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# ENERGY - ENVIRONMENT
# Optimizations and Constraints

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# Content

1. Introduction: state of the art
2. A case study: real irreversible engine
3. Extension to thermo-economics and others
4. A new paradigm : transfer and conversion compromise
5. Conclusion - Perspectives

# 1. Introduction - state of the art

- Concept of efficiency:
  - Carnot efficiency, $\eta_C = 1 - \frac{T_{CS}}{T_{HS}}$
  - Curzon - Ahlborn efficiency,

$$\eta_{CNCA}(Max\,W) = 1 - \sqrt{\frac{T_{CS}}{T_{HS}}}$$

# 1. Introduction - state of the art

- Applications to various engines
  - Otto, Diesel (Mirabet, 2002)
  - Brayton-Joule, Braysson (Feidt, 1996)
  - Stirling - Ericsson (Costea, 1997)

# 1. Introduction - state of the art

- the clump (cluster) for endoreversible models
  - – with heat losses
  - – with fluid flows, ...
- the environment constraint (Angulo Brown, 1991)
  - → ecologic efficiency
- the economic consideration (Gögus, 2002)

# 1. Introduction - state of the art

*Partial conclusions*:

- Endo-reversible case with finite heat source

$$\eta\left(Max\,\dot{W}\right) = 1 - \sqrt{\frac{T_0}{T_{HSi}}}$$

# 1. Introduction - state of the art

- Systematic of imperfect cycles (tentative)

(Feidt, 1997)

$$\eta_{endo\ nonadiabatic} < \frac{\varphi}{1+\varphi}$$

$$\eta\left(Max\ \dot{W}\right) = 1 - \frac{1}{1\sqrt{+\varphi}}$$

with $\varphi = \frac{\dot{Q}_{HS}}{K_L T_{CS}}$ $\Rightarrow$ F.P.D.T.

# 2. Extension to irreversible engines

## 2.1. Endo-irreversible Carnot engine

Two approaches:

– ***ratio*** method (Novikov, Ibrahim)

– ***entropic*** approach (Feidt, Ejap)

$\Rightarrow$ new forms of the nice radical

# 3. Thermo-ecological criteria

– ***Extension of Angulo Brown criterion***:

- ecological objectif of the **converter**

$$\left(\dot{W} - T_0\dot{S}_I\right) = \dot{Q}_H\left(1 - \frac{T_0}{T_H}\right) - \dot{Q}_C\left(1 - \frac{T_0}{T_C}\right) - 2T_0\dot{S}_I$$

- ecological objectif of the **system**

$$\left(\dot{W} - T_0\dot{S}_{IS}\right) = \dot{Q}_H\left(1 - \frac{T_0}{T_{HS}}\right) - \dot{Q}_C\left(1 - \frac{T_0}{T_{CS}}\right) - 2T_0\dot{S}_{IS}$$

# 3. Thermo-ecological criteria

- Ust's criterion of the **converter**

$$ECOP_{conv} = \frac{T_0 \dot{S}_I}{\dot{W}}$$

- Ust's criterion of the **system**

$$ECOP_{system} = \frac{T_0 \dot{S}_{IS}}{\dot{W}}$$

# 3. Thermo-ecological criteria

– ***Exergetic criterion***:

$$\eta_{Ex\,S} = \frac{\left(\dot{Q}_{HS} - \dot{Q}_{LS}\right)\left(1 - \frac{T_C}{T_H}\right) - T_C \dot{S}_I}{\dot{Q}_{HS}\left(1 - \frac{T_0}{T_{HS}}\right)}$$

<u>**relative energetic efficiency**</u> (to the <u>ambiance</u>)

$$\eta_{Ex\,S}(T_0) = \frac{(1 - r_L)\eta_{I\,Conv} - \frac{T_C}{T_{HS}} r_L}{\eta_I(T_0, T_{HS})}$$

# 3. Thermo-ecological criteria

**absolute energetic efficiency** ($T_0 = 0$ K)

$$\eta_{Ex\,S}(0) = (1 - r_L)\eta_{I\,Conv} - \frac{T_C}{T_{HS}} r_I$$

**quality factor**

$$fq(T_{CS}, T_{HS}) = \frac{(1 - r_L)\eta_I(T_C, T_H) - \frac{T_C}{T_{HS}} r_I}{\eta_I(T_{CS}, T_{HS})}$$

identical to Second Law efficiency when $T_{CS} \equiv T_0$

# 4. Transfer and conversion compromise

## 4.1. *Power - efficiency compromise*

O.F.: $\alpha\dot{W} + \beta_{\eta_I}\dot{Q}_0$

$$\dot{W} = K_L(T_S - T_{HS})\left(1 - \frac{T_0}{T_{HS}}\right)$$

$$\eta_I = 1 - \frac{T_0}{T_{HS}}$$

$$T_{HS}{}^* = \sqrt{\frac{T_0(\alpha K_L T_S + \beta\dot{Q}_0)}{\alpha K_L}}, \text{ where } T_S = T_0 + \frac{\dot{Q}_0}{K_L}$$

with irreversibility: loop curve

# 4. Transfer and conversion compromise

## 4.2. *Optimum global efficiency for investment constraint*

$$C_0 = C_T \frac{\eta_T}{1-\eta_T} + C_C \frac{\eta_C}{1-\eta_C}$$

O.F. $\eta_G = \eta_T \cdot \eta_C$

$$\eta_i^* = \frac{2 + C_i\alpha - \sqrt{(2 + C_i\alpha)^2 - 4}}{2}$$

(method)

# 4. Transfer and conversion compromise

## 4.3. A*nother compromise:*
## *investment - operation*

O.F. $C_G = v_I \frac{\eta_G}{1-\eta_G} + v_F \frac{1-\eta_G}{\eta_G}$

$$\eta_G{}^* = \frac{\sqrt{v_I}}{\sqrt{v_I}+\sqrt{v_F}}$$

$$\min C_G = \frac{v_I^2+v_F^2}{\sqrt{v_I \cdot v_F}}$$

# 5. Conclusion - perspectives

Attention should be given to:

- the concepts
- the modelling of the studied system

# Multumesc mult pentru atentie!
# Thanks for your attention!

Babele (Old Women) – Bucegi Mountains, Romania



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