ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Website: www.ijareeie.com

Vol. 6, Issue 3, March 2017

A Review on Understanding of Carnot Cycle

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ABSTRACT: Carnot's process and theorem have played an important role in classic thermodynamics since they were suggested in 1824, though Carnot was unable to prove this due to Caloric heating theory's effect. Then in 1850, in reduction to nonsense, Claudius verified Carnot theorem and proposed the second thermodynamics law. Since then, scholars generally agree that the principle of Carnot cycle is one with the greatest utility and that it is considered the main concept or basis for thermodynamic study. Nonetheless, few scholars are interested in how Carnot explained the principle without the second thermodynamics rule. Without the help of the second thermodynamics law, can we get and prove Carnot theorem? In this article, an analytical approach for thermodynamics is developed based on the Polytrophic Process equations and p-v table. Instead of the second law within thermodynamics, a process of maximum duration is only calculated by a severe concept. The preliminary results show that the cycle of Carnot only gives one aspect of the better cycles and that the output of this cycle only approaches the highest value, only the one of the cycle of Carnot, when the polytrophic exponents (n) of the expansion and compression processes are identical. This work gives new insight into Carnot's theorem and classical thermodynamics, which are essential to light up to the implementation of a new approach for solving the complicated problems that the Second Law of Thermodynamics renders quite difficult to resolve.

KEYWORDS*:* Carnot cycle, Engine efficiency, Extremism Principle, Thermodynamics.

I.INTRODUCTION

About a half hundred years after James Watt presented the steam engine, Carnot suggested the theory that would demonstrate the most high performance in a thermodynamic cycle including the Carnot Cycle and the Carnot theorem. But he could not prove his theorem, deeply influenced by the philosophy of Caloric. Before 1850, Clausius promoted entropy, a central basis for the second law of thermodynamics, and thoroughly validated the Carnot theorem by limiting the principle to absurdity [1]. Then the theorem of Carnot is always seen as the basis of thermodynamic theory, and few people are concerned whether Carnot formulated his theorem in the absence of the second law of thermodynamics. Without the second law of thermodynamics can we get and prove Carnot's theorem?

Figure1 demonstrates a well-known mechanical problem called "Brachistochrone". It is difficult to find, by modern physics, the time-saving direction to an object that only moves through gravity from point A to B. This problem can however be addressed with extreme variation principles via analytical mechanics [2]. The question arises as to whether we may solve the above mentioned thermodynamic problem based on the extremum theory, since some parallels exist between them, as it is that there is a heat source and sink in Carnot cycle at two different temperatures, just as there are points in the "Brachistocrone" at two other places.

In this article, we discuss the efficiency of thermodynamic cycles from another perspective using extreme concepts within theoretical mechanics to figure out the highest performance of engine cycles. The goal is to try to find a new way of analyzing thermodynamic optimization [3]. The preliminary results show that only the law first and the principle of extreme can be derived from the best process rather than from the second law of thermodynamics [4]. This work gives a new overview of motor cycles, which in the lighting of the new method of analysis is very important for solving thermodynamic optimization issues.

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II.MATHEMATICAL MODEL

Several processes exist for a thermodynamic cycle. The loops consisting of two isothermal and two unknown systems are of interest only to simplify the analysis [5]. It is presumed that for reversible cycles there is no heat leakage or frictional depletion [6]. For Carnot cycle the whole procedure is special, provided that there is only one heat source and one heat sink:

- 1-2: Reversible isothermal expansion of the gas at the “hot” temperature, T_1
- 2-3: Isentropic (reversible adiabatic) expansion of the gas (isentropic work output)
- 3-4: Reversible isothermal compression of the gas at the “cold” temperature, $T2$
- 4-1: Isentropic compression of the gas (isentropic work input)

So what with the output of loops, which are not Isentropic in steps 2-3 and 4-1? The cycle is entirely possible if we consider heat recovery. The aim is therefore to find the best cycle type of engine cycles with the highest efficiency, function under a hot source and sink at certain temperatures.

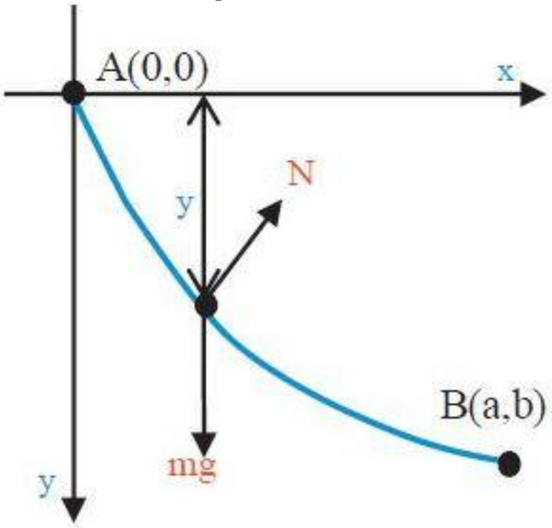

Fig.1 Brachistochrone curve in a coordinate system

The hot/cold temperature of the above process is T1/T2, so that phases 1-2 and 3-4 are special (isothermal). The polytrophic indices of both systems may not necessarily be stable. Nevertheless, the polytrophic index can be called a constant value for an infinitesimal operation [7]–[9]. Thus, for steps 2-3 and 4-1, we define the polytrophic index n orx, as shown in Fig.2. For each phase, heat transmission and process output / input are Q2-2, Q2-3, Q3-4, Q4-1 and W1-2, W2-3, W3-4, W4-1. Equations show motor performance. The purpose is to find out when the engine efficiency is at its maximum value the relation between n and x.

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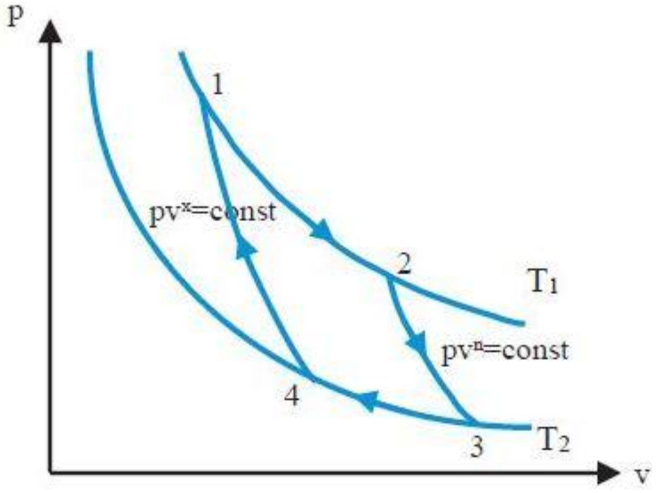

Fig. 2. A certain cycle illustrated on a *p-v* diagram

$$\eta = \frac{RT_1 \ln\frac{V_2}{V_1} - RT_2 \ln\frac{V_4}{V_3} - \left\| \frac{R}{n-1}(T_1 - T_2) \right| - \left| \frac{R}{x-1}(T_2 - T_1) \right\|}{RT_1 \ln\frac{V_2}{V_1} + \left| (c_v - \frac{R}{n-1})(T_2 - T_1) \right| - \left| (c_v - \frac{R}{x-1})(T_1 - T_2) \right|} \quad \ldots (1)$$

Where —cycle efficiency, R — universal gas constant, vi — specific state volume— the engine efficiency will change with a polytrophic index different. And y= x / n is the criterion for evaluation. We set T1=500 K, T2=300 K in the following case study and show the results of the computation in figure 3.

From the curves it can be seen that the ideal point is non-differential and therefore only a quantitative approach is needed. If y=1(x= n), the result indicates that, due to the heating recovery between steps 2-3 and 4-1, the µ achieve the maximum value. The thermodynamic process output is therefore similar to the Carnot cycle (Equation 2).

$$\eta = \frac{RT_1 \ln\frac{V_2}{V_1} - RT_2 \ln\frac{V_4}{V_3}}{RT_1 \ln\frac{V_2}{V_1}} = 1 - \frac{T_2}{T_1} \quad \ldots (2)$$

In short, the optimal cycle method with the highest efficiency can be accomplished without the use of the Extreme Principle without the aid of the Second Law of Thermodynamics, as is the case for "Brachistochrone." Therefore, Carnot cycle is only one mode of thermodynamic cycles of the highest efficiency for two thermal sources and sink temperatures [10]. The above cycle is the recapitulative cycle of Carnot. The next section shows examples where x= n is located.

III.APPLICATIONS

With two heat sources and sink temperatures, the aforesaid definition only shows the optimum value of engine effectiveness if the expansion and compression cycle is the same polytrophic table. Stirling's processes are very similar to Carnot, and the distinction between the two isentropic processes is that they are modified into is volumetric. The Stirling cycle has the same efficiency as the Carnot cycle between the same heat source and drain.

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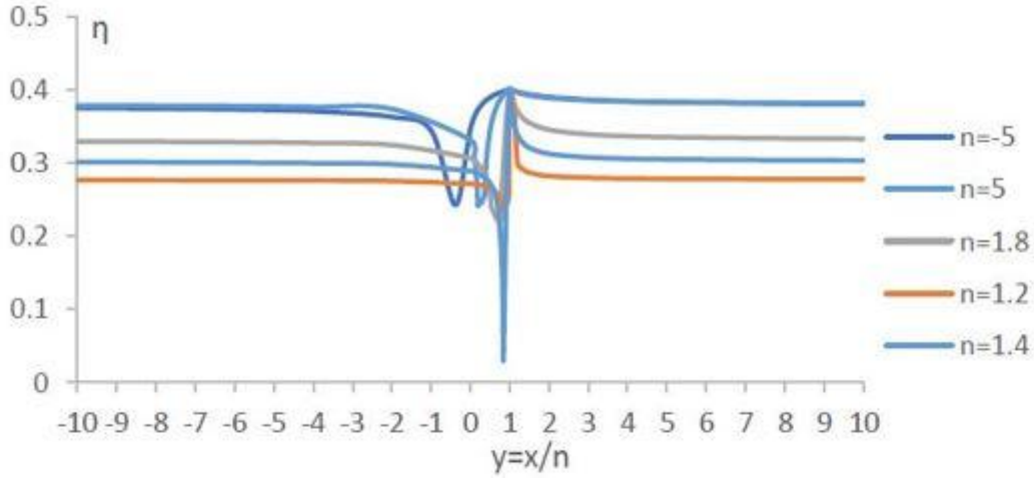

Fig. 3. Calculating result of efficiency with different y value

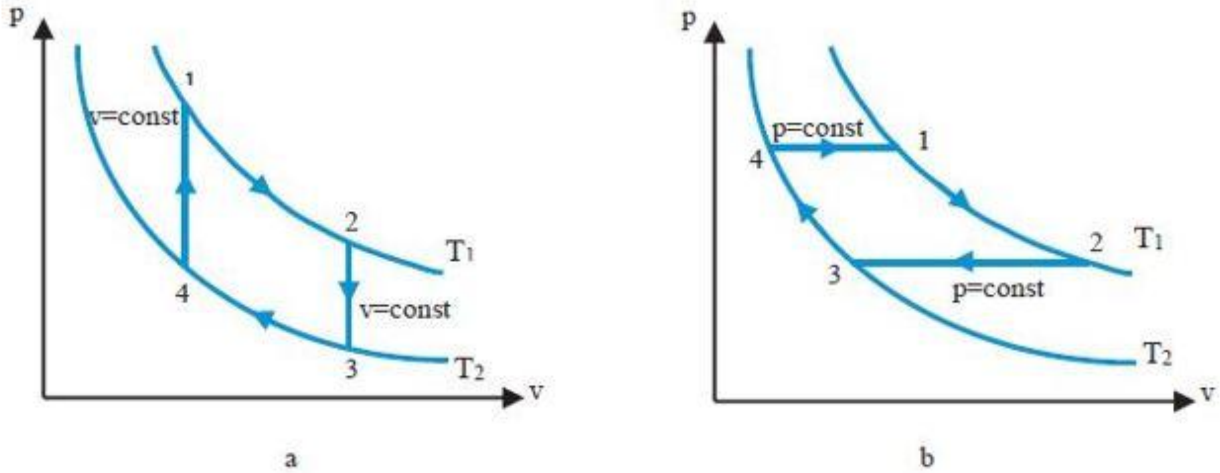

Fig. 4. The Stirling cycle (a) and the Ericsson cycle (b) illustrated on a *p-v* diagram

And the Ericsson cycle is the same as the Stirling cycle except that isobaric is the same cycles. Therefore, the Carnot cycle serves only as a variation of the cycles with highest efficiency between certain heat sources so decline.

III.CONCLUSION

A kind of empirical approach is built in this article to analyze the usefulness of thermodynamic cycles. Yet thermodynamic mechanisms can be studied. The results demonstrate that, rather than the second law of thermodynamics, the most efficient engine process can be determined by the extreme definition. The engine's efficiency always reaches the highest value if the polytrophic expansion and compression indexes match each other just that of the Carnot cycle. This research gives a new insight into motor cycles, which is very useful in lighting the new analysis approach for solving problems of thermodynamic optimization. It also poses more question whether some cases can be found where the new method of analysis can solve a practical problem without a thermodynamic approach. This topic therefore really deserves a lot of further research.

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