing panel distribution after forming processes[7].

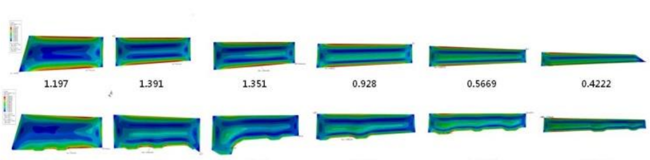


Fig. 6 FE Analysis of wing panel stress distribution after forming processes (5mm)

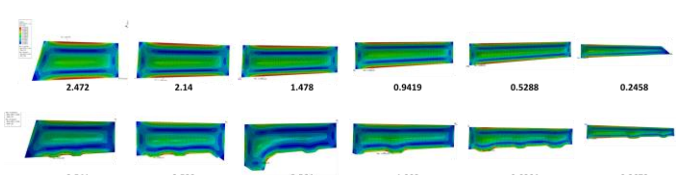


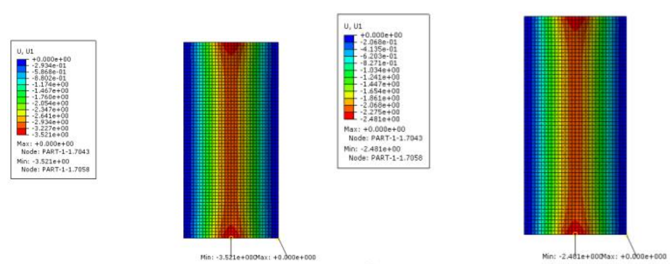
Fig. 7 FE Analysis of wing panel stress distribution before processes

In determining spanwise wing panel distribution from research it was determined that a roughly elliptical approximation would be most accurate. The design due to downwash effects lift decreases from root to tip along the span. This was calculated using a quarter ellipse, the area representing half the weight of the aircraft, as we were only analyzing one wing. The area of an ellipse is tab: Using optimization software we have designed and modeled the wing for the large wing panel. The wing panel is capable of withstanding the loads prescribed by the regulations. This results show FE analysis of 5mm thickness wing panel with base model wing by Optimise@ software in Fig. 6 and Fig. 7.

TABLE II
THE FORMING PROCCESS FOR WING PANEL

Processing speed(mm/s)	30 forming per sec.
30	3
60	5
250	25
500	50
750	75
1000	100
1250	125
1500	150
2000	**200**

B. *Results of Forming Analysis*



(a) 15mm- proceeding speed-60 mm/s (b) 10mm- speed-500 mm/s

Fig. 7 FE Analysis of wing panel proceeding speed

Some method to simulate the shot peen forming process have been presented[5]. This method is to use the thermal loads to set up the resitiual stress profile across the thickness of the sheet in Table III.

This method is presented, which also use the forming loads to produce the equivalent deformation (displacement) not the residual stress field. In this method use Almen strip[5], [6] is a thin strip quantify the intensity of a shot peening process, which can be expressed as follow.

$$\gamma = F(D, \eta, \Lambda....) \quad (1)$$

The variable consisted to main peening variables also should be set up according to experimental data. Where, γ is the arc height of Almen Strip, i.e. the shot peening strength. The loads use to a compressive residual stress layer and modify mechanical properties of metals. It entails impacting a surface with shot peening[8], [9].

TABLE III
THE RESULTS OF PEENING PROCCESS FOR WING PANEL

Arc [mm]			
Thickness	Peening speed	FEM Analysis	Experimental
15	30	2.62	2.62/2.64
15	60	2.38	2.3/2.4
10	250	3.52	3.47/3.66
10	500	2.48	2.48/2.5
10	750	1.74	1.71/1.78
6	500	6.78	6.22/6.34
6	1000	3.81	3.56/4.01
6	1250	2.68	2.55/2.98
6	1500	2.53	2.3/2.5

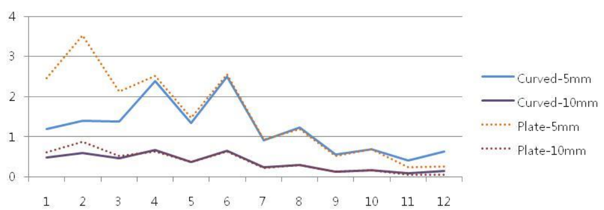


Fig. 8 Results of each shapes of wing panel

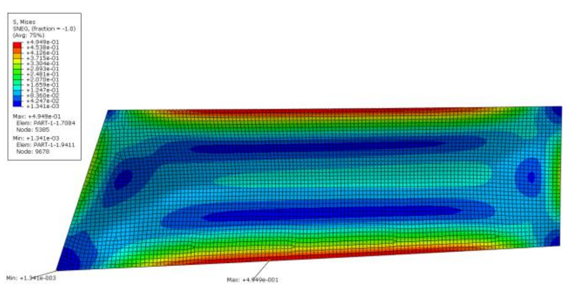


Fig. 9 Results of 10mm thickness, forming press - 0.1N (section1)

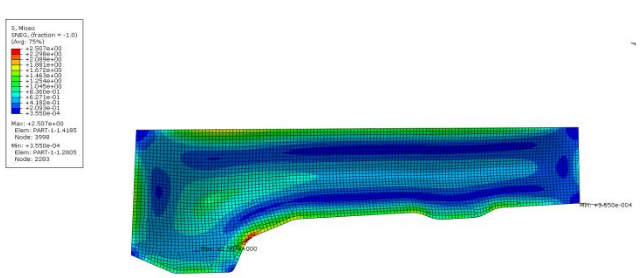


Fig. 10 Results of 10mm thickness, forming press - 0.1N (section 6)

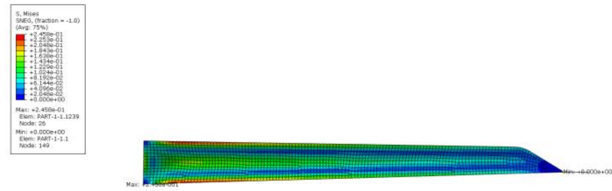


Fig. 11 Results of 5 mm thickness, forming press - 0.1N (section 11)

Table III and Fig. 8 shows the result of FE analysis in each thickness compares FE analysis to experimental results when the load is estimated to be insufficient to withstand. The first point needs special attention here because the residual stresses are very high in wing panel in some section in Fig. 10 and Fig. 11 . Also, in the Fig. 9, Fig. 10 and Fig. 11 showed the FE results of shot peening some different parameters with thickness, forming loads and shot speed.

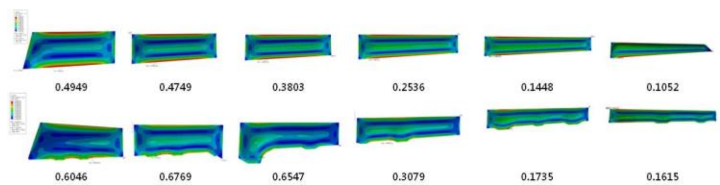


Fig. 12 Results of 10 mm thickness: Analysis of wing panel stress distribution before peening processes

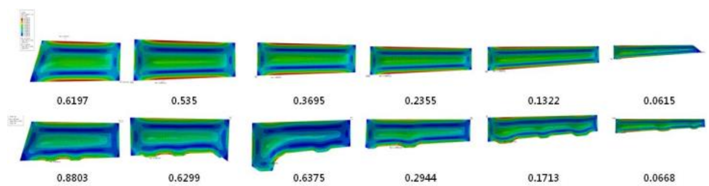


Fig. 13 Results of 10 mm thickness: Analysis of wing panel stress distribution after peening processes

These wing panel complex structures are also able to be simulated with the method. Fig.12 and Fig. 13 are the peening track of a wing-skin panel with strengthening ribs along the longitudinal direction.

IV. CONCLUSION AND DISCUSSION

The simulated shape form of the wing panel is very in agreement with that of peening process. The results show that the shot peen forming process can he simulated using different loads according to the rule of equivalent displacement (strain). Verification calculations prove the model developed in Sim Design and ABAQUS 5.7 and Optimise@ as being accurate. The shot velocity and the shot coverage ratio on the stress distribution and plastic layer were analyzed by impact model with the dynamic explicit FEM. Through comparison of the experimental results and analysis, peeing processes of the results for the FE can secure the with wing panel due to the number of design guidelines to provide for the endurance. The shot peen forming process is able to he modeled with static implicit finite element method through equivalents loads with the help of the Almcn Strip.

http://dx.doi.org/10.15242/IIE.E0514598

ACKNOWLEDGMENT

This research was supported by the Korea Institute for Advancement of Technology(KIAT), supporting fund of Dongnam Leading Industry Office in 2013 by grant No. 2013-0283.

REFERENCES

[1] G. J. Kennedy. Aerostructural analysis and design optimization of composite aircraft, PhD thesis , University of Toronto 2012.
[2] D. Vantuchcne and E. J . Cramcr. Numerical n~odclingo f'a wing sltin peen forming process. *J. of Materials Engineering and performance*, 1996, S(6). 753-760.
[3] Y. Zeng, Finite Element Simulation of Shot Peen Forming, Beijing Aeronautical Manufacturing Technology Research, 2003.
[4] A. Levers, Alan Prior. Finite element onalysis of sliot peening. S. of' Materials Processing, 1998.
[5] "Shot Peening," *Tool and Manufacturing Engineers Handbook* (TMEH), Volume 3, Society of Manufacturing Engineers, 1985
[6] Kirk, David, "Non-Uniformity of Shot Peening Coverage," *The Shot Peener*, Electronics, Inc., Summer 2009
[7] Syed A. Nasar, "Linear electric motors : Theory, Design, and Pratical Applications", 2008, Prentice-Hall. Inc.
[8] P. C. Sen, "On linear synchronous motor (LSM) for high speed propulsion", IEEE Transaction on Magnetics, Vol. Mag-11, No.5, September, 1975, pp 1484-1486.
http://dx.doi.org/10.1109/TMAG.1975.1058873
[9] C. W. Jun, K.Y. Park and Q. S. Kang, "On the Static Test of Aileron Control System for a Basic Trainer" KSAS journal, Vol. 28, No. 3, 2000, pp. 150-155.