EMB-145 NOSE LANDING GEAR DOOR STRESS ANALYSIS

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ABSTRACT:

In the present report the structural analysis of EMBRAER's EMB-145 Aircraft Nose Landing Gear Door (N.L.G.D.) is shown.

The EMB-145 Nose Landing Gear Door is attached to the aircraft fuselage through three hinges which are driven by a hydraulic actuator attached to the central hinge. The EMB-145 N.L.G.D. structure, is made of two solid prepreg carbon/epoxy laminated skins, cold bonded and fastened. Carbon/epoxy tape is used in order to avoid panel buckling and to increase the required stiffness of the Aerodynamic Smoothness Requirements for EMB-145. The hinges are machined from aluminum alloy, attached to the structure by titanium alloy bolts.

The EMB-145 Nose Landing Gear Door is designed to resist the critical aerodynamical loading in normal condition and in case one of the hinges fails.

The EMB-145 Nose Landing Gear Door structural analysis including finite element data, boundary conditions and acting loading are presented in this report. The present output results in MSC/NASTRAN allow one to obtain the most critical condition among all subcases very quickly, when post-processed.

1.0 INTRODUCTION

In the past, Chineses, Egyptians and Hebrew already had the knowledge of the technique of joining materials. For example, straw and clay were used to build walls. Since this period up to the present time, the man with his own bold technical, has benefited from the advantage of joining materials. The new materials, denominated composite materials or filamentary composite, with important characteristics in aeronautics applications, such as stiffness and directioned strength, high stiffness/weight ratio and the manufacture flexibility, offer a new design option for aerospace structures.

For example, one may consider the structural design components of EMB-120 Brasilia Embraer's aircraft [1], the composite structural design of the MD-11 Outboard Flap McDonnell Douglas's aircraft [2], the structural design components of the CBA-123 Embraer's aircraft [3] and more recently, the structural design components of EMB-145 Embraer's aircraft [4].

Taking into account the large application of this materials in aeronautics structures, added to the fact of powerful software development, such as MSC/NASTRAN [5], this report presents the results of EMB-145 Nose Landing Gear Door Stress Analysis.

2.0 FINITE ELEMENT ANALYSIS

2.1 MODEL

The general view of the finite element model is shown in Figure 1. Details of EMB-145 NLG door components (external and internal skin and hinge fittings) are shown in Figure 2.

The skins are modeled with CQUAD4 and CTRIA3 shell composite elements. The hinge fitting support are modeled with CQUAD4 and CTRIA3 shell metallic elements. The elastic properties for these elements are shown in Table 1.

The hinge fittings are modeled with CHEXA and CPENTA solid elements and the actuator with CROD element.

The EMB-145 NLG Door is modeled in the closed position. To simulate the EMB-145 NLG open door condition, a new position is created for the end actuator, in order to supply an open relative position.

2.0 FINITE ELEMENT ANALYSIS

2.1 MODEL (cont'd)

TABLE 1 - MATERIAL PROPERTIES			
EX	66600. MPa	130100. MPa	71070. MPa
EY	66600. MPa	2000. MPa	71070. MPa
NUXY	0.05	0.27	0.33
GXY	4600 MPa	5800 MPa	26890. MPa
GYZ	3450. MPa	4060. MPa	26890. MPa
GXZ	3450 MPa	5800 MPa	26890. MPa
XT	678.4 MPa	1721.2 MPa	482.6 MPa
XC	547.9 MPa	702.6 MPa	441.3 MPa
YT	678.4 MPa	42.9 MPa	482.6 MPa
YC	546.9 MPa	133.3 MPa	441.3 MPa
S	122.0 MPa	88.0 MPa	289.6 MPa
	CARBON EPOXY FABRIC	CARBON EPOXY TAPE	PL AL 7475-T7351

2.2 BOUNDARY CONDITIONS

Four boundary conditions are used to represent the EMB-145 NLG Door condition. The auxiliary coordinate system with boundary conditions are shown in Table 2.

TABLE 2 - BOUNDARY CONDITIONS						
		Hinge Fittings			Actuator	
B.C.	Reference	Front	Center	Rear	Closed Position	Opened Position
		CS = 2	CS = 3	CS = 3	CS = 10	CS = 11
100	Without Fail	Uy=Uz=0	Ux=Uy=Uz=0	Uy=Uz=0	Clamped.	Clamped.
101	Front Hinge. Fail	--	Ux=Uy=Uz=0	Uy=Uz=0	Clamped.	Clamped.
102	Center Hinge Fail	Ux=Uy=Uz=0	--	Uy=Uz=0	Clamped.	Clamped.
103	Rear Hinge Fail	Uy=Uz=0	Ux=Uy=Uz=0	--	Clamped.	Clamped.

2.0 FINITE ELEMENT ANALYSIS

2.3 LOADING

According to reference [6], the critical loading cases selection for EMB-145 NLG Door are listed in Table 3. The loads were applied at element skins with the PLOAD2 card

Table 3 - Limit Loading Condition

L.C.	Reference	Resultant Load
		N
1	closed - max press at 1g flight	121.6
2	almost closed - max operation load	-3948.5
3	opened - sideslip	1824.1
4	closed - sideslip	-1824.1
5	closed - max suction at Vc	-1050.0
6	almost closed - vertical gust	-5986.3
7	closed - 1g without gust, Vc	-684.0
8	closed - 4 psi despressure	-8979.0

Note : (a) positive pressure induces the closing door
(b) negative pressure induces the opening door

3.0 DESIGN CRITERION

The EMB-145 Nose Landing Gear Door, submitted at the critical loading condition with the boundary conditions described in Table 2, will be able to accomplish FAR PART 25, Airworthiness Standards: Transport Category Airplanes [7] requirements.

3.0 DESIGN CRITERION

3.1 COMPOSITE MATERIAL

3.1.1 STRENGTH

In this case, the Tsai-Wu criterion was adopted and the allowable are based in allowable stresses for each utilized material (Cloth or Tape). The allowable values are shown in Table 1.

3.1.2 STIFFNESS

In this case, no panel should be buckle at ultimate loading.

3.2 METALLIC MATERIAL

The material ultimate stresses were adopted as allowable values for design, in this case. These values are listed in Table 1.

3.3 COMPLETE NLGD

The EMB-145 Nose Landing Gear Door should be sufficiently stiff to accomplish the NE-02-041: Aerodynamic Smoothness Requirements for EMB-145 [8], requirements. This condition refers to the loading condition number 7 present in Table 3.

4.0 DISCUSSIONS AND CONCLUSIONS

Combining Table 2 with Table 3, one can have several subcases which can be analyzed. Therefore the difficulty of structural analysis is the selection of the critical subcases. However, making use of the tools offered by MSC/NASTRAN [5] and MSC/XL [9], it is possible to obtain, very quickly, the critical subcase results.

One may quote the post-processor developed in EMBRAER. Based in PUNCH file, two post-processor were used for this analysis. The SPFOR [10] selects the critical subcase by element forces. The FMSPC [11] produces a file with SPCD cards for a set of selected grids and subcases. Based in OUTPUT2 file, the PPLAM [12] selects the critical subcases by margin of safety of the laminate.

The figure that present the TSAI-WU margin of safety was obtained combining the PPLAM post-processor with the MSC/XL. Without this resort, certainly the search of the critical subcases would be very laborious.

The EMB-145 Nose Landing Gear Door Stress Analysis according to the results present in section FIGURES, is able to accomplish the requirements listed in this report.

5.0 ACKNOWLEDGMENTS

We sincerely acknowledge the leader engineer of the Structural Section, Antonio Carlos Victorazzo and the engineer José Celso Bustamante Coura, for the support in making this report possible.

6.0 REFERENCES

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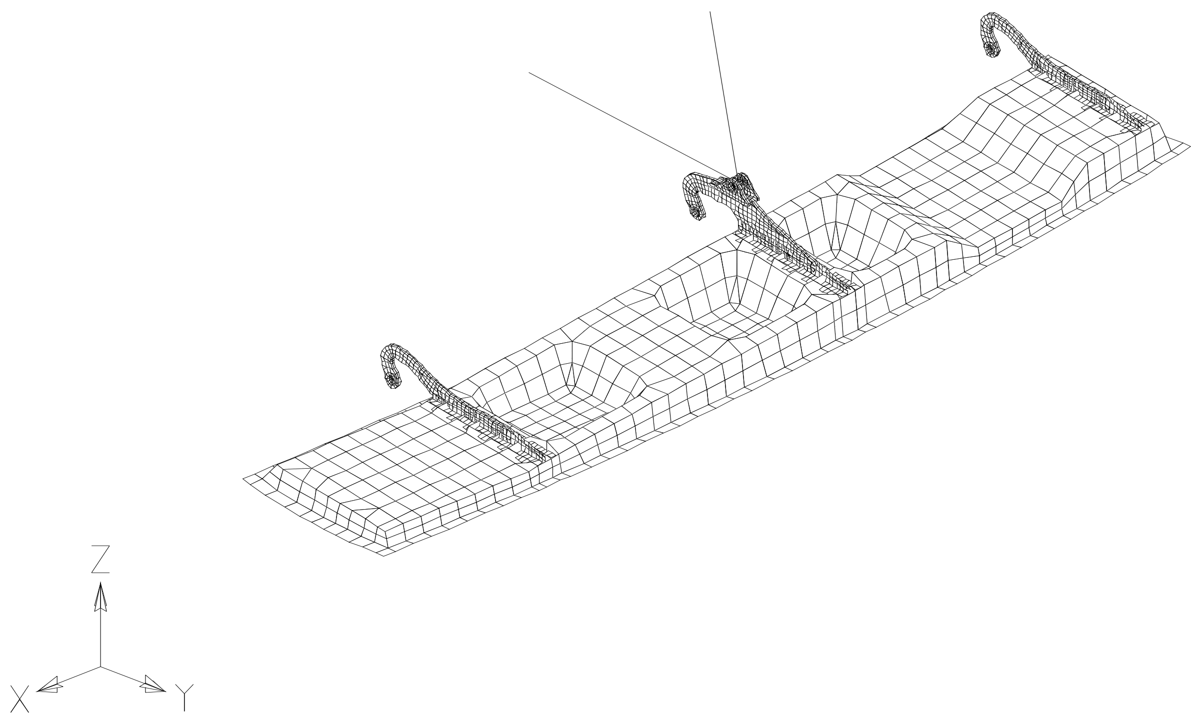


Fig. 1 - EMB-145 NOSE LANDING GEAR DOOR
GENERAL VIEW

Fig. 2a - NLG DOOR REAR HINGE FITTING
MODEL DETAIL

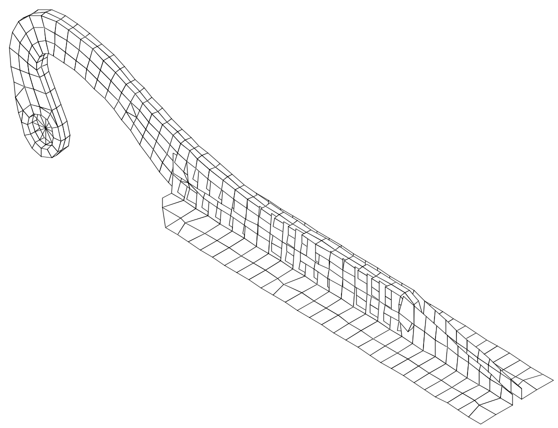


Fig. 2b - NLG DOOR CENTER HINGE FITTING
MODEL DETAIL

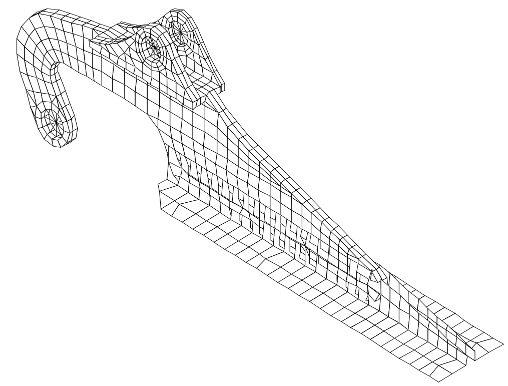


Fig. 2c - NLG DOOR SKIN
MODEL DETAIL

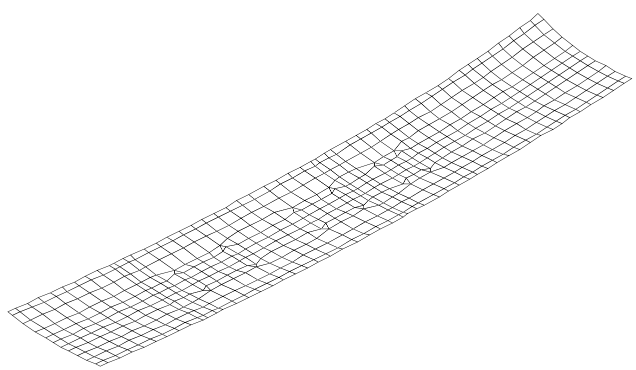
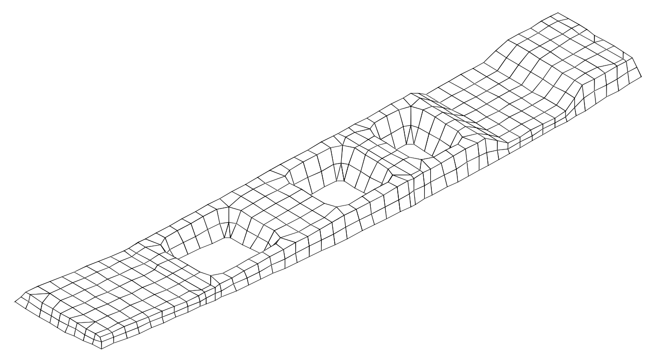


Fig. 2d - NLG DOOR INTERNAL SKIN
MODEL DETAIL



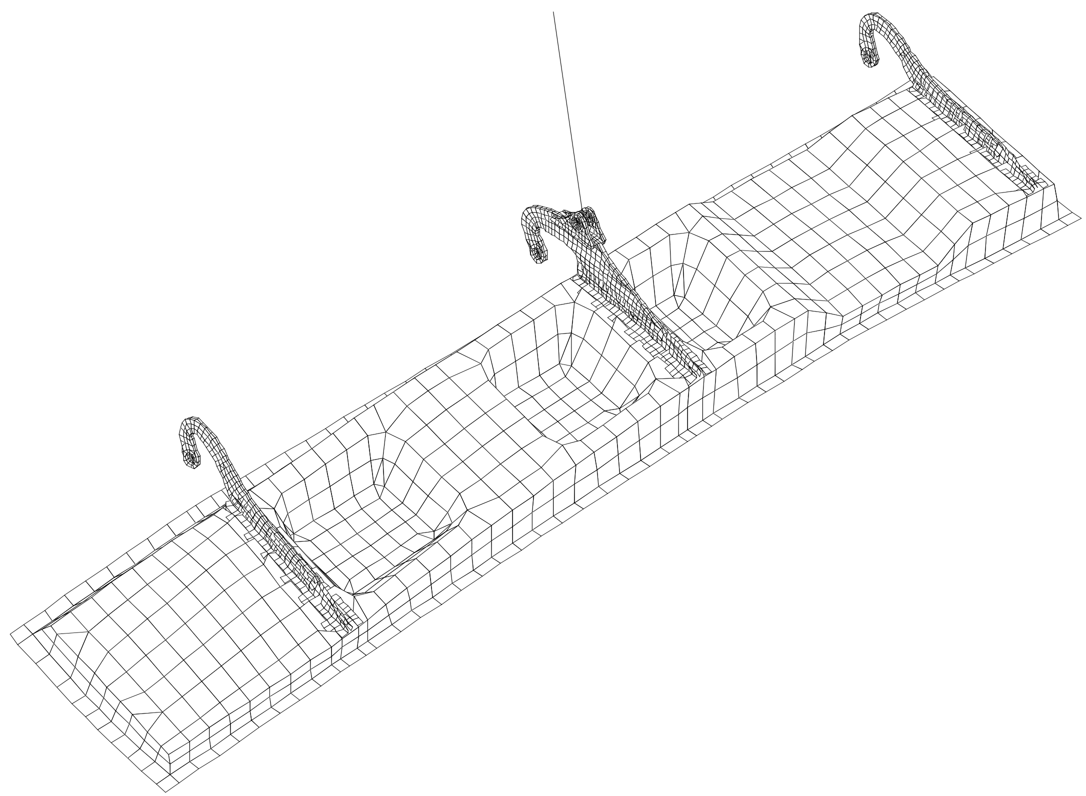


Fig. 3 - NLG DOOR DEFORMED SHAPE
SUBCASE 800

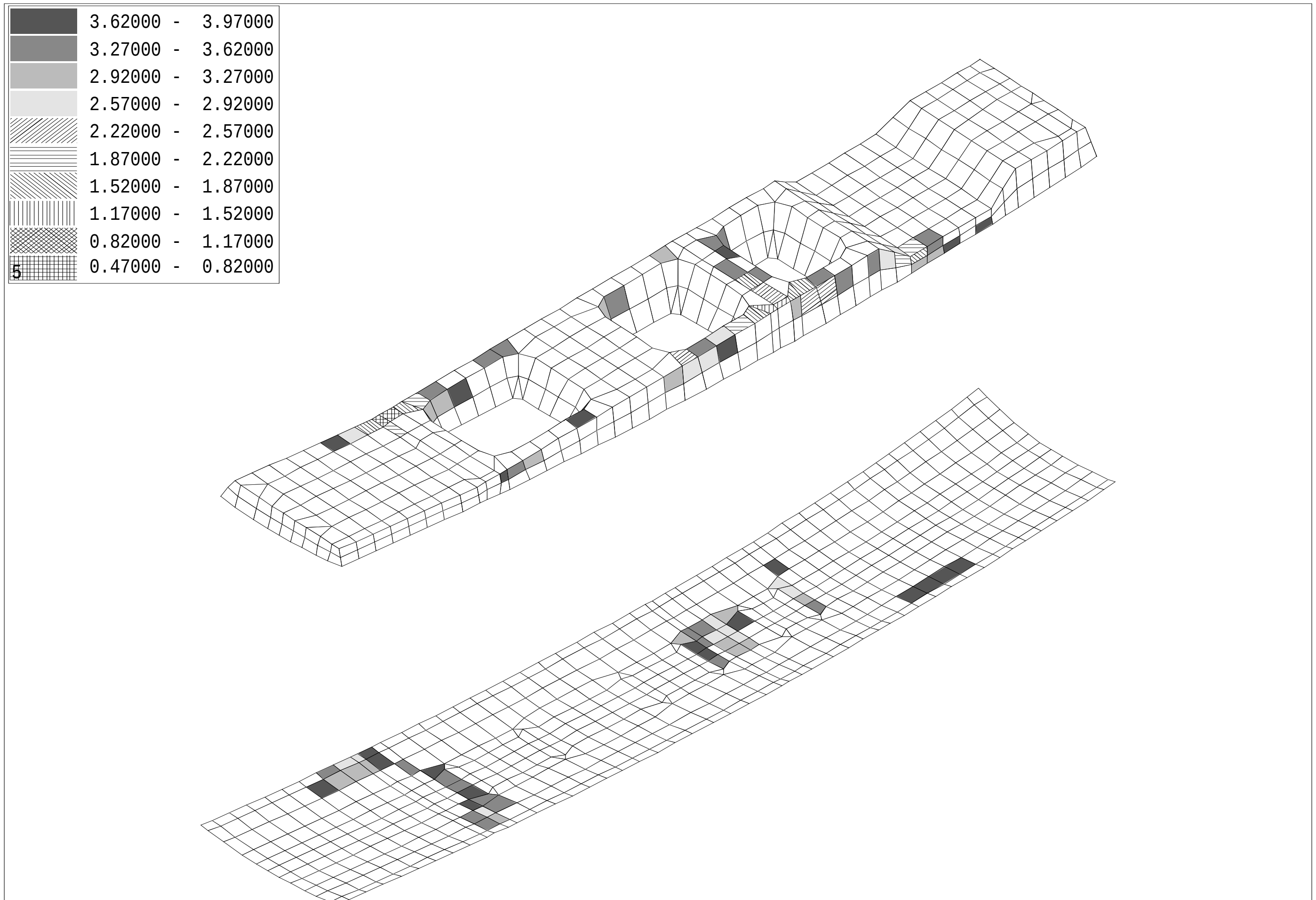


Fig. 4 - NLG DOOR TSAI-WU MARGIN OF SAFETY
SUBCASE 800

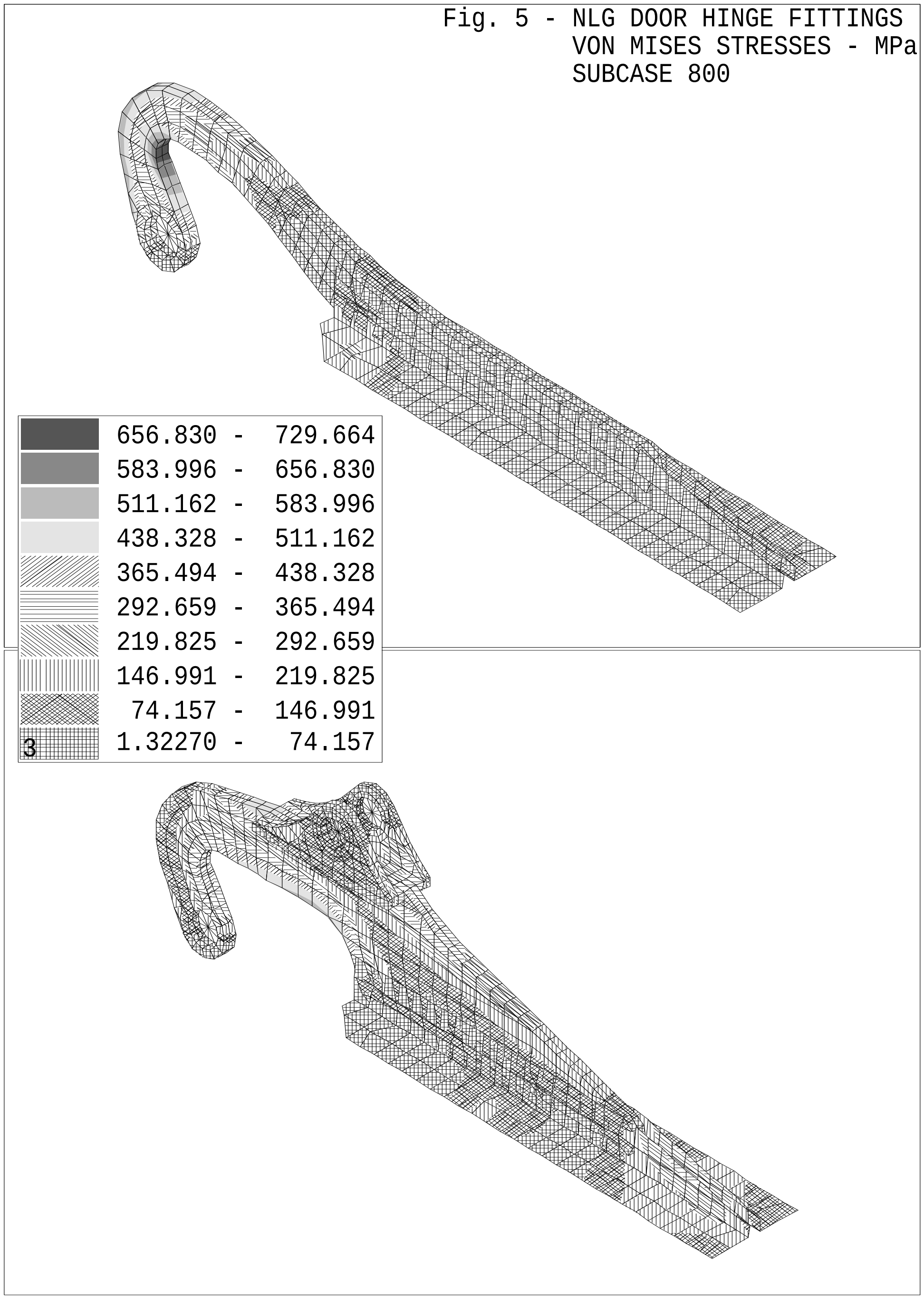


Fig. 5 - NLG DOOR HINGE FITTINGS
VON MISES STRESSES - MPa
SUBCASE 800
656.830 - 729.664
583.996 - 656.830
511.162 - 583.996
438.328 - 511.162
365.494 - 438.328
292.659 - 365.494
219.825 - 292.659
146.991 - 219.825
74.157 - 146.991
1.32270 - 74.157
3

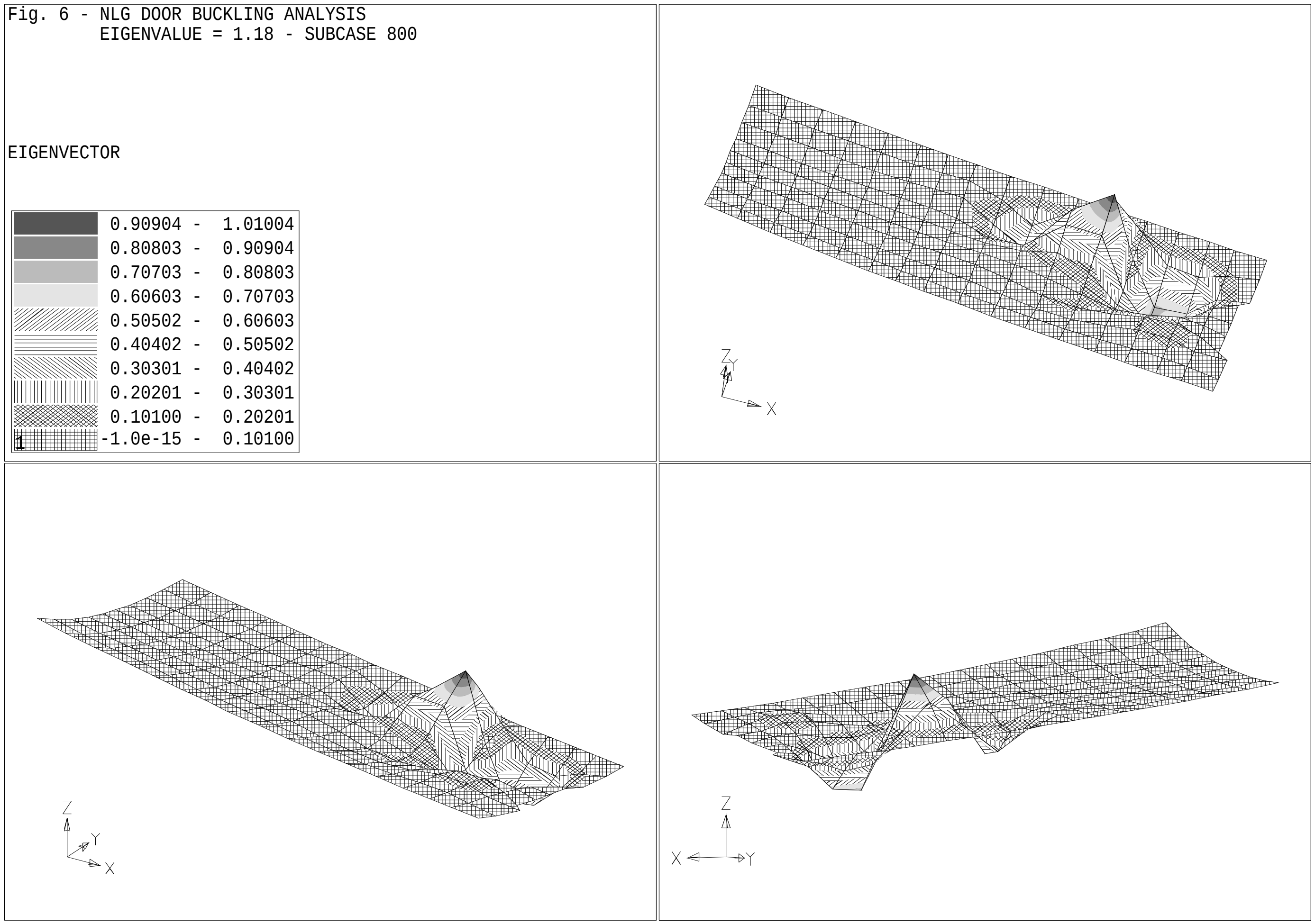


Fig. 6 - NLG DOOR BUCKLING ANALYSIS
EIGENVALUE = 1.18 - SUBCASE 800

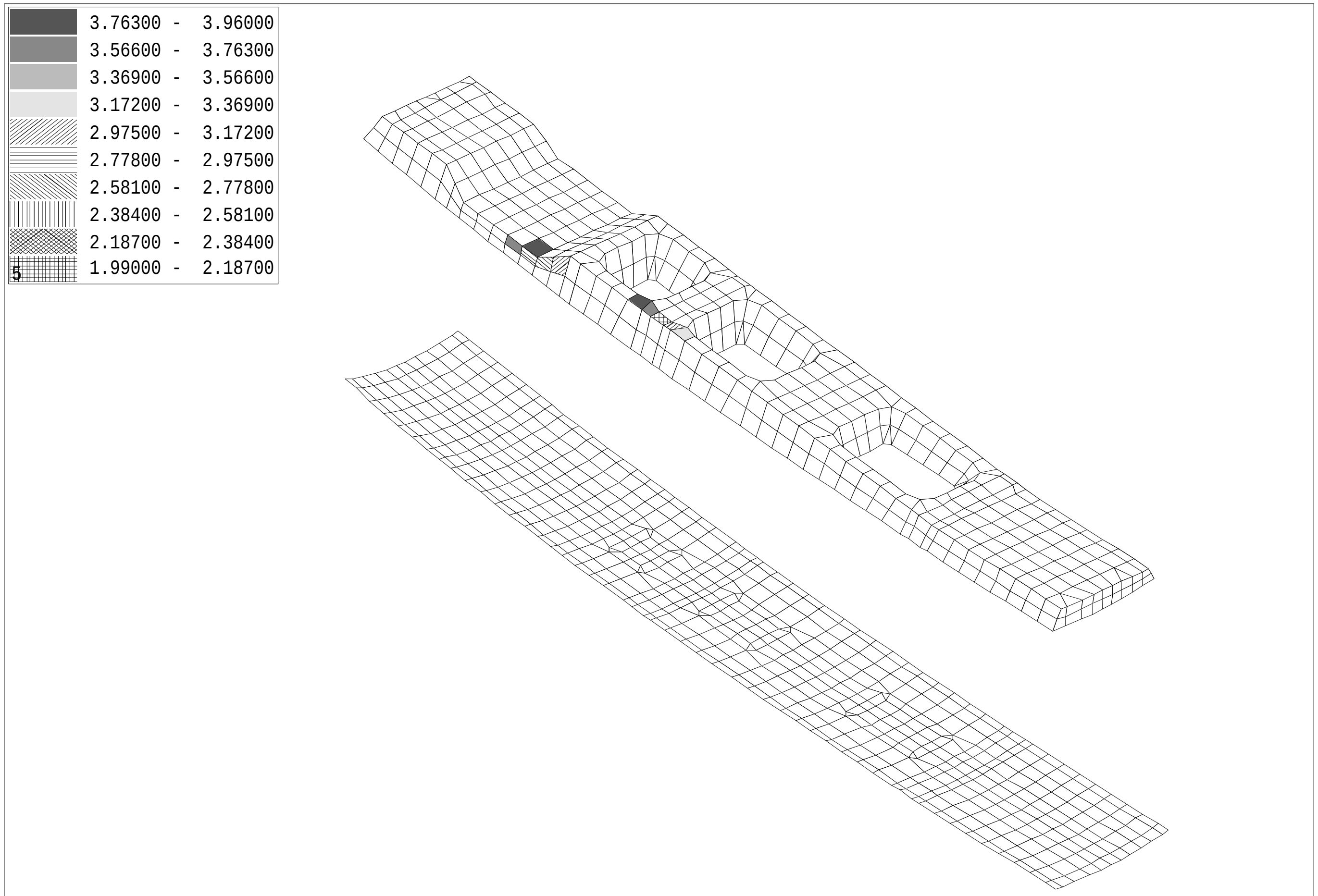


Fig. 7 - NLG DOOR TSAI-WU MARGIN OF SAFETY
SUBCASE 203