The source voice generation on the basis of the “compressed air bubble” principle

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Abstract

The vocal folds are the organ producing human voice. The literature presents several models of the vocal folds function, still none of them offers a consistent and definite explanation of their function. The paper focuses on the new functional model of the generating loud voice. This functional model has been defined and developed on the basis “compressed air bubbles”, in short “bubbles”. The results of the physical compensatory vocal folds are presented in the paper.

1. Introduction

There have been several modified versions of the vocal folds function described in literature. They share a common predominant view whose central idea is an expressive effect of Bernoulli´s underpressure produced within the space of the glottis at an increased speed of the airflow which passes between the vocal folds in motion. In the version of the vocal folds function an important role is played by the flowing air alone and its variable parameters (pressure, speed and mass).

Due to the numerous weak points identified regarding these principles there has been a new principle defined and developed, preliminary called „*compressed air bubbles*“, in short „*bubbles*“. This paper describes this new functional model of generating loud vowels. The plane finite-element model of the vocal folds function has been used for verification of the compressed air bubble principle. The basic parameters of the model are characteristics of the subglottal pressure in relation to the glottis gap, and further the spectral and modal properties of the vocal folds structure. The results of the physical compensatory vocal folds are presented in the paper.

2. The definition of the „compressed air bubbles“ principle

The transport of the compressed air bubble (air column, small air volume) through the glottis from subglottal to the supraglottal space is the fundamental idea of this principle – [1], [2], [5], [6]. The plane model scheme of the vocal folds motion has been used to define this principle – Fig.1.

The air bubble with the highest subglottal pressure should be shifted as soon as possible to the upper part of the closed glottis. After the glottis opening the bubble expands from the higher subglottal pressure and the resulting acoustic pressure amplitude of the generated voice has a higher value in this case. This condition is very important for the higher intensity of the voice generation. This means the bubble should not start to expand during transport within the glottis. This idea is fundamental to the bubble principle and differs from principles defined by other authors.

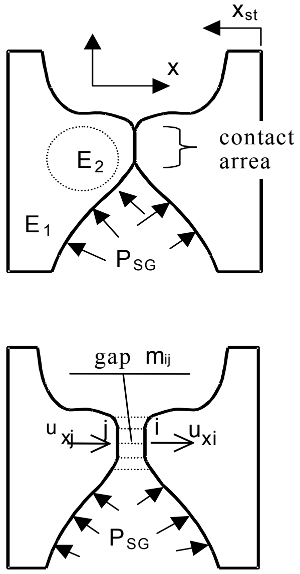

Figure 1: *The scheme of the vocal folds motion*

According to this principle of the vocal folds function, the main forces acting on the vocal folds during phonation are as follows :

- the subglottal pressure under the vocal folds and in the whole trachea; the overpressure acts on the relatively large inner subglottal surface, producing a considerable force opening the vocal folds,

- the flexible (elastic) forces of the vocal folds muscles which act against the opening of the vocal folds,
- the inertia forces of the vocal folds structure.

The inertia forces of the air bubble cannot play a significant role with regard to the low value of air density, the small size of the moved bubble and also to the small airflow speed.

The driving phenomenon for the vocal folds during phonation is the compressed air in the subglottal space, which always reaches a higher value here than within the supraglottal space. As a result the basic characteristics of the model function is the relation of the subglottal pressure, p_{SG}, and the opening between the vocal folds, m, in the form defined by relation $p_{SG}(m)$ – [1], [2], [5].

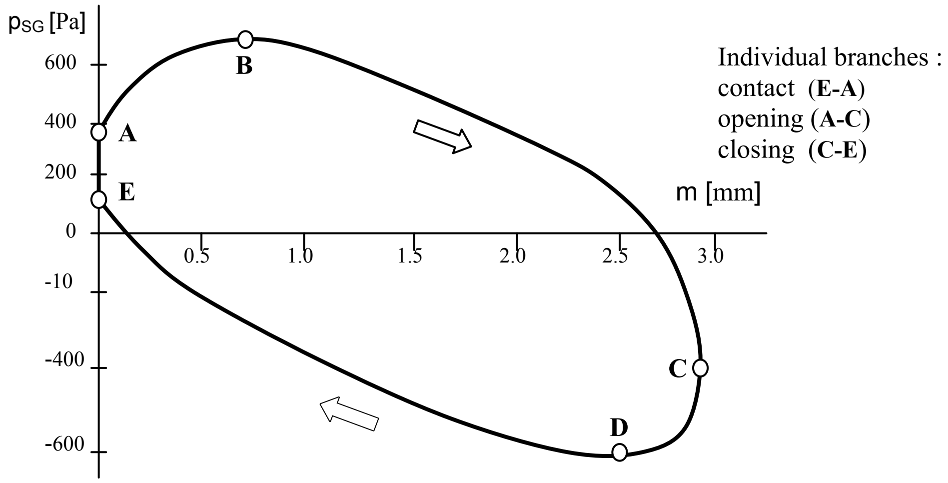

Figure 2: *Subglottal pressure versus glottis, $p_{SG}(m)$*

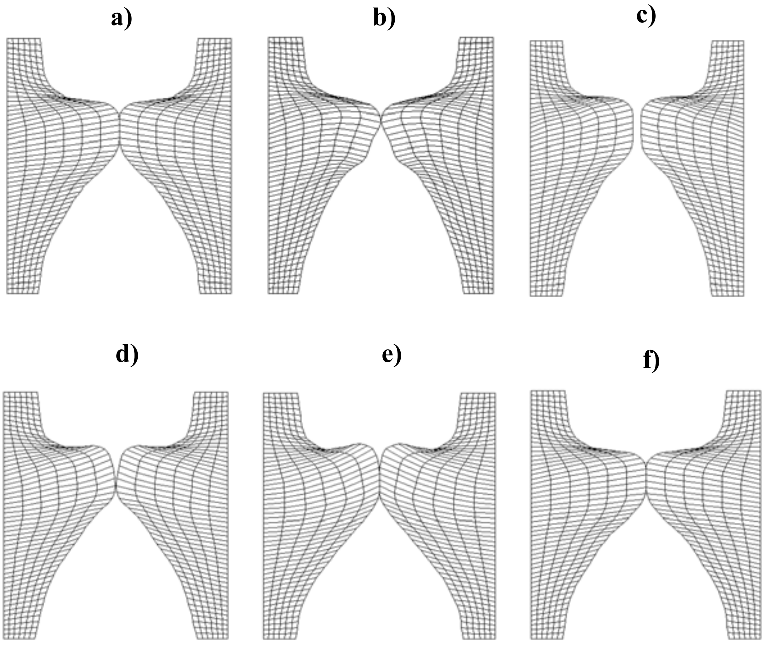

Figure 3: *The important phases of the vocal folds motion*
a), b), c), … *individual phases*

This characteristic, to be measured in artificial vocal folds (type K) is presented in Fig.2. The subglottal pressure has basically three branches – Fig.2.

The finite-element model of the vocal folds function [6] has proved a satisfactory degree of correspondence during phonation between individual parts of the vocal folds and the whole system.

In Fig.3 are presented individual relevant phases of the vocal folds motion when the principle of the compressed air bubble was used.

The analysis of the responses according to Fig.3 indicates that the model based on the principle of the compressed air bubble generates phonation phases in agreement with the real vocal folds system.

On the basis of the principle of the vocal folds function to be presented by the author have been created and developed the real physical models of the vocal folds – see patent application [3].

The source voice spectrum of the individual compensatory vocal folds system is for:

- speaking aloud with the artificial vocal folds (generates the discrete spectrum – Fig.4).
- speaking in a whisper with a special air jet (generates the continuous spectrum – Fig.5).

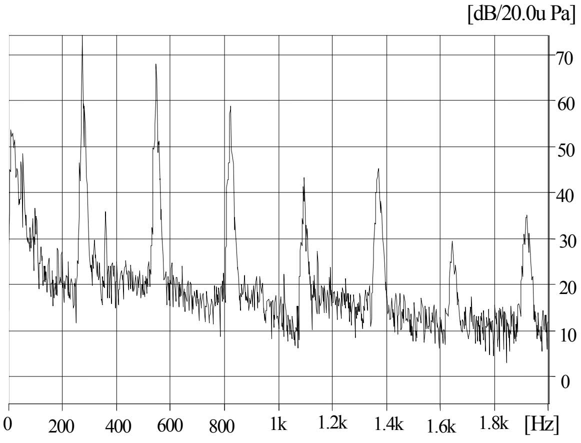

Figure 4: *The discrete spectrum of the source voice*

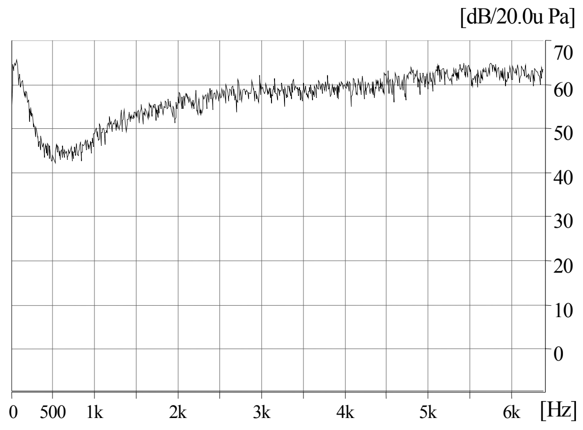

Figure 5: *The continuous spectrum of the source voice*

The vocal tract can also be excited by an external source voice independent of the vocal folds´ activity. The possibility of the external excitation of the vocal tract appears to be the supply of the compressed air through the compensatory vocal folds placed in the sinus nasal – see Fig.6, [4]. The systems stimulate the excitation of the vowel formants (due to the acoustic vawe creation) while the flowing air is able to generate the individual consonants.

The patient´s vocal tract was excited by the external source voice of the compensatory vocal folds for speaking in a whisper. The spectrum of the vowel a obtained is presented in Fig.7– [3], [4].

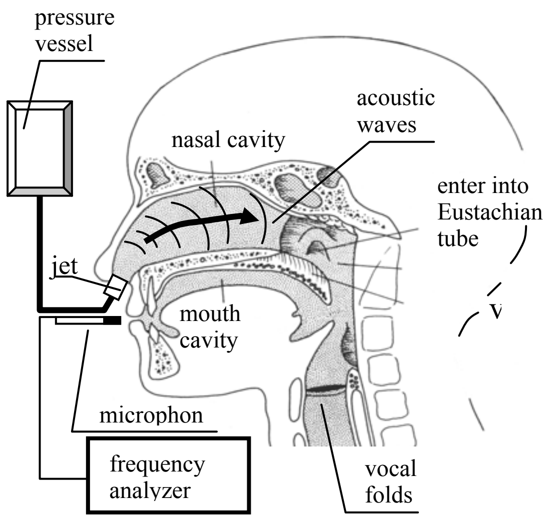

Figure 6: *External excitation of the vocal tract*

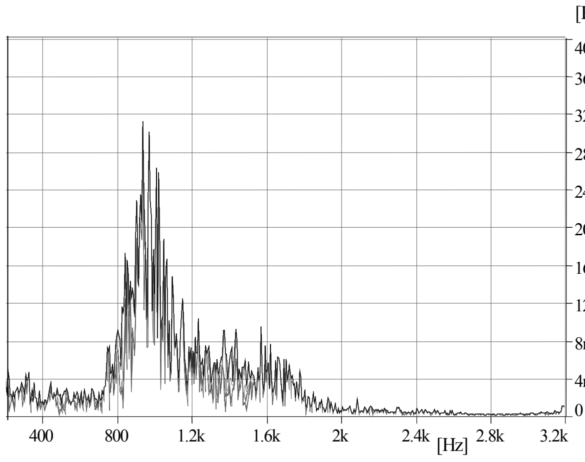

Figure 7: *Spectrum of the vowel* „a“

From this spectrum it is possible to define individual vowel formants correctly and exactly. The vowel spectra to be excited by an external source voice have similar shapes to those generated by the people with healthy vocal folds [4].

3. Conclusion

The created finite-element model of the vocal folds function, based on the principle of compressed air bubble expelled through the intraglottal space up into the supraglottal space and further up into the vocal tract, appears to be viable and corresponding to the observation.

The basic parameters of the model are the characteristics of the subglottal pressure in relation to the glottis, and further the spectral and modal properties of the vocal folds structure.

The validity of the “compressed air bubble principle ” has been confirmed by the physical models of the compensatory vocal folds systems. These artificial vocal folds were used for the patient´s external vocal tract excitation after laryngectomy.

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4. Reference

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