

Proposal of Entropy Concept Learning Using a Stirling Engine Output Control System

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Research Overview

This study proposes an educational methodology for learning the concept of entropy in the field of energy engineering education. By utilizing a “variable-compression-ratio Stirling engine output control system” developed by the author, an experimental apparatus was designed to pseudo-visually represent the difficult-to-visualize concept of entropy, thereby enabling students to intuitively and easily conceptualize the phenomenon. This paper reports the structure of the proposed system as well as its educational applications.

Keywords: Engineering Education, Energy Education, Stirling Engine, Entropy.

Introduction

Entropy is not only one of the central concepts in thermodynamics and energy engineering, but also a universal principle underlying various irreversible phenomena observed throughout the natural sciences. However, because entropy is invisible and highly abstract, many students experience difficulty understanding the concept. In conventional engineering education, entropy is mainly explained through mathematical expressions, ideal thermodynamic cycles, and theoretical models, making intuitive understanding difficult for learners. In particular, conveying this concept at the elementary and secondary education levels

is extremely challenging. Nevertheless, many contemporary global issues, such as energy consumption, resource circulation, and global warming, are fundamentally related to entropy and irreversible processes. Therefore, it is considered highly important to communicate this concept effectively in education.

Purpose of the Study

The purpose of this study is to investigate whether conceptual understanding of entropy can be improved through the use of a visualized thermal engine system. To achieve this objective, a “variable-compression-ratio Stirling engine output control system” capable of controlling engine output during operation was developed. Using this system, students can experimentally observe temperature differences, gas pressure fluctuations, piston motion, rotational behavior, and mechanical power generation. Through experimental observation, students can recognize that useful mechanical energy decreases as irreversible losses increase, thereby developing an intuitive understanding of entropy generation in real systems.

Structure of the Output Control System

The newly developed output-control system used in this study (Fig. 1) has a very simple structure (Kitahara, Sato., 2025). Figure 2 shows the experimental model equipped with the proposed system (Matsunaga, Hisajima., 2024). The basic alpha-type Stirling engine consists of two pairs of cylinders and pistons corresponding to the heating and cooling sections. In the present design, the connection section between these cylinders is branched, and a third control cylinder and piston are additionally connected. This control piston is designed as a free piston that can move freely inside the cylinder. The stroke length of the free piston can be adjusted using a mechanical adjuster. When the Stirling engine is heated and starts operating, the control piston begins oscillating within its stroke range in response to pressure fluctuations

of the working gas inside the engine. This oscillatory motion changes the internal compression ratio of the engine, thereby enabling output control.

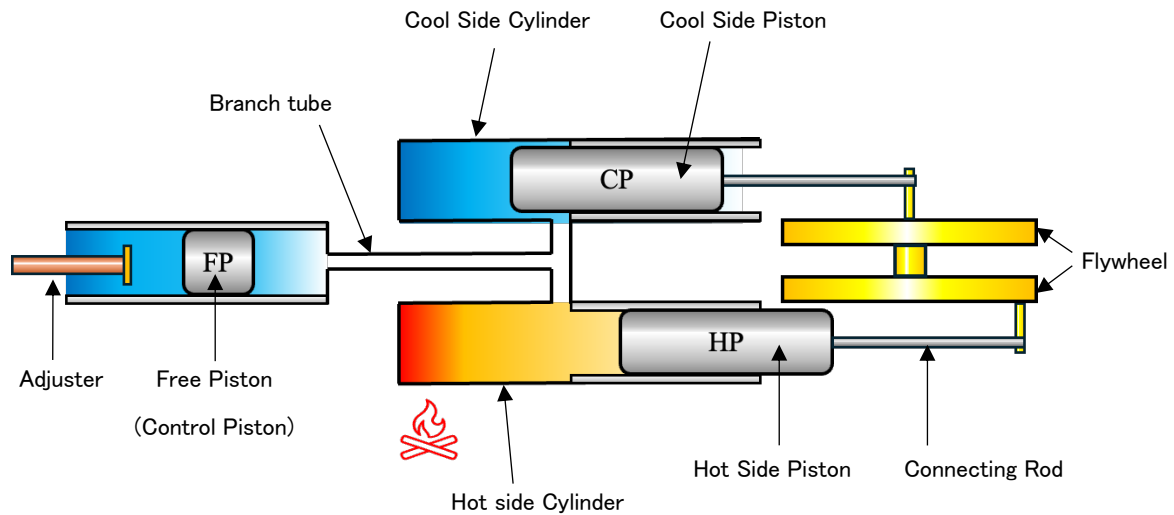


Fig. 1 Output Power Controllable α -Type Stirling Engine (Diagram).

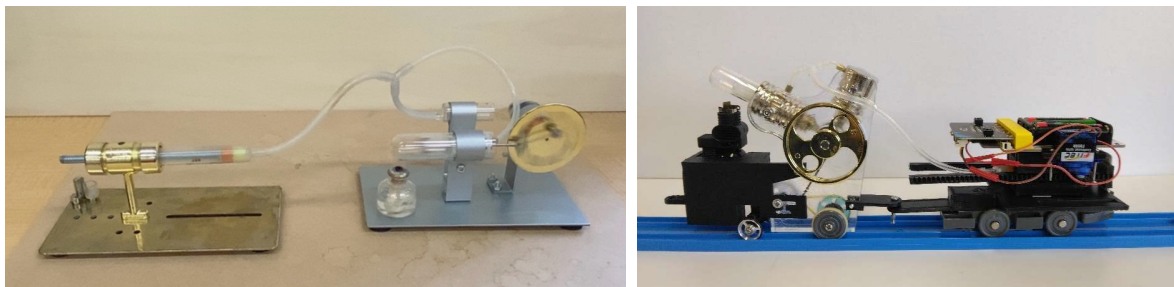


Fig. 2 Photographs of a Stirling engine incorporating an output control system and its educational demonstration model.

Educational Application

In this study, the oscillation amplitude of the control piston is treated as a pseudo-representation of entropy in order to help students intuitively and sensorially understand the relationship between engine output and entropy. In actual operation, the control piston functions as a damper that moderates pressure fluctuations inside the engine. However, in the present educational model, the oscillatory behavior of the control piston is intentionally

interpreted as a representation of disorder or entropy fluctuation. In other words, the oscillation is regarded as energy that is not effectively converted into rotational motion of the engine. The proposed educational program involves direct student interaction with the engine system. Students operate and control the Stirling engine themselves while directly experiencing its behavior. They observe changes in internal motion and fluctuations of the control piston and reflect on their impressions and interpretations during the experiment.

Results and Discussion

The effectiveness of the proposed educational method was examined through classroom practice and student feedback. Compared with conventional lecture-centered instruction, the proposed educational approach suggested improvements in students' conceptual understanding of entropy. Future work will focus on quantitative evaluation of educational effectiveness and optimization of the experimental methodology. Further details and experimental results will be presented orally at the conference.

References

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