Flows and heat transfer in curved ducts and channels have attracted considerable attention because of their ample applications in chemical, mechanical and biological engineering. In this dissertation, a numerical study is presented for the isothermal and non-isothermal flows through curved ducts with square and rectangular cross sections. Numerical calculations are conducted over a wide range of the Dean number, $Dn$, the Grashof number, $Gr$, and the curvature, $\delta$, for fully developed two-dimensional flow of viscous incompressible fluid. The spectral method is used as a basic tool for numerical simulations using the Chebyshev polynomial and the Fourier series expansion.

Steady solutions are obtained for both the isothermal ($Gr = 0$) and non-isothermal flows ($Gr > 0$) through curved ducts with the square and rectangular cross sections. As a result, we obtain multiple branches of steady solutions. Linear stability of the steady solutions is then investigated. It is found that among many branches of steady solutions, only one branch is linearly stable while the other branches are linearly unstable. In order to study the non-linear behavior of the unsteady solutions, time evolution calculations as well as their spectral analyses are performed. It is found that the steady flow turns into chaos through periodic or multi-periodic flows if $Dn$ is increased no matter what $\delta$ is. It is also found that the chaotic solution is weak for small $Dn$, for larger $Dn$, on the other hand, the chaotic solution becomes strong. Nusselt numbers are calculated as an index of horizontal heat transfer, and it is found that convective heat transfer is significantly enhanced by the secondary flow. If the flow becomes periodic and then chaotic, as $Dn$ increases, the rate of heat transfer increases remarkably compared to a straight channel.
論文審査結果の要旨

本研究は、正方形・矩形曲がり管を流れる流体・熱流体のダイナミックスを調べたものである。流れは管軸方向に一様と仮定されているが、それ以外に近似はなくナビエ・ストークス方程式とエネルギー方程式から導かれた連立方程式をスペクトル法により数値的に解いています。精度は大変高いことが打切項数を変化させることによって調べられている。得られた主な結果は以下の様である。両側壁間に温度差がない場合、ディーン数を大きくしたとき、定常解はサドルノード分岐により不安定化しヘテロクリニック軌道を巡る周期解が実現される。さらにディーン数を大きくすると周期解はカオス解となる。一方、温度差がある場合は、ホップ分岐によって周期解が現れ、その後カオス化する。本研究は、上に述べたような流れの変化を体系的に調べ上げていて、実験結果と良い一致を示している。また、カオス解の熱伝達率への寄与などを調べた工学的価値の高いものであり、博士（工学）に値するものであると考える。