Hot air engine (Stirling engine)

OPERATE A FUNCTIONAL MODEL OF A STIRLING ENGINE AS A HEAT ENGINE

- Operate the hot-air engine as a heat engine
- Demonstrate how thermal energy is converted into mechanical energy
- Measure the no-load speed as a function of the thermal power

UE2061010

06/06 JS

BASIC PRINCIPLES

The thermodynamic cycle of the Stirling engine (invented by Rev. R. Stirling in 1816) can be presented in a simplified manner as the processes thermal input, expansion, thermal output and compression. These processes have been illustrated by schematic diagrams (Fig. 1 to Fig. 4) for the functional model used in the experiment.

A displacement piston P1 moves upwards and displaces the air downwards into the heated area of the large cylinder, thereby facilitating the input of air. During this operation the working piston is at its bottom dead centre position since the displacement piston is ahead of the working piston by 90°.

The heated air expands and pushes the working piston upwards. Due to this, mechanical energy is transferred to the flywheel rod via the crankshaft.

While the working piston is in its top dead centre position: the displacement piston retracts and air is displaced towards the top end of the large cylinder so that it cools.

The cooled air is compressed by the working piston extending. The mechanical work required for this is provided by the flywheel rod.

If the Stirling engine is operated without any mechanical load, it operates with at a speed which is limited only by internal friction and which depends on the input heating energy. The speed is reduced as soon as a load takes up some of the mechanical energy. This is most easily demonstrated by allowing a frictional force to act on the crankshaft.

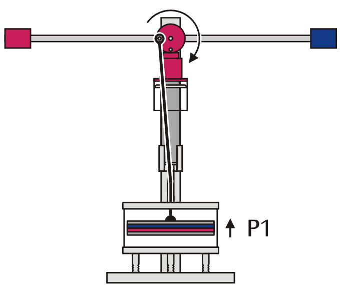

Fig. 1: Heating

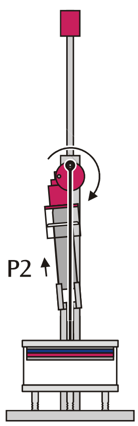

Fig. 2: Expansion

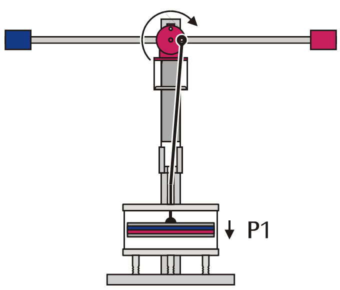

Fig. 3: Cooling

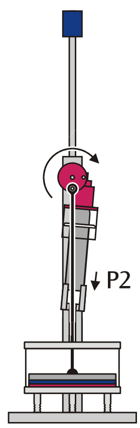

Fig. 4: Compression

LIST OF APPARATUS

1	Wilke-type Stirling engine	U8440480
1	Power supply unit 8-15 V, 2 A, e.g.	U8521121
1	Set of safety experiment leads, 75 cm	U13802
1	Mechanical stopwatch (60 seconds)	U40800

SET-UP

- Release the transport lock of the crankshaft and the displacement piston.
- Insert the loop of nylon string, onto which the displacement piston is suspended, into the front end of the crankshaft.
- Firmly screw on the second flywheel rod to the crankshaft at its rear end.
- Seal off the large cylinder with the black covers.

EXPERIMENT PROCEDURE

- Connect the power supply unit to the heater voltage input.
- Set the heater voltage to 12 V. Wait for a few minutes and manually start the Stirling engine by moving the flywheel rod.
- Vary the heater voltage from 8 V to 15 V in steps of 1 V.
- In each case, wait for one minute. Measure the time required for 10 revolutions of the engine shaft and calculate the corresponding speed (rpm).

Fig. 5: Set-up for the operation of a Stirling engine as a heat engine by means of electric heating

SAMPLE MEASUREMENTS

Table 1: Measured values for no-load speed *n* in relation to the heater voltage *U*

U (V)	10 *T* (s)	*n* (s^{-1})
8	27.5	0.36
9	24.6	0.41
10	21.3	0.47
11	19.0	0.53
12	16.9	0.59
13	15.0	0.67
14	13.4	0.75
15	12.0	0.83

EVALUATION

If we consider the internal friction to be constant, then the no-load speed is proportional to the mechanical energy output of the Stirling engine in its unloaded state. If, in addition, we assume the resistance of the heater to be a constant, then the heating energy is proportional to the square of the heater voltage. In Fig. 6, therefore, the no-load speed *n* of the Stirling engine (as a measure for the mechanical energy output) has been plotted as a function of the square of the heater voltage *U* (as a measure of the heat energy input).

Fig. 6 thus shows that the mechanical energy output increases when the heat energy input is increased.

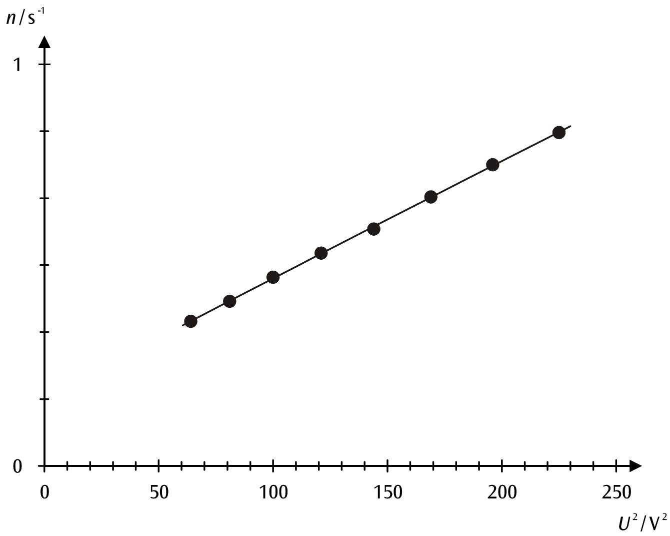

Fig. 6: No-load speed of a Stirling engine plotted against the square of the heater voltage

RESULTS

While operating as a heat engine, the Stirling engine converts part of the supplied thermal energy into mechanical energy and releases the remaining energy into the environment as heat.