FACULTY OF MECHANICAL ENGINEERING
UNIVERSITY OF WEST BOHEMIA

UNIVERSITY OF WEST BOHEMIA IN PILSEN
FACULTY OF MECHANICAL ENGINEERING
DEPARTMENT OF POWER SYSTEM ENGINEERING

Lecture on the subject
KKE/TSM - Boosting combustion engine theory

doc.Ing. Jiří Polanský Ph.D.

evropský sociální fond v ČR
EVROPSKÁ UNIE
MINISTERSTVO ŠKOLSTVÍ, MLÁDEŽE A TĚLOVÝCHOVY
OP Vzdělávání pro konkurenceschopnost
INVESTICE DO ROZVOJE VZDĚLÁVÁNÍ

Podpořeno v rámci projektu CZ.1.07/2.2.00/15.0383
Inovace studijního oboru Dopravní a manipulační technika
s ohledem na potřeby trhu práce

Boosting combustion engine theory

Basic parameters

BASIC PARAMETERS

- **Time of one stroke**
- $t_z = \frac{1}{2.f} = \frac{60}{2.n}\ [s]$

f – fekvency of the revolution[Hz]

n – engine revolutions[min^{-1}]

- **Average piston speed**
- $c_s = \frac{Z}{t_z} = \frac{Z.n}{30}\ [m.s^{-1}]$

Z – stroke [m]

- **Air density (inlet)**
- $\rho_s = \frac{p_s}{r.T_s}\ [\mathrm{kg.m^{-3}}]$

p_s – inlet pressure [Pa]

r – gas constant[J.kg^{-1}.K^{-1}]

T_s – inlet temperature [K]

- **Compression ration**
- $\varepsilon = \frac{V_1}{V2}\ [-]$

V_1 – Volume on the compressiron start[m^3]

V_2 – Volume on the compressiron end [m^3]

BASIC PARAMETERS

- **Fuel mass flow rate**
- $\dot{m}_p = \frac{m_p}{t}\ [kg.s^{-1}]$
- m_p – fuel amount [kg]

- **Fuel caloric value H_u**
- $H_u = \frac{Q}{m_p}\ [\mathrm{J.kg^{-1}}]$

Q – energy released [J]

- **Specific fuel consumption**
- $m_{\mathrm{pe}} = \frac{\dot{m}_p}{P_e}\ [\mathrm{kg.s^{-1}.W^{-1}}]$

P_e – Effective power [W]

- **Middle indicated pressure- p_i**
- $p_i\ [Pa]$
- Theoretical constant value. Work during one stroke equals work during entire cycle
- **Middle effective pressure- p_e**
- $p_e = p_i.\eta_m [Pa]$
- Indicated pressure multiplied by mechanical efficiency (pressure recalculated to the engine clutch). With mechanical losses

BASIC PARAMETERS

- Specific work– **w**
- Specific work (turbines) – $\mathbf{w_t}$
- Ratio of specific volume work – $\mathbf{w_V}$ and swept volume $\mathbf{V_{Z1}}$

$$w_V = \frac{W}{V_{z1}} = \frac{\int_{oběh} p.dV}{V_{z1}} \qquad V_{z1} = \frac{\pi.D^2}{4}.Z$$

BASIC PARAMETERS

- Power **– P**
- Adiabatic cycle: $P = \dot{m}.\left(h_p - h_0\right)$
- Power of the internal combustion engine:

$$P = \frac{W_1.i_v.i_p}{t_1} = \frac{W_1.2.f.i_v.i_p}{\tau} = \frac{W_1.n.i_v.i_p}{30.\tau}$$

- W_1 – work of one cycle during time t_1
- f – frequency of revolution of the crankshaft
- n – engine RPM
- i_v – number of cylinders
- i_p – number of active surfaces
- τ – number of strokes

BASIC PARAMETERS

- Effective power**–** $\mathbf{P_e}$ [kW]
- Power of the internal combustion engine :

$$P_e = \frac{i_v.i_p.V_{z1}.p_e.n}{30.\tau}$$

- V_{z1} – swept volume of one cylinder [dm^3]
- p_e – effective middle pressure[MPa]
- i_v – number of cylinders
- i_p – number of active surface
- τ – number of strokes
- V_{z1} . i_v – engine swept volume

BASIC PARAMETERS

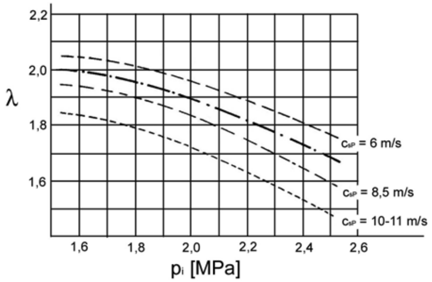
- Torque**–** $\mathbf{M_M}$ (W_M=W_e) [kN.m]

$$M_M = \frac{i_v.i_p.V_{z1}.p_e}{\pi.\tau}$$

- V_{z1} – swept volume of one cylinder [dm^3]
- p_e – effective middle pressure[MPa]
- i_v – number of cylinders
- i_p – number of active surface
- τ – number of strokes
- V_{z1} . i_v – engine swept volume

BASIC PARAMETERS

- **The coefficient of excess air in cylinder λ_e.**
- $\frac{\rho_s}{\lambda_e} = \rho_s . m_p . \frac{L_t}{V_z . \rho_s}$
- Nondirective effect of λ_e to p_i



Graph of dependence λ,p_i and c_s [2]

ρ_s – inlet density
m_p – amount of the fuel
L_t – fuel consumption
c_s – average piston speed

BASIC PARAMETERS

- **Transport efficiency η_d**
- $\eta_d = \frac{m_e}{V_z . \rho_s} [-]$

m_e – mixture amount in cylinder [kg]

V_z – swept volume [m^3]

ς_s – density at inlet [kg.m^3]

- **Volume efficiency η_o**
- $\eta_o = \frac{V_e}{V_z} [-]$

V_z – clearance volume[m^3]

V_e – volume of inlet air [m^3]

- **Filling efficiency η_{pl}**
- $\eta_{pl} = \frac{m_s}{\rho_s . V_z} [-]$

m_s – amount of media at engine inlet[kg]

V_z – swept volume[m^3]

ς_s – inlet density of the filling media[kg.m^3]

- **Mechanical efficiency η_m**
- $\eta_m = \frac{W_e}{W_i} = \frac{P_e}{P_i} [-]$

Radio of effective mechanical work (W_e *[kJ]*) / effective power (P_e *[W]*) at engine inlet ande indicated (theoretical]) mechanical work(W_i *[kJ]*) /indicated power (P_i *[W]*) at engine poutput

BASIC PARAMETERS

- **Thermodynamic efficiency η_t**
- $\eta_t = 1 - \frac{Q_o}{Q_{pc}} [-]$

Q_o – amount of output heat[J]

Q_{pc} – amount of input heat[J]

- **Chemical efficiency η_{ch}**
- $\eta_{ch} = \frac{Q_p}{Q_d} [-]$

Q_p – amount of heat during combustion[J]

Q_d – chemical energy of the fuel (given by caloric value of the mixture) [J]

- **Coefficient of indicator diagram - η_p**
- $\eta_p = \frac{W_i}{W_t} [-]$

W_i – indicated mechanical work [J] (work of working media – depends on evolution of the pressure)

W_t – theoretical work of the cycle[J]

- **Indicated efficiency η_i**
- $\eta_i = \frac{W_i}{Q_d} = \eta_t . \eta_{ch} . \eta_p [-]$

BASIC PARAMETERS

- **Effective efficiency η_e**

$$\eta_e = \frac{W_e}{Q_d} = \eta_i . \eta_m [-]$$

Ratio of the effective (real) mechanical work(W_e *[J]*) on the crankshaft output and chemical energy given by fuel (Q_d *[J]*). It's indicated efficiency multiplied by mechanical efficiency.

References

[1] J. Macek; B. Suk : Spalovací motory I. - Praha 1996

[2] L. Bartoníček: Přeplňování pístových spalovacích motorů – Liberec 2004

[3] K. Hoffman: Regulované přeplňování vozidlových motorů. Brno, 2000.

[4] J. Macek; V. Kliment: Spalovací turbyny, turbodmychadla a ventilátory (Přeplňování spalovacích motorů) – Praha 2003

[5] Hiereth H., Prenninger P.: Charging the Internal Combustion Engine, Springer, Wien 2007

[6] Bell C : Maximum Boost, Bentley Publishers, Cambridge – 1997

[7] Baines C.N.: Fundamentals of Turbocharging, NREC, Vermont 2005

evropský sociální fond v ČR EVROPSKÁ UNIE MINISTERSTVO ŠKOLSTVÍ, MLÁDEŽE A TĚLOVÝCHOVY OP Vzdělávání pro konkurenceschopnost

INVESTICE DO ROZVOJE VZDĚLÁVÁNÍ

Poděkování

Tento projekt je spolufinancován
Evropským sociálním fondem a státním rozpočtem České republiky

Projekt CZ.1.07/2.2.00/15.0383
Inovace studijního oboru Dopravní a manipulační technika
s ohledem na potřeby trhu práce

DISCUSSION...

...QUESTIONS