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UNIVERSIDAD AUTÓNOMA METROPOLITANA

Otto and Diesel cycles modeled by considering non-instantaneous adiabats

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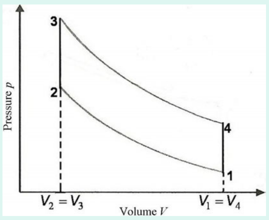
Abstract

In the present work we propose a simple procedure to obtain alternative expressions for power output and thermal efficiency for the Otto and Diesel cycles, including time for adiabatic processes in the cycle, despite being very small as these, it may take into account to obtain theoretical results for more in line with reality. In case of Curzon-Ahlborn cycle, some authors have proposed a way to take into account the duration of adiabatic processes7,8, so that they can obtain approximate expressions of the power function with a parameter that includes the compression ratio. The time for adiabatic processes is proposed by comparing the adiabatic work with the isothermal work and assuming the same thermal engine model discussed in referneces 2 and 3.

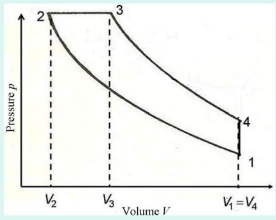
Classical Equilibrium Thermodynamics

The Classical Equilibrium Thermodynamics has the objection that a reversible process is only made if it is infinitely slow. The power output for the cycle, P, is definite as the ratio between the total made work, W, and the time of duration of the cycle, t, namely, $P=\frac{W}{t}$. For the adiabatic processes it is possible to assume a good approximation to a reversible process but it is not possible for the processes involving heat transfer. Efficiency is defined as a ratio between total work W_{tot} and the absorbed heat Q_{abs}. In case of Otto and Diesel cycles we have, respectively

$$\eta_\theta = 1-\frac{1}{r_C{}^{\gamma-1}}; \qquad \eta_D = 1-\frac{(r_C^\gamma - r_E^\gamma)}{\gamma}(r_C r_E)^{1-\gamma}$$



Idealized Otto cycle



Idealized Diesel cycle

r_C = Compression ratio;

r_E = Expansion ratio:

$\gamma = \frac{C_P}{C_V}$

Finite Time Thermodynamics

Instantaneous adiabats

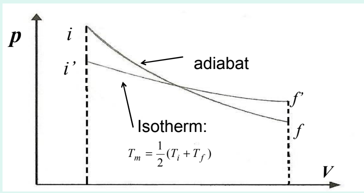
The Otto and Diesel cycles have been analyzed into the finite time thermodynamics by some authors. So, Salamon et. al. made a general analysis of performance of some cycles, including the Ottoand Diesel cycles under the criterion of minimum entropy production; particularly the Otto cycle has been analyzed finding efficiency values near to the real values known. Some other problems on the Otto cycle are analyzed including the case of the non-endoreversible cycle. The Diesel cycle has been analyzed also. The efficiency has been found as below.

Otto cycle:

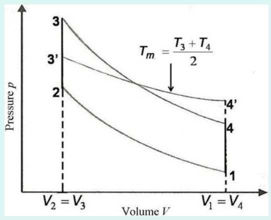
$$\eta_{\theta P}(r_C) = 1-\frac{C_{V2}}{C_{V1}}r_C{}^{1-\gamma} - \frac{b(r_C-1)^2}{C_{V1}}(K_1+K_2 r_C{}^{1-\gamma})$$

Diesel cycle:

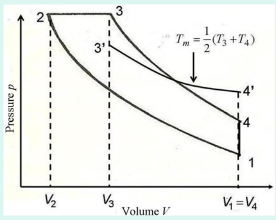
$$\eta(r_C) = 1-\frac{(r_E)^\gamma-(r_C)^\gamma}{\gamma(r_E-r_C)(r_E r_C)^{\gamma-1}} - \frac{b(r_C-1)^2\left\{K_1(r_E-r_C)(r_E r_C)^{\gamma-1}+K_2\left(r_E^\gamma-r_C^\gamma\right)\right\}}{C_P(r_E-r_C)(r_E r_C)^{\gamma-1}}$$



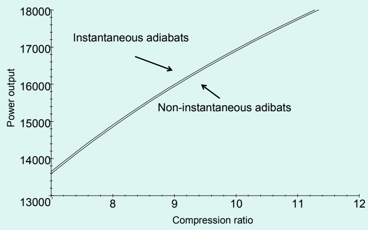
Comparison between adiabatic work and isothermic work



Otto cycle



Diesel cycle



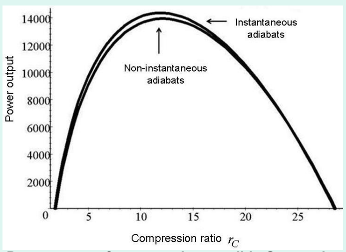
Power output for endoreversible Otto cycle

Non-instantaneous adiabats

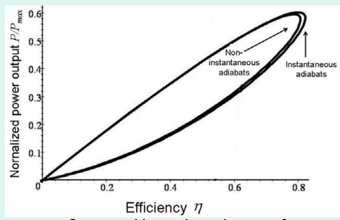
As it is known that the Otto and Diesel cycles are idealized cycles in order to describe real cycles of internal combustion, in which the limit value of temperature could exceed the temperature of stroke of machinery, when continuity changes the agent of transformation receives the heat not trough the walls of machinery but by generation of heat into its own volume, besides the real cycles are open systems and the agent of transformation is renewed for each cycle (air + fuel). Since the mechanical interpretation of work, in a (V, p) plane can be shown that the work in an adiabatic process is near to isothermal work at the middle isothermal for the same variation of volume. So that, can be written attending to initial states i and i', and for the final states f and f',

$$W_{ad}(i\to f)\approx W_{isot}(i'\to f') \Rightarrow t_{ad}(i\to f)\approx t_{isot}(i'\to f')$$

$$Q^* \approx R\frac{1}{2}(T_i+T_f)\ln\frac{V_f}{V_i} \Rightarrow \quad t_{ad} = \frac{R\frac{1}{2}(T_i+T_f)}{\alpha(T_i-T_f)}\ln\frac{V_f}{V};$$



Power output for non-endoreversible Otto cycle



Compared loop-shaped curves for normalized power against efficiency

$$P_{\theta I} = \frac{(C_{V1}-C_{V2}r_C{}^{1-\gamma})}{(K_1+K_2 r_C{}^{1-\gamma})} - b(r_C-1)^2 - \frac{\alpha}{2}(T_3-T_1 r_C{}^{\gamma-1})(1-r_C{}^{1-\gamma});$$

$$P_{DI} = \frac{C_P(r_C-r_E)(r_C r_E)^{\gamma-1} - C_V(r_C^\gamma-r_E^\gamma)}{K_1(r_C-r_E)(r_C r_E)^{\gamma-1}+K_2(r_C^\gamma-r_E^\gamma)} - b(r_C-1)^2 - \frac{\alpha T_4(1+r_E^{\gamma-1})(1-r_E^{\gamma-1})(1+r_C^{\gamma-1})\ln r_E}{(1+r_E^{\gamma-1})(1-r_C^{\gamma-1})\ln r_E + (1-r_E^{\gamma-1})(1+r_C^{\gamma-1})\ln r_C}; \qquad \eta = \frac{P_{tot}}{Q_{tot}/t_{tot}}$$

CONCLUSIONS

As can be seen, to introduce the fictitious isothermic processes in the idealized Otto and Diesel cycles, one can be assume non-instantaneous adiabatic processes, and it permits us take into account some internal effects when an adiabatic process is doing into the engine, whose appear necessarily in real engines. Non instantaneous adiabats can be took into account to improve models of cycles. It is expected that numerical values calculated with this idea can be more near to the experimental values than others in the literature of finite time thermodynamics. Many authors have analized Otto and Diesel cycles while other cycles recently, but they still considering instantaneous adiabats in the analysis (Rocha et al, 2002; Zheng, 2002; Khaliq, 2005 among others).

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