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The Stirling engine mechanism optimization☆

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Summary A special type of the gas engine with external combustion is called Stirling engine. The mechanism has two pistons with two volumes inside. The pistons are connected together through cooler, regenerator and warmer. The engine effectivity depends on the piston movement behaviour. The usual sinusoidal time curve leads to low effectiveness. The quick movement from lower to upper position with a certain delay in both top and bottom dead centres is more effective. The paper deals with three types of mechanisms, analyzing the piston movement, and their behavior. Special emphasize is taken to the piston movement regime.

Introduction

The special type of the gas engine with external combustion is called Stirling engine. The kinematic driving mechanism of the engine consists of two pistons (working and transferring) with two volumes (compressive and expansive) inside, connected together through cooler, regenerator and warmer. The design of the engine can have three forms (see Fig. 1, where 1 is expansive volume, 2 is compressive volume, 3 is warmer, 4 is regenerator and 5 is cooler).

The ideal cycle of the Stirling engine is shown in Fig. 2. The cycle has 4 phases (Míka, 2004).

1. Point 1 to point 2 in Fig. 2. The working piston is in the lower position; compressive volume is large and cold. The transferring piston is in the higher position, expansive volume is near zero. The working piston moves upward, the compressive volume decreases but due to cooling the gas keeps its low temperature.
2. Point 2 to point 3 in Fig. 2. The working piston is in the higher position; compressive volume is small and cold. The transferring piston moves downward and presses the gas from compressive volume through warmer to expansive volume. The total volume keeps the temperature and pressure increase.
3. Point 3 to point 4 in Fig. 2. The transferring piston is in the lower position; the compressive volume is near zero. The working piston moves downward drawing the

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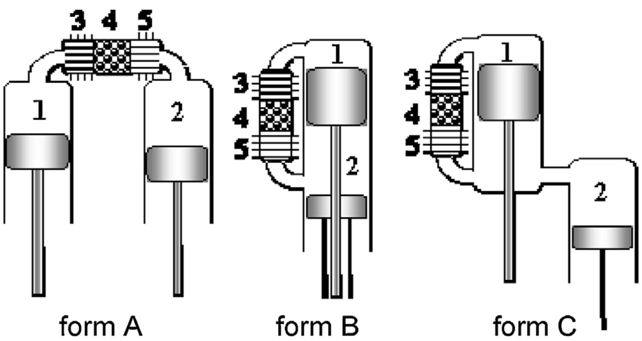

Figure 1 Three forms of the Stirling engine.

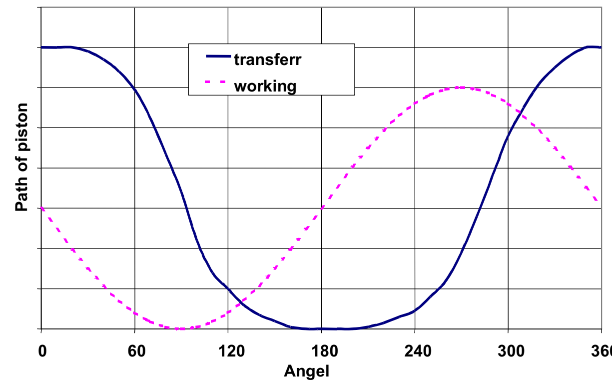

Figure 3 The path of the working and transferring piston.

gas from expansive volume through warmer to increasing compressive volume. Due to warming the gas keeps its high temperature.

4. Point 4 to point 1 in Fig. 2. The working piston is in the lower position. The transferring piston moves upward pressing the rest of the gas from expansive volume through cooler to the compressive volume. The total volume keeps, due to cooling, the temperature decreases.

The motions of both pistons are similar; the working piston is late in the phase. The efficiency of the engine is higher if the transferring piston moves from one position to another more quickly and then stays in the position for a certain time (see Fig. 3, solid curve). This leads to the higher pressure in the p—V diagram (see Fig. 4) in the beginning of the expansion phase and subsequently higher torsion moment. The piston path depends on the gear mechanism, realizing the piston motion.

Solution with the crank mechanism

The scheme of the crank mechanism is shown in Fig. 5.

The piston path—crank rotation relationship (Vinogradov, 2000; Huston, 2002) is:

$$y = r \cdot \cos\phi + \sqrt{b^2 - r^2 \cdot \sin^2\phi} \tag{1}$$

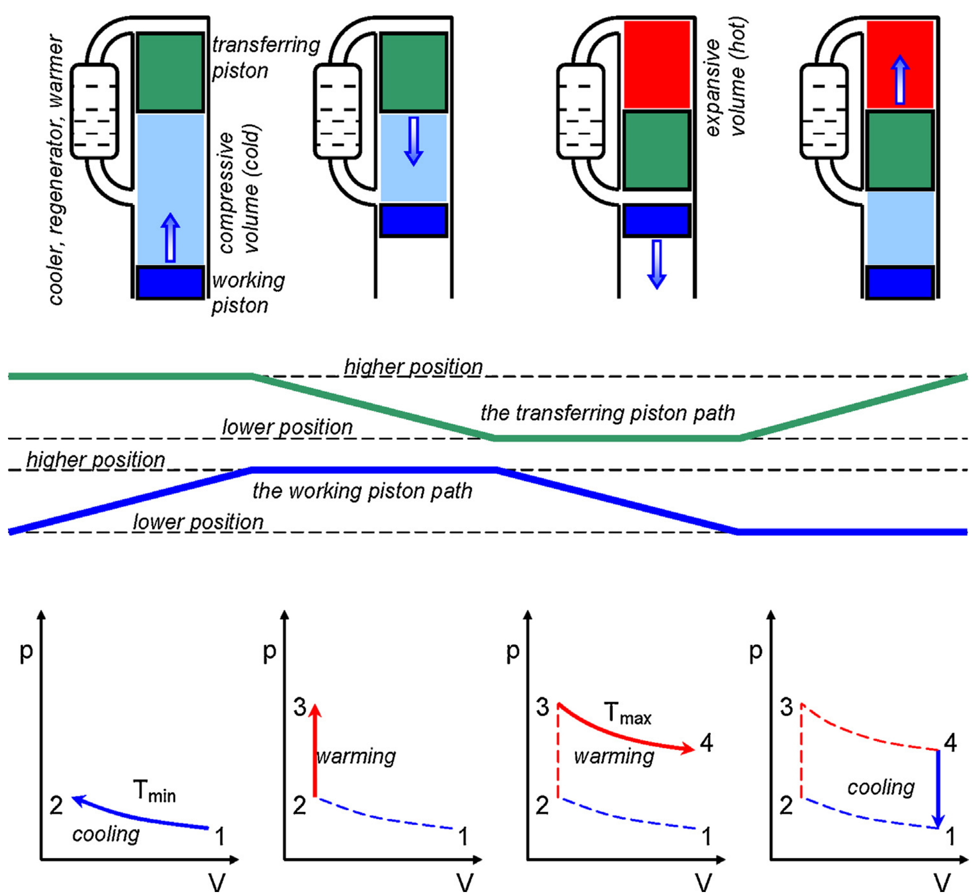

Figure 2 The ideal cycle of the Stirling engine.