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Adaptive engine concept

(e.g. rockets, supersonic rocket combustors, air-breathing engines such as jet engines, subsonic ramjets, ramjets, scramjets, dualmode, pulsejets, detonation engines, rocket ramjets, Laval/nozzles) and **structural concept** (e.g. for aircraft and rockets) for flexible and selectively variable geometries

CONTENT: **SHEET**

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Adaptive engine concept

General

Overview:

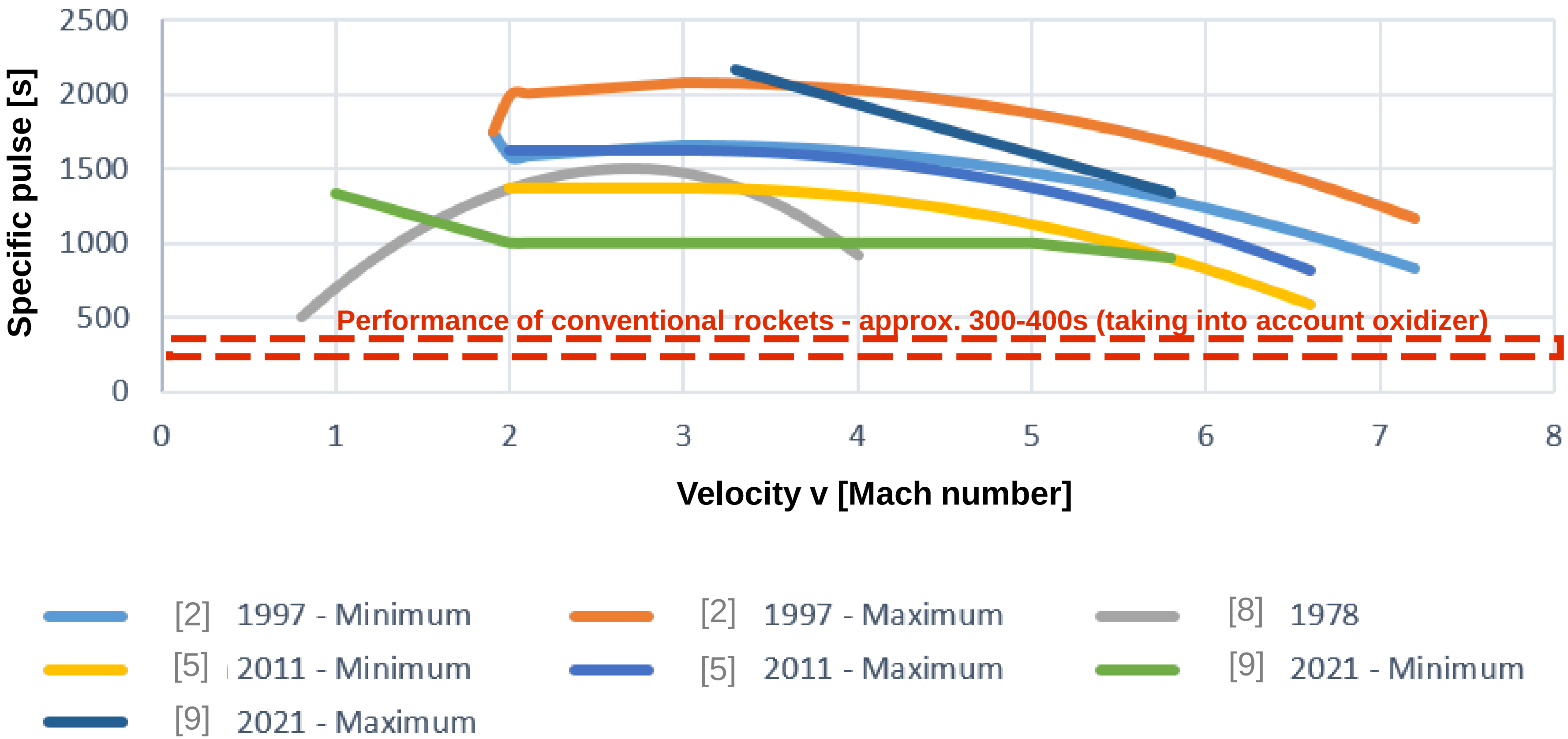
- Aircraft engines [2] → [2] Müller: LUFTSTRAHLTRIEBWERKE ISBN 978-3-322-90325-9
  - Airscrew engines
  - Jet engines
    - Air jet engines
      - Turbine air jet engines
      - Air jet engines Without turbo set
        - Pulse jet engines
        - **Ramjet engines**
          - Hypersonic engines
    - Rocket thrusters

Principle

Ram effect compaction:

- Chemical engines with thermodynamic conversion of chemically bound energy into thermal and finally kinetic (usable thrust) energy.
- Flow energy of incoming atmosphere is converted into compression by engine geometry → ram-steel engines generally not capable of self-launching
- moving compressors can be omitted, such as axial compressors in turbine engines

Subsonic jet engine and Ramjets – Overview of the performance



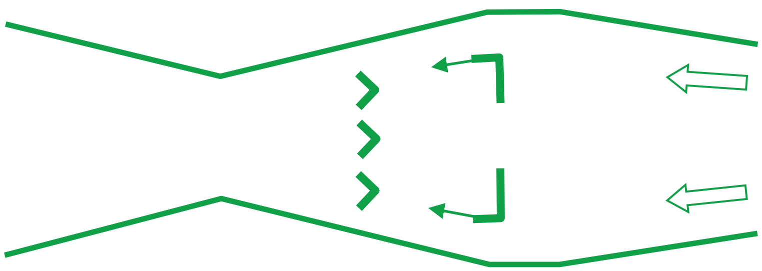
[2] Reinhard Müller: Luftstrahltriebwerke …, ISBN 978-3-322-90325-9
[5] Ernst Messerschmid et al: Raumfahrtsysteme; ISBN 978-3-642-12816-5
[8] THE POCKET RAMJET READER; CHEMICAL SYSTEMS DIVISION; 1978
[9] Antonella Ingenito: Subsonic Combustion Ramjet Design; ISBN 978-3-030-66880-8; S. 6

Subdivision according to speed ranges

(different required compressor ratios require different geometries).

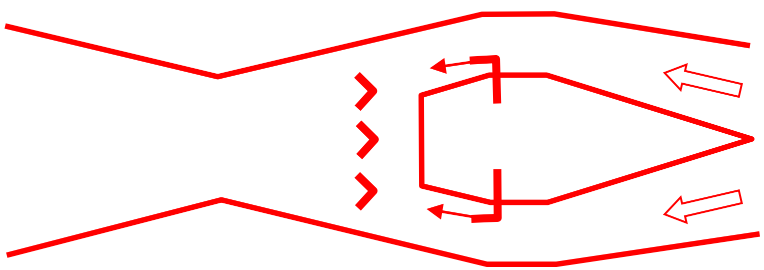
Subsonic combustion

Subsonic Ramjets:



approx. Mach 0.75 to max. approx. Mach 2
simple structure
relatively low efficiency of propellant utilization
but compared to conventional rocket engines,
oxidizer can be omitted

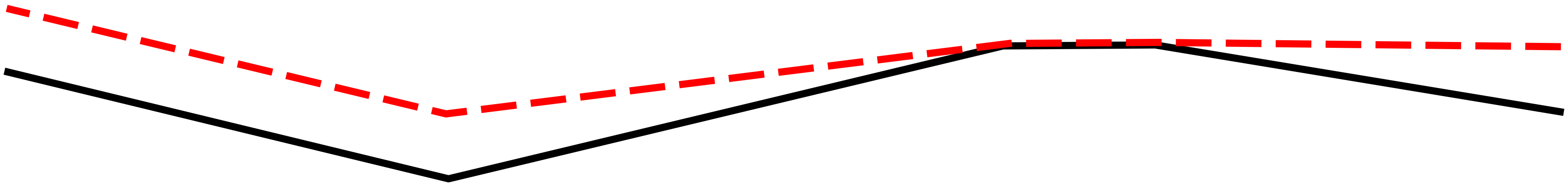
Ramjets:



approx. Mach 1.5 to max. approx. Mach 5
(higher with hydrogen)
Intermediate body in the inlet
higher efficiency of fuel utilization
compared to conventional rocket engines,
oxidizer can be omitted

+ Special forms such as combined propulsion (rocket ramjets), dual-mode ramjets or supersonic combustion with Supercombustion Ramjets (SRAMJETS)

Regulation - requirement

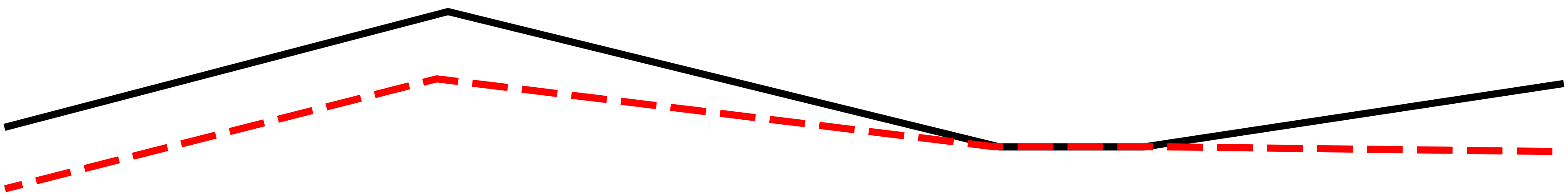


Control refers to the change of process parameters according to certain laws in order to realize the desired work process.

e.g. inlet geometry, blade adjustment for turbines, injection, etc.

generally optimization often at minimum of required control means maximum of fixed geometrical conditions

⟶ simpler, less effort and limitation of efficiency losses



"Adaptation" or "Wandlung" of adaptation wall of the engine duct

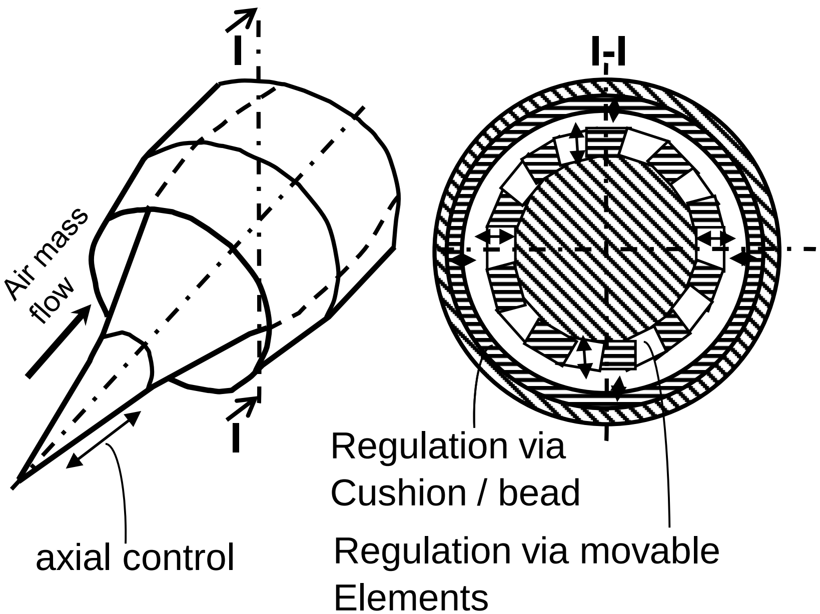
(„Wandler-Concept"), i.e. special regulation from outside

⟶ Less intervention in flow channel to reduce efficiency losses

Air-breathing engines generally designed for narrow range only

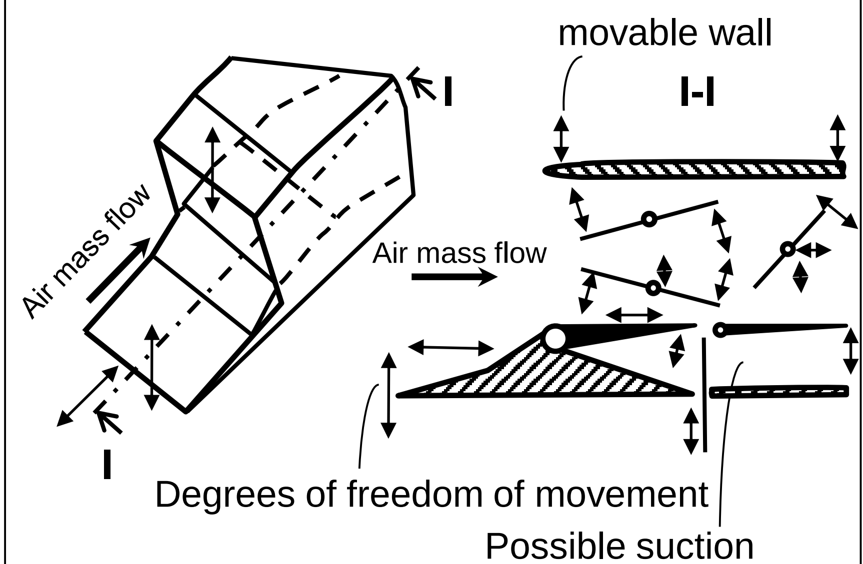
→ Inlet decisive, e.g. to prevent flushing over

Axial symmetrical inlet



→ **uniform control according to the limited reasonable possible according to the state of the art**

Level inlet



→ **uniform control according to State of the art simplified**

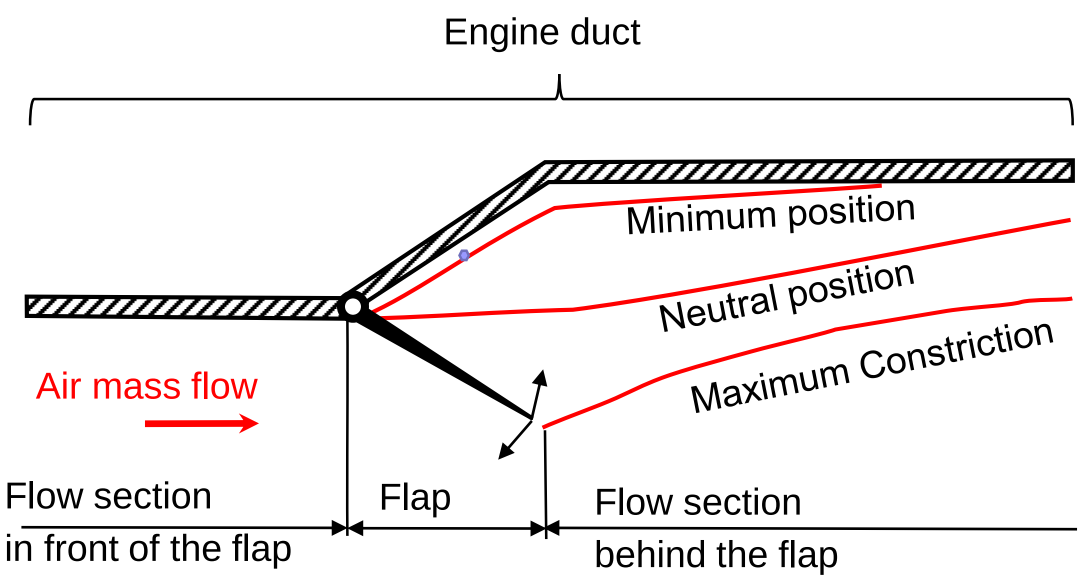
→ Control via level inlet advantageous

Air-breathing engines generally designed only for narrow operating range
→ Control demanding complex and difficult

mechanical control requires moving parts:

heavy motors or cylinders,
lubrication if necessary, bearings + seals

→ prone to failure, or heavy and complex



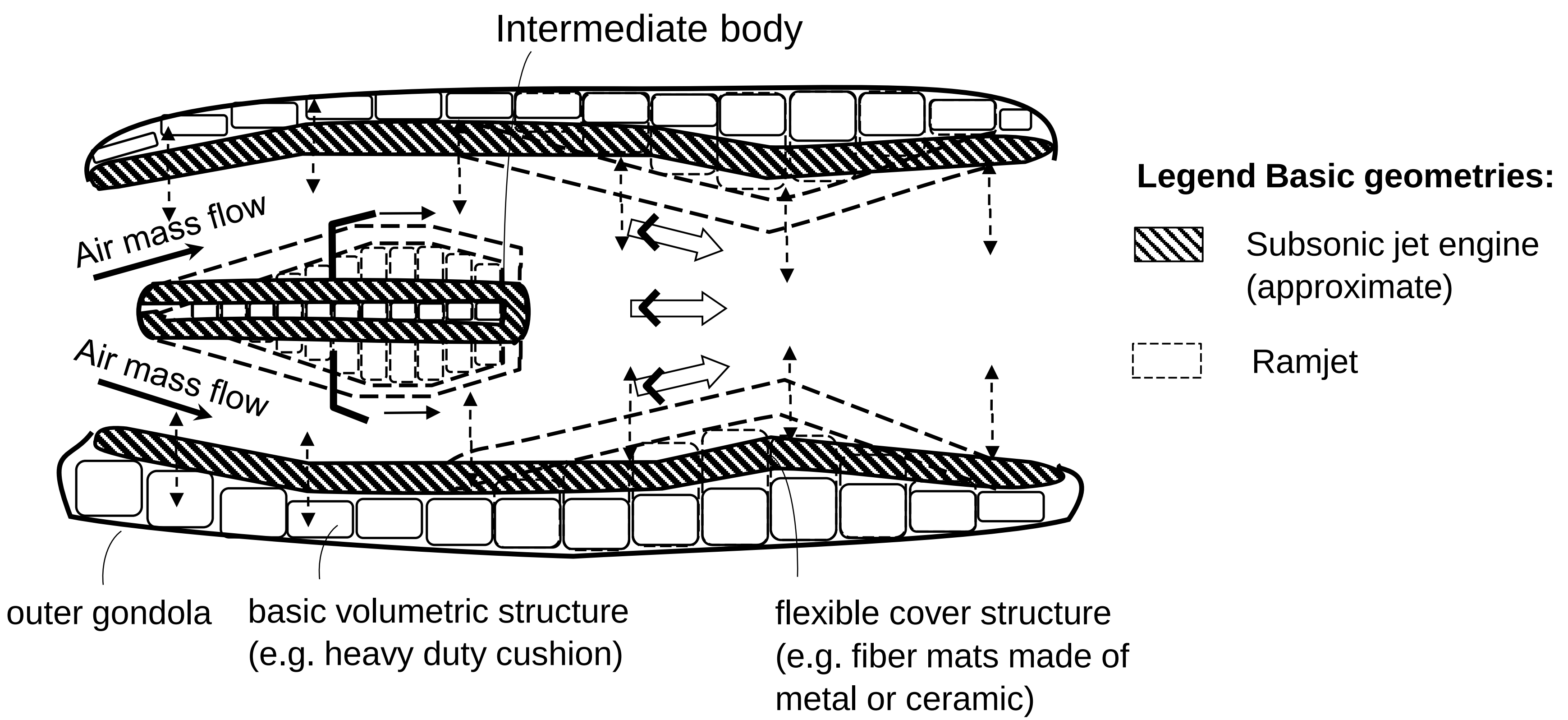
Post-expansion possible, partly unavoidable

controllability limited

Partial efficiency losses

Air-breathing engines generally designed for narrow range only
Regulation demanding complex and difficult

→ Separate concept for adaptive engine geometry
Goals: light, simple and flexible



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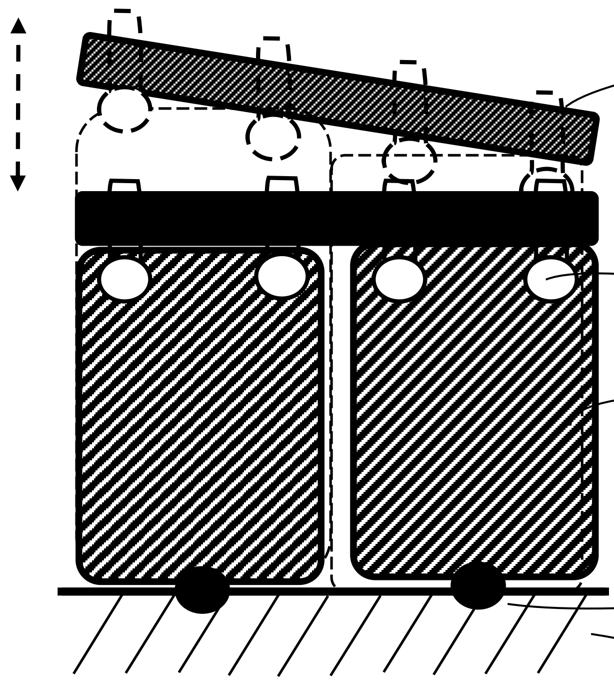
Adaptive engine concept

CONSTITUENTS

simplified scheme of one element
Combination with other fixed or movable sections possible



Components:
- **flexible or movable envelope**
- **source of pressure (pneumatic or hydraulic)**
- **"fluid" (e.g. air or possibly fuel)**

Example: Heavy duty cushion

- Pneumatic operation
- Active use against loads possible
  Light and inexpensive
- Proven e.g. in construction industry and warehousing

Illustration: Lifting of concrete element by means of pneumatic heavy duty cushion (https://www.traco-online.de)

alternatively: chambers as volumetric elements

Composite structure

- Cover structure - cover structure
- Basic structure - cover structure
  alternatively also load-bearing structure - deck structure
  - Basic structure - cover structure in the edge area
- supporting structure - basic structure

Basic structure - cover structure (examples of possible composite structure)

1. Flexible friction-locked connections

Fig.: Pull rings
e.g. on rope guides
www.thal-versand.de

Fig.: flexible clamps
e.g. on rope guides
www.edelstahl-niro.de

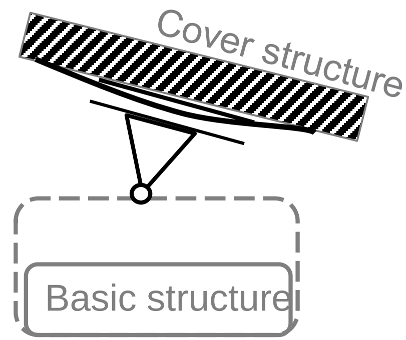


Fig.: Sliding guide with joint
(floating bearing)

2. in operation, frictional connection of flow/combustion chamber pressure to counterpressure Basic structure

→ for simplification in other areas predominantly positive connection

Ceramic fibers / composite structures - examples

Fig.: **Zircon fabric (up to 2,200°C)**
Source final-materials.com
good insulation, use in nozzles!

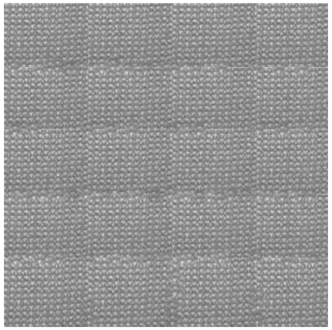


Fig.: Ceramic fibers (up to 1,700°C)
Source final-materials.com
good insulation, fire protection!

Fig.: Silicate fibers (up to 1,200°C)
Source final-materials.com
Good insulation

Metal fibers - examples

Fig.: **Alumina fibers (up to 1,300°C)**
Source final-materials.com
schuba-shop.com

Isolation - Examples

Fig.: Silica fleece (up to 1,000°C)
Source Steinbach AG

Fig.: Insulating sleeves (up to 1,200 °C)
Source heatprotection.de

Coatings for heat reflection in development / research (e.g. furnace coatings up to approx. 1,000°C)

Cooling - Examples

flexible + larger specific surface ⟶ cooling effect

Fig.: Corrugated hose
(up to 700°C)
www.esska.de

Fig.: Metal bellows
www.zeitz-gmbh.de

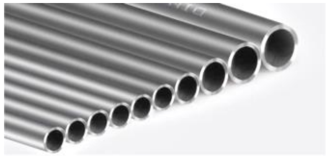


Fig.: Piping (up to approx. 1,250°C)
www.abtersteel.com

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Adaptive engine concept

SUMMARY

design advantages:

- can be combined with fixed sections (e.g. in combustion chamber)
- light structures (especially in pneumatic systems)
- less complex than mechanical control systems
- versatile design possibilities for the walls of engines / nozzles, flaps, outer contours of engines, flying objects

energetic advantages:

- in the engine, stepless control of thermodynamic conditions by means of adapted cross-sectional geometries → different compressor ratios
- versatile design possibilities of the wall to prevent e.g. thermal blocking of the intake

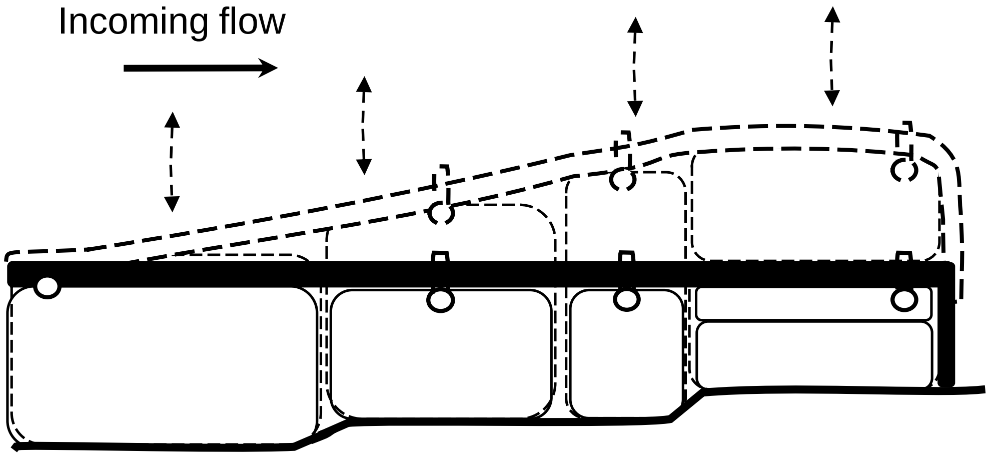
chemical propulsion in general (including rockets):

- Design of variable nozzles

air-breathing propulsion systems:

- Use for ascents by horizontal launches (singer concept) or vertical launches (e.g. Heber concept)
- adaptation of diffusers or bypasses to flaps

Use: inlets, wings, flow bodies (e.g. ships)



Possible influence:

Boundary layer

Re-attachment site

Reduction of harmful surface