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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

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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 control methods

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*

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 (GE)

Basic types of turbocharger control:

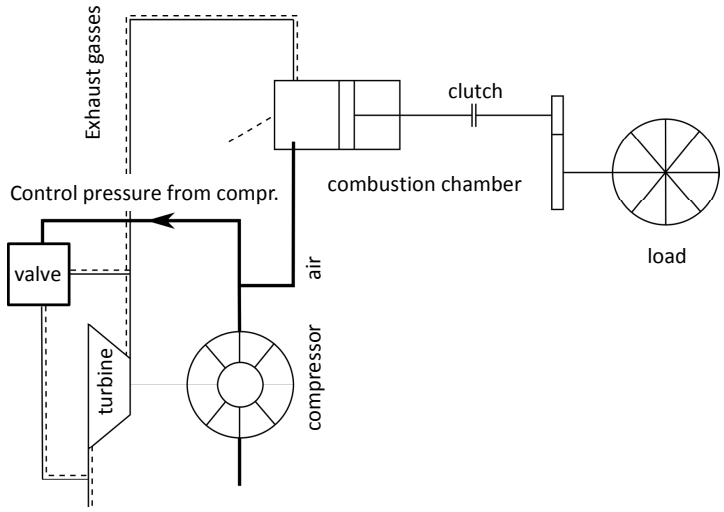
- Exhaust gasses blow-off before turbine (WASTEGATE)
- Air throating at compressor output
- Air blow-off behind compressor
- HYPERBAR
- Variable geometry control

WASTEGATE

Exhaust gasses blow-off before turbine (WASTEGATE)

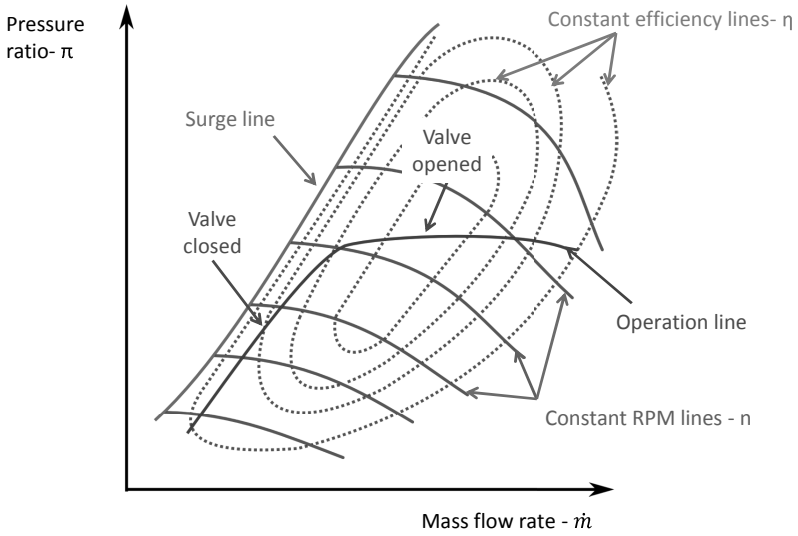
- Most used control
- For small turbochargers
- Optimizes turbocharger's operation at low engine modes (compressor and turbine work optimization)
- **Usually smaller turbine to ensure higher charging pressure and higher air supply to the combustion chamber at low engine speed. At high engine speed by air draining is reduced the turbine power which means that the air supply to combustion chamber decrease as well.**
- **Control is provided by**
  - **Clapper**
  - **Poppet valve**

WASTEGATE



WASTEGATE system – schematic

WASTEGATE



System WASTEGATE – operation line during opened/closed blow-off valve

WASTEGATE

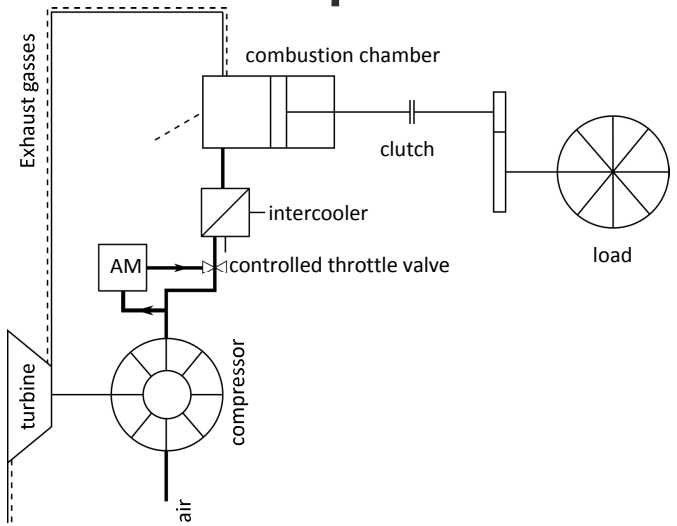
Outer view - WASTEGATE [8]

Air throating at compressor output

Air supply control at compressor output

- Nondirect engine power control
- For petrol engines (for aircraft APU)
- Influence the turbocharger operational line
- Ensure avoiding compressor stall
- Compressor ratio control
- **Flow control is provided by throttle valve, which is controlled by active member (pedal). The valve is located between the compressor and the combustion chamber before the intake valve. Pressure behind the compressor is a control parameter and a control medium as well.**

Air throating at compressor output



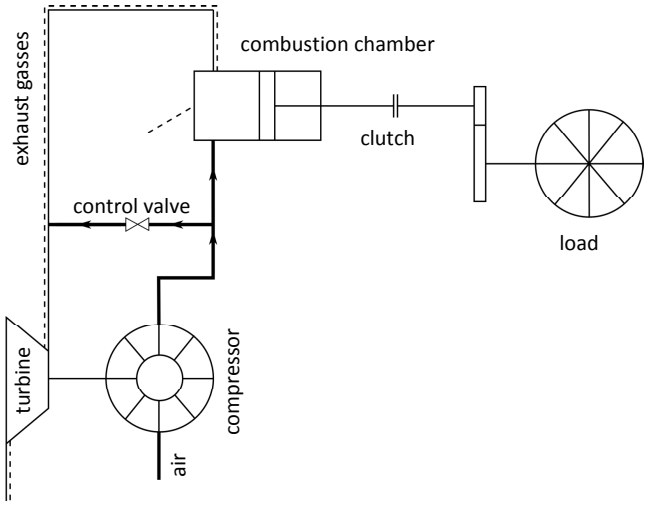
Air throating at compressor output – schematic

Air blow-off at compressor output

Air supply control at compressor output

- Positive effect to fuel consumption
- Decreasing temperature before turbine and the amount of the smoke
- Efficiency of the compressor is increasing at low RPM values (increase performance by up to 20%)
- At higher RPM values the efficiency is decreasing
- System efficiency is given by the manifold design and pressure ratio
- **With control valve transmits pressure from compressor output to the manifold before turbine. Decrease back pressure at compressor output. Necessary power to drive the compressor decrease, air supply and turbine performance increase. The result is increase mass flow rate through the engine and turbine (allows to increase fuel supply → engine performance)**
- **The valve is usually designed one-way valve (backflow prevention)**

Air blow-off at compressor output



Schematické znázornění sytému odpouštění vzduchu z výtlaku dmychadla před turbínu

HYPERBAR

Air supply control at compressor output and its subsequent use for afterburning

- High engine and turbine performance
- Low compression ratios
- Necessary to use APU for start
- Complex engine heating
- Possibility to adjust the engine characteristic at very wide range
- **Control valve transmits pressure from compressor output do the manifold before turbine. A significant turbine performance increase is caused by additional heat, which is provided by additional combustion chamber located before turbine. The transmitted pressure (air) from compressor output is used in additional combustion chamber to burn more fuel. By this method is increased the energy of exhaust gasses which entering into the turbine.**

HYPERBAR

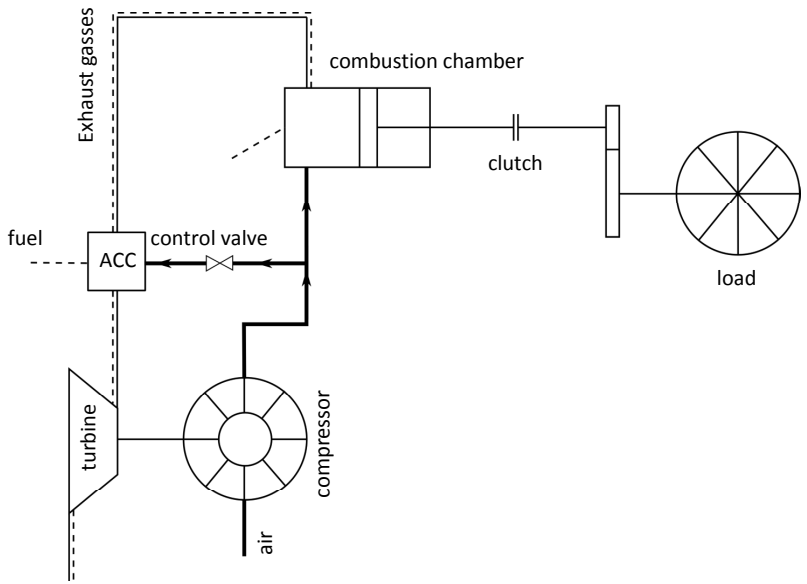
Advantages of the HYPERBAR system

- High specific power (2,5 kW/kg)
- Low temperature load of the engine
- Suitable course of external engine characteristic
- Rapid reaction to the load change
- Correction of losses given by altitude
- Safe start at low temperatures
- Reduce emissions

Disadvantages of the HYPERBAR system

- Higher specific fuel consumption (up to 8%)
- A complex construction

HYPERBAR



Schematické znázornění sytému HYPERBAR

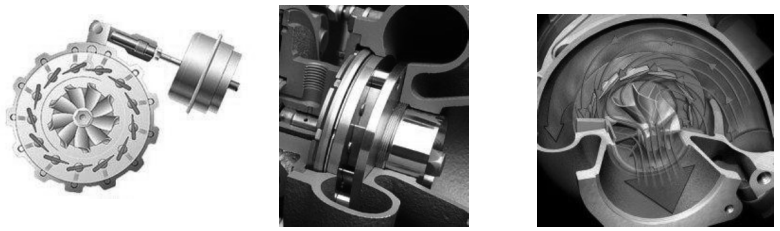
Variable geometry control

Control via variable guide vanes

- Constant mass flow rate through the turbine (maximum)
- Turbine is design for maximal mass flow rate (average value of the entire range)
- Turbine performance control is provided just via guide vanes – outlet surface from guide vanes (angle and velocity of the flow at turbine inlet)
- More efficient than blow-off control (less significant temperature and pressure fluctuation)
- Complex construction
- **The regulated output surface of guide vanes there have influence to the flow parameters. Via increasing friction losses there is just a small stage reaction change. At low RPM are vanes partially closed and accelerates the exhaust gasses toward to the turbine (under 90 degrees angle) which causes turbine RPM increase. At high RPM are vanes fully opened because the exhaust gasses have enough energy**

Variable geometry control

a)



b)

Principle of the geometry change[8]

a) At low RPM
b) At high RPM

References

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DISCUSSION...

...QUESTIONS

INVESTICE DO ROZVOJE VZDĚLÁVÁNÍ

Poděkování

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

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