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On the thermodynamics of waste heat recovery from internal combustion engine exhaust gas[1] G.P. MEISNER, GM Global R and D — The ideal internal combustion (IC) engine (Otto Cycle) efficiency η_{IC} = 1-(1/r)$^{(\gamma-1)}$ is only a function of engine compression ratio r=V_{max}/V_{min} and exhaust gas specific heat ratio $\gamma = c_P/c_V$. Typically r= 8, γ = 1.4, and η_{IC} = 56%. Unlike the Carnot Cycle where η_{Carnot} = 1-(T_C/T_H) for a heat engine operating between hot and cold heat reservoirs at T_H and T_C, respectively, η_{IC} is not a function of the exhaust gas temperature. Instead, the exhaust gas temperature depends only on the intake gas temperature (ambient), r, γ, c_V, and the combustion energy. The ejected exhaust gas heat is thermally decoupled from the IC engine and conveyed via the exhaust system (manifold, pipe, muffler, etc.) to ambient, and the exhaust system is simply a heat engine that does no useful work. The maximum fraction of fuel energy that can be extracted from the exhaust gas stream as useful work is (1-η_{IC}) $\times$ η_{Carnot} = 32% for T_H = 850 K (exhaust) and T_C = 370 K (coolant). This waste heat can be recovered using a heat engine such as a thermoelectric generator (TEG) with $\eta_{TEG} >$ 0 in the exhaust system. A combined IC engine and TEG system can generate net useful work from the exhaust gas waste heat with efficiency η_{WH} = (1-η_{IC})$\times\eta_{Carnot}\times$ η_{TEG}, and this will increase the overall fuel efficiency of the total system. Recent improvements in TEGs yield η_{TEG} values approaching 15% giving a potential total waste heat conversion efficiency of η_{WH} = 4.6%, which translates into a fuel economy improvement approaching 5%.

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