Stirling alpha engine with circulation

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1. Motivation

When we use natural gas or pellets as a source of heat, the temperature may be easily controlled. This is clearly their advantage but we depend on the delivery of such fuel. Our motivation is the fact that we may still use coal or firewood. The production of electricity under varying revolutions per minute was handled a long time ago in automotive industry. The question is what to optimize in the case of the use of wood as a source of heat. We suggest the temperature difference (TD) is the answer because the temperatures vary depending roughly on how much wood goes in the stove or how much air is allowed to flow in. To keep the required TD we can look at its definition and focus on the subtrahend. We may try to improve cooling by decreasing the temperature of the gas after it has delivered the mechanical work. An improved cooling can be seen in Crema (2011), but the dead space seems to be increased.

2. Introduction

The best way to understand how the Stirling engine of type alpha works is to see its animations. There are some available on the internet. There are two cylinders in a Stirling alpha engine, hot cylinder and cold cylinder. Pistons in the cylinders are called hot and cold, respectively. Both pistons are connected to a common crankshaft. The cylinders are arranged in such a way that they are perpendicular to each other. The cold piston is ninety degrees behind the hot one. The heads of the hot and cold cylinders are connected by a pipe, a regenerator fits in between them. The space between the hot and cold cylinders is called a dead space. The smaller the dead space, the better is the functioning of the engine. But, if we completely removed the dead space, there would be no room left for the regenerator. We will solve this dilemma in a different way. Siddiqui (2019) studies the effect of the dead space in detail. In our case such a reasoning cannot be used anymore because the setting will be different but the main idea applies. Some people believe in the necessity of a regenerator so let us check the literature. We may summarize the result of research by Senviboon (2021) as: “The regeneration installation resulted in reducing of power and torque output, and also the engine speed” in the section Conclusion, 2nd paragraph, 2nd sentence. Secondly, it might also be a good idea to recall the formula $pV = nRT$ from an elementary school. Here p is the pressure, V is the volume, n is the amount of gas, R is the gas constant, and T is the absolute temperature in Kelvins. When n is the same and the temperature increases from T_0 to T_1, then p_1V_1/p_0V_0 increases T_1/T_0 times. It follows that it is better to fill the hot cylinder with cold gas rather than preheated because the preheated gas expands less. The gas flows out and back tranferring the heat to the regenerator and a part of undissipated heat is again transferred back to the gas. It is something we cannot avoid if the regenerator is used. It may get even worse when we put something that would increase the aerodynamic drag inside the regenerator because it may cause the flow to change from laminar to turbulent. The dead space may be decreased when we place the hot and cold cylinders with their heads as close to each other as possible while the space for thermal insulation must be provided. We place the cylinders in the parallel direction so they could be connected to the same crankshaft with the angle of ninety degrees. This can be seen in engines with internal combustion where it is called a cross plane crankshaft.

3. Circulation

The main topic of our invention insists in the gas circulation. Let us recall the two-stroke engine as we studied it in an elementary school. When the piston is in the position that is close to the crankshaft axis, it opens the exhaust port. We are not interested in the intake port at this point. The gas moves to the pipe, then to the cooler, and towards the intake port of the cold cylinder. When the cold piston is at the position closest to the crankshaft axis, the intake port opens and the gas moves to the cold cylinder. Unlike in the case of the two-stroke engine with exhaust and intake ports at one cylinder, in the case of the Stirling engine the exhaust port is in the hot cylinder, the intake port is in the cold cylinder.

We may elaborate on this. When the piston is in the position that is the closest to the crankshaft axis, this position is called a bottom dead center (BDC). In the context of the exhaust port of the hot cylinder, it gets fully open precisely when the hot piston is in the position of its BDC. When the hot piston is leaving the BDC position, it is also closing the exhaust channel. To verify this idea, we assume the hot piston is moving towards BDC position, the pressure in the hot cylinder is higher than that in the exhaust pipe and we consider the gas leaving the hot cylinder through the exhaust port when the piston is in the BDC position. The gas in the exhaust pipe has lower pressure and lower temperature. The pressure of the gas left in the hot cylinder decreases and so does its temperature even though it is heated by the head of the hot cylinder. The heat from the head of the hot cylinder has been considered negligible as it is transferred to the gas during a short period of time. The intake port of the cold cylinder opens when the cold piston is in its BDC position.

The gas can get to the crankshaft case because it leaks between the piston and the cylinder, which is known as a blow-by. A blow-by in a broadersense occurs when the piston is close to the head of the cylinder and the exhaust port opens below it enabling the flow from the pipe back to the hot cylinder and the crankshaft case.

Measures to handle the leaking gas may vary:

A: The crankshaft case may be partitioned into two parts so that the gas from the hot part of the crankshaft does not move easily into the cold part. The barrier may have the form of a ring on the crankshaft, a ring may be placed on the crankshaft case, or both.

B: The length and shape of the piston should enable it to close the exhaust or intake port even if the piston is at the longest distance from the crankshaft.

C: The blow-by from the exhaust or intake pipe may be decreased by using a valve, such as Tesla valve as an example.

Another question is the improvement of the gas flow on its way from the hot cylinder through the cooler to the cool cylinder. Since we don't need to create any higher pressure in the pipe, because we just want to increase the flow, we use only a fan. To minimize the number of moving parts we connect the fan directly to the crankshaft.

4.Further research and verification

One way to proceed is a mathematical model buildup as a continuation of our reasoning. We refer to Organ (2014) and just state that the model of a type of engine with any kind of cooling by circulation is not mentioned. Anyway, any detail in the real engine could change its performance substantially, for example, even a subtle change may cause a turbulent flow to replace the laminar one thus changing the engine performance. The final verification of the above ideas means building such an engine with the required design. But this is very expensive and funding is curtailed. The only way out might be the use of parts of some old 2-cylinder 2-stroke engine

5. References

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