

論文の内容の要旨

Thesis Summary

論文題目: Control for dissimilar momentum and heat transfer with streamwise travelling wave-like wall blowing and suction

(流れ方向進行波状の壁面吹き出し・吸い込みを用いた運動量と熱輸送の非相似制御)

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Increasing the efficiency of thermo-fluid devices like heat exchangers is of great interest to the heat transfer community owing to its use in a wide range of industrial applications. This is, however, quite challenging due to the similarity in the governing equations as well as the transport mechanisms of momentum and heat transfer as discussed in chapter 1. In this thesis, the dissimilar response of the velocity and temperature fields under a traveling wave-like wall blowing and suction control input is analyzed in detail.

In chapter 2, we present the results from a series of direct numerical simulations(DNSs) of heat and momentum transfer in a fully developed laminar channel flow (LCF) subject to a traveling wave-like wall blowing and suction. By systematically changing the wavelength λ_x and the phase speed U_p of a traveling wave, their impacts on the skin friction coefficient C_f , the Stanton number St , and their ratio, $A = 2St/C_f$, named the analogy factor, are evaluated at different Reynolds numbers. Significant dissimilar heat transfer enhancement is confirmed for $U_p > 0$. It is also found that such a control input remains advantageous even when the power consumption for applying the control input is taken into consideration. In order to analyze the dissimilar responses of the velocity and thermal fields to the

applied control input, we introduce the influential layer thickness and the magnitude, of the Reynolds shear stress and the convective heat flux. It is shown that the influential layer thicknesses for the velocity and thermal fields are kept relatively similar for fast traveling waves, and can be well correlated with the Stokes layer thickness determined by the temporal period of the wave and the fluid viscosity. In contrast, a significant difference in their magnitudes is confirmed. Phase and budget analyses of the coherent velocity and thermal fluctuations reveal that the continuity constrain on the velocity field is the primary reason for dissimilar heat transfer enhancement.

Chapter 3 acts as an extension of Chapter 2 and discusses the results from the DNSs of a fully developed turbulent channel flow (TCF) to clarify the effects of travelling wave-like wall blowing and suction on dissimilar heat transfer enhancement. A parametric study is performed by systematically changing λ_x and U_p of the traveling wave. The instantaneous velocity and thermal fields are decomposed into coherent and random components, unlike the case of LCF where there exists only the coherent component. Then, the contribution from each component to dissimilar heat transfer enhancement is evaluated separately. It is found that the random component makes a dominant contribution to dissimilarity, and this can be explained by an indirect effect through the modification of the coherent field by the applied control. Based on the above mechanisms, we propose a simple unsteady Reynolds-averaged Navier–Stokes (URANS) approach, where the phase-averaged velocity and thermal fields are solved directly whereas the effects of the random component are modelled by the Boussinesq eddy viscosity and diffusivity hypothesis. It is shown that the present URANS can capture the overall trend of dissimilar heat transfer enhancement in a wide parameter range of λ_x and U_p . In analogy with LCF, the impact of continuity constraint on the generation of dissimilarity is confirmed from both the phase and budget analyses.

In Chapter 4 we propose and explore the use of porous media as a passive means to generate a travelling wave-like wall blowing and suction. Since it is important to induce a travelling wave from the leading edge of the channel for effective heat transfer enhancement, a source of disturbance is introduced upstream of the porous media. It is found that by fine tuning the porous and geometric parameters, dissimilar heat transfer enhancement can be achieved using porous media.

Chapter 5 contains the summary of all the works and discuss some of the potential future works. In Appendix A, there is a detailed derivation of the budget equations for dissimilarity.