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Model of a Steam Engine Built by Modifying an Internal Combustion Engine

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Abstract: The steam can be generated using any heat source such as solar energy, wood, crude oil, biofuel, etc. In contrast to the Internal Combustion (IC) engine which must use a specific type of fuel to run. This flexibility of energy sources for the steam engine encouraged as to build a model of it. Moreover, the renewable energy resources represent the most important modern research projects in alternative energy resources field due to the limited fossil fuel resources. The aim of this research is modify an IC engine by manipulating the valve'sopening and closing timing. In another words, the camshaft in IC engine is modified to make it run as external combustion engine as showed in details through the manuscript. The amount of steam needs to run a 3.5 HP engine (our case of study model) is about 3 g/sec at 4 bar steam pressure and this flow rate will decrease when steam pressure increases. The modified steam engine model tested at 4 bar steam pressure and showed promising results. The theoretical efficiency expected to be up to 34% at the tested pressure.

Key words: Renewable energy, steam engine, alternative fuels, modified, camshaft, manuscript

INTRODUCTION

At the recent decades there was serious interesting in the renewable energy resources and how to use it to decrease fossil fuel consumption and decrease emissions as well (Kalogirou, 2001; Haralambopoulos and Polatidis, 2003). Solar energy represents one of the most important renewable energy resources of our region (Iraq). Therefore, using heat to generate steam then run a steam engine represents a promising future project (Dufo-Lopez *et al*., 2007).

Ferrara *et al.* (2013) found that there is a big chance building a reciprocating steam engine that can use any heat source to generate electricity for the off grid homes. Moreover, the outcome of their research was proved the big chance of using it in the Combined Heat and Power (CHP) systems.

Badami and Mura (2009) built a reciprocated steam engine to research on the waste wood and their outcome was promising. The built model came out with a suggested control strategy that may help make this model more reliable. In Iraq there too many houses located off electric grid and need for an electric source. Moreover, the electricity in Iraq is off frequently because of the poor electric infrastructure. Emissions from Internal Combustion (IC) engines considered very danger on our era and they using these engine everywhere due to the poor electricity (Al-Samari, 2014, 2017).

The most important privilege of a steam engine is the flexibility of heat energy source such as fossil fuel, solar energy, wood, waste oil, …, etc., since, it is an external combustion engine (Ferrara *et al*., 2013; Badami and Mura, 2009).

This research is aiming to evaluate the opportunity of modifying the IC engine to research as steam engine. Any heat energy source (such as fossil, wood and solar energy) could be used to generate steam and this steam can run the engine to generate electricity. This type of small steam engines can be used in the off grid areas.

MATERIALS AND METHODS

Method of operation: Figure 1 shows the diagram of how IC engine researches and the location where the exhaust and intake valves are opens (Ganesan, 2012). The reciprocating steam engine is working basically as following, receive steam at high pressure through the intake valve (intake stroke) when the piston at Top Dead Center (TDC) from the steam vessel, piston moving down in the working stroke at the Bottom Dead Center (BDC) the exhaust valve open and release steam at low

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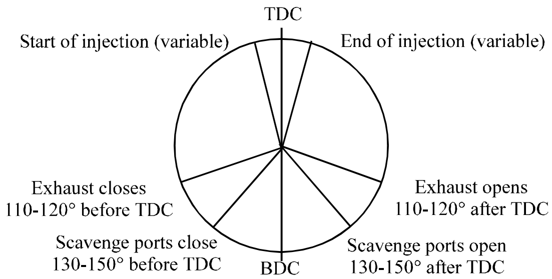

Fig. 1: Timing diagram of the internal combustion engine

pressure to the condenser after the steam got condensed, the water pumped to the boiler the to the steam vessel as super-heated steam and so on as shown in the Fig. 1. In other words, the exhaust and intake valves are open every one revolution (i.e., 360°) each one in different times. However, the exhaust and intake valves in a four strokes Internal Combustion (IC) engine are open per two revolutions (720°) each one in different times as shown in Fig. 2.

Engine parameters: For a comprehensive understanding of the cycle, following parameters will be explained in details. Volumetric compression ratio:

$$\rho = \frac{V_1}{V_2} \tag{1}$$

Admission grade (cut-off ratio):

$$\rho = \frac{V_3 - V_5}{V_D} \tag{2}$$

where, V_D is the engine displacement:

$$V_D = V_1 - V_2$$

The expansion Grade is defined as:

$$\varepsilon = \frac{V_4}{V_3} \tag{3}$$

Define the non-dimensional dead space as

$$\mu = \frac{V_2}{V_D} \tag{4}$$

$$MEP = \frac{\text{Net work}}{\text{Stroke volume}} = \frac{w}{V_1 - V_2} \tag{5}$$

where, MEP is the mean effective pressure. These parameters must consider for calculating air or steaming mass flow rate.

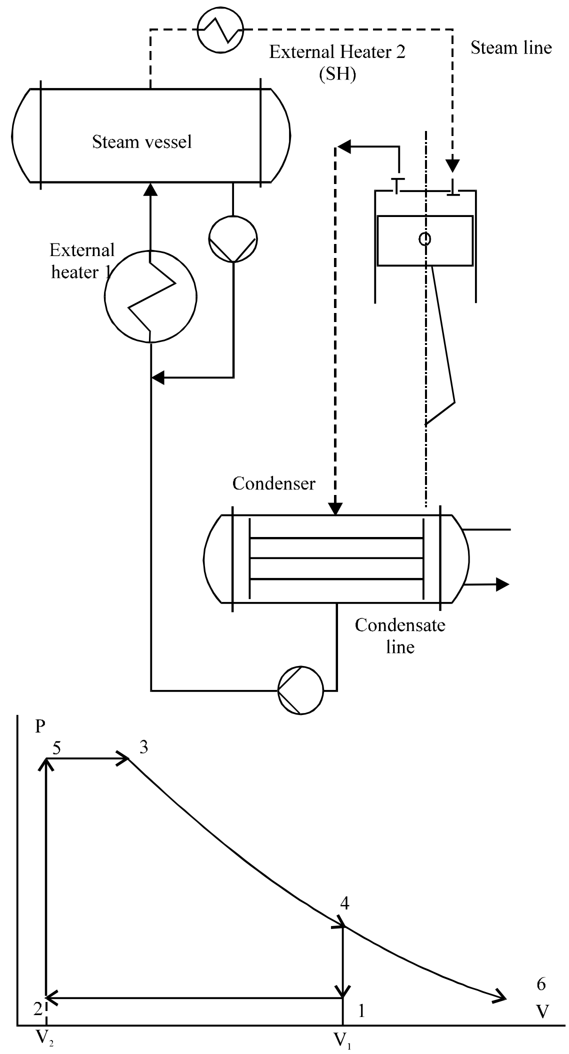

Fig. 2: a) Schematic of the steam engine, condenser and steam vessel and b) Diagram of the compression and expansion of the reciprocated steam engine model

Proposed modification on an IC engine: The proposed modification is by manipulating the closing and opening time of the intake and exhaust valves. The camshaft has been rebuilt to make valves open every revolution (360°) for each one at different time. Figure 3a-c show the camshaft before and after modification. Moreover, in the reciprocating engine as IC engine the research stroke was done every two spins but after the modification the research stroke will be every one rotation as steam engine.

Experimental setup: The new reciprocating steam engine has been tested and evaluated at the Laboratory MOF the Mechanical Department of Engineering College/Diyala University as shown in Fig. 4. The steam generator

Fig. 3: a) Schematic of the camshaft before and after modification; b) The camshaft before the modification and c) The camshaft after the modification

Fig. 4: The modified steam engine and steam generator setup for test

used to get steam at pressure 4 bar (the design limitation of the boiler in the laboratory). Several measurement instruments such as barometer, thermometer and ammeter, used to watch the different parameters during the tests.

RESULTS AND DISCUSSION

Figure 5 shows the initial running of the modified IC engine to be a steam engine. The compressed air succeeds running the new model and light up the bulb as shown in the Fig. 5. Moreover, Fig. 6 shows the actual running of the new model at the steam with pressure of 4 bar. The initial running was very promising about the visibility of this project. The engine cylinder could handle more pressure but the limitations were from the boiler that used to generate the steam in the lab (Heat Transfer Laboratory at Mechanical Engineering Department/Engineering College/ Diyala University). Figure 7 shows the expected maximum efficiency of the steam engine model relative to admitted steam pressure. Based on Carnot cycle, the engine efficiency proportional directly to the input pressure (temperature). Moreover, increasing steam pressure will lead to decrease steam flow rate at the same engine load as shown in the Fig. 8. Figure 9 shows the real cycle of the compression and expansion of the reciprocated steam engine model. The barometer used to measure to input and output pressure and the intermediate processes are predicted, since, that we unfortunately don't that equipment can measure it precisely.

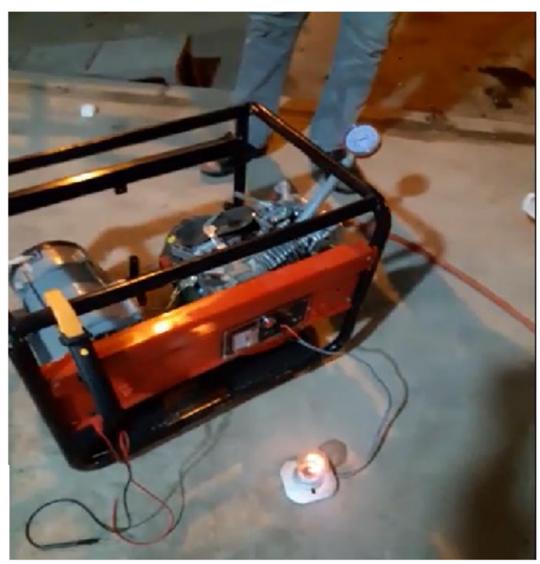

Fig. 5: Running of the steam engine model and collecting data

Fig. 6: The initial running of the new steam engine model

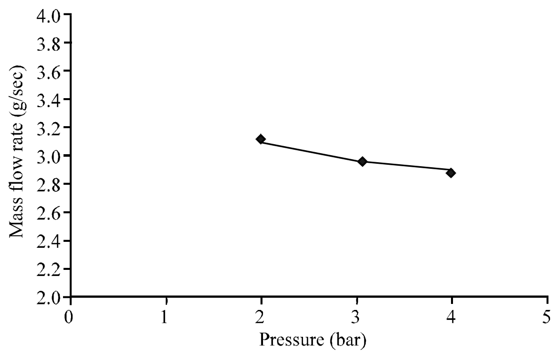

Fig. 7: Relation between the mass flow rate and the steam pressure

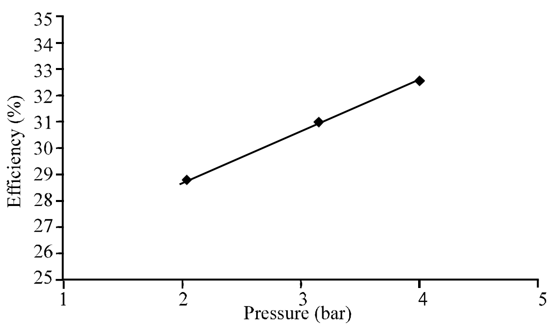

Fig. 8: Impact of input steam pressure on the engine efficiency

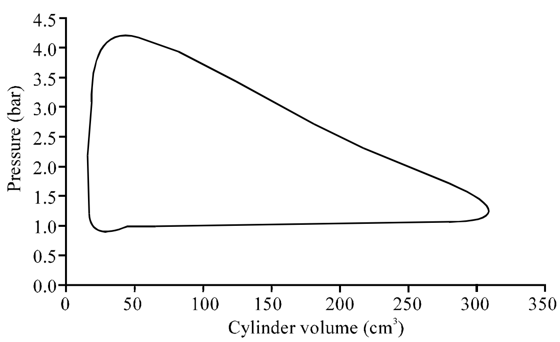

Fig. 9: Real cycle of the compression and expansion of the reciprocated steam engine model

CONCLUSION

The operation of the new steam engine model was successful and very promising. The most important challenge may face this new model is the steam leakage and oil contamination with water that condensed inside the oil ban. However, there are several approaches to solve this problem such as oil separator that using in the diesel engines.

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