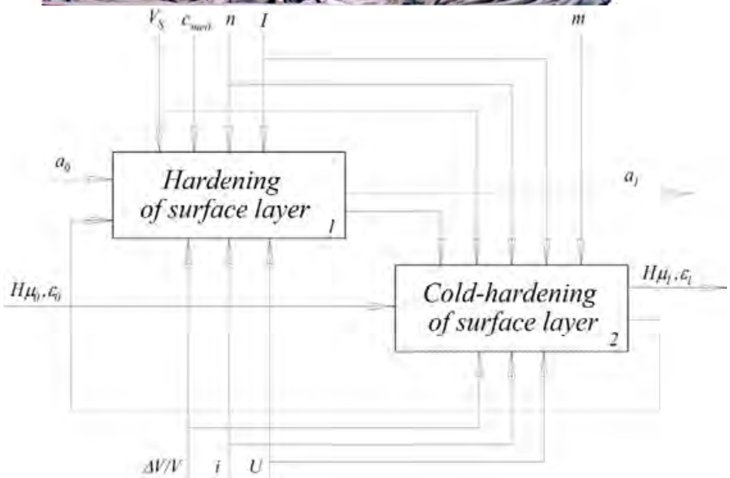

Fig. 3. Decomposition of the unit for formation of physical-mechanical parameters of the surface layer of the material

Relations $a=f\ (V_S,\ c_{звед.},\ n,\ m,\ I),\ =f\ (V_S,\ c_{звед.},\ n,\ m,\ I)$ between physical-mechanical parameters of the surface of material and technological modes of treatment of parts were obtained by applying a fractional factor experiment 2^{5-2} and processing of the experimental data in accordance to [3].

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FINITE ELEMENT SIMULATIONS OF RUBBER SEALS IN AUTOMOTIVE INDUSTRY

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Rubber profiles are used as weatherstripin doors, windows and trunks in the automotive industry [3]. Apart from keeping rain water and dust from entering the vehicle cabin (sealing), rubber profiles have also an effect onto noise control, vibration control and decorative trim [3].

In the process of construction of rubber profiles, numerical calculations using the Finite Element Method are very important. The use of nonlinear analysis software, such as MSC.Marc/Mentat, allows to speed up the design process and fully optimize rubber profiles in terms of the requirements [1].

The paper presents some aspects and problems regarding construction of car rubber seal profiles. For modelling rubber materials, formulation based on strain energy density function was used. Assuming incompressible isotropic material [2]:

$$I_3 = \lambda_1^{\,2}\lambda_2^{\,2}\lambda_3^{\,2} = 1 \tag{1}$$

the strain energy density function takes the form [2]:

$$W = \sum_{i,j=0}^{n} C_{ij}(I_1 - 3)^i\,(I_2 - 3)^j \tag{2}$$

$$I_1 = \lambda_1^{\,2} + \lambda_2^{\,2} + \lambda_3^{\,2} \quad , \quad I_2 = \lambda_1^{\,2}\lambda_2^{\,2} + \lambda_2^{\,2}\lambda_3^{\,2} + \lambda_3^{\,2}\lambda_1^{\,2} \tag{3}$$

$$\lambda_k = 1 + \varepsilon_k \,, \quad k = 1,\ 2,\ 3 \tag{4}$$

where:

- n – polynomial degree
- C_{ij} – constants
- I_1, I_2 – invariants of deformation state
- λ_1, λ_2, λ_3 – stretch ratios

For modeling solid rubber materials, the most often used model is the Mooney-Rivlin model, which reproduces correctly the stress-strain curves [2]:

$$W = C_{10}(I_1 - 3) + C_{01}(I_2 - 3) + C_{11}(I_1 - 3)(I_2 - 3) + C_{20}(I_2 - 3)^2 + C_{02}(I_2 - 3) \tag{5}$$

For modelling sponge rubber materials, the most often used model is the Ogden model [2]:

$$W = \sum_{n=1}^{N} \frac{\mu_n}{\alpha_n}\left[\lambda_1^{\,\alpha_n} + \lambda_2^{\,\alpha_n} + \lambda_3^{\,\alpha_n}\right] + 4.5K\left(J^{\frac{1}{3}} - 1\right)^2 \tag{6}$$

where:

- α_n, μ_n – constants
- K – bulk modulus
- J – compressibility

$$J = \lambda_1\lambda_2\lambda_3 \tag{7}$$

Figure 1 presents an example of car door seal cross-section. For such rubber seal profiles, the following are important [1]:

1) bubble deformation (crush) force through the door at the nominal position and 2 mm more deformation (Fig. 2),
2) flange slip-on and remove forces for a different flanges thicknesses and two seals configurations: a hammer montage and a roll forming (Fig. 3).

In the case of bubble deformation, the required value of crushing force is obtained by appropriate shaping and thickness change of the bubble. In the case of flange slip-on and remove, the required values of forces for the minimum and maximum flange thicknesses are obtained by the proper shaping of the lips.

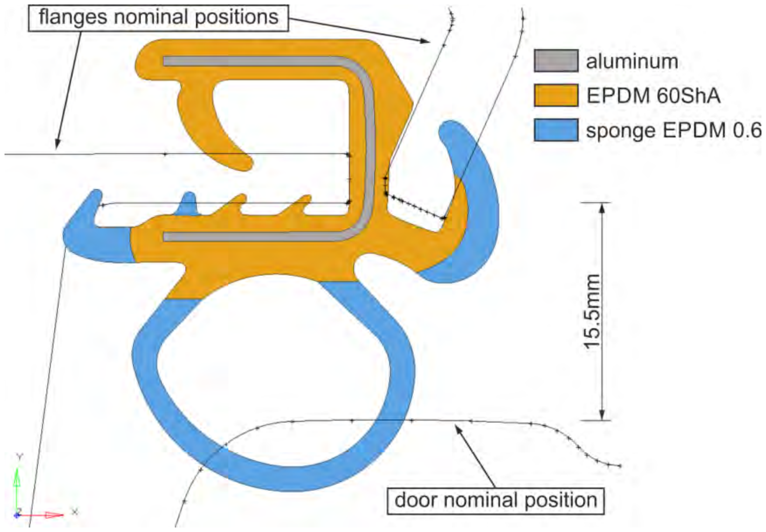

Fig. 1. Example of car seal profile cross-section.

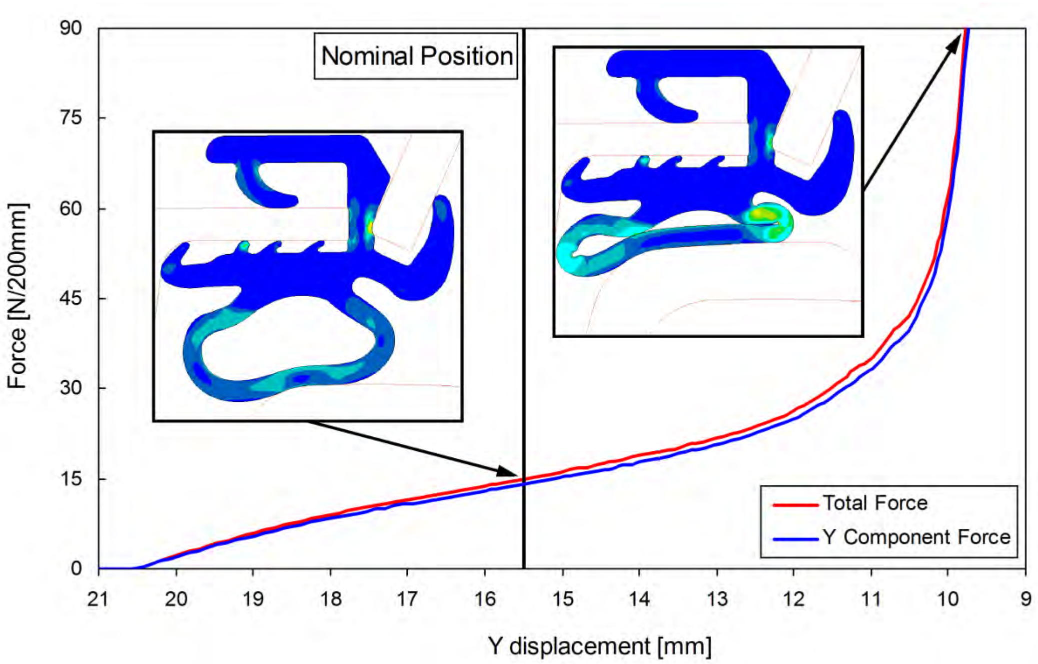

Fig. 2. Example of crush force plot for bubble deformation.

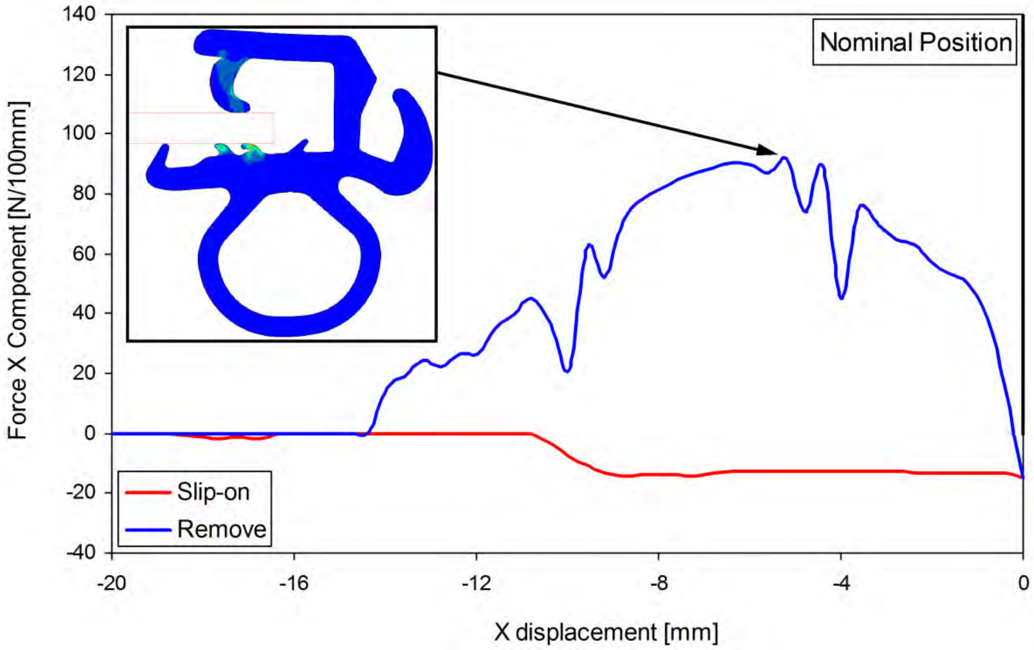

Fig. 3. Example of flange slip-on and remove force plot.

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