NUMERICKÉ A MODELOVÉ VYŠETROVANIE NOSNÝCH LETECKÝCH KONŠTRUKČNÝCH SPOJOV

NUMERICAL AND MODEL INVESTIGATION OF LOAD-CARRYING AIRCRAFT STRUCTURE JOINTS

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Abstrakt

V článku je prezentovaný komplex problémov týkajúci sa účelného návrhu silne zaťaženej nosnej konštrukcie lietadla, ktoré má zvýšenú životnosť. Súčasne bola vypracovaná základná metodológia pre vykonanie numerického výpočtu metódou konečných prvkov a vykonaná experimentálna verifikácia skúmaním modelu fotoelascimetrickými metódami. Bolo brané do úvahy spolupôsobenie všetkých častí povrchu a ich kontakt, pričom bol skúmaný vplyv geometrie spoja na rozloženie napätia. Detailne bol uvažovaný vplyv spôsobu zavádzania zaťaženia na stredový prvok znižujúci tuhosť konštrukcie ako aj na hodnoty a rozloženie napätí, a na životnosť spoja. Bola tiež urobená numerická analýza životnosti skúmaného spoja.

Článok obsahuje množstvo príkladov poznávacieho aj praktického charakteru týkajúcich sa lepšieho pochopenia návrhu nosných konštrukčných spojov.

Kľúčové slová: spoj lietadla, modelový výskum, napätie, MKP.

Abstract

The complex of issues referring of rational designing of strong loaded aircraft load-carrying structure, having the increased fatigue life was presented at the paper. Based methodology was elaborated on simultaneous for executing of numerical computations by finite elements method and of experimental verifications with the model investigation by photo-elastic methods. Collaborating in all pairs of the surfaces a contact was taken into consideration and influence of geometry of the joint elements on the stress distribution was analyzed. An influence of entered to the chain of the loading of the mediating element reducing the stiffness of the structure on the value and stress distribution, and as the result for the fatigue life of the joint was considered in details. They also made the numerical analysis of the fatigue life of the analyzed joint.

The paper is summarized with a number of conclusions about the cognitive and utilitarian character, referring to issues understood extensively of designing of load-carrying structure joints.

Keywords: aircraft joint, model investigation, stress, FEM.

INTRODUCTION

The joints of the wing – fuselage connection of an aircraft belong to the most important zones of the structural design. Fundamental requirement put into these kind of structures is adequately great static strength according to the air regulations.

Exploitation circumstances exacting frequent of wings disassembly determine additional requirements, which influence on the joints geometry, and exactly on the details of solution. Large

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extensive practice of aircrafts design constituted a whole series characteristic solutions which perform mentioned requirements. The solutions are differential by details according to loading and category of aircraft. Numerous experiences demonstrate that service life of structure is depended not only from stress level, but equally from stress distribution. One of the way of counteraction of precocious failure is rational forming of the structure elements.

In the paper comparative analysis of two kind of solution for wing – fuselage joint is presented on the example of cantilever agricultural aircraft joint.

FUNDAMENTAL ASSUMPTION

Two fundamental constructional solution are considered. The first of them includes five elements, which after assembling constitute the separable joint (Fig. 1 left). The second one were modified by revision of the draft of mediating sleeve between expanded bolt and lug (Fig. 1 right). Both solutions characterize the same mass.

Geometry of considered joint corresponds to real structure solution of lower joint connection of agriculture aircraft. The extreme loading of real joint constituted tensile force P=215 kN.

NUMERICAL CALCULATION

In order to determine the stress distribution in the individual elements of the joint structure numerical calculation were executed using MSC PATRAN – AFEA programs. In both solutions contact elements on the borders of all collaborated elements were imported assuming friction factor $\mu=0.1$.

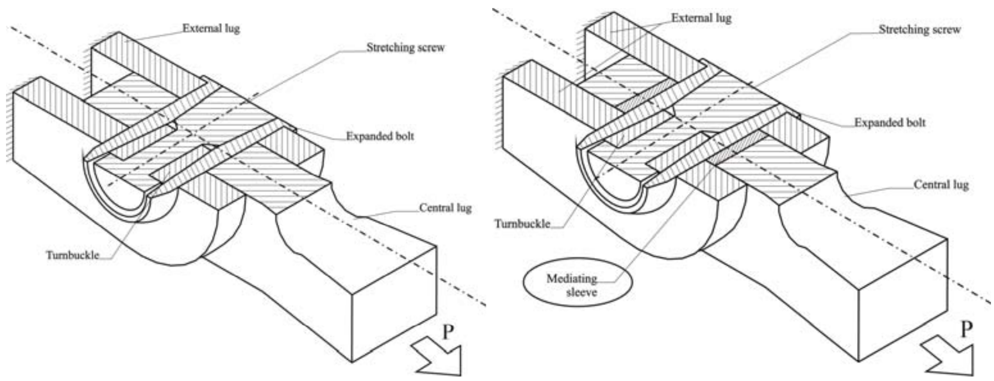

Fig.1 The joint before an after modification

On the basis of hexahedron 8 nodes elements numerical models were grounded. Fig. 2 shows the grids for both solution respectively.

The first solution (before modification) constituted the base of the datum, and on this base influence of mediating sleeve on the stress distribution were executed.

In the Figs. 3, 4, 5 the results of numerical calculations for the first version of structure solution are presented.

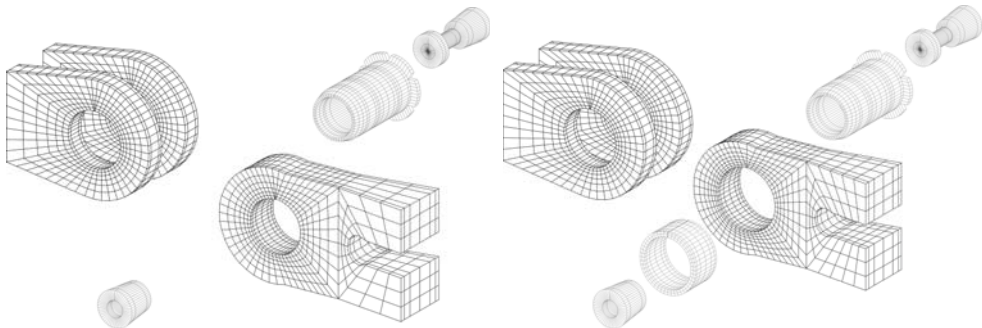

Fig. 2 Numerical meshing of structure before and after modification

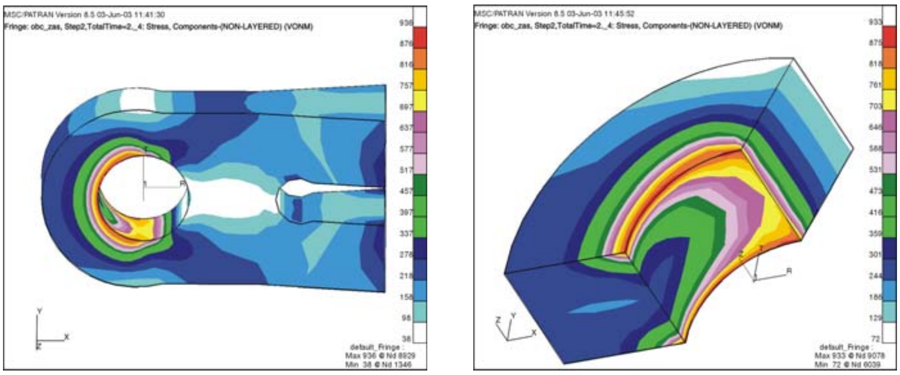

Fig. 3 Effective stress distribution in the lug

In the Figs. 3 effective stress distribution according to von Mises criterion in the central part (lug) are presented. Contour lines of effective stress on the external surface of considered element presents Fig. 3 - left, while the stress distribution in the characteristic orthogonal sections and on the external surface of lug from contact side with bolt shows Fig. 3 - right. On the basis of the above results dependence curves of effective stress in the function of width and thickness lug are presented.

Effective stress distribution on the expanded sleeve surface of the fundamental solution presents Fig.4. An abrupt change of stress level in the zone of the cut element paid attention.

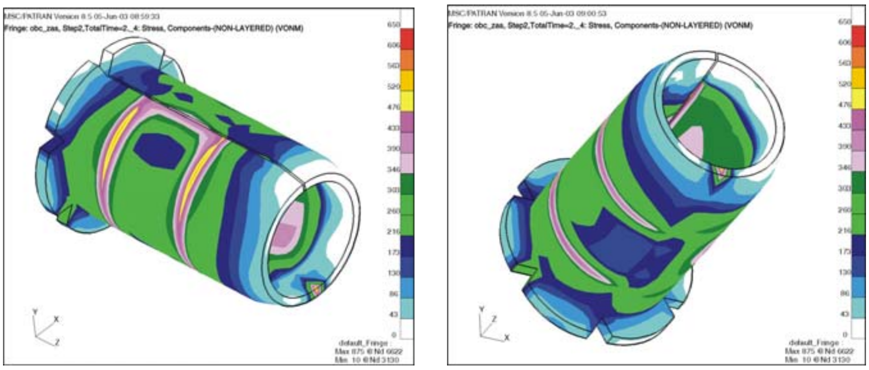

Fig. 4 Effective stress distribution on the expanded sleeve surface. Fundamental solution

Figs. 5 present the effective stress distribution in the external lugs of fundamental solution. Give attention to fact, that maximum effective stress are almost identical with the central lug area, however gradients in this case are more soft.

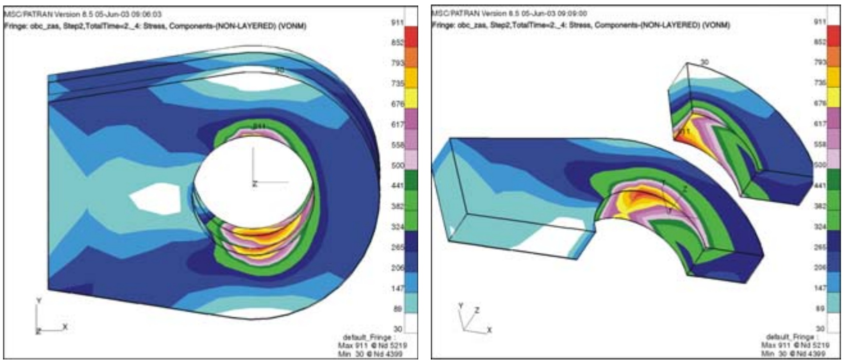

Fig. 5 Effective stress distribution in the external lugs. Fundamental solution

Fig. 1 – left presents the second construction solution which makes up presence of mediating sleeve. So, in the chain of the loading transfer by contact way, mediating element were inserted without overall dimensions modification. Such solution caused sensible changes both in the levels of stress and in the stress distribution. Effective stress distribution in individual elements of modified solution are presented respectively central lug (Fig. 6), external lugs (Fig. 7), expanded sleeve (Fig. 8), mediating sleeve (Fig. 9).

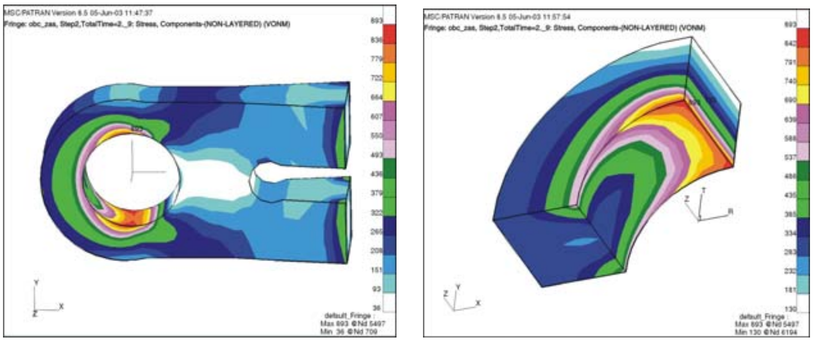

Fig. 6 Effective stress distribution in central lug – modified solution

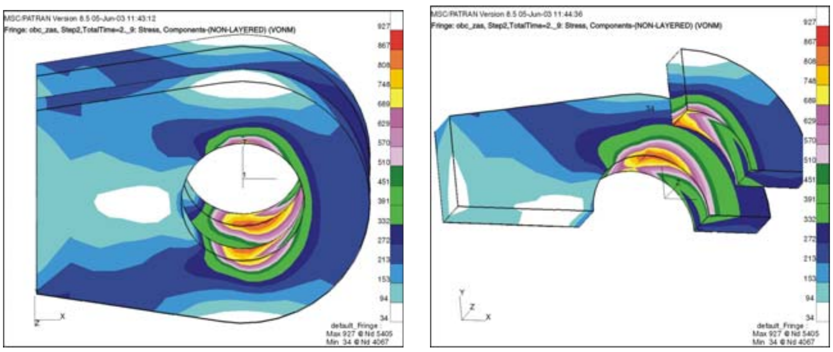

Fig. 7 Effective stress distribution in external lugs – modified solution

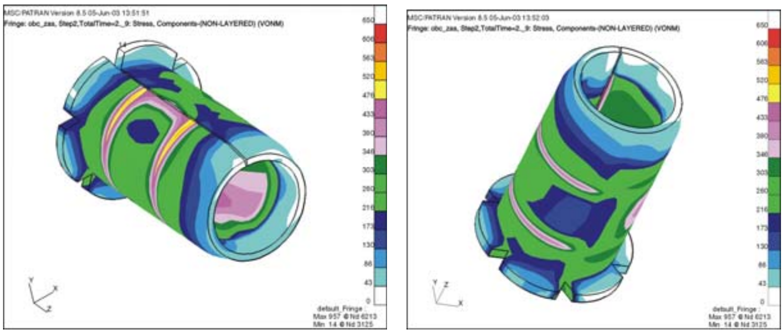

Fig. 8 Effective stress distribution in expanded sleeve– modified solution

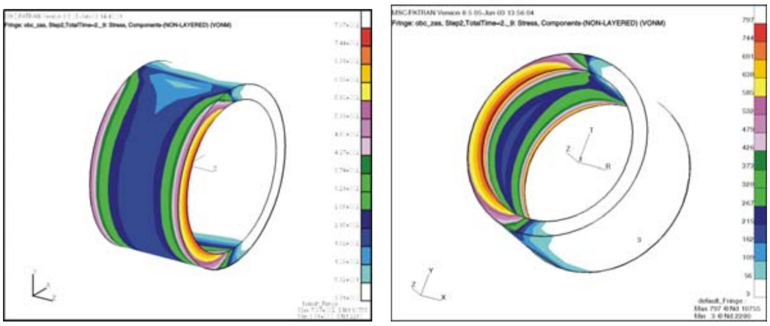

Fig. 9 Effective stress distribution in meditative sleeve – modified solution

Estimating quantitative level stress results and qualitative stress distribution of modified solution it is necessary to find the biggest differences in central lug, where maximum effective stress and stress gradients are smaller. Similar remark we can make in relation to all the rest elements of modified solution.

PHOTOELASTIC MODEL INVESTIGATION

Matter of course the most important is experimental verification both static and fatigue analysis. As to static investigation driving to determine the stress distribution on experimental way, very useful look to be photo elastic model investigation.

Experimental studies were carried out in the considered problem in the form of model examinations using photo-elastic frozen method. Basic, making it possible to execute models to examinations tool was posing laser stereo-lithography.

An executed with stereo-lithography technique two basic elements of one of the joint variations are presented in the fig. 10 on the left, whereas on the right a model of complete joint prepared to examination is presented.

Fig. 10 Models of two basic joint elements and complete joint prepared to examination

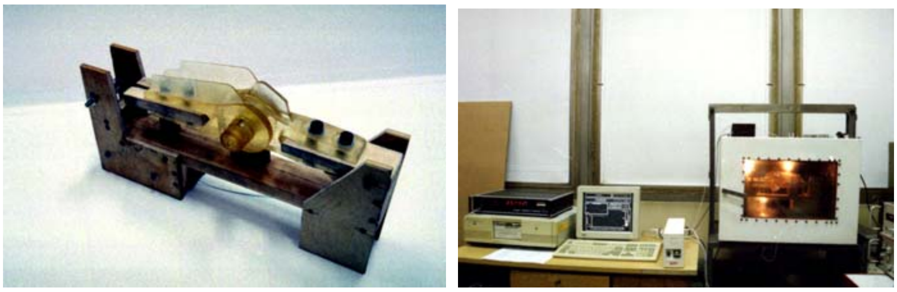

Fig. 11 Model fixed on the special station and general sight of the research position

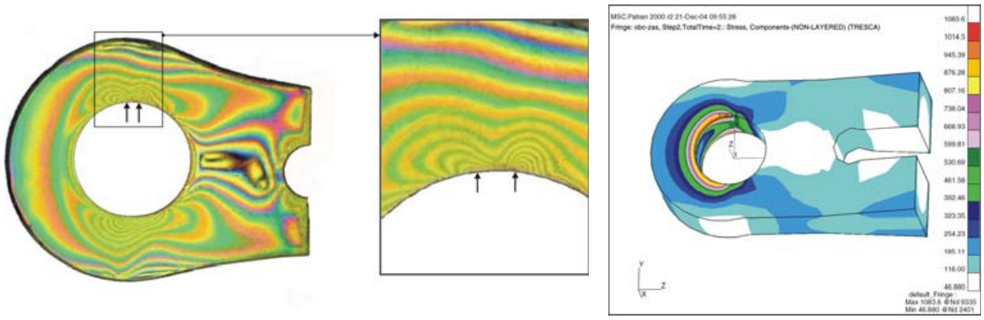

Fig. 12 Orders of isochromatics and effective stress distribution in central lug. Fundamental version

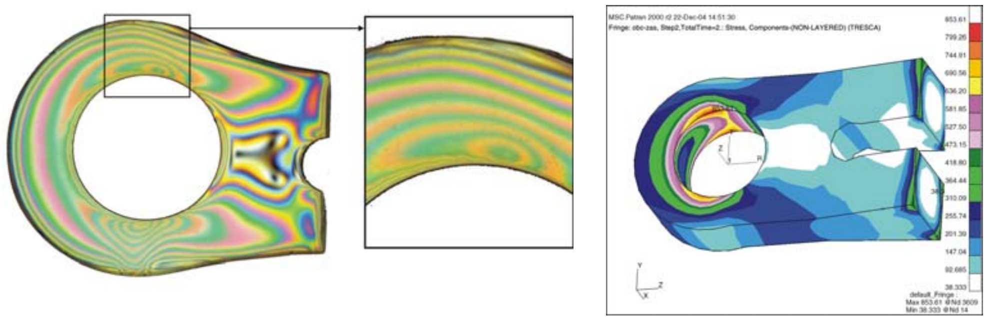

Fig. 13 Orders of isochromatics and effective stress distribution in central lug. Modified version

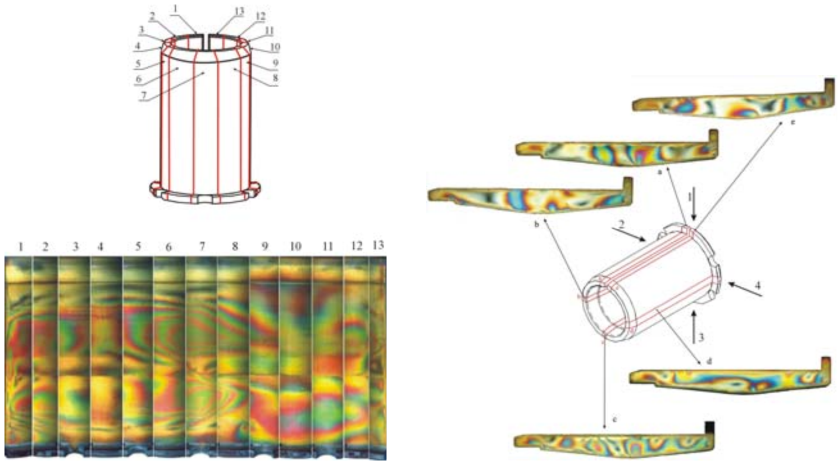

Fig. 14 Sight of isochromatics in expanded sleeve (in expansion) and in four zones of the sleeve (in cross section). Fundamental version

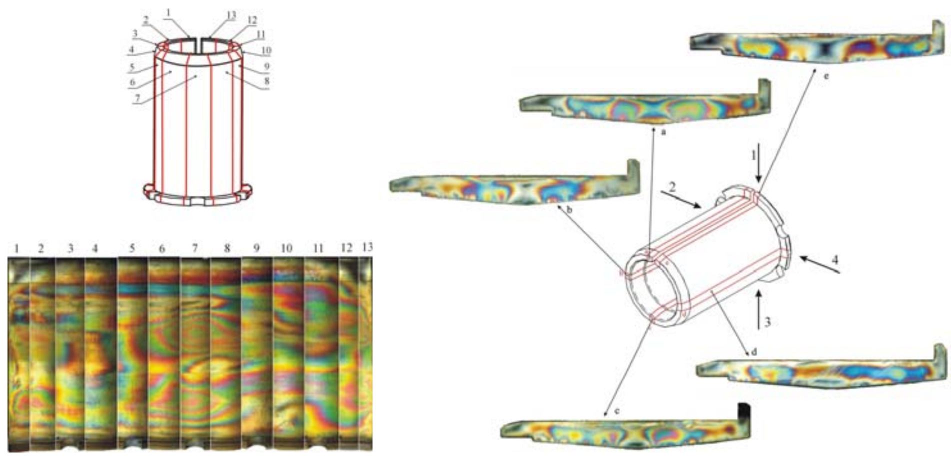

Fig. 15 Sight of isochromatics in expanded sleeve (in expansion) and in four zones of the sleeve (in cross section) - modified version

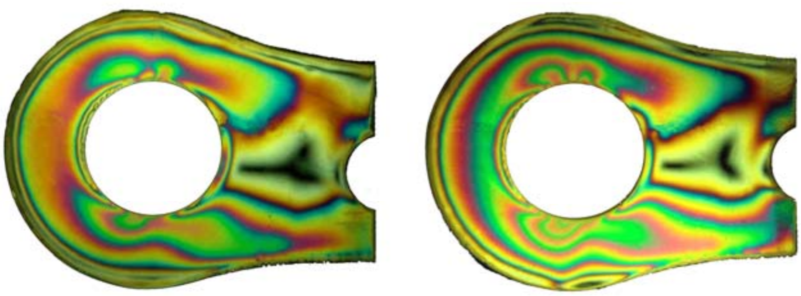

Fig. 16 Isochromatics distribution in external lugs: left and right respectively. Fundamental version

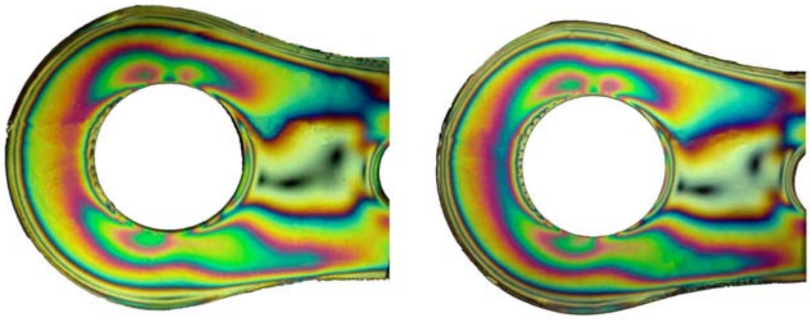

Fig. 17 Isochromatics distribution in external lugs: left and right respectively. Modified version

Pay attention that qualitative concordance of optical effects with numerical results will constitute the base to construct the adequate numerical FEM model. After verification justified look to be numerical fatigue investigation, before too expensive and labour-consuming experimental fatigue investigation.

CONCLUSIONS

Obtained results enable find, that inserting mediating element to the joint we are able to receive more advantageous solution. The explanation of this fact we can look for in local reduction of joint stiffness. In result the structure becomes more elastic and at the some time less flexible on the precocious fatigue damage.

Introductory numerical analysis (executed by MSC FATIGUE program) has shown that fatigue life of modified solution is repeatedly bigger than fundamental one.

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