

## Preface

The modern society demands mechanical work and electric energies produced by engines or motors from complex machine systems, such as vehicles, trains, ships and plains. However, in general, it is thermodynamically well known that a system can only use  $1/3$  of the produced total heat-energy, and the remaining  $2/3$  of the heat-energy is not used effectively, which is dissipated eventually into external environment. The electric energy generated by way of clean energy processes is essential for conservation of nature and ecological systems in Earth.

The electric energy-convertible motions, vibrations and waste heat-energy dissipations are important to be activated and reused as much as possible in the modern world. Technologies designed to improve energy efficiency from sustainable and renewable energy sources, such as solar, wind and wave, thermal energy have been actively investigated to reduce negative human impacts on natural environment and ecosystem, which is known as clean and energy-harvesting technologies.

In this article, the mechanical motions of fascinating toys, such as a drinking bird (DB) and a low temperature Stirling engine (LTSE) shown in figures 1 and 2, are exhibited in detail and studied comprehensively in terms of nonequilibrium irreversible thermodynamics. The DB and LTSE convert thermal energy into mechanical motions (vibrations and rotations), which is then converted into electricity. The phenomena expressed by oscillations, heat and energy have important information on thermal changes and mechanical work in terms of dynamics. The mechanical motion of DB is also employed to a device to cultivate genetically engineered *Escherichia coli*, and the nonlinear oscillations are applied to the Lynx-Hare data of 200 years as

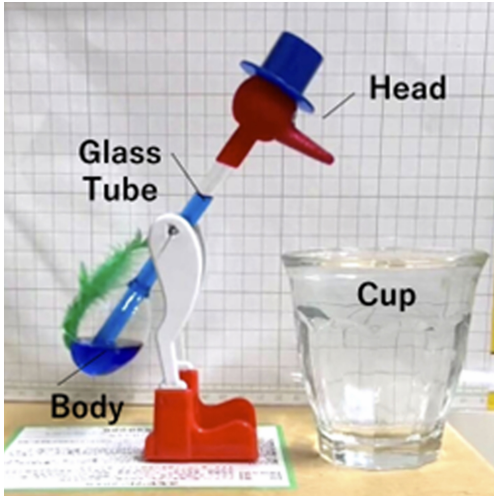


Figure 1: The drinking bird's motion is constructed with thermodynamic and mechanical motion, which is denoted as the thermo-mechanical state.



Figure 2: A low temperature Stirling engine (LTSE) works with heat flows (entropy flows), creating nonequilibrium irreversible states (NISs).

the nonlinear conserving interaction to understand biological interactions from conservation laws and stability. The engineering applications are also abundant as discussed in several chapters.

A drinking bird (DB) is a simple and efficient heat engine. A cup of ordinary water produces mechanical motion, and the mechanical motion can be changed to electric power (thermoelectric generation). The analysis leads to a profound extension of thermodynamics into nonequilibrium irreversible thermodynamics. The low temperature Stirling engine (LTSE) is extended to a thermoelectric power conversion device, which is termed as the thermoelectric generator (TEG). The DB and LTSE are excellent devices to study mechanics, thermodynamics and heat engines.

Thermoelectric converters are traditionally categorized as:

(1) heavy-weight, high-pressure and temperature thermoelectric generators

The traditional thermomechanical converters use turbines driven by high pressure and temperature, called the radial flux generator (RFG) by the classification of magnetic flux lines, which is suitable for huge energy productions but requires heavy-duty, high-speed rotations of turbines, resulting in huge heat-energy dissipations.

(2) Microscopic, thermoelectric power generators

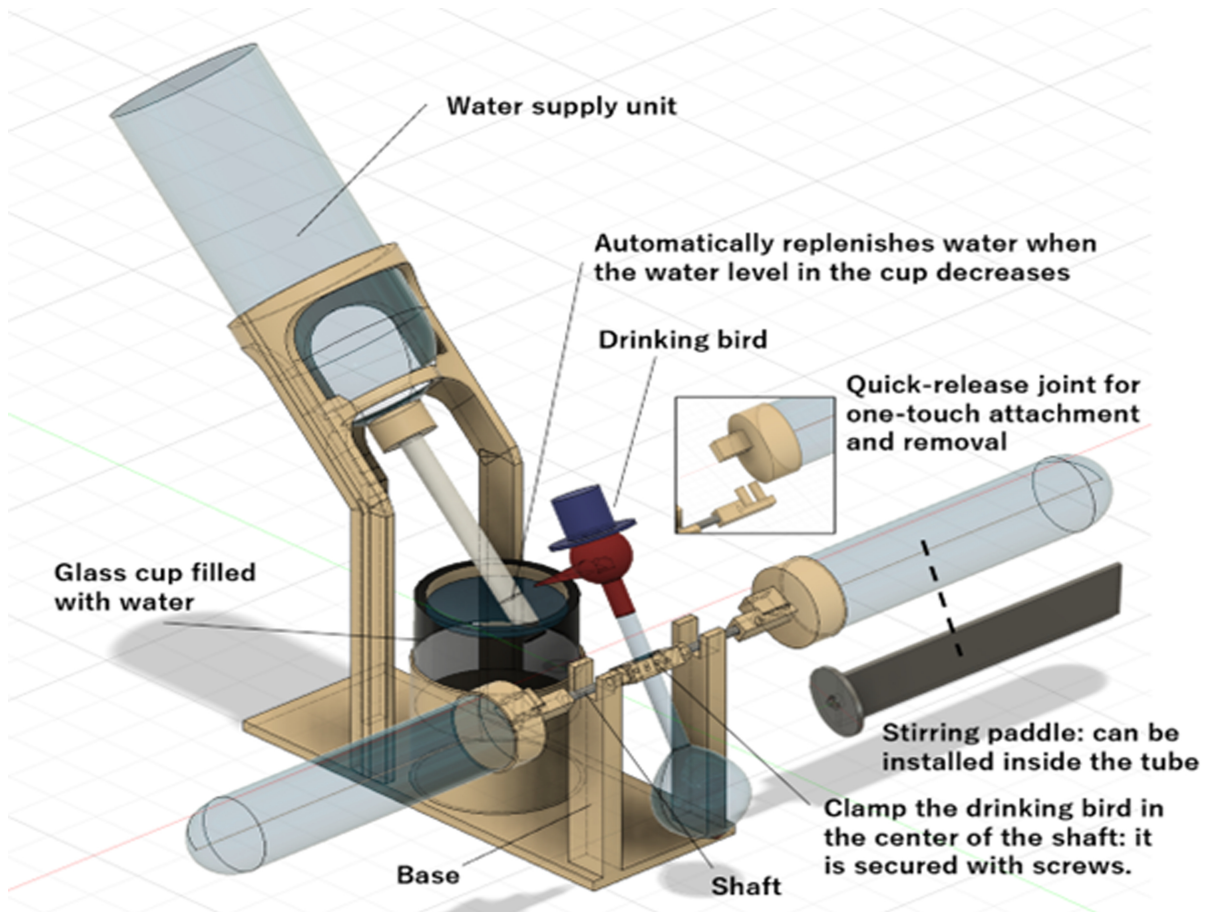


Figure 3: A device to cultivate *Escherichia coli* (*E. coli*) .

The second traditional devices for thermoelectric generations are microscopic power generators using crystal structure, transistors, a thermocouple (thermoelectric thermometer) mechanism known as Seebeck effect and Peltier effect. Microscopic and thermoelectric power generators are known as expensive and vulnerable to high temperature and heat.

(3) The 3rd-kind, new thermoelectric energy converters: the axial flux generator (AFG).

The axial flux generator (AFG) is most suitable for activating energy from boiled water, hot-springs, hydraulic streams and waste heat from industries. This is an important consequence derived from the analysis of thermomechanical dynamics (TMD), which is proposed by the authors to study nonequilibrium irreversible states (NISs) of heat engines. The disk-magnet electromagnetic induction (DM-EMI) technique made realistic, energy-efficient applications possible.

The topics are presented in 10 chapters. The chapter 1 exhibits the performance of shaking cultivation driven by a drinking bird through a modeling and experiments shown in Fig. 3. The chapter 2 clarifies a biological behaviors and variations, which is called ethology (branch of zoology) that studies the behavior of animals. The chapter 3 is for the analysis of a drinking bird (DB) by thermomechanical dynamics (TMD). The chapter 4 introduces TMD to study the nonequilibrium irreversible motion of LTSE. The chapter 5 discusses applications to the international roughness index (IRI) for ride-quality of road-surface, based on Lagrangian method. The chapter 6 discusses the thermoelectric energy conversion of a drinking bird by disk-magnet electromagnetic induction (DM-EMI). The chapter 7 discusses techniques of DM-EMI theoretically in detail. The chapter 8 discusses a mechanical vibration-induced electric energy generation (MVEG) and applications to ride quality of vehicles and IRI. The chapter 9 discusses thermoelectric energy generations based on the axial and radial flux electromagnetic inductions. The chapter 10 discusses thermodynamic consistency and thermomechanical dynamics (TMD) for nonequilibrium irreversible mechanism of heat engines.

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