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INFLUENCE OF THE GEOMETRIC CONFIGURATIONS OF THE HUMAN VOCAL TRACT ON THE VOICE PRODUCTION

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Abstract: *The three-dimensional (3D) finite element (FE) model of the human vocal tract was constructed, based on CT measurements of a subject phonating on [a:]. A special attention is given to the higher frequency range (above 3.5 Hz) where transversal modes exist between piriform sinuses (PS) and valleculae (VA) and where the higher formants can create a formant cluster known as the speaker's or singer's formant. Since the human ear is most sensitive to frequencies between 2 and 4 kHz concentration of sound energy in this frequency region (F4-F5) is effective for communication.*

Keywords: ***Biomechanics of voice, 3D FE model, acoustics characteristics, singer's formant***

1. Introduction

At present, a considerable attention is given to the computer simulation of voice production in relation to the sound pressure field inside the human vocal tract during phonation. Main effort is focused on understanding the generation of the articulated audio signal and all the factors influencing this process and the voice quality. The mathematical models of the human vocal tract allow much easier and detailed computer analysis of the acoustic pressure in the vocal tract than it can be obtained by acoustic measurements *in vivo*. A number of simplified 1D models of the vocal tract cavities can be found in literature - see e.g. Titze at al. (1997) or Laukkanen at al. (2009). However, it is necessary to accept, that these models were derived under the assumption of planar acoustic waves travelling in the vocal tract and don't accept the 3D geometric configuration of the real human vocal tract (Vampola at al., 2008).

2. Simplified model of the human vocal tract

The influence of geometric configuration of the human vocal tract on the generated acoustic pressure was in the first step simulated by the simplified model shown in *Fig* 1. The method of direct physical discretization was used for the derivation of physical parameters of this model. This method is sufficient for a quantitative assessment of the influence of geometric modification of the vocal tract on the acoustic characteristics. The condition of the static pressure equilibrium can be reformulated as

$$\mathbf{K}(\mathbf{p})\,\mathbf{k} = \mathbf{f}\,, \tag{1}$$

where **K(p)** is the stiffness matrix whose elements are functions of the pressure obtained from the analysis of 3D FE model. The vector **k** contains unknown stiffness parameters of the linear chain (*Fig.1)* and the vector **f** results from the inhomogeneous boundary condition $p(x_0,t)=p_0(t)$ at the vocal folds. The stiffness parameters of the simplified model are computed by using the additional condition on the first eigenfrequency that is identical with the 3D model.

3. Influence of geometric configuration of the model on the position of the resonant peaks

The influence of the volume changes of the piriform sinuses (PS) and valleculae (VA) to the generated pressure characteristics of the vocal tract was simulated on the simplified model. The *Fig*. 2 presents

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the output pressure at the point defined by the coordinate x_7 in dependence on the excitation frequency for a nominal size of the PS and VA. The PS and VA cavities generate anti-resonances in the frequency response. At the antirezonance frequencies the acoustic energy is concentrated in the "parallel" branches of PS and VA where relatively high vibration amplitudes appeared. These findings were compared with the more complicated phenomena found in the 3D volume models (see Fig. 3).

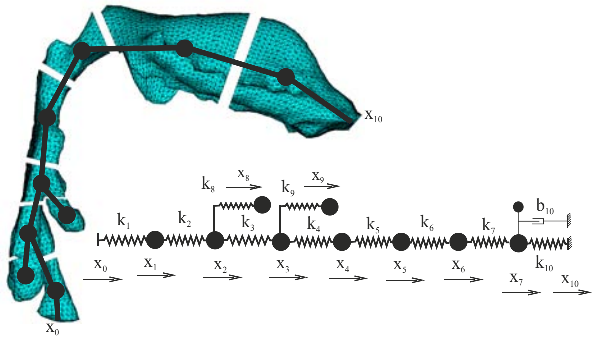

Fig.1 Simplified model of the human vocal tract derived from the 3D FE model based on CT images.

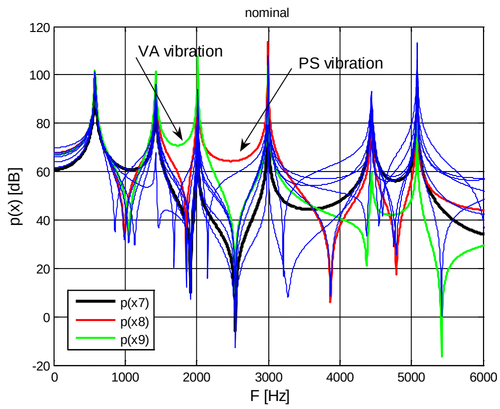

Fig.2 Numerically simulated acoustic pressure using the simplified model of the vocal tract.

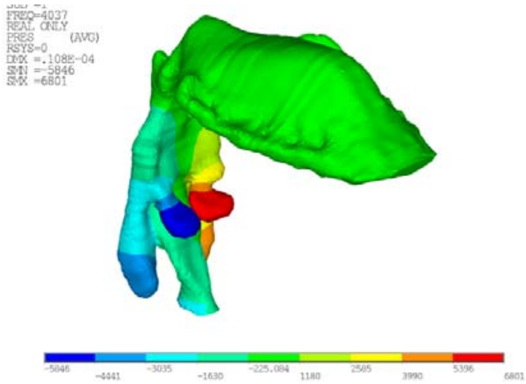

Fig.3 Acoustic mode shape of vibration at first significant antiresonant frequency.

4. Conclusions

The simplified, computationally efficient 1D model of the vocal tract was assembled and used for prediction of the pressure fields for a more clear explanation of effects of geometrically changed configurations of the human vocal tract resulted from the size of piriform sinuses and valleculae. The findings were compared with the results acquired from the 3D FE models with the good correlation.

Acknowledgement

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