別紙４－１（課程博士（英文））

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Abstract (Doctor)

Title of Thesis	Analysis for Jet Fluctuation and Acoustic Radiation of Flute-Like Instruments

Approx. 800 words

To elucidate the mechanism by which the radiated sound changes with conditions of blowing and the instrument's shapes, this study performed numerical simulations and experiments simulating actual conditions. Focusing on the interaction between the airflow and the sound of flute-like instruments, this study proposed an analytical method for sound changes taking into account the jet deflection observed in the simulations. The effects of the jet deflection on the harmonic structure and its mechanism were also clarified.

First, an analytical method for quantifying jet fluctuations was proposed to determine conditions of blowing or instrument shapes that mainly contributes to sound changes. This method was first utilized in the recorder, which has fewer variable parameters of blowing than the flute. To decompose jet fluctuations into an acoustic and a fluid dynamic oscillation, a formula represents jet fluctuations was proposed by modifying the Fletcher's formula (*JASA*, 1976) based on the jet fluctuations predicted by direct aeroacoustic simulations. This formula takes into account the initial amplitude at the exit and the jet deflection toward the edge, which were observed in the simulations. The jet fluctuations in the simulations were represented by this formula, and the characteristics of fluctuations (the convection velocity, the amplification rate, the acoustic feedback effects, and the actual jet offset) were quantified. As a result, the difference in the mode predominancy seems to be produced by the difference in the amplification rate probably due to a difference of exit shape (straight- or arch-shaped). This analytical method seems to be useful for investigating mechanisms of sound changes.

Second, the effects of the jet angle (angle between the jet and the mouth opening) on the harmonic structure and their mechanism were shown for the flute. The jet angle is an additional parameter for the flute, whereas it is generally fixed to zero in the recorder. The effects have remained unclear. This study compared the effects of jet angle with those of other parameters within a practical range. Blowing parameters were varied independently by an artificial blowing device with reference to the actual blowing condition measured for a flute player. The radiated sound showed that the effects of the jet angle on the harmonic structure is less than those of the jet offset and almost equal with those of the flow rate and comparably larger than the distance. The mechanism for the change of harmonic structure with the jet angle was investigated from the flow

field measured with a hot-wire anemometer. In this measurement, the jet offset was fixed to zero. Periodical jet fluctuations were determined by phase-averaging the measured values to quantify the characteristics of jet fluctuations. As a result, with increasing the jet angle (the jet direction approaches vertical to the mouth opening), the jet was found to deflect more inside. Due to the deflection, the actual jet offset was found to decrease with increasing the jet angle. This decrease of the actual jet offset was almost consistent with the change of harmonic structure with the jet angle. The amplitude of the second and the third mode of jet fluctuations can also affect the harmonic structure; however, the amplitude was found to affect little. The variation of the harmonic structure with the jet angle seems to be mainly caused by the change of the actual jet offset due to the jet deflection.

Third, the mechanism of the jet deflection was investigated by direct aeroacoustic simulations, reproducing the shapes of the flute head joint and the oral cavity used in the experiments. The acoustic and the flow fields were investigated for the two jet offsets (the relative height of the jet from the edge). The acoustic field showed that ΔSPL increases as the actual jet offset increases. This tendency is consistent with the experiments. The velocity vector in the flow field showed that, when the jet deflects inward, the jet is bent toward the inner wall and flows along the wall due to the Coanda effect on the jet. As the jet offset decreases, the distance between the jet and the edge increases. This can increase the air entrained into the jet and thus the Coanda effect. Due to the Coanda effect, the jet is drawn to the inner wall, which possibly promotes the outward movement of the jet. As the jet offset decreases, the Coanda effect seems to increase, resulting in the outward deflection of the jet. Also, the distance between the jet and the edge changes with the jet angle. The inward deflection of the jet when increasing the jet angle, which is observed in the second work, is probably caused by the decrease of the Coanda effect.