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A Numerical Simulation of Unsteady Flow in a Quasi-Seesaw Glottal Model

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Abstract: We present a model for forced oscillatory motion of vocal folds. In this model, we incorporate oscillatory motion of the glottis by considering the moments of glottis about its fulcrum point which is very similar to seesaw motion. By changing the position of the fulcrum point, we can have different scenarios for the motion of the glottis. Forced oscillatory motion of vocal folds, together with the solution of Navier-Stokes equations, approximates the flow within an idealized human glottis. Typical results are obtained by considering Reynolds number 1000 for the cases when fulcrum point is in the middle of the glottis and when it divides the glottis in the ratio 1:3. Fulcrum point plays a pivotal role in determining the characteristics of glottal flow. It has strong effect on the central pressure and axial velocity profiles, cross-sectional velocity profiles at the inlet, outlet and within the glottal constriction and formation and structure of vortices in the glottal flow. When the fulcrum point is located nearer the entry section, amplitude of the forward flow at the entry decreases, reverse flow at the outlet is reduced, jet flow is smoothed out at the outlet and flow separation locations are concentrated at the exit.

Key words: Quasi-seesaw glottal model · Unsteady flow · Vocal folds · Jet flow · Separation locations

INTRODUCTION

Vibration of the vocal folds plays a central role in the production of human voice. A mathematical and numerical model could be very helpful in the study of laryngeal aerodynamics. Due to flow-induced vibration of the vocal fold is, computational simulations of vocal fold oscillation include h airflow and tissue dynamics models.

The simplest models are one- and two-mass models which were presented by Flanagan and Landgraf and Ishizaka and Flanagan respectively [1, 2]. These models are assumed to be one dimensional, inviscid and quasi-steady so that the Bernoulli's law can be applied. Many improvements and variations to these models have been employed in [3-8].

Some important effects such as flow separation in the glottis [9,10], Coanda effect [11-12], intraglottal pressure and velocity distribution [10, 12-16], glottal airflow rate [10, 17, 18], pulsating air jet flows [19-21] and supraglottal jet turbulence [12] have been studied in higher dimension by means of the computational dynamics. The experimental and numerical results indicate that the airflow can be approximated by boundary layer theory [22] and it is greatly influenced by the wall motion [4, 9] as pressure distribution, friction factor which contribute considerably in the oscillation of the vocal folds.

The behavior of fluid motion in the glottal constriction is looked like incompressible and earlier works show that along with monopole source, a dipole source should have significant importance in the voiced sound production [23]. The sound pressure cannot be estimated well with the Navier-Stokes solvers at low Mach numbers. Alternatively a two step procedure has been reported in [24-25]. The aerodynamic sources are computed in the first step which are, then, used to estimate the propagation and radiation of the sound in the next step. Some effort has been made in compressible form of the Navier-Stokes equations but leads to concern about the order of magnitude between acoustic fluctuations and other variations in the fluid variables [26, 27].

The flow behavior has also been investigated over a wide range of wall-mounted geometries [28-39] and it is shown that the presence of a polyp disrupts the normal

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