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FACULTY OF MECHANICAL ENGINEERING
DEPARTMENT OF POWER SYSTEM ENGINEERING

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

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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

Supercharging of petrol engines (gasoline and gas engines)

Supercharging of petrol engines

- ***Aims of supercharging:***
  - *Increase engine power*
  - *Economy aspect*
  - *Decrease emission in exhaust gasses*
- *Increasing of efficiency is limited by **detonation combustion***
  - It's necessary to avoid detonation combustion during normal operation condition of the engine
  - Used fuel
    - **Liquid fuel – petrol engines (BM) stoichiometric mixture λ=1**
    - Gas fuel- stoichiometric mixture λ=1, lean mixture λ>1

Supercharging of petrol engines

Principles and aspects of detonation combustion:

- *Anti-knock properties of the fuel and a mixture λ*
- *Temperature and pressure at the end of the compression given by:*
  - *Compression ratio ε*
  - *Degree of supercharging p_s, t_s*
  - *Ignition timing α_z*
  - *Degree of cooling*
- *Susceptibility and resistance of the combustion chamber to detonation combustion*

Supercharging of petrol engines

Complication

- *Economical at very small range of the mixture approximately $\lambda=1$*
- *Ecological aspect – necessary a tree-component catalytic converter (with λ-probe) – must work with higher specific fuel consumption*

Detonation combustion

Effect of fuel resistance (for n=konst and ε)

- Inlet pressure is decreased p_s but inlet temperature t_s is increased
- At given fuel, the limit of the detonation combustion is increasing according to richness of the fuel
- The limit of the detonation combustion is increasing according to octane number

Conclusions for supercharging

- High octane number
- Low inlet temperature (intercooler)
- Rich mixture

Detonation combustion

Effect of compressed medium at the beginning od the compression (for n=konst and λ=konst, ON= konst)

- Compression ratio ε affects mixture temperature and pressure
- Near the detonation combustion limit, according compression ratio ε decrease inlet pressure p_s
- Decrease ε of help to avoid detonation combustion but decrease η_t , η_i .
- Intercooling have very big effect in this process.

Detonation combustion

Effect of ignition timing

- Effect to combustion temperatures and their gradients
- Smaller ignition timing values cause increase of the effective and inlet pressure
- If p_s = constant, than p_e decrease according to α_z decrease
- Effect of intercooling – p_s increase even if α_z decrease

Detonation combustion prevention – gasoline engines

- Higher fuel octane numbers + additives:
  - special (metyl-terc-butyléter – MTBE)
  - Mixture with methanol, ethanol etc.
- Richer mixture
- Air/mixture cooling
- Optimizing the valve shape
- Two ignition sparks (short combustion time)
- Higher RPM (no time for detonation combustion)
- **Turbocharger control**

Turbocharger control – gasoline engines

Basic possibilities of turbocharger control for :

- Control of inlet pressure p_{sT} for:
  - Avoid detonation combustion
  - Obtain necessary torque for the turbine M_t
- Increasing acceleration possibilities
- Avoid compressor stall

Turbocharger control – gasoline engines

Inlet pressure control p_{sT}:

- Exhaust gasses blow-off (most effective)
- Throating exhaust gasses behind the turbine:
  - Slower inlet pressure p_{sT} increase – complicated stabilization
  - Negative work increase
- Throating at compressor input (increasing underpressure at compressor inlet, increase temperature)
- Air Blow-off behind compressor
- Air By-pass back to the compressor inlet

Turbocharger control – gasoline engines

Increasing acceleration:

Exhaust gasses mass flow rate depends just on the engine load (negligible effect of RPM) → decrease of the load causes rapid decrease of turbocharger (long time acceleration). Better acceleration could be obtained with:

- The flap before compressor
  - Faster acceleration
  - Better position of working point in compressor map (avoid stall)
  - Better sealing is necessary

Turbocharger control – gasoline engines

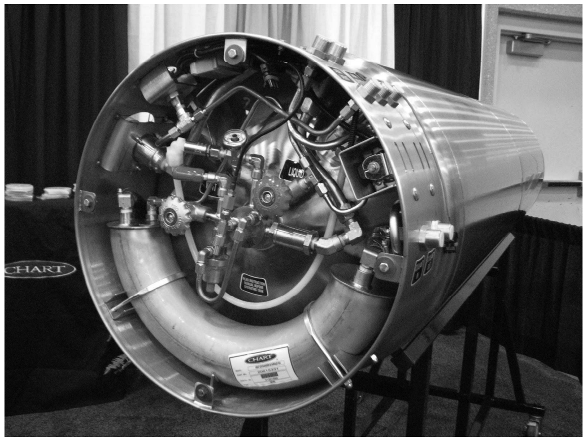
Increasing acceleration:

- The flap behind compressor
  - Turbocharger's efficiency decrease η_{TD}
  - Working points near by surge line – necessary further control
- Flaps behind and before compressor
  - Universal - for gasoline an diesel engines

Gas engines

- Wide range of the mixture richness
- Fuels – Metan, propan, natural gas, LPG
- Commercial – propan-butan(PB), CNG, LNG
- Engine arrangement depends on used fuel (on ignition type, on catalytic system)
- **Catalytic system:**
  - Controlled three-component (operation with stoichiometric mixtures)
  - Oxidation (operating with a lean fuel mixture)
- **Ignition type:**
  - **Spark (petrol engine)**
  - Auxiliary jet fuel (diesel engine)

Gas engines



Fuel tank for gas engine[8]

Gas engines

Operation with stoichiometric mixture (λ=1)

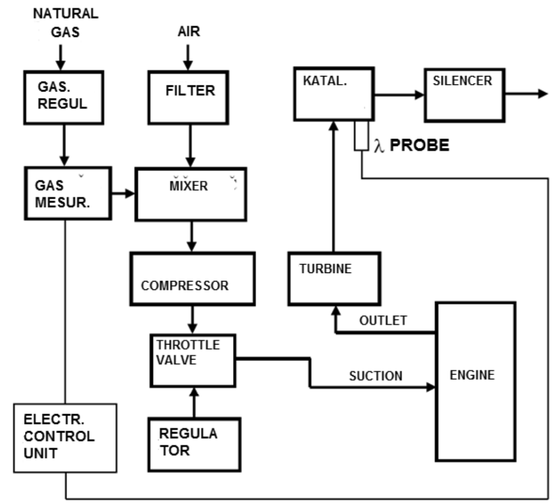
- Supercharging is unnecessary
- Tendency to detonation combustion, is necessary
  - Decrease compression ration ε
  - Decrease inlet pressure T_s
  - Swirl combustion chamber, etc..
- Higher octane number of gaseous fuels (supercharging is unnecessary)
- Mixture richness is controlled by control system according to data from λ-probe
- Fuel supply is controlled
  - By changing of the delivery nozzle cross-section by stepping motor
  - Blown gas supply management

Gas engines

Turbocharger control

- Exhaust gasses blow-off (most effective)
- Integrated throating flap - f(n)
- Throating compressor output - f(n)
- Air By-pass back to the compressor inlet
- Mixture richness control according to engine load and RPM

Gas engines



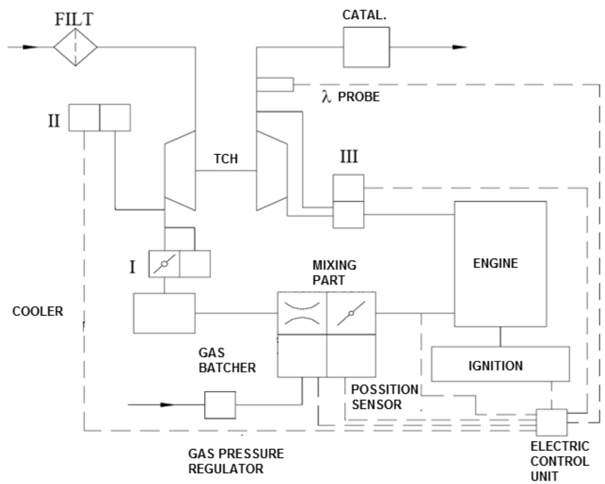
Engine arrangement with stoichiometric mixture[2]

Gas engines

Operation with a lean fuel mixture (λ>1)

- Wide range of ignition
- For smaller values of mixture richness is necessary to improve ignition system
- Usually supercharged
- **Turbocharger regulation :**
  - Exhaust gasses blow-off (most effective)
  - Integrated throating flap - f(n)
  - Throating compressor output - f(n)
  - Air By-pass back to the compressor inlet
  - Mixture richness control according to engine load and RPM

Gas engines



Engine arrangement with loan fuel mixture[2]

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DISCUSSION...

...QUESTIONS

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

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Poděkování

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

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