Abstract of Doctoral Thesis

Title：Chaotic gas turbine and applications of its dynamics to engineering

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My thesis is concerned with a chaotic gas turbine, nondimensionalized equations of motion of the turbine rotor, and an application of the nondimensionalized dynamical model to chaotic cryptography. In 1970s, Malkus and Howard invented a chaotic waterwheel subject to the Lorenz equations as a simplified hydrodynamic model for turbulent thermal convection. I have developed a physical method for embodying the mechanism of Rayleigh-Bénard convection into the rotational motion of a gas turbine and have actually designed and manufactured a prototype of the turbine.

At the first stage of my thesis study, the chaotic motion of the turbine was recorded with a digital measurement system. The angular velocity of the rotor as a function of time was compared with the corresponding numerical data generated by the equations of motion of the rotor, which I mathematically derived. A good agreement between the experimental and numerical data was recognized. I nondimensionalized the equations of motion and found that the nondimensionalized equations represent a star network of Lorenz subsystems sharing the dimensionless angular velocity of the rotor as the central node. In this sense, the nondimensionalized dynamical model are referred to as augmented Lorenz equations. Through the comparison of the numerical solutions of the augmented Lorenz equations with previous experimental results of turbulent Rayleigh-Bénard convection with high Rayleigh numbers exceeding 10^6, the augmented Lorenz model was shown to well reproduce the statistical properties of the velocity field of actual convective flows.

At the second stage of my study, the augmented Lorenz model was applied to chaotic cryptography, in which the chaotic time series generated by the model is used as pseudo random numbers to encrypt a plain text into a cipher text. To make a secret key with an inhibitively large size of the key space against attacks to crack the key, the integer diagonal matrix that specifies the augmented Lorenz equations was extended into a real diagonal matrix used as a binary secret key that can be delivered with a quantum key distribution. The proposed chaotic cryptography aided by a quantum key distribution may be practically used as one-time pad cryptography, which can circumvent the critical weak point of quantum cryptography that existing quantum ciphers are considerably time-consuming in delivering random numbers to encrypt a plain text.