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## STRENGTH AND BUCKLING ANALYSIS OF A COMPOSITE WING STRUCTURE USING MSC.PATRAN AND MSC.NASTRAN

**Abstract:** The Wing of airplane considers the most important component between other components of airplane due to simple fact that the airplane has no ability to fly without wing and other elements depend on it. These importance's of wing come from the aid of wing that it must supply airplane with sufficient lift force (L). So due to this important, modern design are achieved by using software to enhance the design and produce better results. The aim is to describe wing structure and components by using Patran 2011 by MSC Software Company and then analyze this structure by using Nastran 2011 by MSC Software Company to see the behave of this wing under strength and buckling test for different composite material and estimate the proper structure of wing and material which will provide minimum value of Equivalent stress and maximum value for buckling load factor. We will have a model of wing for small acrobatic airplane with high overloads acting on the wing ( $n = 12$ ) and safety factor equal 1.5 to insure maximum safety design.

**Key words:** Stress, Buckling, Skin, Ribs, Spar, Support, MSC. Patran, MSC. Nastran, Wing, composite material.

**Language:** English

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### Introduction

We will concentrate on analysis of aircraft wing structure. The designed wing for small aerobatic airplane with mass is not greater than 650 kg. We select airplane with one wing (Monoplane) and mid vertical wing position with trapezoidal shape, Symmetrical airfoil has been chosen - NACA 0015 with dimension, wing span = 7m, wing width = 3m, Root chord = 1.6m and Tip chord = 0.8m see Fig.1, nine ribs used with distance between each ribs is 0.375 m, two spars (front & rear) the main spar is located in 25% of ribs length (from leading edge), the rear spar is located in 75% of ribs length see Fig.2. Fig.3 shows the wing components of our model. For aviation regulation for aerobatic airplane the value of overloading capability must be more than  $n = 6$  as example "Red Bull Air Race,  $n = 10$ " so for us we assume  $n = 12$  to insure high performance. Safety factor also must be taking into account due to the Certification Specification. Regulation CS - 23.303, which stays that safety factor equal (1.5).[1][2][3][4]

### The Aim and Scope

1. Estimate required thicknesses for metal structure to satisfy statics and stability requirements. Determine the mass of metal wing.
2. Propose a wing skin manufactured as sandwich material (layered composite skins of sandwich). Determine the mass gain - still stress and buckling limits have to be satisfied.
3. For Sandwich structure check the Failure Indices (Max Stress theory).

### The Entry Assumptions

1. Simplified wing design, given as an input data
2. "Metal version" design applied also to composite structure without modification.
3. Aileron omitted in wing structure.
4. Simplified load value and application - constant pressure resulting from smearing lift force over the wing. Only bottom surface overpressure, no under pressure on top surface.
5. The lift force approximated from assumed load factor  $n=12$ , without precise recalculation from

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e.g “equilibrium of aircraft for D point of the load envelope”.

### The Simplifications

1. Global structural model, without local effects (connections, rivets, bolts, glue, cutouts).
2. Varying thickness of the skin – larger for inner part of the wing, smaller for outside part.
3. Common mid-surface for both sandwich skins, offset not used.
4. The spars and ribs kept in metal – only wing skin modeled as sandwich.
5. As bending load only considered – no 45deg layer used in skin of sandwich – only 0/90 layers used.
6. Linear statics and linear buckling analysis performed.
7. Thin shell elements applied.
8. Linear Laminate Theory used – classic.
9. Failure of composite estimated using “Max Stress theory” – more advanced material data not available.

### Materials

From material point of view wing analysis will be performed for two cases. First case assumes that wing is made of aluminum, whereas second one applies composite material.

1-Aluminum: - Aluminum has been chosen for the former case due to the fact that it is one of the most common materials used in wing structure design. We used Aluminum Alloy 2024 T3 see Table 1.

2-Composite material: - Among many composite materials available an E – Glass / Epoxy has been selected. Analysis of composite structure requires more attention than metal one, because of its specific failure behavior, which is more complex than in case of aluminum. Sandwich plate system is an alternative to conventional stiffened plate composition that consists of two metal plates separated by a core. Considering high strength to weight ratio, simplicity, blast and ballistic properties of the material. The properties for region 1&2 in the Table 2. In Table 3 we can see composite material properties E – Glass / Epoxy for layer and core. [5][6][7][8][9][10]

### Test Models

After complete the drawing the model in Patran, Fig. 4 we can see the model without the upper surface to show the details of the model. Fig. 5 we can see the all model after finishing the mesh. Fig. 6 we specify the (Loads/BCs), we applied uniform pressure with value = 0.0161 on the lower surface of the wing. We chose for materials (Aluminum) with property shown in “material

section” and without applied any pressure on the upper surface Fig.7.

### Case 1

In this Case we divided the wing into two region with different thicknesses see Fig.8, Region 1, 2 & Flange, (A) The wing (Our model), (B) Region 2 with properties (Sandwich plate region), (C) Region 1 with properties (Sandwich plate region), (D) Flange, The rest (front & back spar, ribs, support) of model except flange (2mm thickness) Fig.9. Flange divided to five groups with different thickness (14, 12, 10, 8, 4mm) Fig.10.

### Case 2

In Case 2 we using composite material instead of aluminum in the Sandwich plate region, Fig.11 A (region1 Sandwich plate region with 8 layer (thickness = 0.125 mm for each layer) and one layer core (thickness = 10 mm) B, region 2 Sandwich plate region with 6 layer (thickness = 0.125 mm for each layer) and one layer core (thickness = 10 mm), and the property of material we can see it in material section, and other group (flange, ribs, support and front & back spar are the same in the Case 1).

### Results

When we run the program we run it for stress and buckling, and the results are:-

#### Case 1

Results for stress shows in Fig.12 (A) we can see the Equivalent stress result for all model with maximum value is 571 MPa and it happened in the contact region between fuselage and wing see also (B), (C), (D) and (E). Fig.13 BLF (buckling load factor) = 2.1361.

#### Case 2

Results for stress shows in Fig.14 (A) we can see the Equivalent stress result for all model with maximum value is 562 MPa and it happened in the contact region between fuselage and wing see also (B) connection region between fuselage and wing, (C) flange, (D) Front & Back spar, Ribs and support. If we see Fig.14 (A) we see result for all model but it's not give as good clarification to what really happened because we use Sandwich plate with composite material and we see the result in von Mises At Z1 so if we want to see good clarification just see Fig.15 Stress Tensor result in x component direction, (A) For all model, (B) layer 1, (C) layer 2, (D) layer 3, (E) layer 4, (F) layer 5, (G) layer 6, (H) layer 7, (I) layer 8, (J) layer 9. Due to the Sandwich plate in region 1 composed of, 8 layer 1 core for region 2, 6 layer 1 core so we but picture to all layer because not all layer have the same influence due to the direction of layer so from Fig.15 we see layers 2, 3, 7 and 8 is effected because it's in the direction of X components but layers 1, 4, 5, 6 and 9 with almost not effected. Fig.16 we can see the Equivalent stress

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result in z component direction, (A) For all model, (B) the most effected part (lower skin) because the applied force on the (lower region), (C) layer 1, (D) layer 2, (E) layer 3, (F) layer 4, (G) layer 5, (H) layer 6, (I) layer 7, (J) layer 8, (K) layer 9, layer 1, 4, 6 and 9, is the most influential layers see Fig. 18 because this layers in direction of Z direction, layers 2, 3, 5, 7, and 8 less effected.

Fig.17 we can see BLF (buckling load factor)= 2.5016, (A) For all model, (B) region 1&2 buckling, (C) flange buckling, (D) Front & Back s par, Ribs and support buckling. Fig.18. Show the layer organize and orientation and  $\sigma_x$ ,  $\sigma_z$  directions and according to this Figure we can see why they're difference in layer in behavior against the stress.

Now after finishing from result of Equivalent stress result and BLF (buckling load factor) we will calculate the failure indices (FI) for E – Glass / Epoxy, using the information in Table 3 (Composite material properties E – Glass / Epoxy) and the result shown in Table 4. Fig.19, Fig.20 can see a detailed description to each layer for region 1&2.

### Conclusions

Simulation is the one of best way that are used in mechanical design, especially in aircraft structure

due to fact that the simulation provide complete picture about design and give us primary indication to weak point of the design which allow us to modification the structure to reach the best design.

MSC Patran and MSC Nastran is the one off the leader program in this field, we using it to build our model from different composite material and test it to strength and buckling.

Case 1&2 we use the same structure component but with different composite material. Case 1 we use Aluminum Alloy 2024 T3, Case 2 E – Glass / Epoxy and according to result we get it in two Cases we can see in Case 1 the value of stress = 571 MPa and for Case 2 the value of stress = 562 MPa and for us minimum value of stress is better. For buckling we can see in Case 1 the value of BLF = 2.1361 and happened in region 2, for Case 2 the value of BLF = 2.5016 and happened in region 1 and for us maximum value of BLF is better.

Weight of the wing is important parameter, in Case 1 the mass of wing = 38.27 kg, in Case 2 the mass of wing = 23.98 kg so the difference in weight almost 15 kg and it's very important to us to minimize the mass of wing. Such as in modern aerobatic airplane the engineering using composite material.

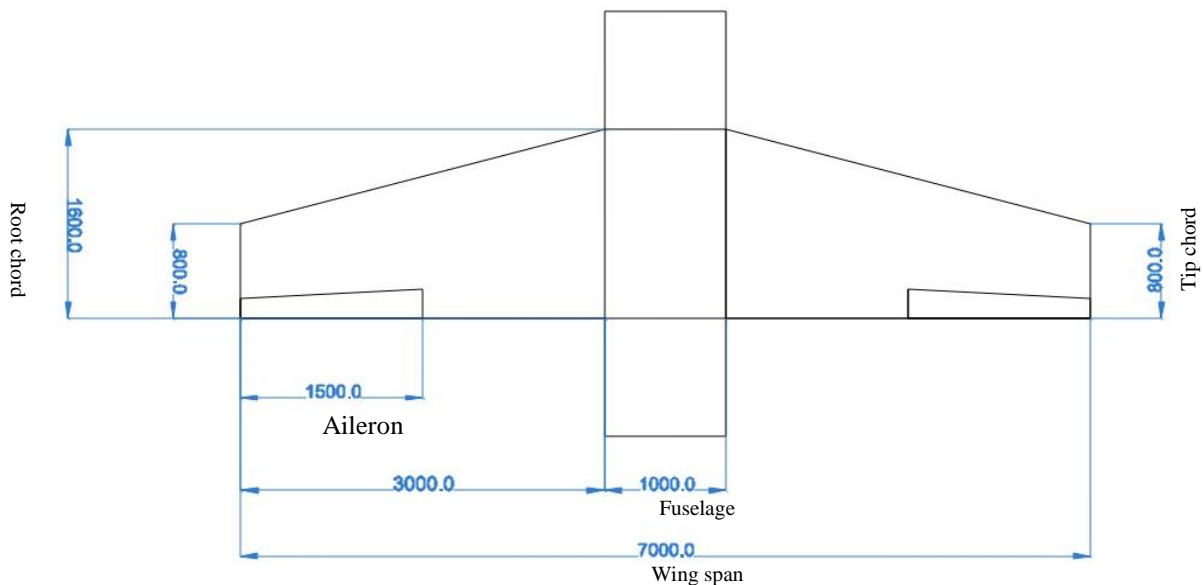


Figure 1 - Wing sketch (all dimensions in mm, drawn in AutoCAD software).

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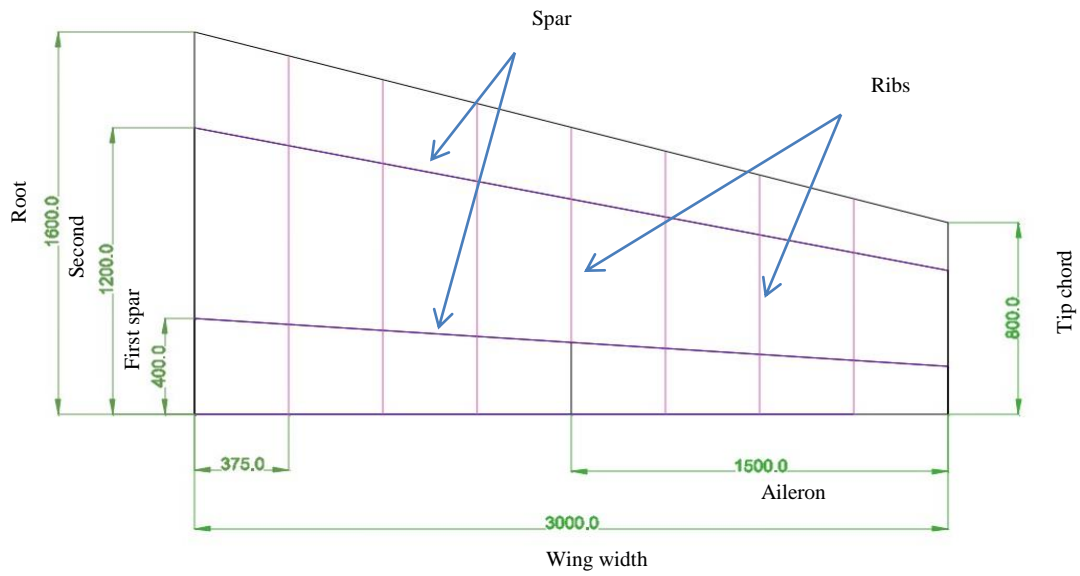


Figure 2 - Wing sketch (all dimensions in mm, drawn in AutoCAD software).

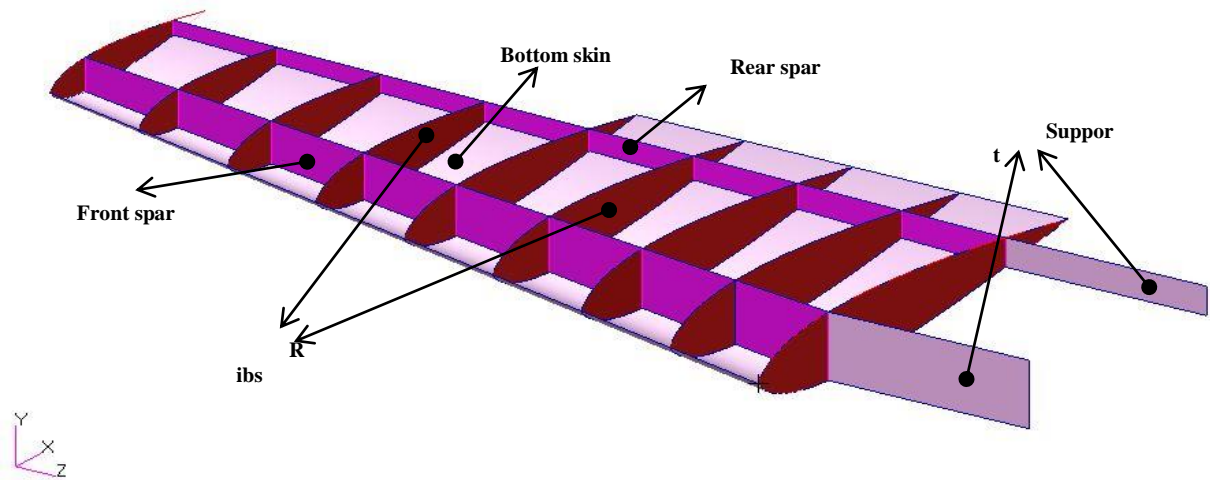


Figure 3 - Wing components of our model.

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**Table 1**

**Metal material property – Aluminum Alloy 2024 T3.**

Parameter	Value	Unit
Elastic Modulus	73000	MPa
Poisson Ratio	0.33	-
Density	2.77E-09	t/mm3

**Table 2**

**Properties for region 1&2.**

Region	Layer No.	Thickness (mm)	Orientation (degree)
Region 1	Layer 1	0.125	0°
	Layer 2	0.125	90°
	Layer 3	0.125	90°
	Layer 4	0.125	0°
	Core	10	0°
	Layer 5	0.125	0°
	Layer 6	0.125	90°
	Layer 7	0.125	90°
Region 2	Layer 1	0.125	0°
	Layer 2	0.125	90°
	Layer 3	0.125	0°
	Core	10	0°
	Layer 4	0.125	0°
	Layer 5	0.125	90°
	Layer 6	0.125	0°

**Table 3**

**Composite material properties E – Glass / Epoxy.**

Region	Parameter	Value	Unit
Layers	Elastic Modulus 11	43000	MPa
	Elastic Modulus 22	9700	MPa
	Poisson Ratio	0.26	-
	Shear Modulus	6200	MPa
	Density	2e-09	t/mm <sup>3</sup>
	Tension Stress Limit 11	1 070	MPa
	Tension Stress Limit 22	38	MPa
	Compression Stress Limit 11	870	MPa
	Compression Stress Limit 22	185	MPa
	Shear Stress Limit	72	MPa
	Bonding Shear Stress Limit	28.8	MPa
Core	Elastic Modulus 11	1000	MPa
	Elastic Modulus 22	1000	MPa

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Poisson Ratio	0.3	-
Shear Modulus 12	400	MPa
Shear Modulus 23	1000	MPa
Shear Modulus 13	1000	MPa
Tension Stress Limit 11	100	MPa
Tension Stress Limit 22	100	MPa
Compression Stress Limit 11	100	MPa
Compression Stress Limit 22	100	MPa
Shear Stress Limit	50	MPa

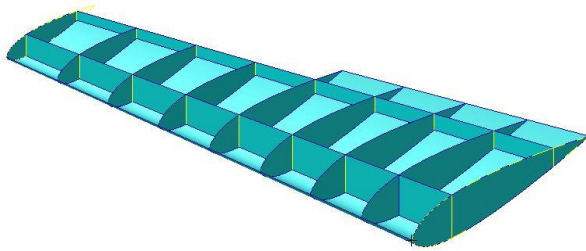


Figure 4 - Wing draw in Patran.

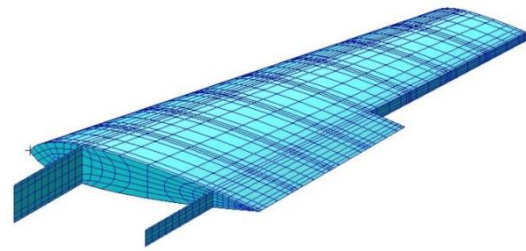


Figure 5 - Wing after meshing draw in Patran.

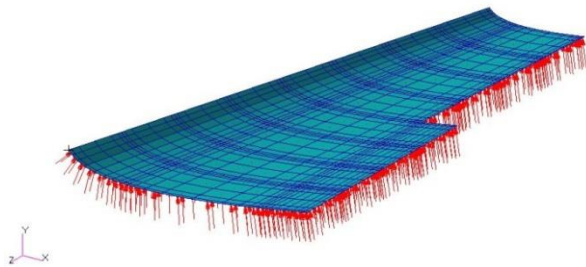


Figure 6 - Pressure applied in the bottom surface.

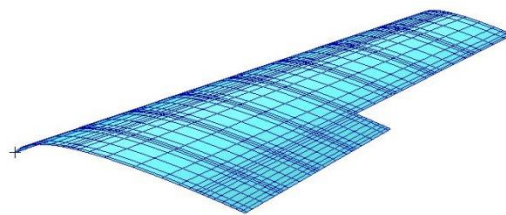


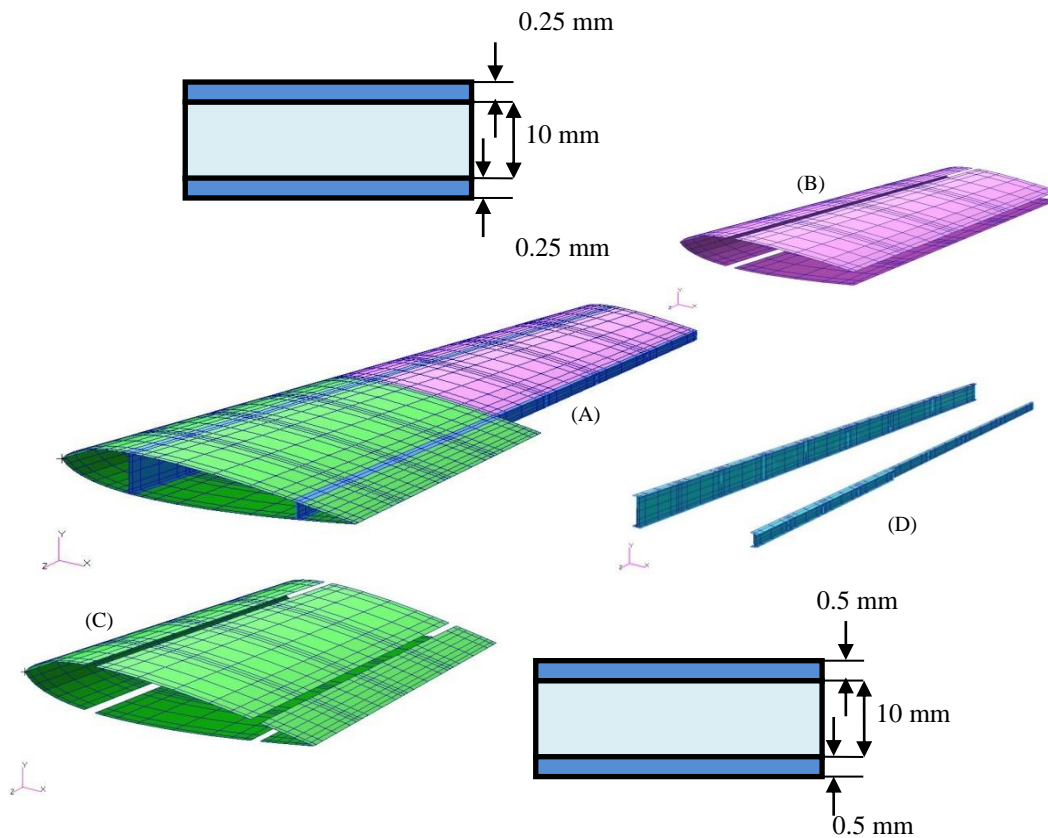
Figure 7 - Upper skin of the wing.

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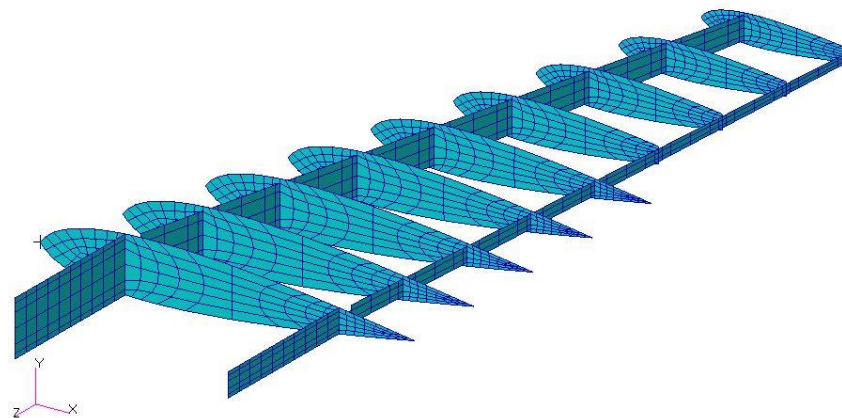
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**Figure 8 - Region 1, 2 & Flange, (A) The wing (Our model), (B) Region 2 with properties (Sandwich plate region), (C) Region 1 with properties (Sandwich plate region), (D) Flange.**



**Figure 9 - Front & Back spar, Ribs and Support.**

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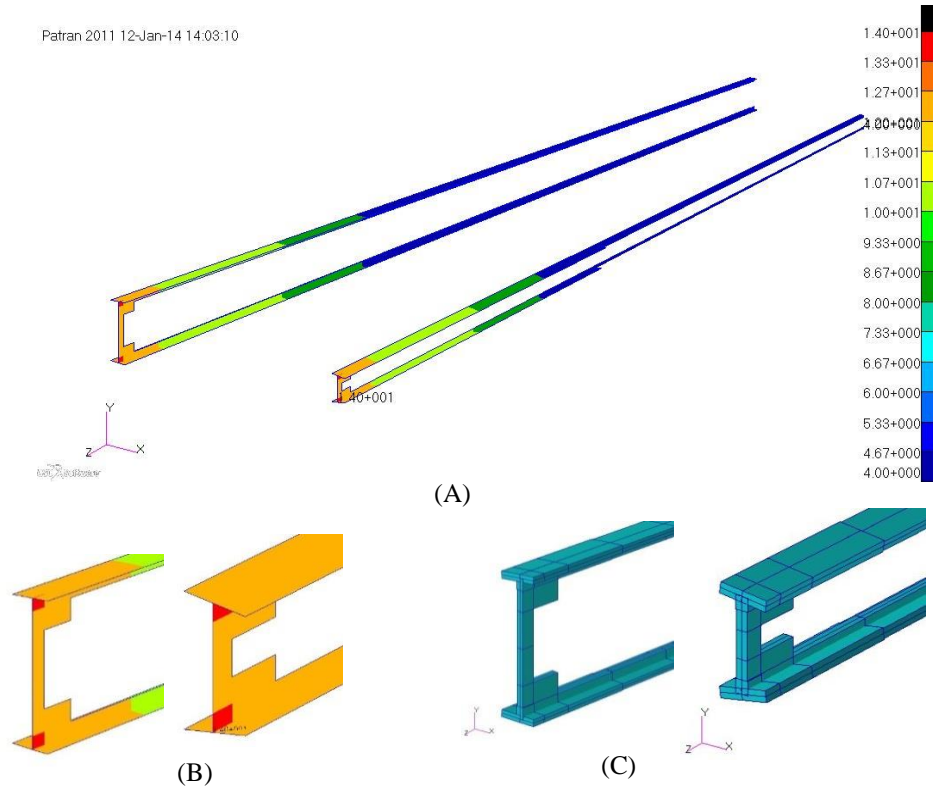


Figure 10 - (A) Flange according to thickness, (B) Close image of flange, (C) 3D view.

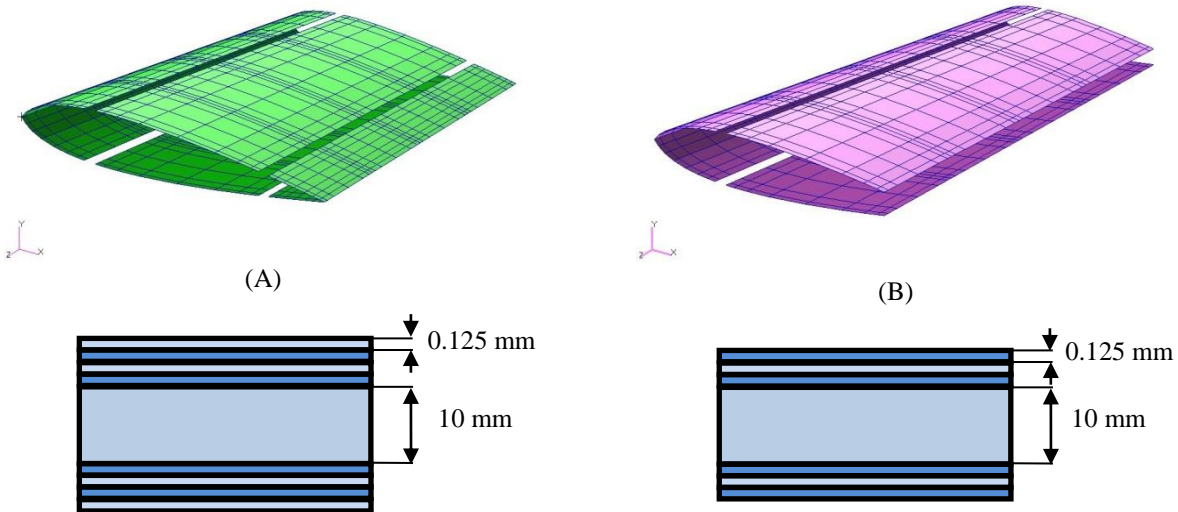


Figure 11 - (A) region 1 Sandwich plate region with 8 layer (thickness = 0.125 mm for each layer) and one layer core (thickness = 10 mm), (B) region 2 Sandwich plate region with 6 layer (thickness = 0.125 mm for each layer) and one layer core (thickness = 10 mm),



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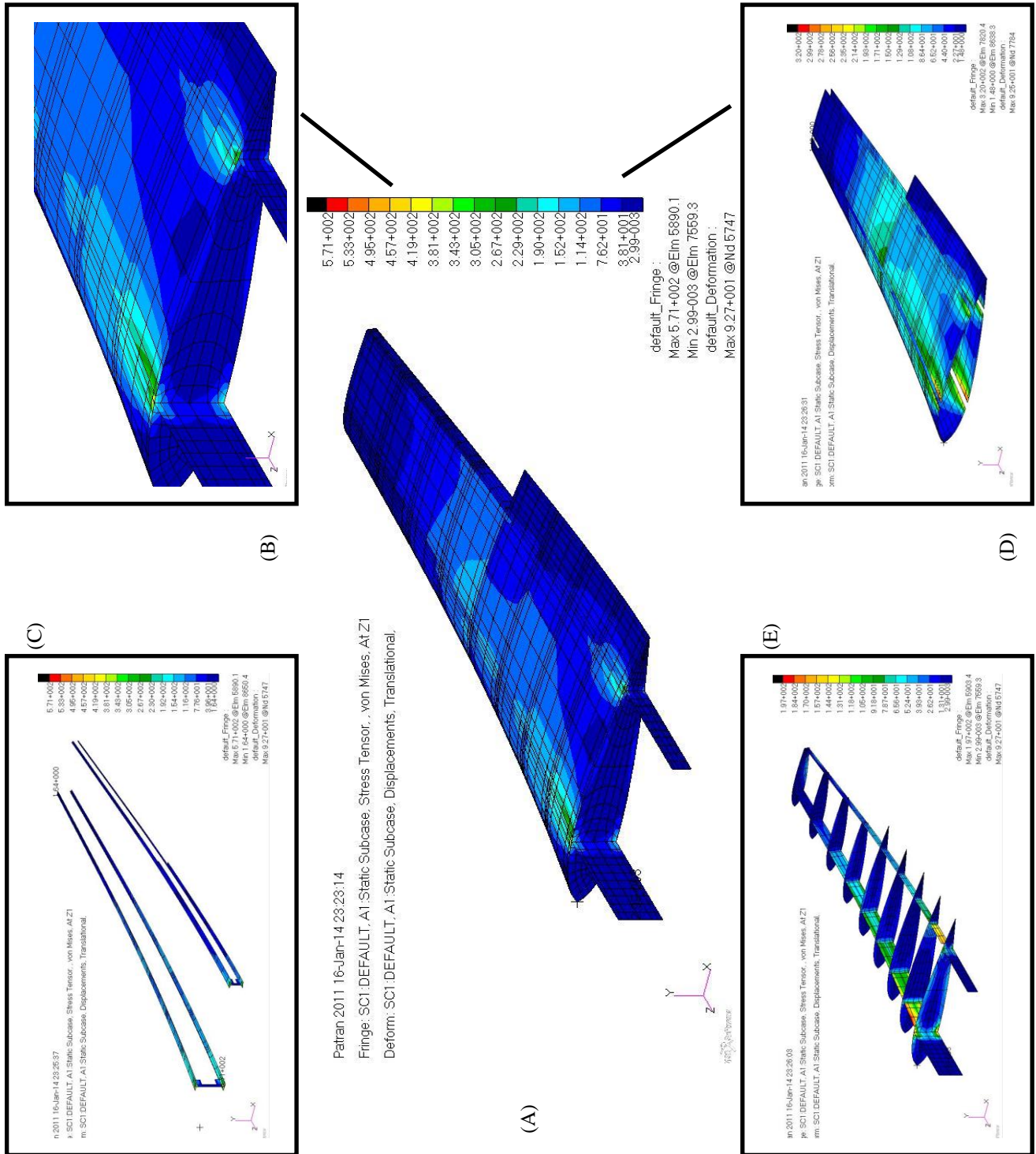


Figure 12 - Stress Tensor, (A) For all model, (B) connection region between fuselage and wing, (C) flange, (D) Region 1&2 (E) Front & Back spar, ribs and support.

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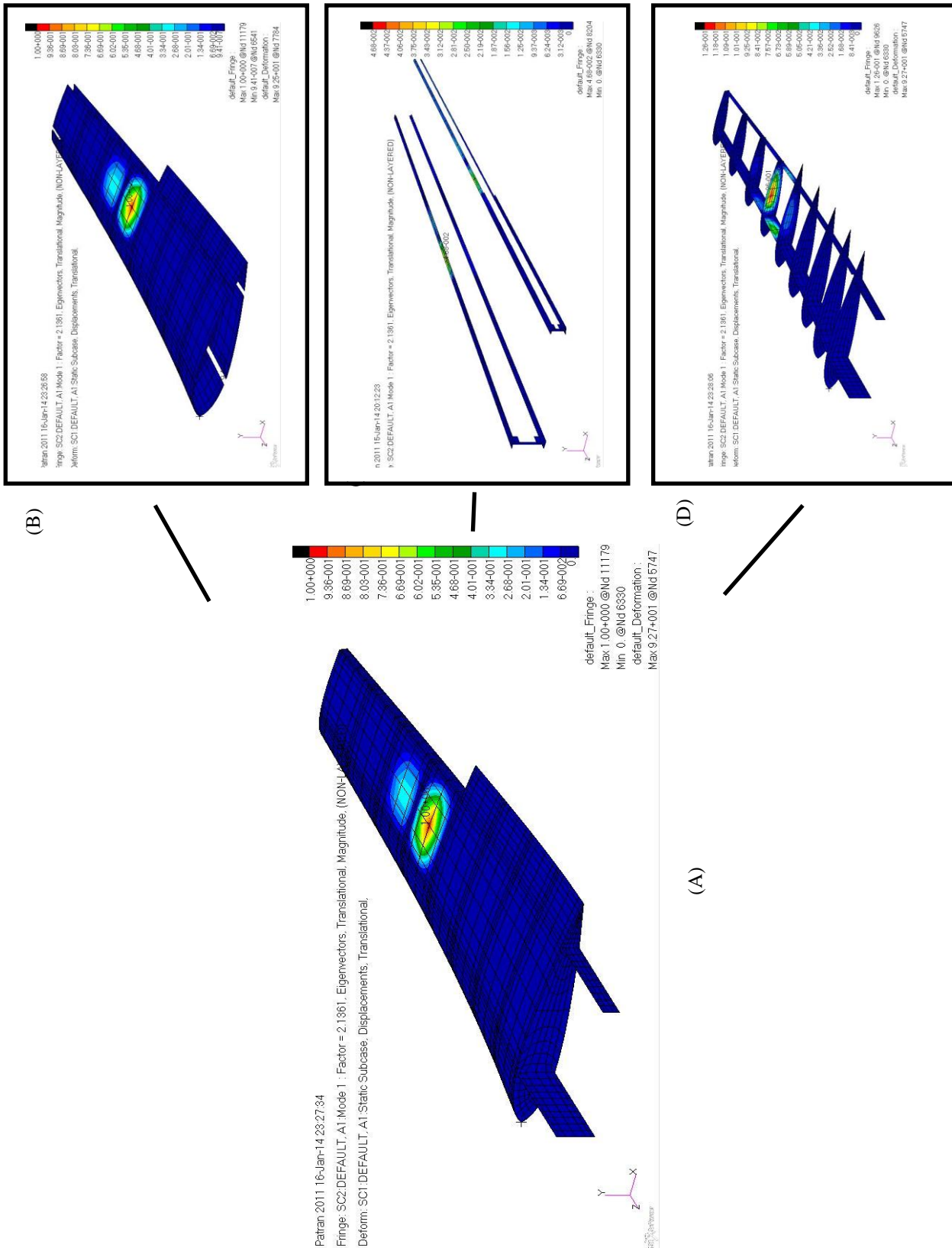


Figure 13 - Buckling result, (A) For all model, (B) region 1&2 buckling, (C) flange buckling, (D) Front & Back s par, Ribs and support buckling.

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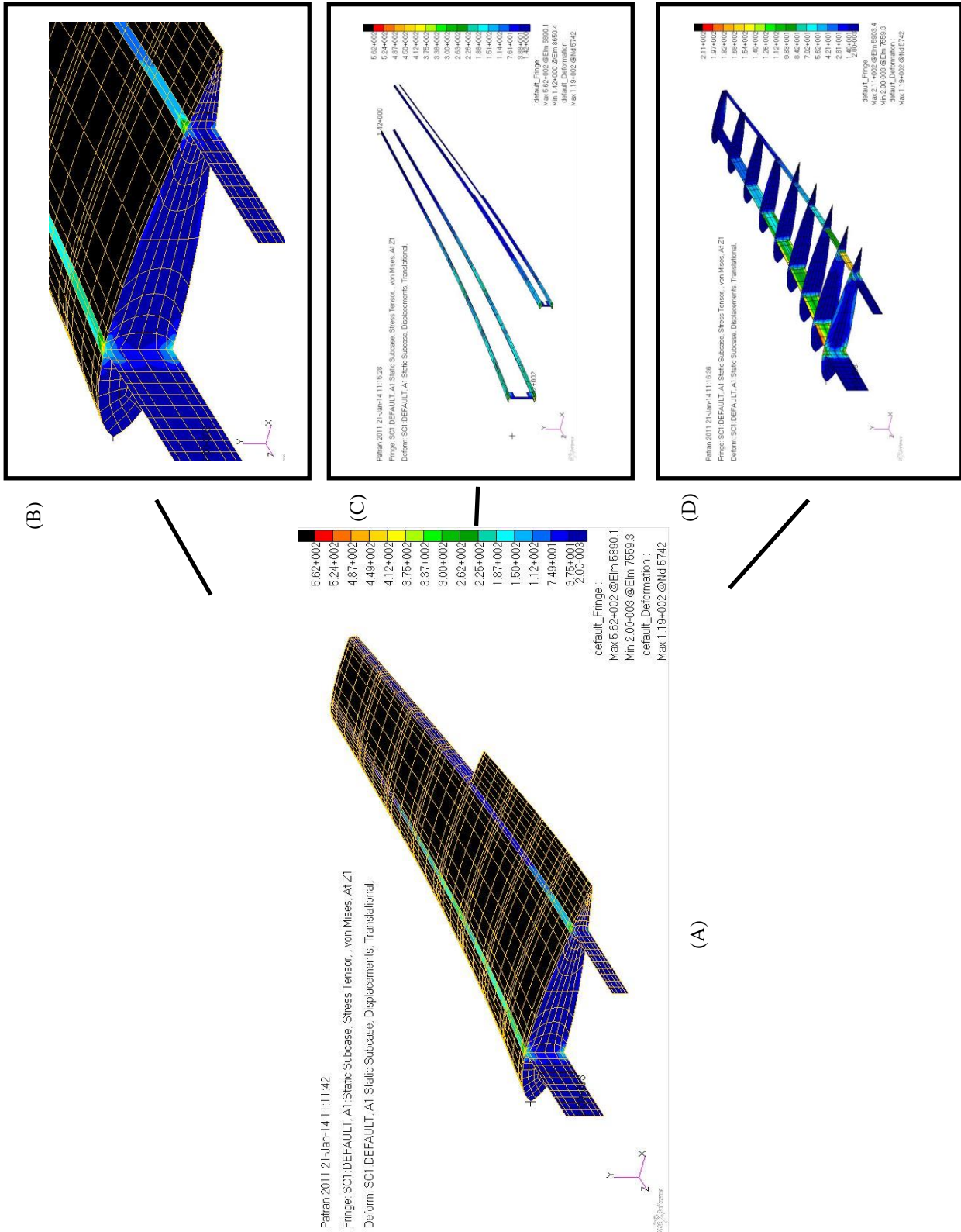


Figure 14 - Stress Tensor result, (A) For all model, (B) connection region between fuselage and wing, (C) flange, (D) Front & Back spar, Ribs and support.

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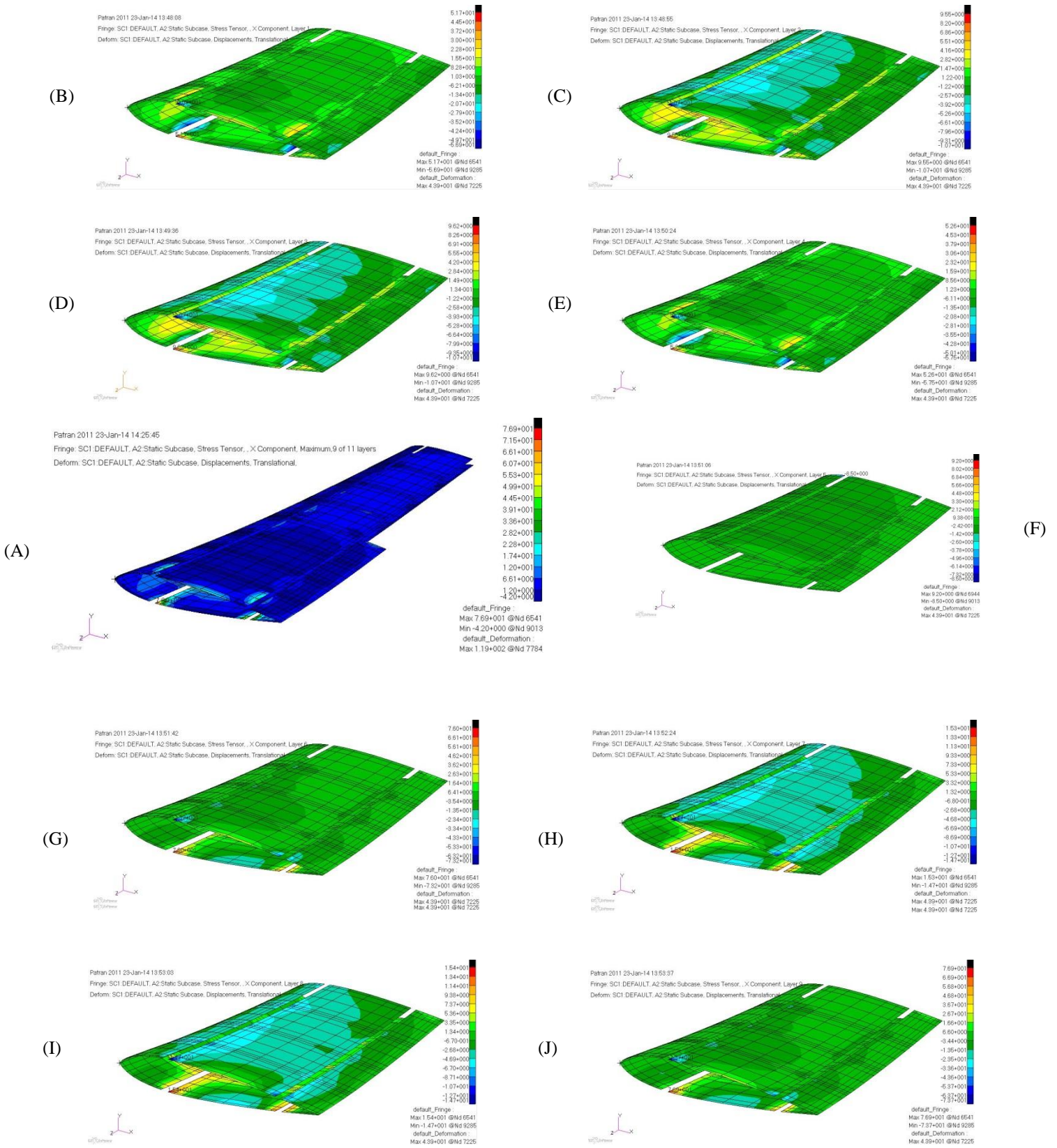


Figure 15 - Stress Tensor result in x component direction, (A) For all model, (B) layer 1, (C) layer 2, (D) layer 3, (E) layer 4, (F) layer 5, (G) layer 6, (H) layer 7, (I) layer 8, (J) layer 9.

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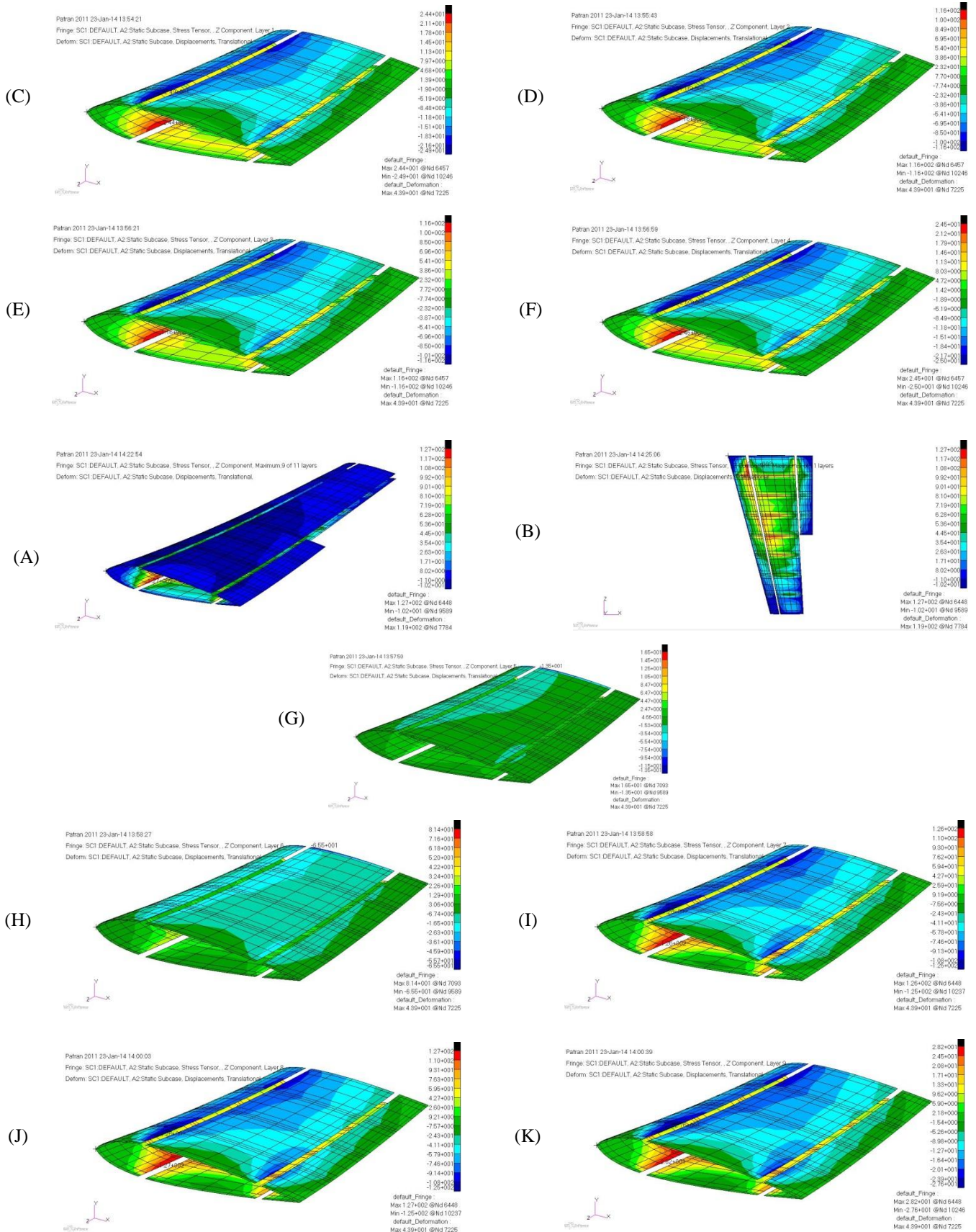


Figure 16 - Stress Tensor result in z component direction, (A) For all model, (B) the most effected part (lower skin), (C) layer 1, (D) layer 2, (E) layer 3, (F) layer 4, (G) layer 5, (H) layer 6, (I) layer 7, (J) layer 8, (K) layer 9.

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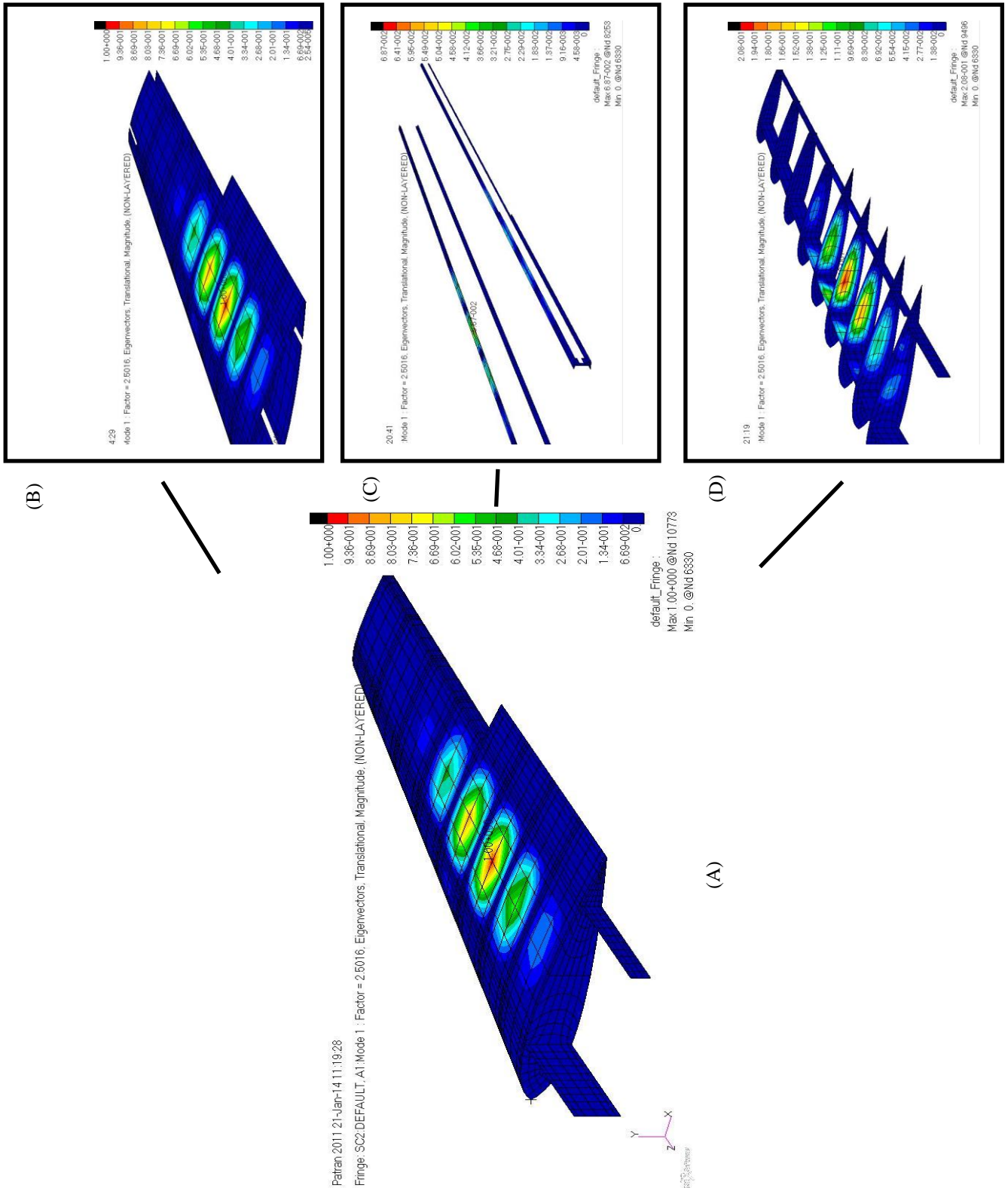


Figure 17 - Buckling result, (A) For all model, (B) region 1&2 buckling, (C) flange buckling, (D) Front & Back s par, Ribs and support buckling.

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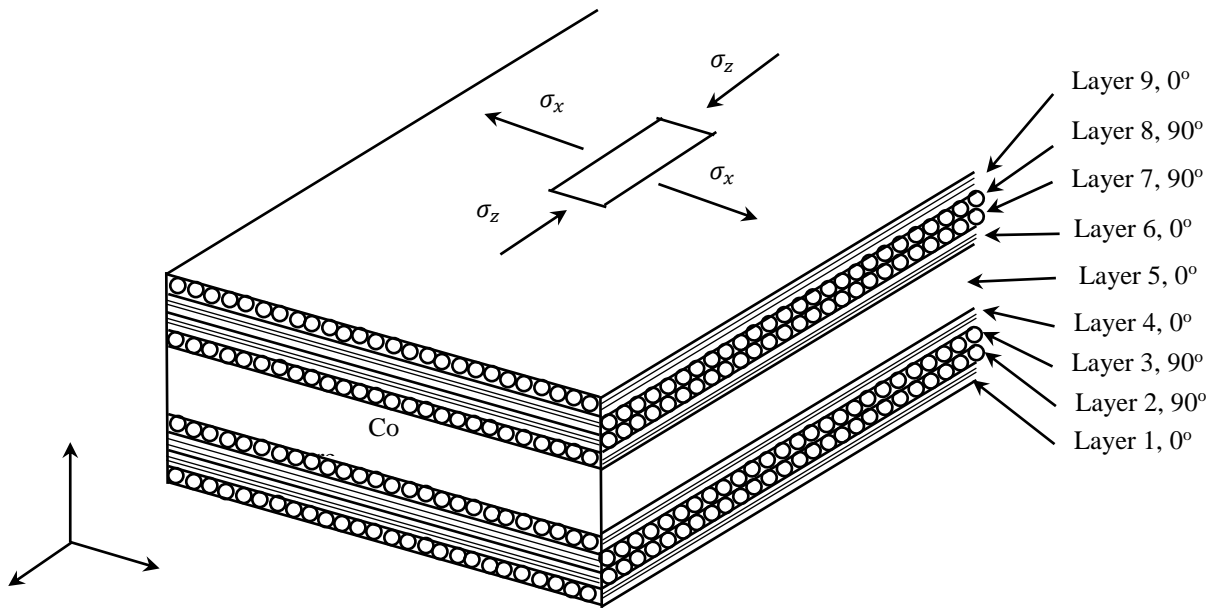


Figure 18 - Show the layer organize and orientation and  $\sigma_x, \sigma_z$  directions.

Table 4

The failure indices (FI) for E – Glass / Epoxy.

Region	Layer No.	Max. FI for layer	Orientation (degree)
Region 1	Layer 1	0.690	0°
	Layer 2	0.679	90°
	Layer 3	0.679	90°
	Layer 4	0.692	0°
	Core	0.062	0°
	Layer 5	0.744	0°
	Layer 6	0.663	90°
	Layer 7	0.663	90°
Region 2	Layer 1	0.529	0°
	Layer 2	0.258	90°
	Layer 3	0.530	0°
	Core	0.023	0°
	Layer 4	0.824	0°
	Layer 5	0.246	90°
Layer 6	0.840	0°	

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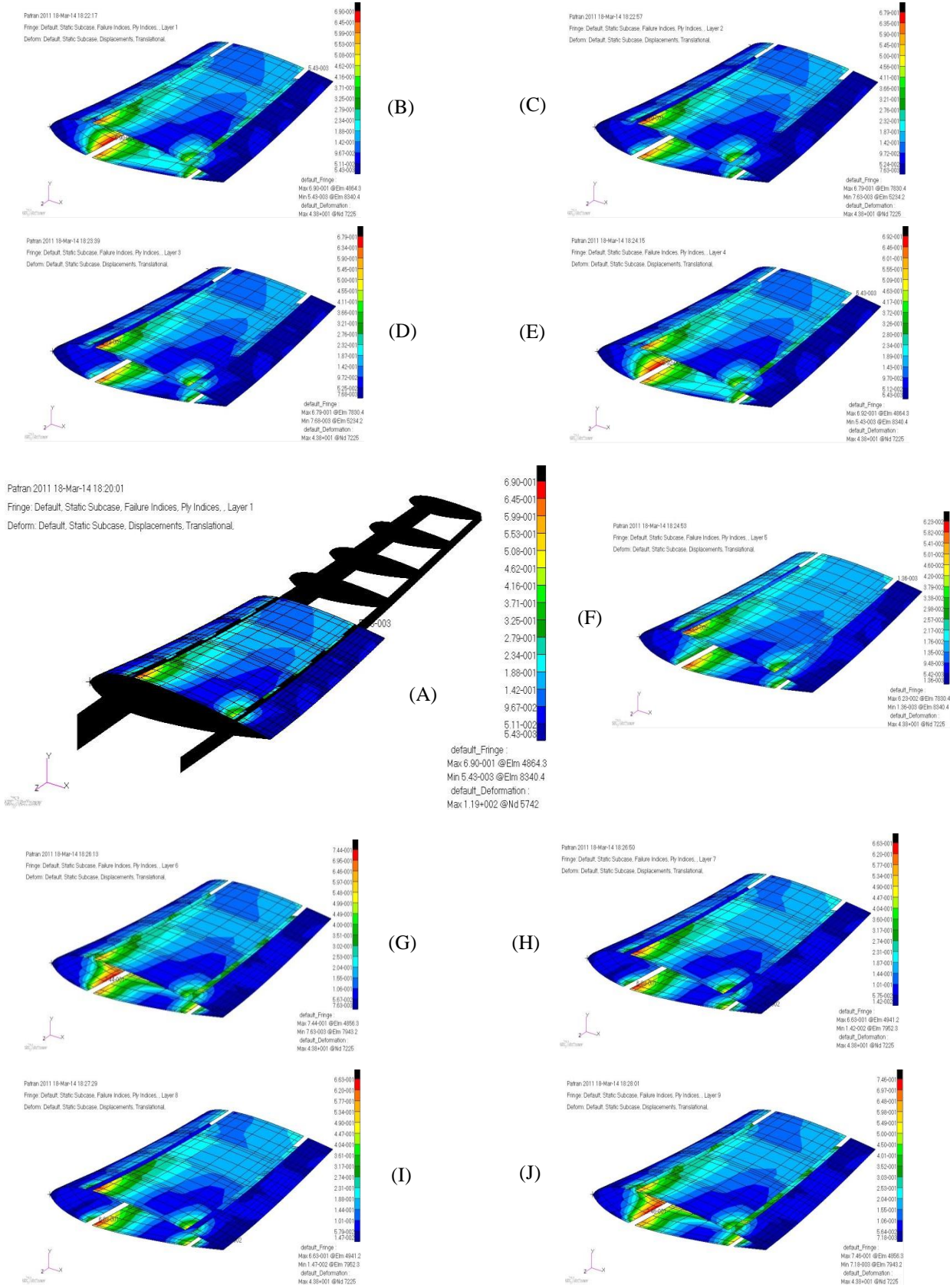


Figure 19 - Failure indices result, (A) For region 1 with all model, (B) layer 1, (C) layer 2, (D) layer 3, (E) layer 4, (F) layer 5, (G) layer 6, (H) layer 7, (I) layer 8, (J) layer 9.



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 ПИИЦ (Russia) = 0.179  
 ESJI (KZ) = 1.042  
 SJIF (Morocco) = 2.031

ICV (Poland) = 6.630

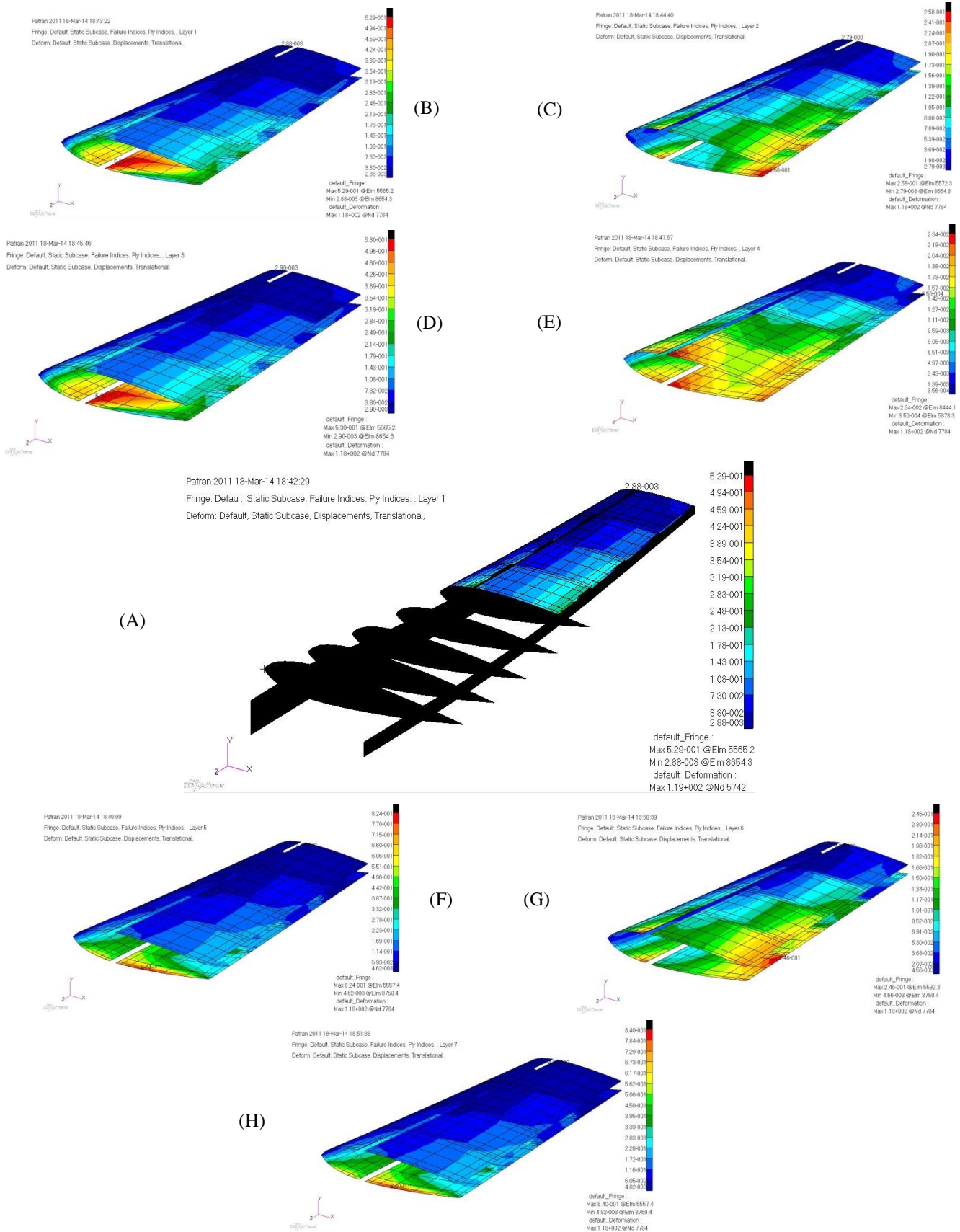


Figure 20 - Failure indices result, (A) For region 2 with all model, (B) layer 1, (C) layer 2, (D) layer 3, (E) layer 4, (F) layer 5, (G) layer 6, (H) layer 7.

## Impact Factor:

ISRA (India) = 1.344  
ISI (Dubai, UAE) = 0.829  
GIF (Australia) = 0.356  
JIF = 1.500

SIS (USA) = 0.912  
ПИИИ (Russia) = 0.179  
ESJI (KZ) = 1.042  
SJIF (Morocco) = 2.031

ICV (Poland) = 6.630

## References:

1. (2015) Available: [http://www.aeronautics.nasa.gov/pdf/wing\\_desi\\_gn\\_k-12.pdf](http://www.aeronautics.nasa.gov/pdf/wing_desi_gn_k-12.pdf) (Accessed: 01.08.2015).
2. (2015) Available: <http://airfoiltools.com/airfoil/details?airfoil=naca0015-il> (Accessed: 01.08.2015).
3. (2015) Private pilot- Handbook of Aeronautical Knowledge, by pro Aviation Media LLC.
4. (2015) Available: <http://www.gpo.gov/fdsys/pkg/CFR-2008-title14-vol1/pdf/CFR-2008-title14-vol1-sec23-303.pdf> (Accessed: 01.08.2015).
5. (2015) Available: [http://www.alcoa.com/mill\\_products/catalog/pdf/alloy2024techsheet.pdf](http://www.alcoa.com/mill_products/catalog/pdf/alloy2024techsheet.pdf) (Accessed: 01.08.2015).
6. (2015) Available: <http://www.makeitfrom.com/material-data/?for=2024-T3-Aluminum> (Accessed: 01.08.2015).
7. (2015) Composite materials: Science and application, by Deborah D. L. Chung.
8. (2015) Structural Composite Materials, By F. C. Campbell.
9. (2015) Available: [http://www.oceanica.ufrj.br/ocean/coursead/materiaiscompositos/compositomaterials/f\\_aerosp ace\\_applications.pdf](http://www.oceanica.ufrj.br/ocean/coursead/materiaiscompositos/compositomaterials/f_aerosp ace_applications.pdf) (Accessed: 01.08.2015).
10. (2015) Available: <http://www.flightglobal.com/news/articles/creating-a-titan-199071/> (Accessed: 01.08.2015).

