THE INFLUENCE OF MATERIAL AND GEOMETRIC NON-LINEARITIES TO ACCURANCY FEM STRESS ANALYSIS OF LANDING GEAR

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Abstract

The paper provides description of FEM stress analysis of several landing gears for new Czech aircraft. In all loading cases, there is considered material and geometric non-linearity, contacts and friction between some parts of landing gear and carried out verification of analysis results with comparative testing. The structural tests of the landing gears of Zlín Z143-L, small GA and aerobatics plane and KP2U-Sova, an ultralight plane, were tested in the IAE laboratory. The structural test of nose and main landing gear of Aero Vodochody´s new commuter were tested in test laboratory of Technometra Radotín, the Czech producer of landing gear. The certification processes require the structural testing of all parts. It means that each modification should be verified by a test. The FAR 23 and JAR 23 regulations provide the possibility to certify the aircraft components, landing gear inclusive, without verification by structural test under condition that the employed analysis was proved reliable in the past for very similar component. The aim of this paper is to compare the results of the FEM analysis with the real structural test results and to confirm the agreement between these two results (on the one hand the computer modelling, on the other the values measured during real test) for Landing gear. This can help to reduce the number of structural tests and reducing the costs and time necessary to develop a new or modified landing gear. The results of analysis confirm that precision of the FEM stress analysis in comparable with the test of real structure depending mainly on material and geometrical non-linearity included to the FEM analysis.

1 General Introduction

The aim of this paper is to compare the results of the finite element analysis with the real structural test results. And to confirm the agreement between these two results (from one side the computer simulation and from the other one the values measured during the real test) for the landing gear. This can help to reduce the number of structural tests. The aeronautical regulations for the aircraft from our category (FAR23 and JAR 23) provide a possibility to certify the aircraft component without any confirming structural test on condition that the employed analysis was proved reliable in the past for a very similar component. This offers a possibility to reduce the costs and time necessary for developing the new landing gear, considering the financial and time demands on a structural test.

2 Applied load

The analysis of loads is not a subject of this paper; all the applied loads correspond with the real load cases defined by FAR 23 –JAR 23 regulations.

3 Description of the types of solved landing gears

Four different types of Czech aircraft landing gears were chosen for the comparison of the FEM analysis results and structural tests.

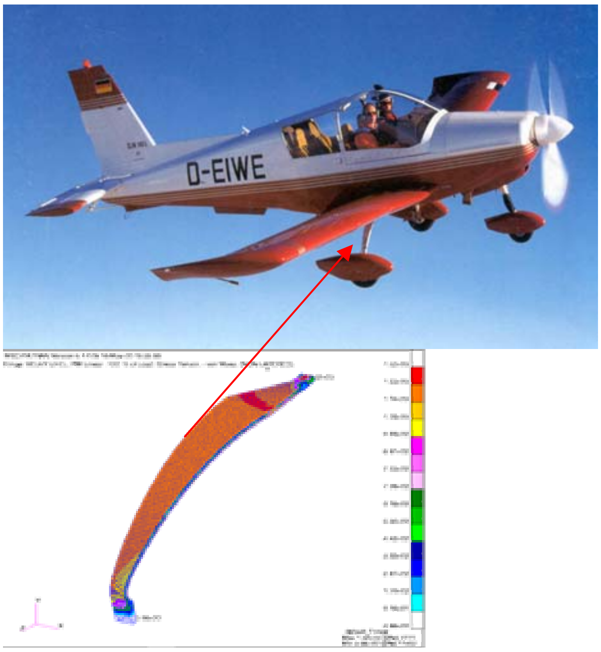


Fig. 1 - The Zlin Z 143 L spring type of landing gear

Fig. 2 - The KP2 U - SOVA main landing gear

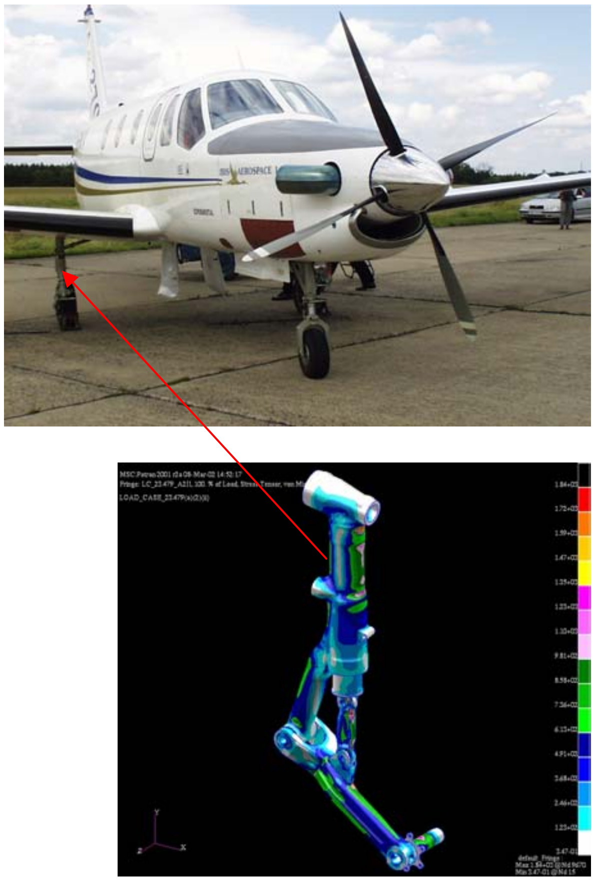


Fig. 3 – The main landing gear of Ae 270 Czech small commuter

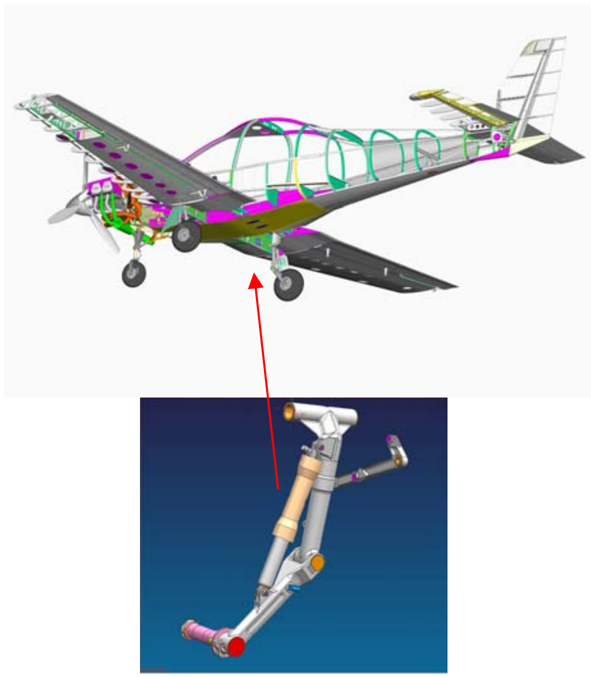


Fig. 4 – The main landing gear of VUT 100, new GA project of IAE

4 FEM model preparation using MSC.Patran and MSC.Nastran

For the structural analysis of each load case, the finite element models were created. It includes the creation of a geometry model and then the meshing procedure for development of the finite element structure, boundary condition and load modeling. For all of the considered models, the boundary conditions and loads were completely identical with the experimental conditions. For defining the FEM model, the MSC.Patran was used. The four mentioned models are performed in figure 1 to 4.

The first model consists of 4500 linear volume elements CHEX8. The second one is built up from 50,000 shell elements CQAD4. The third model consists of five main parts, connected with respect to the contact and friction boundary condition. The 108000 various type of elements (CHEXA, CPENTA, and CTETRA) were used for entire model. The contacts between main parts of the landing gear were modeled using slot element CGAP.

5 FEM analysis using MSC.Nastran

The deformation of the landing gear causes a change of the load conditions. The points of the load application are moved and the bending and torque moments usually grow up and in addition to this, the local stresses may reach the Y.T.S. of the material. That causes a change of the material constants (stress-strain curve) at the same time. It is necessary to use the non-linear solution. The force is applied in steps with an increment dF. In each load step from F to F+dF, the displacements for all the nodes, the load application point and the stiffness matrix are updated. Simply, the force follows the deformed shape. At the same time, the stress-strain curve is taken into account. The stress-strain curves of M300 and AL2024 materials, which was used for calculations are showed in the figure 4 and 5.

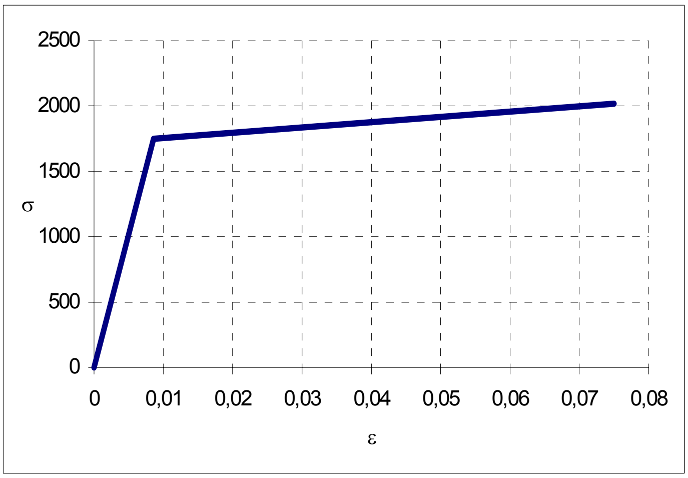


Fig. 4 – material model for M 300 steel

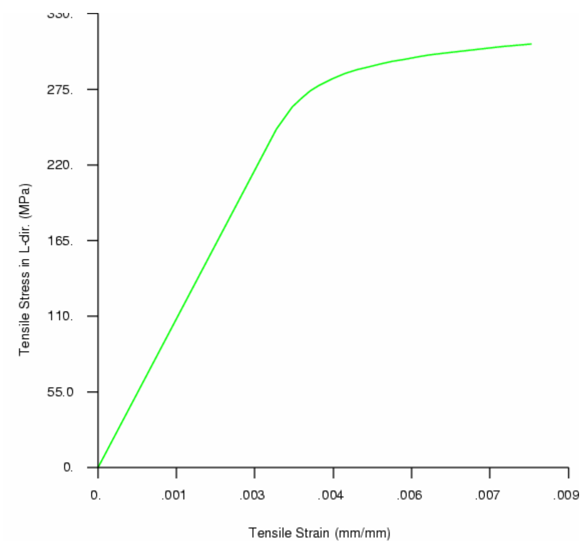


Fig. 5 – Typical tensile stress-strain curves for AL2024, MSC.Mvision material Databanks, MIL-HDBK-5

Analysis parameters

a) Z 143L gear
4500 linear volume
Elements CHEX8
Necessary disk space: 300MB
Necessary CPU: 8 hours

b) KP 2 U - Sova gear
50,000 shell elements CQAD4
Necessary disk space: 1.5GB
Necessary CPU: 12 hours

c) Ae 270 main landing gear
108000 various type of elements (CHEXA, CPENTA, and CTETRA) s
Necessary disk space: 5GB
Necessary CPU time depends on computational procedure- with effect of friction 13-19 hours.

d) VUT 100 main and nose gear
Similarly as for Ae 270 with apply new element for contact problems.

6 Structural tests

The testing was accomplished in the laboratories of Institute of Aerospace Engineering (IAE) and in producer of landing gear Technometra Radotin. The configuration of tests are showed on the following figures. The load was generated with a hydraulics actuator. The strain measurement was conducted in the single points. The load step during the tests was 10% of the ultimate force, except the load step from 60% to 67% which represents the ultimate force. For each load step, the stress in the single points and the deformation were recorded.

6.1 Result evaluation

6.1.1 Zlin Z 143L landing gear

The stress was calculated using the stress strain curve of the applied material in the points in which is the strain values measured. The stress distribution is shown on the fig.. At the same figure, the stress, found by the FEM analysis is visualized. The maximal difference between the computed and measured stress is 11.3%.
The displacement was evaluated just in one single point (the point of force application). The relation displacement-force theoretical and experimental is shown on the fig. 7. The maximum difference is 2.3%.

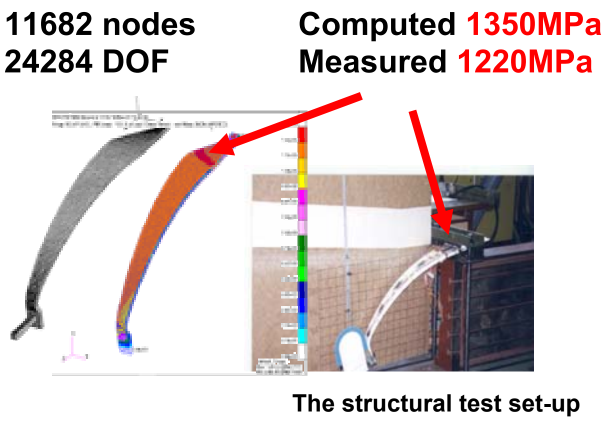


Fig. 6. - Model FEM and the structural test set-up

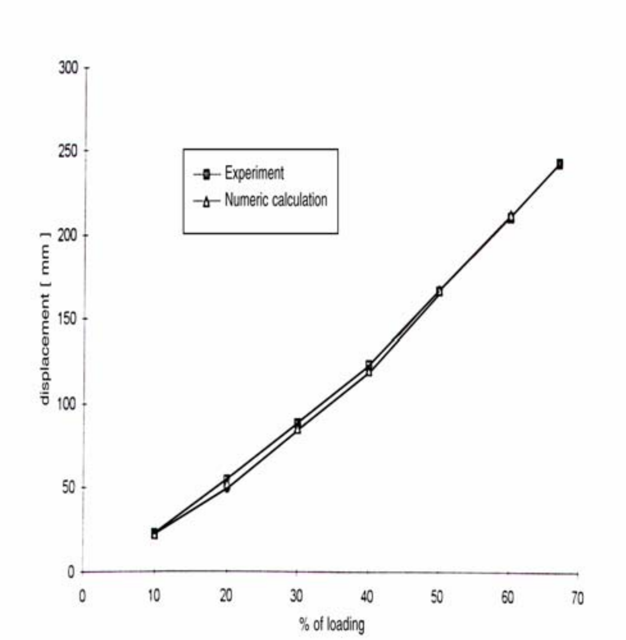


Fig. 7 – the displacement of the tip of landing gear

6.1.2 The KP2 U Sova landing gear

The stress was calculated using the stress strain curve of the applied material in the points in which is the strain values measured. The computed stress-loading and measured stress-loading is shown on the fig. 9. The maximal difference between the computed and measured stress is about 10%. The displacement was evaluated in five points. The maximum difference is 3 %.

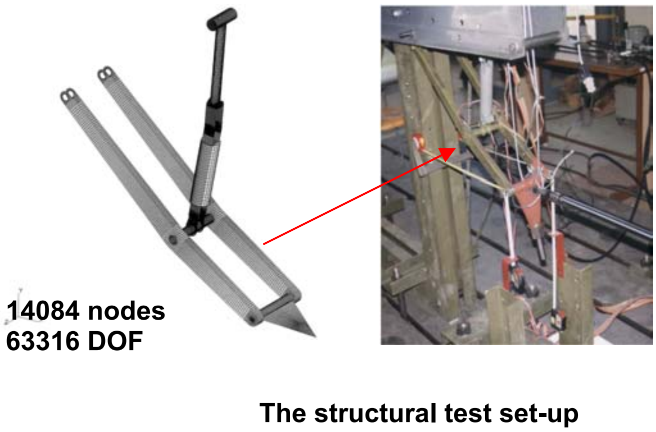


Fig. 8. - Model FEM and the structural test arrangement

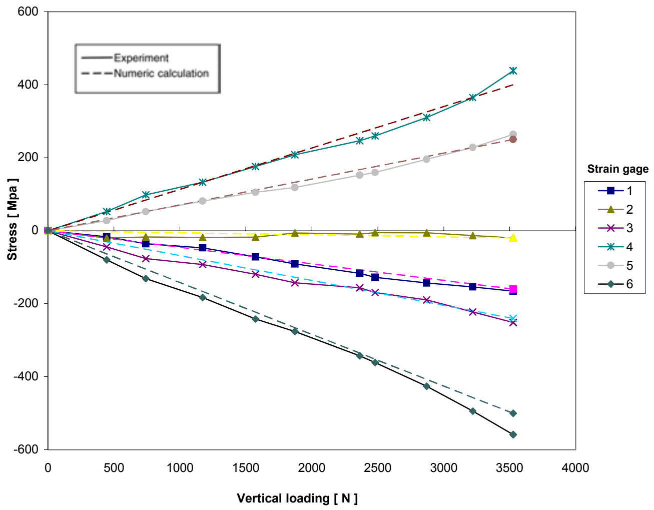
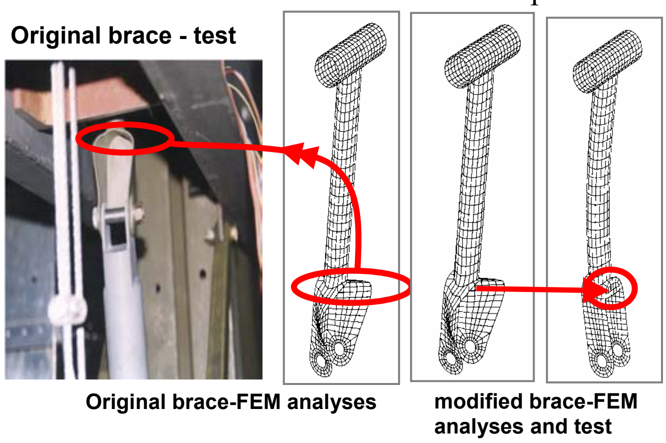


Fig. 9. – The stress distribution of FEM model and results of measurements

The deformed shape of the Sova gear brace from the experiment and FEM analysis is shown on the following figures where it is evident that the deformed shape prediction is really very close to reality. The type and level of the load markedly changed after a small reinforcement of the critical part.



6.1.3 The Ae 270 landing gear

The structural test of real landing gear was performed in the test laboratory of Technometra Radotin, the Czech producer of landing gear for GA and military training aircraft. The strain gauges were located at points corresponding to the areas with maximum stress level, predicted by FEM analysis. The difference between computed and measured values of stress varied from 5 to 8 percent. Compared to not considering material and geometric non-linearity analysis, the difference was approximately 25 percent especially due to geometric non-linearity.

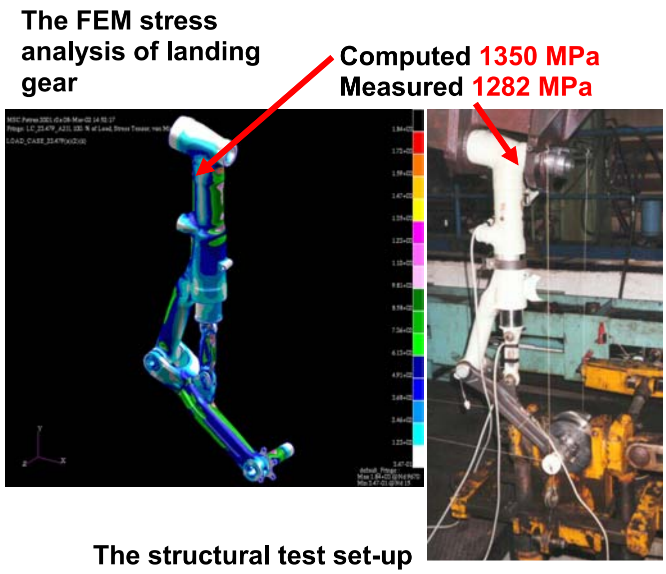


Fig. 10. - Model FEM and the structural test set-up

6.1.3 The VUT 100 landing gear

The landing gear for VUT 100 is now in the stage of production of the prototype and preparation of static tests. On the basis of good agreement of the FEM stress analysis and a results of experimental measurements on Ae 270 landing gear, the CAA Czech Republic permited the first flight of VUT 100 prototype without the static test.

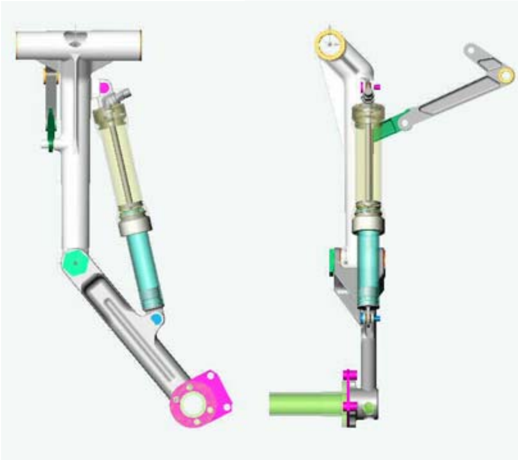


Fig. 10. – CAD model using SolidWorks

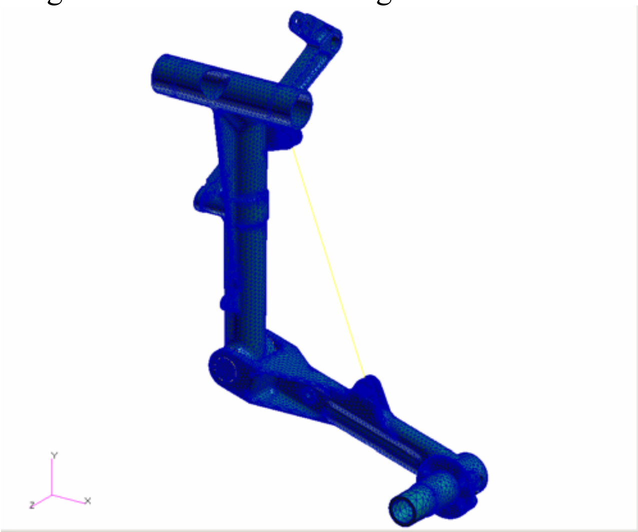


Fig. 11. – FEM model of all parts of main landing gear of VUT 100

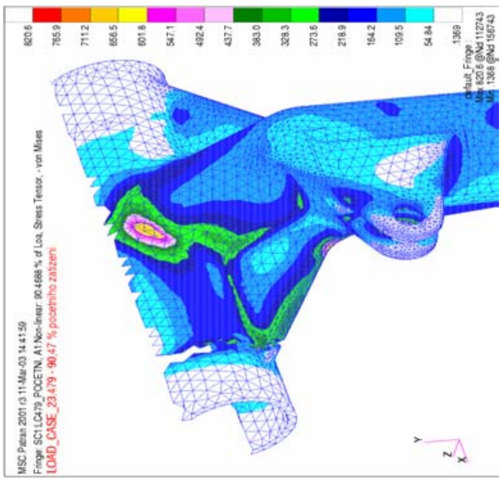


Fig. 6. – Non linear,100 % of load, fon Mises Stress Tensor distribution

7 Conclusion

Finally, it can be said that the precision of the FEM simulation was successfully verified for the discussed FEM models with structural test. In the future, developing of new landing gear, similar conception, and small modifications present landing gear could be certified using just the numerical simulation without expensive static tests **but only with respect to material and namely geometric non-linearity.** The effect of friction can be neglected. The results of stress analysis, using MSC.Nastran, were fully acceptable for certification by Czech Aviation Administration. The difference between computed and measured values of stress varied from 5 to 8 percent. Compared to not considering material and geometric non-linearity analysis, the difference was approximately 25 percent especially due to geometric non-linearity.

8 References

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