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FINITE ELEMENT ANALYSIS OF MEMBRANE OF AUTOMOTIVE KEY

KONEČNOPRVKOVÁ ANALÝZA MEMBRÁNY AUTOMOBILOVÉHO KLÍČE

Abstract

The subject of this paper is solving process of pressing button of automotive key in environment of software ANSYS. Physical model include hyper elastic material, nonlinear spring and prescribed boundary condition of structural analysis. The main aims of this work were to get actuating forces of automotive key as well as to get stress and strain level of rubber membrane.

Abstrakt

Předmětem tohoto článku je řešení procesu stlačování tlačítka automobilového klíče v prostředí software ANSYS. Fyzikální model zahrnuje hyperelastický materiál, nelineární pružinu a předepsané okrajové podmínky strukturální analýzy. Hlavním cílem této práce bylo získání síly působící na automobilový klíč a napěťově-deformační analýza pryžové membrány.

Keywords

FEM, numerical analysis, hyperelastic material, Mooney-Rivlin, automotive key.

1 INTRODUCTION

One of criteria during development of automotive key is necessary force for button activation. Final force is purposely different for each button. However the force has to be in some optimal range because when the force is too low button can be spontaneously actuated and when the force is too high user can have trouble to use it. On mentioned property has the biggest influence design itself as well as material properties. However the most significantly is possible move the forces thru the membrane which is placed between button and switch. Especially from this reason is effective to focus simulation on this membrane and deformations behavior.

2 MATERIAL AND METHODIST

To determinate reaction forces together with structural analyses was solved by creating finite element model base on 3D geometry from CAD. The geometry was a bit simplified especially on plastic button which is used only for force transfer to the rubber membrane. Button was discretional by solid elements (solid 185) with linear base function and three degree of freedom in each node. On rubber membrane was effort to create as much as possible regular and mapped mesh base on solid185. For solving incompressible materials as has to be used for mentioned membrane obtain solid185 next degree of freedom hydrostatic pressure which is involved into internal nodes [4]. Element formulation calls „*mixed u-p*“ where final stiffness matrix has this form

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$$\begin{bmatrix} K_{uu} & K_{uP} \\ K_{pu} & K_{pp} \end{bmatrix} \begin{Bmatrix} \Delta u \\ \Delta \overline{P} \end{Bmatrix} = \begin{Bmatrix} \Delta F \\ 0 \end{Bmatrix} \tag{1}$$

where

Δu = displacement increment

$\Delta \overline{P}$ = hydrostatic pressure increment

The last part is switch, which is described by shell181 elements which has linear base function and six degree of freedom. By shells was set only position of switch, but stiffness is described by combin39. In this case it represents only nonlinear behavior of actuating process, see chart 1.

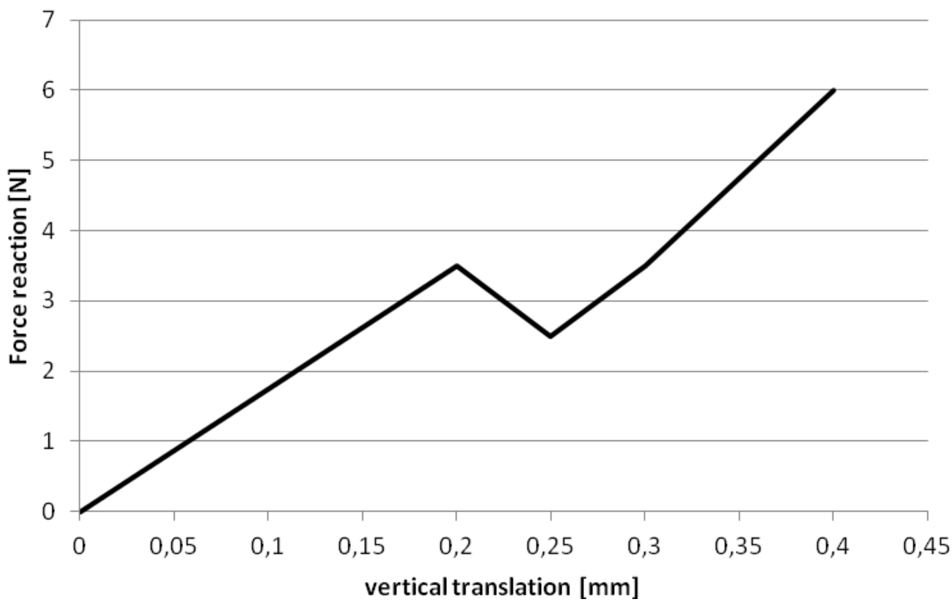

Fig. 1 Force dependence on translation of switch itself

Material of switch and button was linear elastic isotropic. See table 1.

Table 1 Material properties for switch and button

property	values	units
density	2900	kg/ m^3
E	4600	MPa
μ	0.3	-----

Membrane material is hyper elastic and from this reason appropriate constitutive low had to be determinate. Regarding to measured information two variants of constants were solved for 2 parametric Mooney-Rivlin and for Yeoh model [3].

In this paper we consider 2 parametric Mooney-Rivlin model

$$\sigma = \frac{\partial W}{\partial \lambda} = 2\left(C_1 + \frac{C_2}{\lambda}\right)\left(\lambda - \lambda^{-2}\right) \tag{2}$$

where

C_1 = material constant

C_2 = material constant

λ = stretch ratio

and the model of Yeoh

$$\sigma = 2\cdot\left(\lambda_1 - \frac{1}{\lambda_1^2}\right)\cdot\left[C_{10} + 2\cdot C_{20}\left(\lambda_1^2 + \frac{2}{\lambda_1} - 3\right) + 3\cdot C_{30}\cdot\left(\lambda_1^2 + \frac{2}{\lambda_1} - 3\right)^2\right] \tag{3}$$

where

C_{10} = material constant

C_{20} = material constant

C_{30} = material constant

λ_1 = stretch ratio

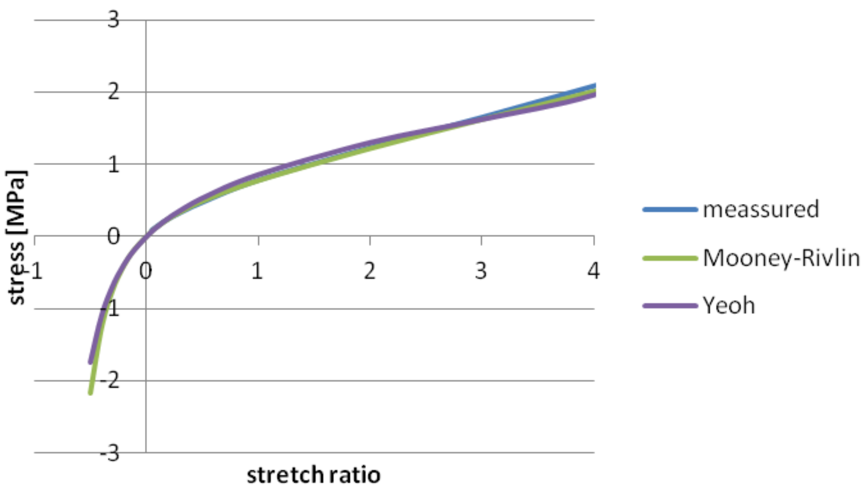

Fig. 2 Stress - stretch curve

According to limited experimental data (only tension and compression tests) it is recommended to use Yeoh model [4].

Table 2 Constants of Yeoh model

C10	C20	C30
0.255887	-0.00265	4.06E-05

Boundary condition definition was regarding to real position on complete key and the fact of symmetrical geometry (only ¼ were solved). Membrane was around perimeter clamp and button move into the contact with membrane. Switch has only one DOF as well as button to move vertically against to nonlinear spring. The spring was connected with switch on top side and on bottom side was fixed. The symmetry surface has removed DOF in normal direction.

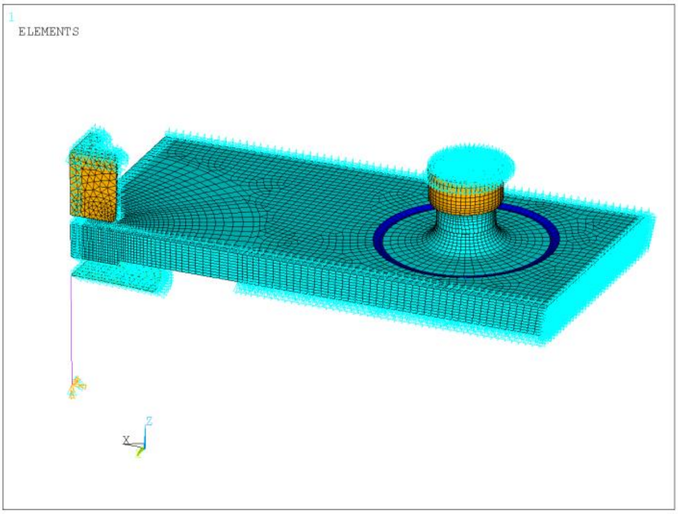

Fig. 3 3D geometry and applied boundary condition

3 Results

Deformation behaviour in whole usable range of button translation as well as curve of force reaction necessary for switch actuating has been obtained.

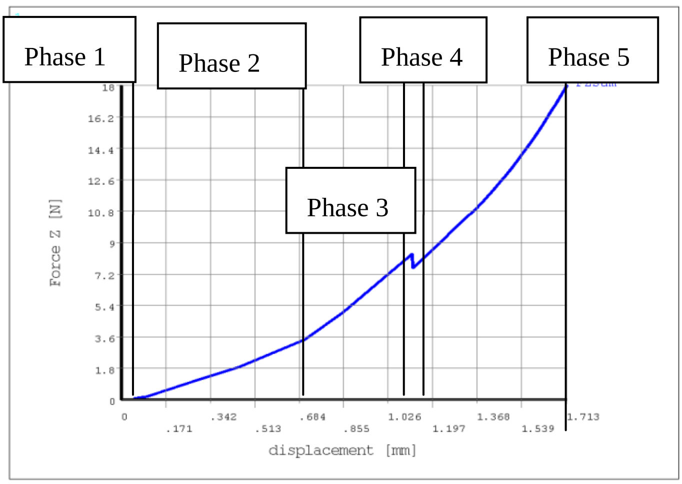

Fig. 4 Reaction force from button translation

The curve can be divided to the 5 phases. In first phase the button move into the contact with membrane and reaction force is zero. When contact occurs it is possible to see almost linear increasing of force (Phase 2) until membrane touch the switch where membrane is pressed between button and switch (Phase 3) till the force is high enough (3,5 N). The switch is actuated and reaction force goes abruptly down (Phase 4). Finally the force grows till damage of some component.

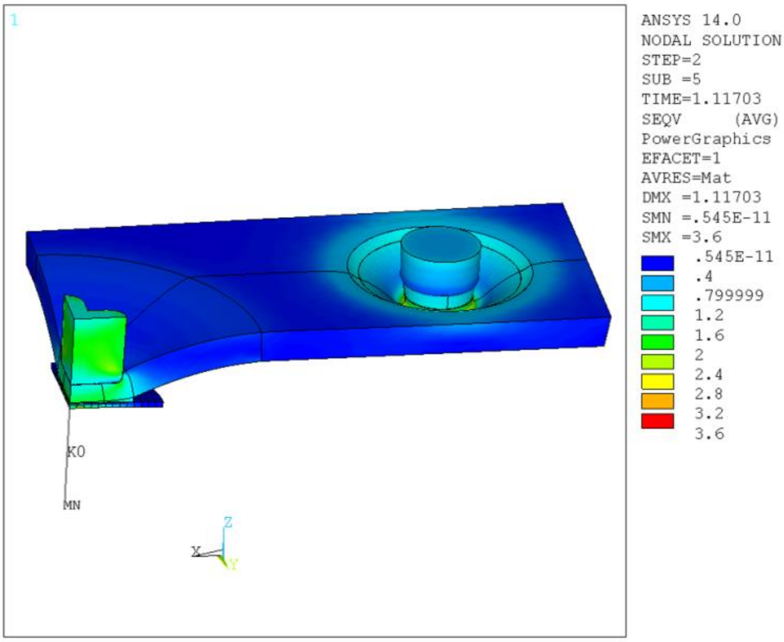

Fig. 5 Deform shape and HMH stress in time of switch actuating

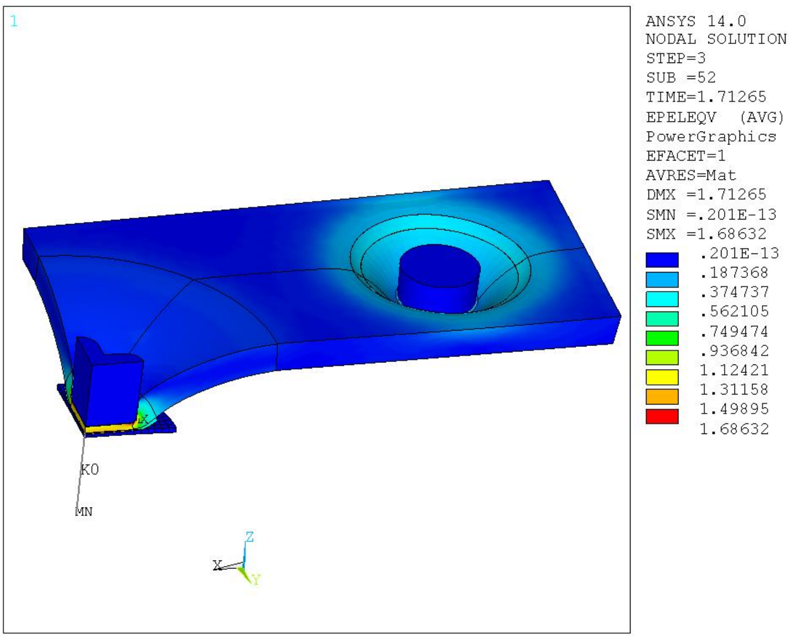

Fig. 6 Deformed shape and HMH strain in last time of test

4 Conclusion

There are presented main numerical results of nonlinear structural analysis performed on part of automotive key using ANSYS. The results were in the form of curve of reaction forces during switch actuating. The process of switching has been described and reasons why to do it. The next way in development should be looking for optimal shape of rubber membrane to degrease limit values of strain and avoid self contacts.

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