# EFRC Training Workshop Lubrication and Wear

Effect of wear and lubrication on compressor valves

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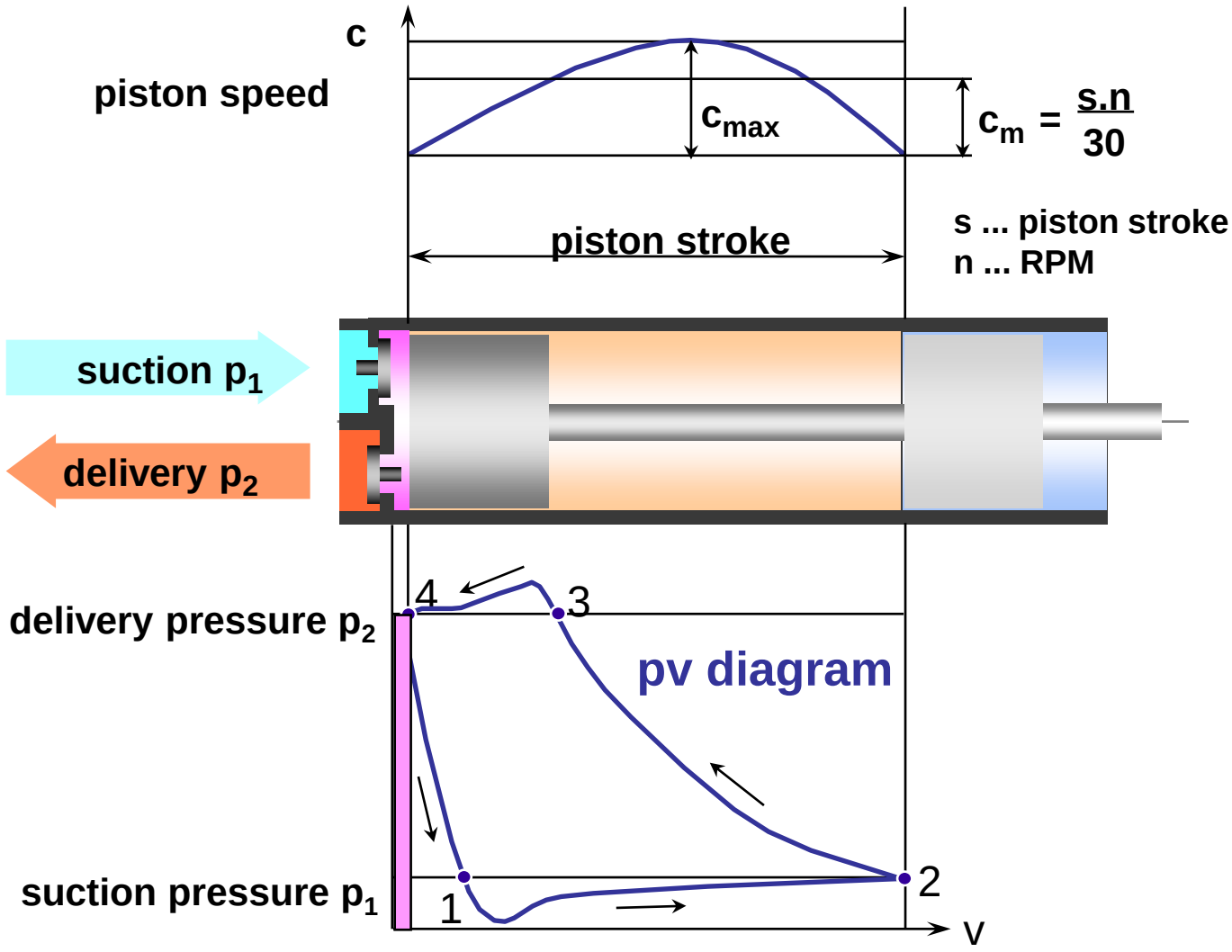
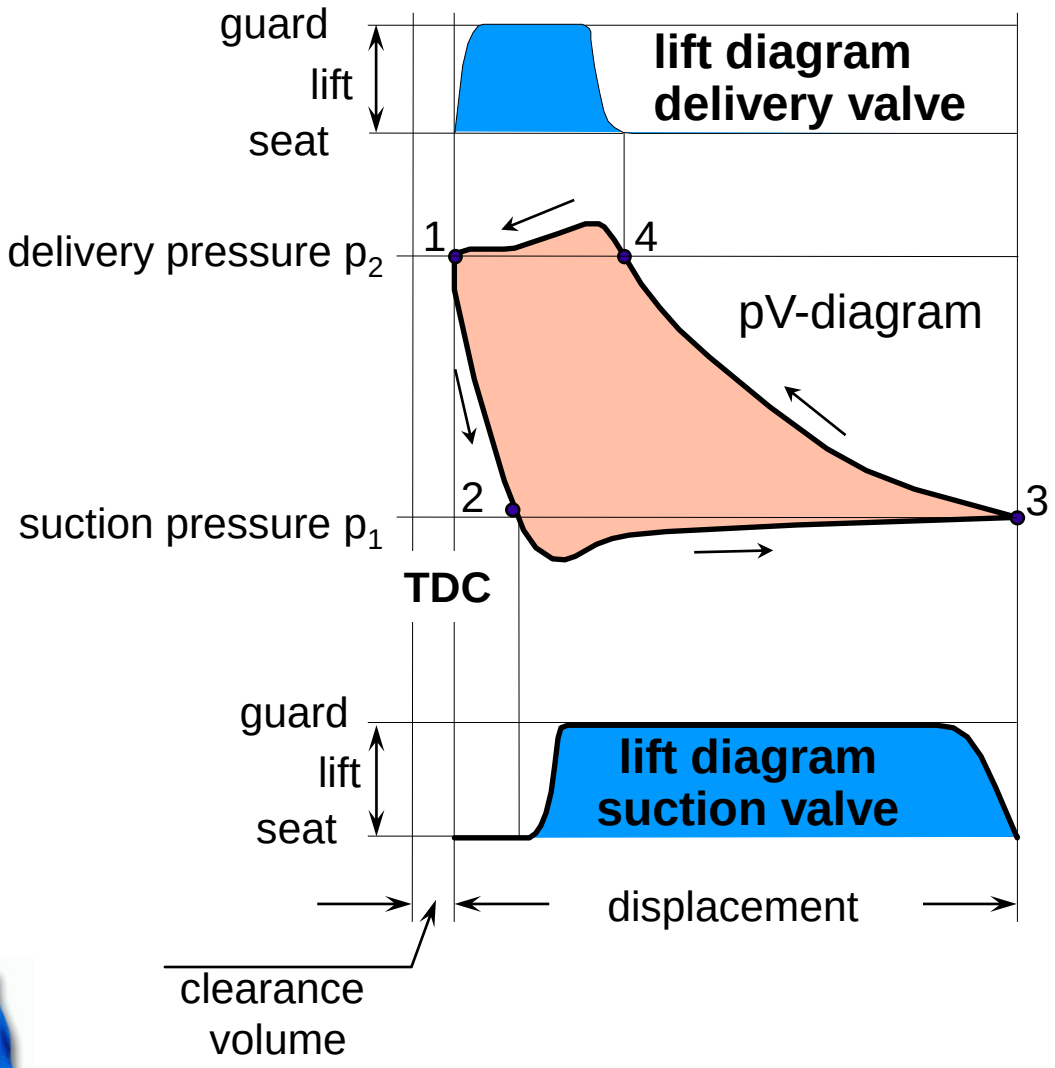
- Compressor Valve Fundamentals
  - Operating principle
  - Valve motion, design criteria
- Application based Valve Selection
  - Combining data & application knowledge
  - Overlubrication and other factors, examples of failures & wear
  - Countermeasures

# Reciprocating compressors



# Valve characteristics




**Bottom dead center**

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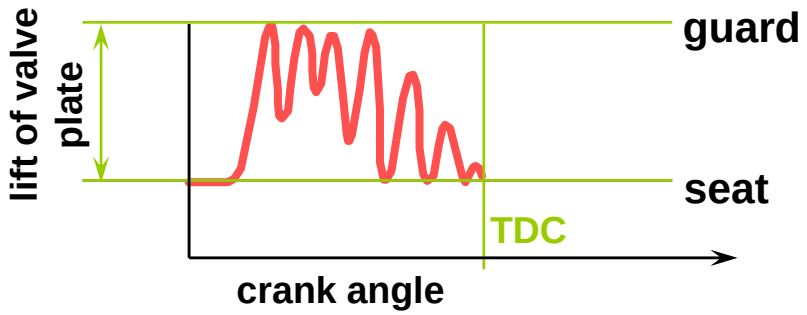
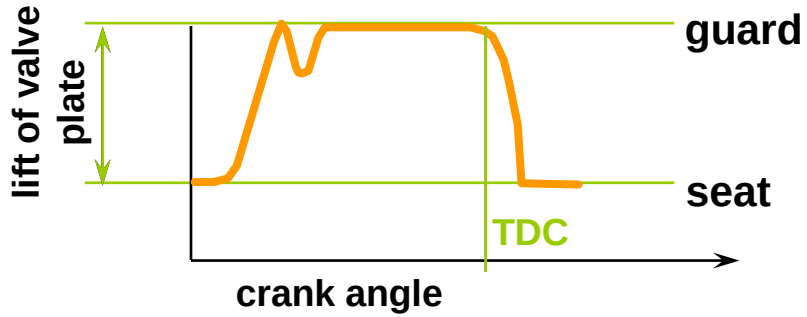
# Valve dynamics




**valve flutter**

- too strong spring load
- Multiple impacts

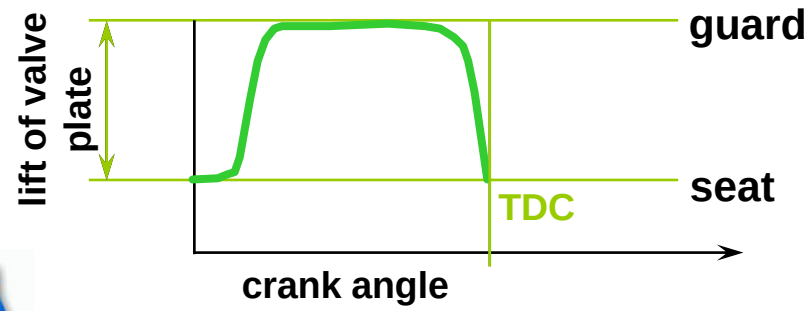
→ wear




**delayed closing**

- oil sticktion effects
- weak spring load
- Highly increased closing impact

→ Wear & breakage



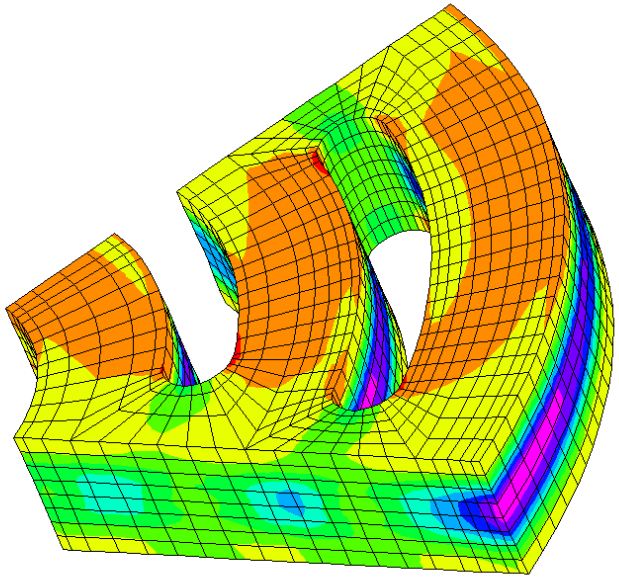

**ideal motion of valve plate**

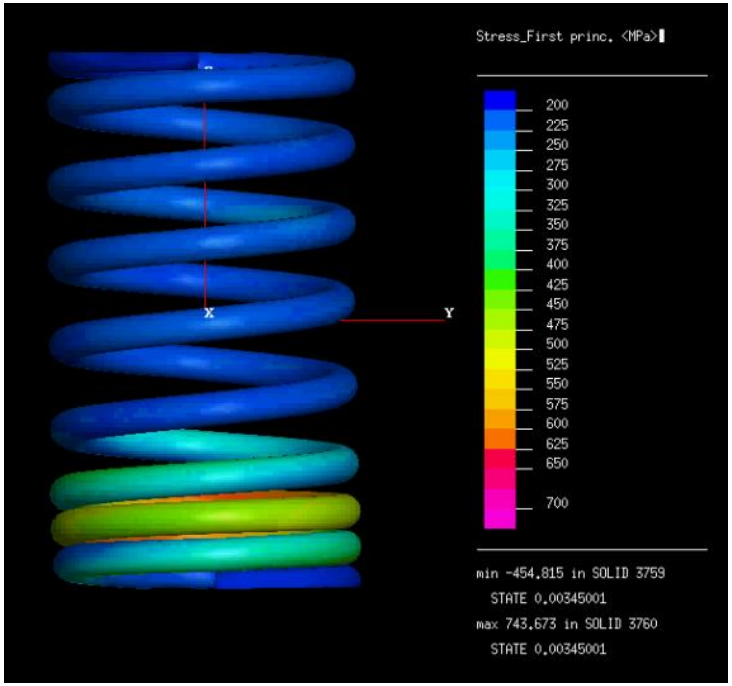
# Valve Design

**The impact velocity of the sealing element against the guard / seat is the most important design criterion for a compressor valve!**

*Stresses in the*

*-Sealing Element and*
*-Closing Springs*






*are directly proportional to the impact speeds!*

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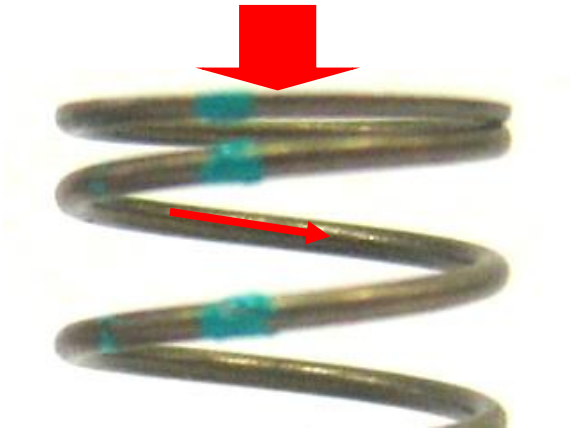
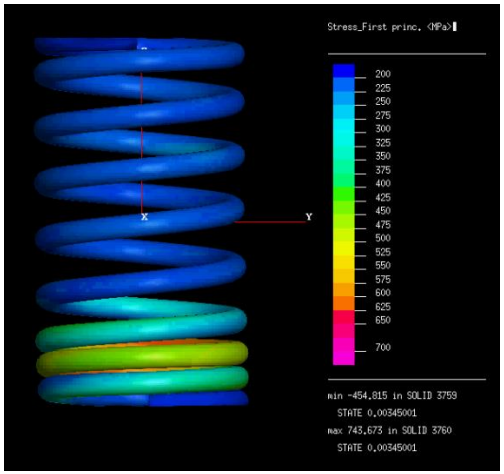
# Spring design

**Dynamic & static spring design criteria:**

- Solid height stress (spring fully compressed, static)
- Individual coil contact (dynamic contact of spring coils)
- Lift off (spring ends jump off the guard / sealing element)

***Shock***






→ Coil contact & lift off cause wear and eventual breakage of springs
→ Breakage of springs causes sealing element wear and breakage

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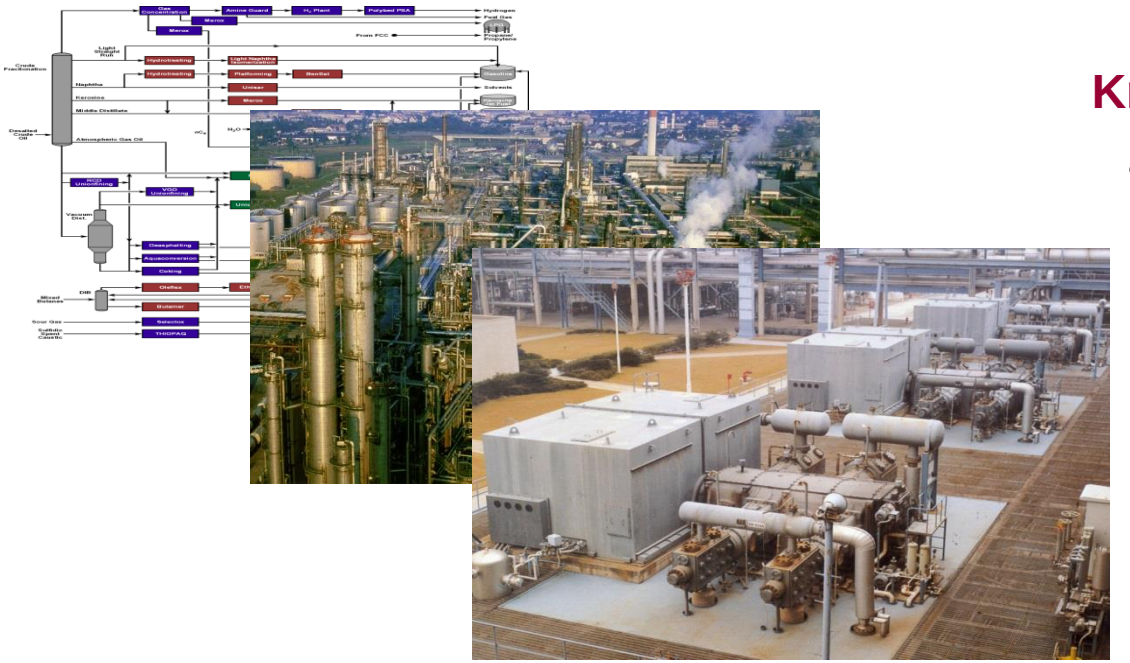
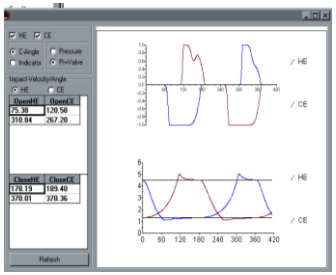
# Knowledge of the application is the key!

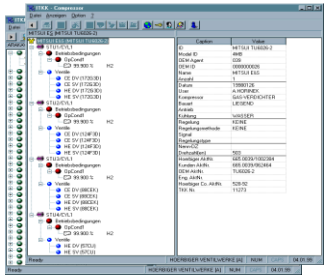


## Knowledge of application

- **Hidden info on**
  - *overlubrication*
  - *Dirt/Polymerisation*
  - *Liquids*
  - *Corrosive components*
  - *Process characteristics*

## Valve sizing & engineering





***Both sides need to be considered for a correct valve design!***

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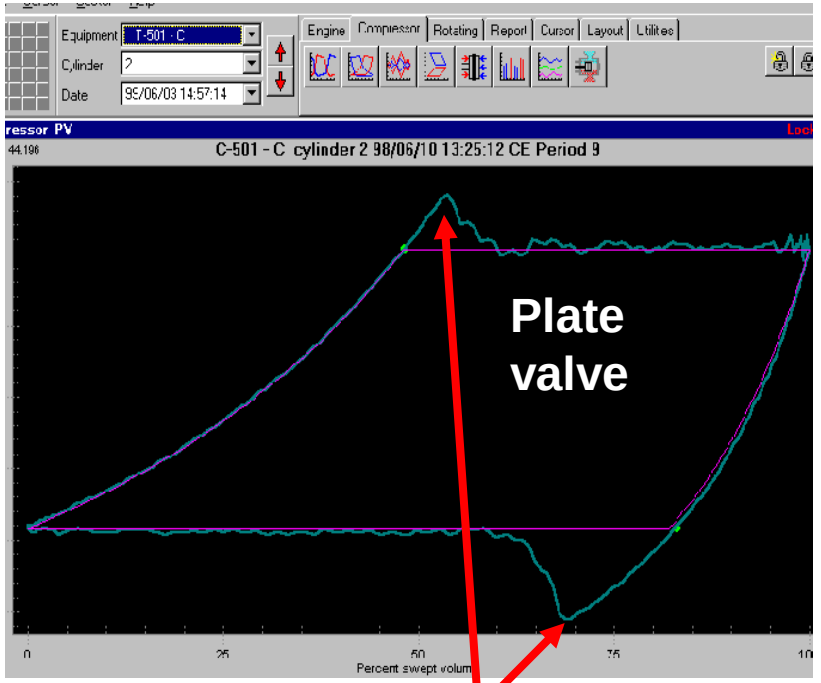
# Typical failure modes: over lubrication

## Hydrogen Compressor

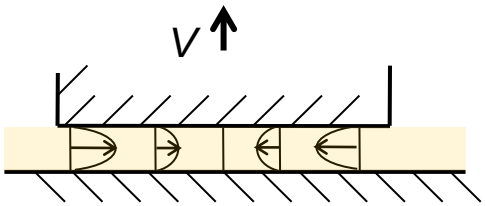
Plate valve failing after short amount of time – pV reading revealed sticktion effects:

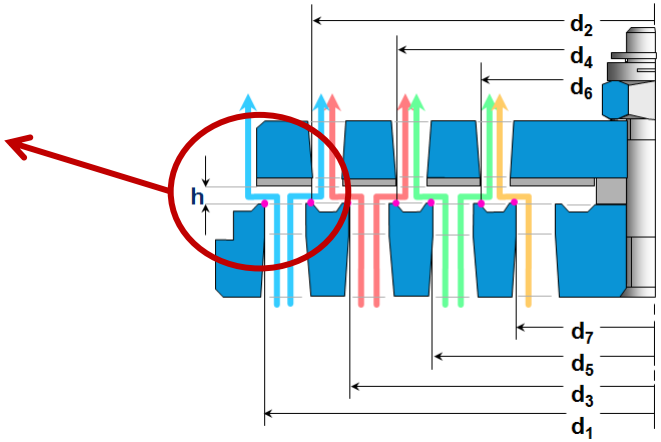
- Oil is trapped in parallel surface between plate and seat lands
- Diff. pressure needed to pull surfaces apart
- Delayed opening of sealing element
  → huge pressure overshoot, acting on plate
- Huge pressure overshoot accelerates plate
- Dramatically increased impact speed

**→ springs and plate breakage!**




***Sticktion effect***

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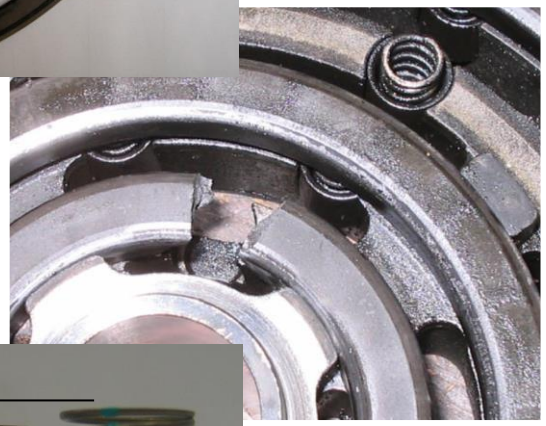
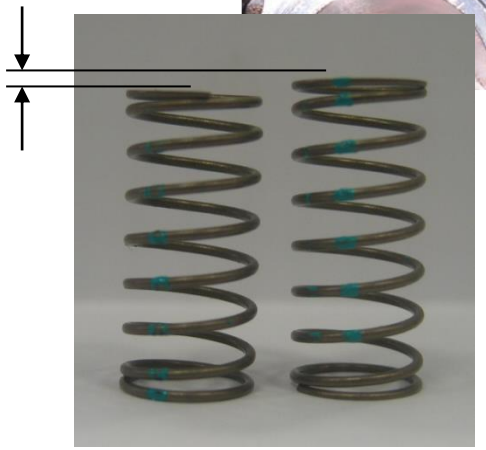
# Typical failure modes of over lubrication

Oil sticktion effects:

- lead to high impact of the sealing element
  - outer section of valve plate starts failing because of forced rupture
  - Rings break
  - Springs settle

Remedy: Reduce cylinder lubrication rate (if possible), increase spring load

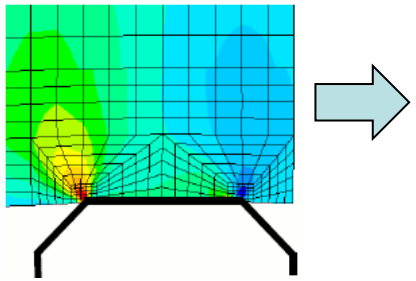




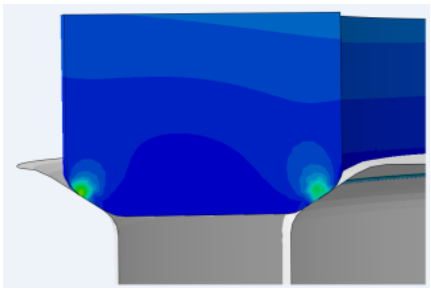
*Plastic deformation of the spring wire leading to a lower uncompressed spring length*

# Countermeasures for reliable operation

## Measures to reduce impact stress: advanced designs



Conventional sharp seat lands for flat plate valves



Profiled seat designs

- **Profiled seat / guard / sealing element design → line contact**
- **Dynamic load resistant coil springs → no coil contact**
- **Spring savers (nonmetallic enclosure for spring) → no wear**

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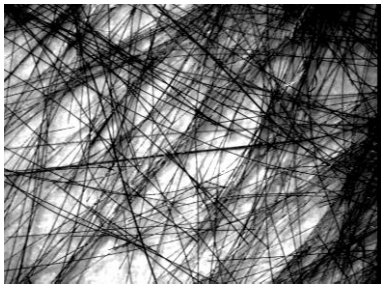
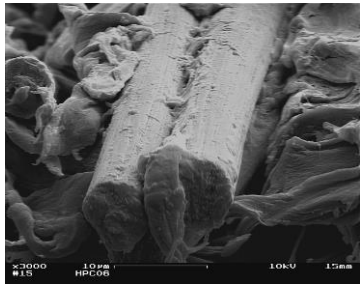
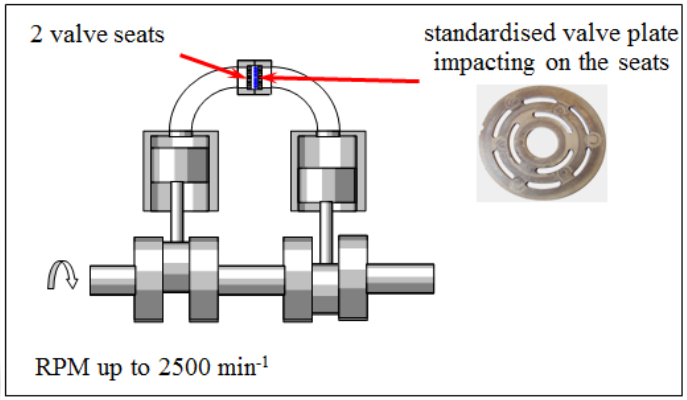
# Countermeasures for reliable operation

**Advanced nonmetallic sealing elements:**

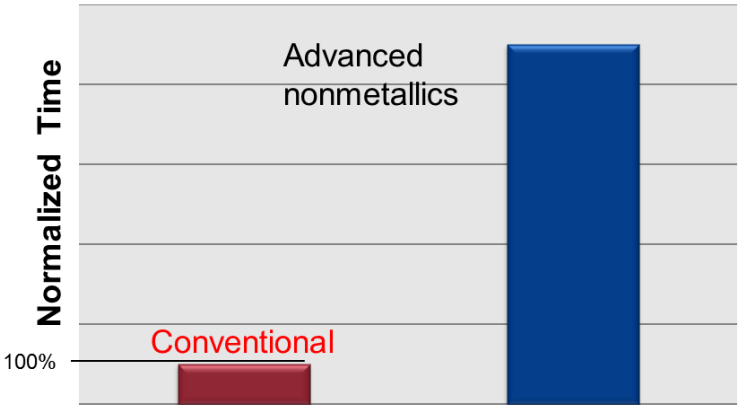
- can withstand much higher impact speeds

Lifetime tests and sealing element development can be done on a lifetime tester → ***up to 10x longer lifetime***:




*Accelerated life time test under controlled laboratory conditions*

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# Overlubrication – design solutions

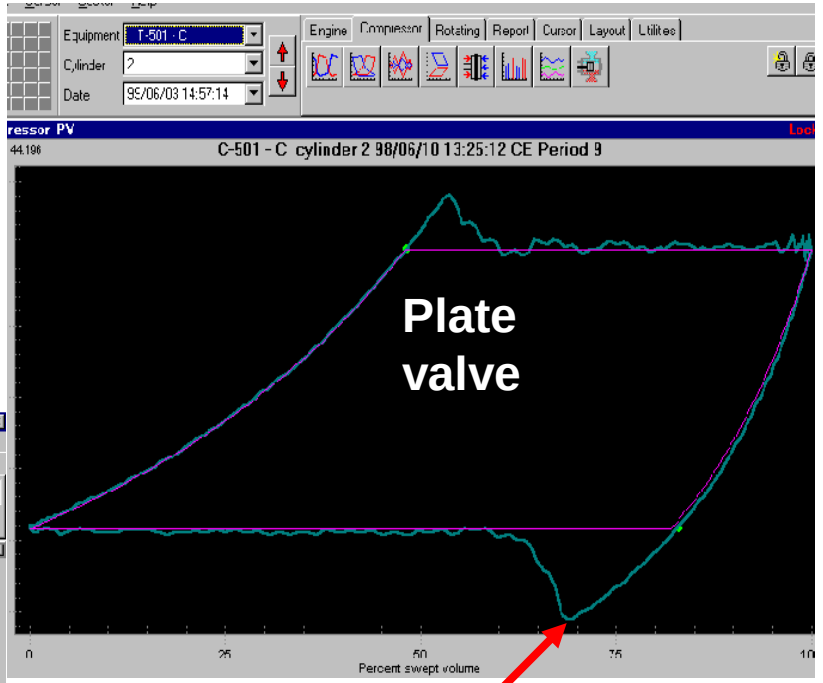
## Hydrogen Compressor

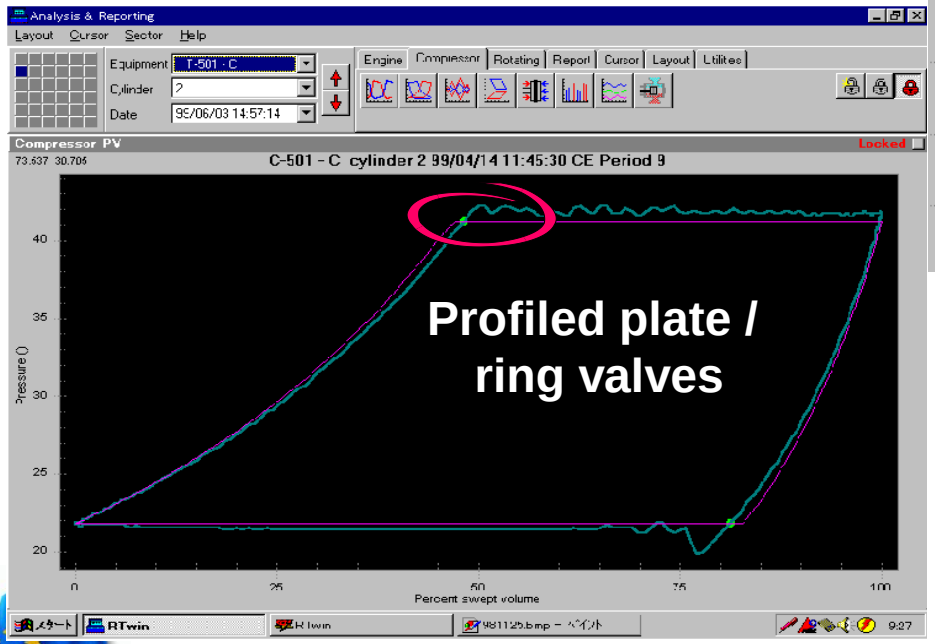
### The problem:

Plate valve failing after short amount of time – pV reading revealed sticktion effects

### The Solution:

Changed to ring valve -
lifetime now 16.000 h




***Sticktion effect:***
*huge pressure overshoot due to delayed opening of sealing element*

***The profiled geometry of ringvalves / profiled plate valves (line contact) leads to less sticktion!***

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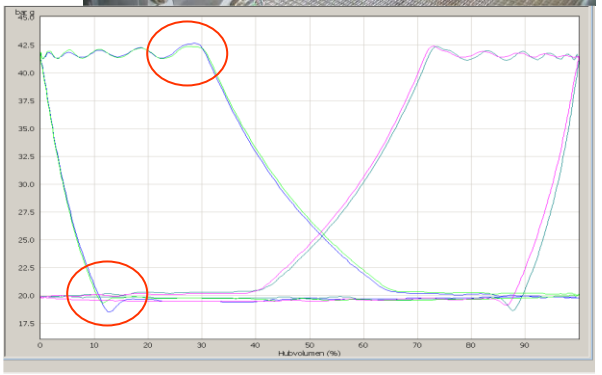
# Overlubrication – sealing material solution

| | |
|---|---|
| **Process:** | **Refinery HDS** |
| | Hydrodesulphurisation |
| **Gas:** | **Hydrogen** |
| **Stages:** | **2-stages Make-up, Recycle** |
| **Pressure:** | **p1=22 bara, pfin=83 bara** |
| **Problem:** | **instable conditions and overlubrication after commissioning despite selected ring valves** |




***Ring valves with advanced nonmetallic sealing elements → 3 years runtime!***

# Other factors contributing to wear / failure of compressor valves

- **Harsh conditions for valves, application specific:**
  - *Liquid carry over*
  - *Particles (e.g. catalytic dust, sand, …) in the gas stream*
  - *Corrosive attack*

- **Valve problems due to process problems, plant problems e.g.**
  - *process modification*
  - *gas composition deviates from specified values*
  - *polymerisation, condensation, freezing*
  - *etc.*

# Failure examples

## Refinery

Valve type: 143CGD

Gas: 78%-82% H2, CH4, C2H6 +

other hydrocarbons + H2S

P1: 17-24 bara

P2: 30-48 bara

T1: 30-50 deg C

T2: 100 deg C

- ***Dirt***
- ***Clogging of valve ports (flow restriction)***
- ***Sticktion effects***

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# Failure examples

## Polypropylene

vertical Labyrinth piston type compressor

Valve type: 154CROK

Gas: C3H6 (C3H6+C2H4)

P1: 1,1 bara

P2: 5,3 bara

T1: 40 deg C

T2: 120 deg C

- ***Polymerisation***
- ***Clogging of valve ports (flow restriction)***
- ***Sticktion effects***

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# Failure examples

- ***Valve plate failure due to liquid or condensate***
- ***breakages not on the outside of the plate***
- ***Remedy: Prevent condensation e.g. by insulating of suction line, prevent liquid carry-over***

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# Failure Examples

- ***Corrosion***
- ***valve plate not yet broken but***
- ***leakages increase the gas temperature***
- ***happens very often not during operation but during stand-by period***
- ***Remedy: Upgrade material, conversion to non-metallic material***

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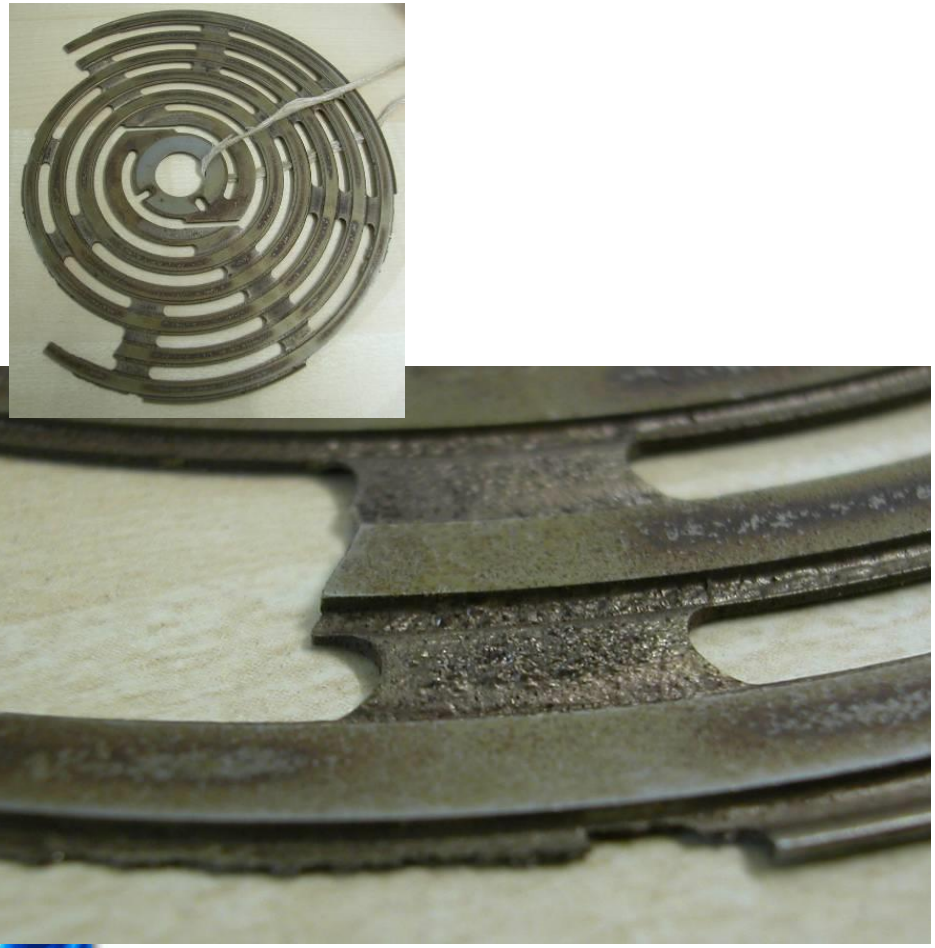
# Failure examples



- ***Heavy corrosion of martensitic material (50) in a Cl2-compressor***
- ***Remedy: Improve material to austenitic grade (60) or nonmetallic HP-material***

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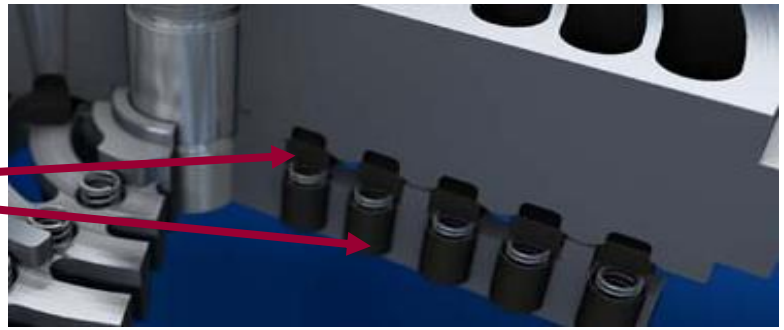
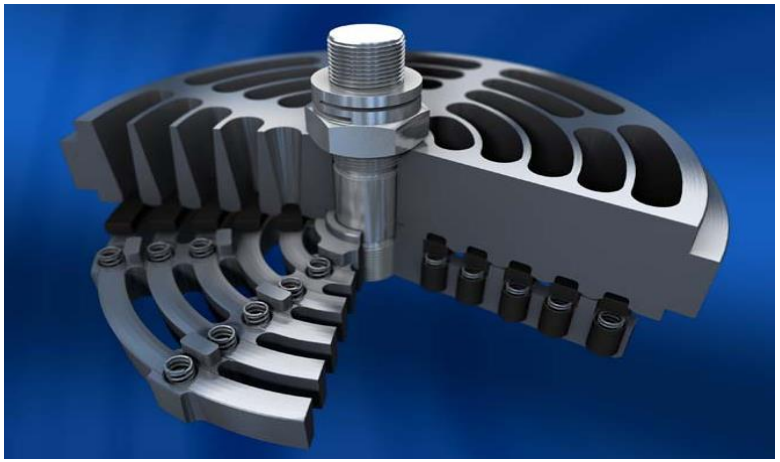
# Knowing the application helps to find the solution

- **H2 from steam reforming**
  - ***The problem:***
    - *Chemical reaction taking place: CH4 + H2O -> H2+CO -> H2+CO with C-particles → extremely abrasive!*
  - ***The solution:***
    - *use valve design with spring savers and nonmetallic inner parts*



- **CCR catalytic reforming**
  - ***The problem:***
    - *organic chlorine used in process (cannot be seen from gasanalysis)*
    - *extreme corrosion through chlorides on valve seat / guard and springs*
  - ***The solution:*** *correct material specification*



- **LDPE - Polyethylene Booster Primary**
  - ***The problem:***
    - *Frequent polymerisation in 1st stage*
    - *Sticky white substance which cloggs springs, spring pockets → highly loaded sealing element and springs*
  - ***The solution:***
    - *usage of nonmetallic sealing elements with high impact resistance, optimized dynamic design of springs*

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# Conclusions

- Reliable performance of compressor valves requires design and engineering beyond pure specification – the key is the application knowledge
- There are very innovative design / material solutions available to solve every problem out there!

# Questions