Aeroacoustic simulation on a simplified vocal tract model with tongue movement for the articulation of [s]

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Introduction

Sibilant [s] is one of fricative consonants, and known to be pronounced by forming a jet flow and its aeroacoustic sound in the front part of vocal tract [1]. When the [s] is produced, a constricted flow channel is formed by elevating a tongue tip towards an alveolar ridge.

The production mechanisms of [s] have been investigated by several researchers. Hamlet *et al.,* [2] used electro-magnetic sensors and showed that the tongue contact on the hard palate occurs after the appearance of fricative noise, whereas the duration of the sound is longer than the duration of the tongue contact. In our group, to clarify the relationship between the flow and sound generation, a simplified vocal tract model of [s] was constructed based on medical images, and large eddy simulation (LES) was conducted [3]. In addition, effects of tongue movement speed on the articulation of /s/ were investigated by experiments using the movable tongue model [4]. However, the mechanisms of jet flow and source generation during the tongue movement are still unclear. Therefore, in this study, the LES is conducted on the simplified vocal tract model with movable tongue to clarify the relationship between the flow and sound generation in the articulation of [s].

Methods

The simplified vocal tract model is depicted in Fig. 1. The tongue model ascended and descended by 3 mm with tongue speed 40 mm/s from the position of [s] with constant flow rate 18 L/min. The three-dimensional Navier-Stokes equations were solved by finite difference method and volume penalization method which allows the wall boundary to move in the vocal tract.

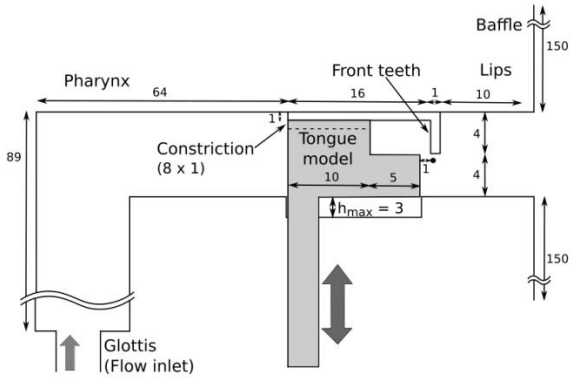

Figure 1: Simplified vocal tract model for the articulation of /s/.

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Results and Discussion

The velocity distribution on mid-sagittal plane of the simplified vocal tract model and iso-surfaces of second invariant of velocity gradient tensor during tongue ascent are shown in Fig. 2. Results showed that the turbulence started occurring and the jet flow formed the vortex tubes which becomes the sound source during the tongue ascent. This suggests that the proposed simulation is applicable for the investigation of fricative articulations.

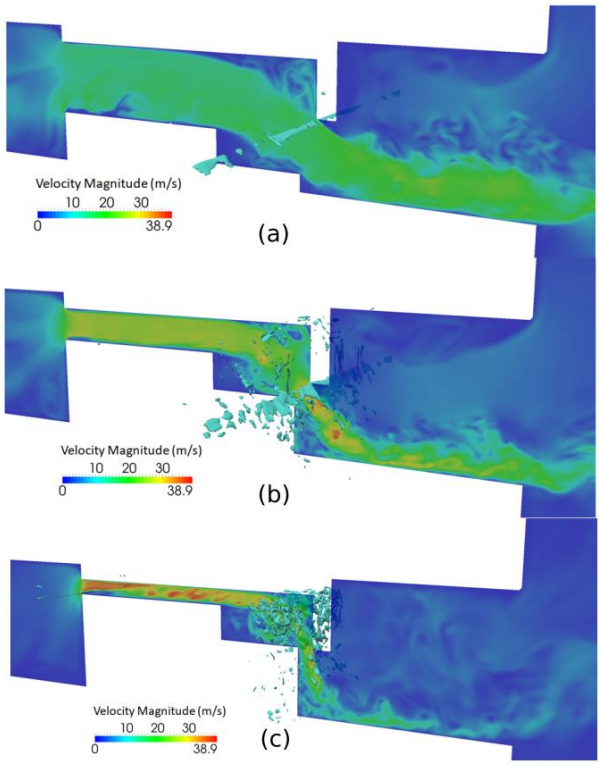

Figure 2: Velocity distribution on mid-sagittal plane of the simplified vocal tract model and iso-surface of Q during tongue elevation (a)h = 0 mm, (b)h = 2.16 mm, (c)h = 3 mm.

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References

[1] Stevens, K. N., *Acoustic Phonetics* (The MIT Press), 1998.
[2] Hamlet *et al.*, J. Acous. Soc. Am., 65:1276-1285, 1979.
[3] Yoshinaga *et al*., Phys. Fluid. 30:035104, 2018.
[4] Yoshinaga *et al*., PLoS One 14:e0223382, 2019.