Test and Simulation of Energy Absorption System

R. Doubrava [1,a]

[1] *Výzkumný a zkušební letecký ústav, a.s.*
[a] *doubrava@vzlu.cz*

Abstract: An energy absorbing device is a dedicated structural member to absorb an optimum amount of energy from different types of degradation in the constituent materials in an accidental event. Indeed, the structures of a plane or a car must absorb the kinetic energy introduced during a crash for the human does not suffer from acceleration exceeding the allowable physiological threshold. This paper utilized advanced nonlinear finite element modelling for simulating tests performed by the VZLU to understand and analyses loading behaviors and parameters that influence the failure of metal material. The research was focusing on application of control failure for energy absorption system design and application. This study shows the possibility of applying realistic boundary conditions using a simplified numerical model and transferability to the complex problem analysis. This paper contributes to the region of scale test design for verification of numerical analysis of complex engineering problems such as analysis of emergency cases.

Keywords: impact; FE; energy absorption.

Nomenclature:

A	:	Yield stress (Johnson Cook material model)
B	:	Strain hardening modulus (Johnson Cook material model)
C	:	Strain rate coefficient (Johnson Cook material model)
E	:	Young’s modulus
n	:	Strain rate coefficient (Johnson Cook material model)
d1,d2,d3	:	Triaxial stress state (Johnson Cook damage parameter)
d4	:	High strain rate stress state (Johnson Cook damage parameter)
d5	:	High temperature environment (Johnson Cook damage parameter)
FE	:	Finite element
ε_0	:	Strain rate factor
ρ	:	Density
ν	:	Poisson ratio

1 Introduction

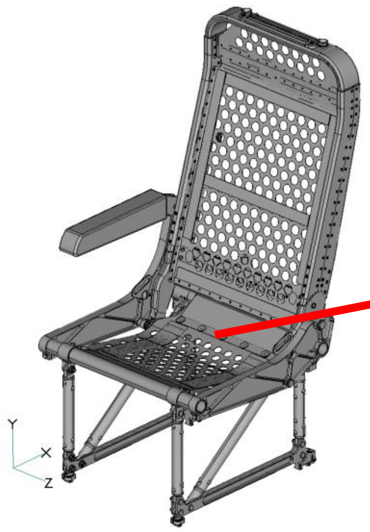
Simulations are useful support tests carried out on scale models. The applications of these results to real situations depend on the appropriateness of the assumptions used to simplify the models and evaluations of their influence. For numerical simulations, solvers that produce explicit solutions are most commonly used. The solutions to these simulations require a numerical convergence of the variables and are dependent on the quality and the size element of the finite elements used in the model. To incorporate certain parameters, e.g., material type or stiffness, it is often necessary to discretize alternative models.

2 Problem Formulation

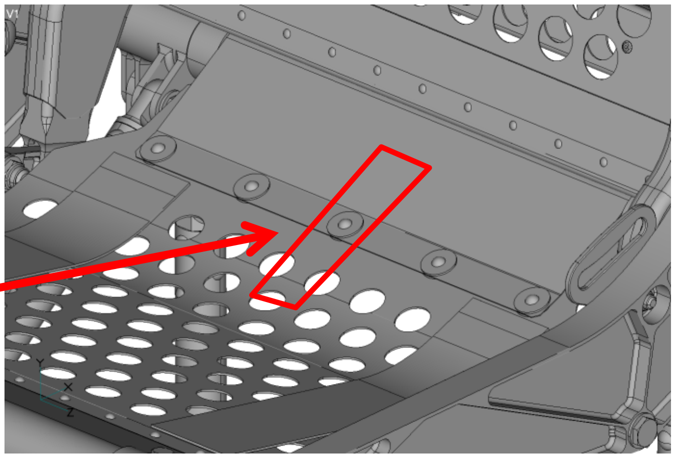
In aircraft, the forces involved when a collision takes place are enormous, and will produce permanent deformations, cracks, local buckling, collapse and tearing of the plane structure. The objective of this work is to find and validate the properties of a specified material to be used when performing a FE-analysis considering large deformation and ductile fracture of the material. The main objective is to make simplifications to the input data in order to simplify the modelling procedure and concentrate studies in a simply models to be able to execute it in the real model.

2.1 Design of energy absorption system

The absorber system is design for application in aircraft passengers seat (see figure). The aim of this system is absorbing high energy during emergency lending. The figure 1 shows 3D model of passenger seat and detail of energy system application.



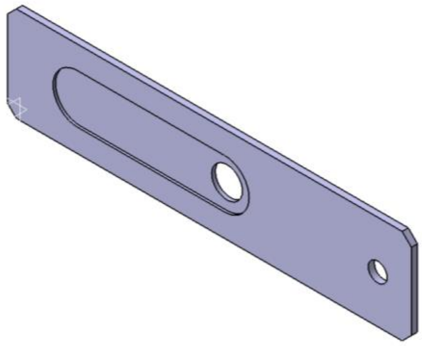
a) 3D model of passenger seat



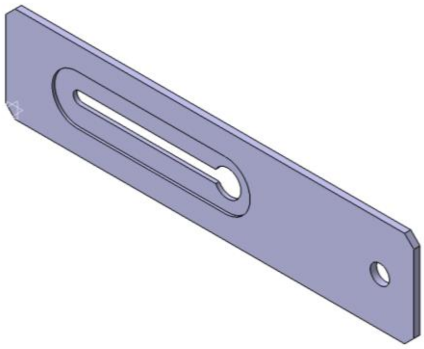
b) Selected area with energy absorption system

Fig. 1: Passenger seat with application of energy absorption system

The figure 2 shows proposed simplify model of energy absorption system for test and numerical verification.



a) 3D model



b) Detail of 3D model

Fig. 2: Energy absorption simplify model

2.2 Test

The test consisted to apply a tension created by a drop of weight and analyses the strain contained inside the sample and also measured the evolution of the force in relation to the time of the experiment. The schema of test is on the figure3.

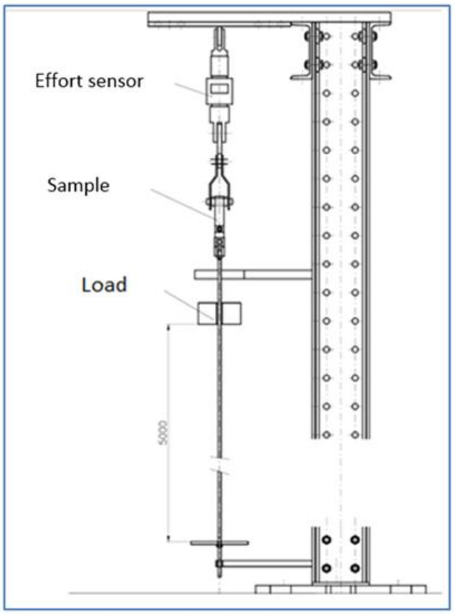
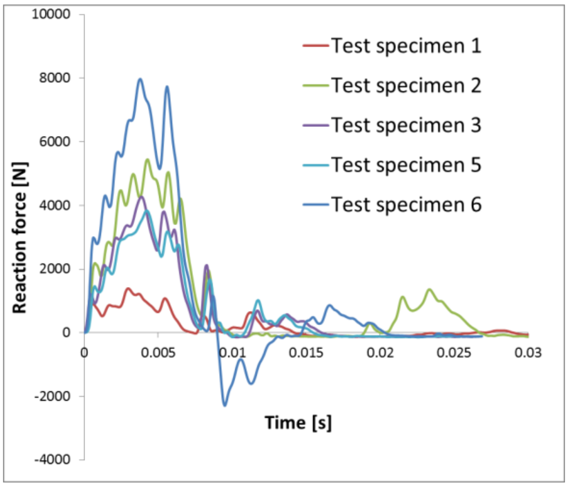
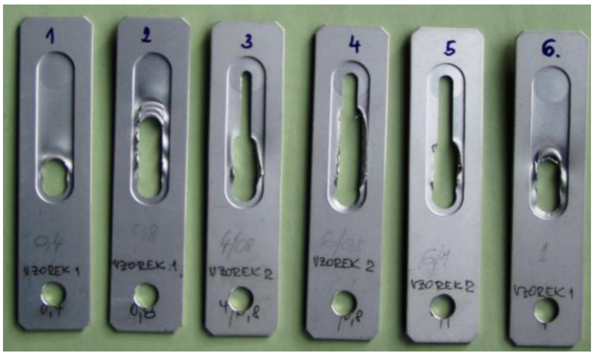


Fig. 3: Drop test set up

The results from test were analyzed from point of view reaction force measurement and plastic deformation (figure 4).



a) Reaction force results



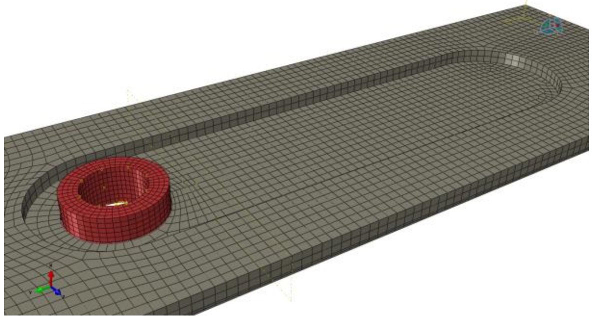
b) Deformed shape of test specimen

Fig. 4: Results from test (force vs time and deformed shape)

2.3 FE model of test

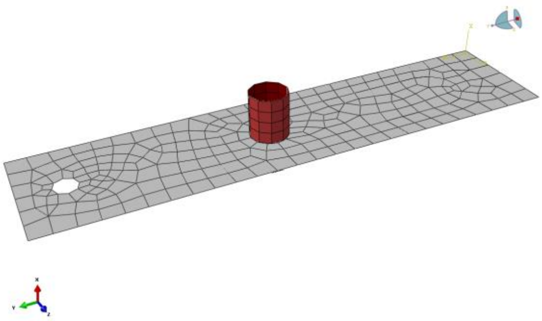
Models of test specimen and drop test set up were computed in ABAQUS code. The model was built from 2D 3D elements with Al alloy 2024 T351 isotropic material properties. The figure 5 and figure 6 shows proposed 2D a 3D FE model.

a) 3D model

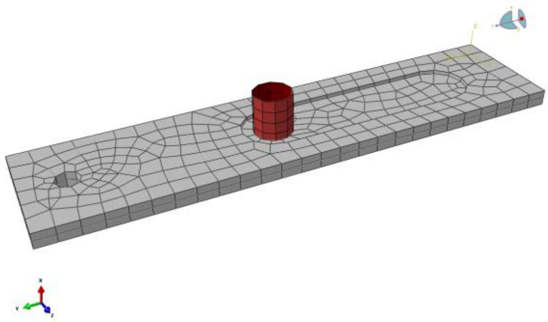


b) Detail of 3D model

Fig. 5: 3D FE model



a) 2D model



b) 2D model with thickness visualization

Fig. 6: 3D FE model

A Johnson-Cook material model was used for the body elements of the proposed energy absorption system and is an accumulative-damage model that accounts for the loading history, which is represented by the strain-to-fracture parameter expressed as a function of the strain rate, temperature, and stress. This model is an instantaneous failure model, which means that no strength or stiffness remains after failure. Failure was also dynamically modelled based on the equivalent plastic strain at individual element integration points. Failure was assumed to occur when the damage parameter exceeded 1. The parameters of the incorporated Al alloy material model are listed in table 1.

Table 1: Properties of Johnson Cook material model of 2024 T351 Al alloy [2]

Parameter	**ρ [t/mm^3]**	**E [GPa]**	**ν [1]**	**A [MPa]**	**B [MPa]**	**n [1]**	**C [1]**	**ε_0 [s^{-1}]**	**d1 [1]**	**d2 [1]**	**d3 [1]**	**d4 [1]**	**d5 [1]**
Value	2.77E-09	73.1	0.33	352	440	0.42	0.0083	1	0.13	0.13	-1.5	0.011	0

The result from FE simulation was compared with test results from point of view reaction force measurement and deformed shape of test specimen. The figure 7 shows example of the comparison between test and simulation.

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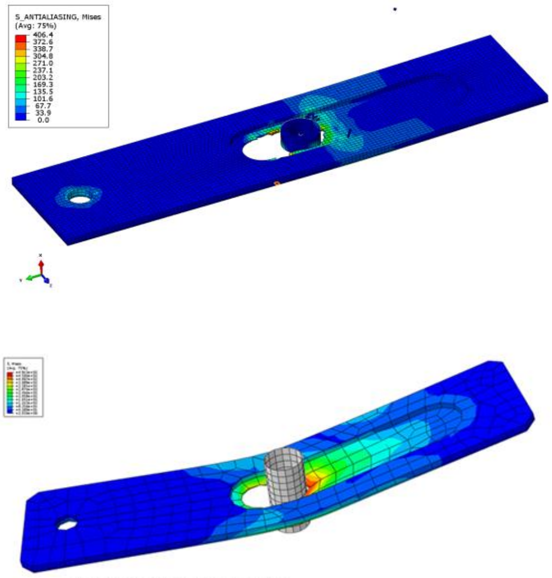
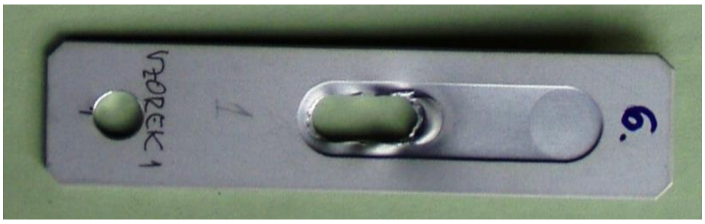


a) Results from FE analysis on 3D and 2D model



b) Results from test

Fig. 7: Comparison between FE simulation and test from point of view deformed shape

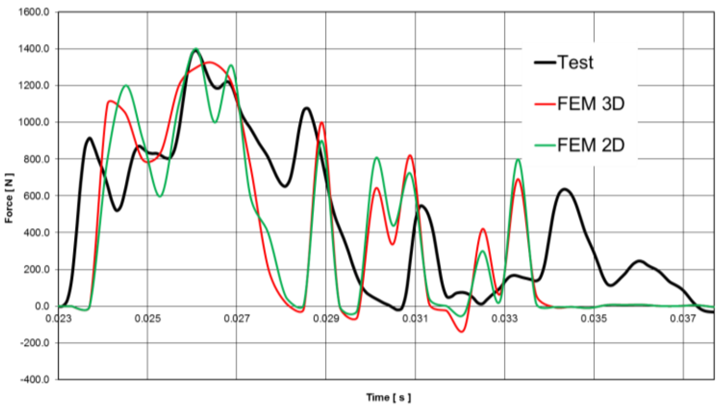


Fig. 8: Reaction force vs time

The set-up from 2D FE model was used for simulation of real structure with help to minimize mesh size especially from point of view explicit FE analysis.

The figure 9 shows summary of energy absorption system design and verification on the base of simplify model for test and simulation.

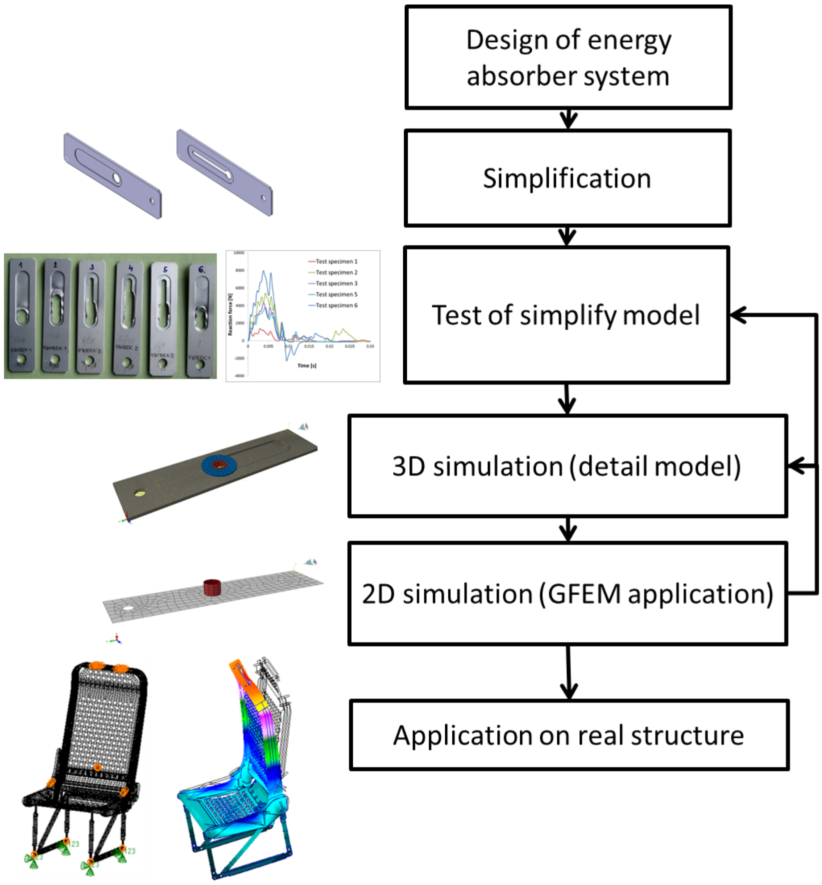


Fig. 8: Shema of energy absorption system design and optimization

3 Conclusion

This study showed the possibility of applying simplification of FE model (from 3D to 2D) by verification of test results. The simplified FE model verified by test is possible apply on real global structure simulation and optimization.

Acknowledgement

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References

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