EFRC Training Workshop Design and operation of reciprocating compressors

COMPRESSOR VALVES

Claudio Vaglini Dott. Ing. Mario COZZANI S.r.I.



Training Workshop

Topics

- Compressor valves
 - Operating principle
 - Valve types
 - Valve design
 - Failure analysis
- Flow Control
 - Step control
 - Stepless control



Training Workshop

How cylinder valves work?

- The gas flows in and flows out the cylinder flowing through the cylinder valves.
- Valves open and close automatically under a differential pressure between the cylinder and the suction and the discharge side.



Main Valve Parts



The seat, together with the shutter, supports mechanically the differential pressure. The gas flows through its ports (slots or holes) which are opened or sealed by the shutter.

The component that alternately opens and shuts the flow ports. It can be made as plate, rings or poppet using different materials (plastic or metallic)

Component returning the shutter onto the seat.

It's the part against which the shutter stops; therefore, it determines its lift.

Training Workshop

EFRC

Cylinder valves

In every cylinder there is one (or more) suction valve and one (or more) discharge valve fitted in the cylinder housings for each compression effect.



Concentric valves

Concentric valves are coaxially installed on the cylinder head and have a body able to perform both suction and discharge duties.

Mainly used:

- for small cylinders diameters;
- for single cylinders head effect;
- in applications where small clearance volume is very important to achieve;





Training Workshop



Suction valves

Suction valves can be provided with a device called "finger" or "plunger" which, acting on the shutter, can keep it blocked in the valve open position.

These devices are used to unload the "end" of the cylinder (head end or crank end) where the valve is mounted.



Suction valve with finger

Assembled valve



The seat are mostly discshaped. The valves are installed and locked in the valve housing arranged on the cylinder body.

The valve is locked between the cylinder housing and the valve cage that pushes on it.

The valve cover pushes on the cage and consequently on the valve, keeping everything locked.

Safety Guard

Suction and discharge valves can be open or closed type

Open type valves have only their seat blocked in the cylinder.

The <u>closed type valve</u> has seat and guard of the same diameter both blocked in the cylinder.



EFRC

Cylinder Valves



Suction Plate Valve with finger



Suction Plate Valve



Reed Valve



Poppet Valve



Discharge Ring Valve



Concentric Valve



Training Workshop

Main Valve Types

METALLIC

PLASTIC



In these valves the shutters are circular concentric rings. Both these types can be made in metal or plastic material





Plate Valves

In these valves the shutter is a slotted disk (as would be obtained if the rings were connected together with spokes)







Training Workshop

Main Valve Types

Ring Valves

Metallic Ring Valves



Thermoplastic Ring Valves





Training Workshop

Main Valve Types

Plate Valves

Metallic Plate Valves

Thermoplastic Plate Valves







Training Workshop

Main Valve Types

Frictionless valve type





Some springs can be in contact with plate and others with damper plates



Training Workshop

Main Valve Types

Poppet Valves





And many other special valves

Training Workshop

Valve design



Training Workshop

EFRC

Pressure-Volume diagram





Training Workshop

Valve Dynamics



Training Workshop

EFRC

Valve Efficiency

passage area in the valve

Geometric flow area is the smallest geometric



Valve losses are the losses incurred in the valves





September 23/24 2015

Training Workshop

Valve Efficiency



Ks = Flow Coefficient

2D axial symmetric models



Experimental results







Training Workshop

Valve Efficiency

Ks, in flat shutter valve, is affected by:



Valve Efficiency

"Ks" can be also affected by different profile of the rings or plate





2,5% energy saving of indicated power compared with flat ring profile (experimental result on the field)

Valve Efficiency



Valve Reliability

The most important criteria in the valve design:

High impact speed of the

sealing elements

- Impact speed of the sealing elements
- Spring design and safety solutions

Shutter Impact Speed using software simulation





Training Workshop

High LIFT

Valve Reliability

Springs are one of the most critical valve components.

Approximately 50% of all valve sealing elements failures are preceded by spring failures.

Static & dynamic spring design criteria:

- Solid length stress
- High fatigue resistance
- Coil contacts



Spring plates

Helical spring



Training Workshop

Valve Reliability

Spring safety solutions



EFRC

Training Workshop

Valve Reliability

Spring safety solutions



EFRC



Example of no-contact spring solution



Training Workshop





September 23/24 2015

Valve Reliability

Spring safety solutions



EFRC

Training Workshop

Modal Analysis

Natural Frequencies values of plate & springs must be far away from the compressor ones and the dominant frequencies in the pulsation's spectrum.





Training Workshop

Ring Valve vs Plate Valve

Each ring moves independently

- lower torsion and bending movements
- better sealing effect for all rings







in High pressure



Training Workshop

PEEK Material Benefits







- Higher service life of valves
- Excellent impact resistance
- Less problems with foreign agents such as solid particles and liquids in the gas
- Lower maintenance cost
- Lower noise emission
- Good chemical resistance

Training Workshop

Main causes of valve failure:

- Improper valve assembly (in the compressor)
- Variation of the design conditions
- Corrosive elements
- Foreign particles
- Presence of liquid in the cylinder
- Improper lubrication
- Valves not properly repaired
- Extreme temperatures (low or high)



Valves are subject to:

- Tensile and compressive forces
- Impact forces
- Twisting forces
- Bending forces
- Abrasion
- Corrosion



Training Workshop

Valve assembly problem in the compressor:



Contact between cage and guard



Training Workshop

Valve assembly problem in the compressor:





Cage not properly fixed -> valve seat rotation

Training Workshop

Metal plate suction valve with plunger:





Possible causes:

- -High frequent acting of the actuator
- -Wrong actuator selection
- -Insufficient air control pressure of the actuator
- -Solenoid valve not properly works



Failure Analysis

Plate broken:



- High impact speed or fluttering
- Improper spring selection
- Springs broken



Training Workshop

Failure Analysis

High local temperature:





Training Workshop

Spring wear due to:

- Flutter
- Pressure pulsations







Training Workshop

Failure Analysis

Improper lubrication or lubricant:





Training Workshop

Failure Analysis

Liquid slug:



Broken seat of the suction valve





Training Workshop

Valve plate not replaced and turned up-side down to reuse:



Shorter life compared with a new plate



Training Workshop

Failure Analysis

Foreign particles:



Sealing elements broken



Training Workshop

Valve components not properly assembled in the valve:



Failure Analysis

Valve components not properly assembled in the valve:



EFRC

Flow control

Flow Control

Conventional Control Methods

External Devices

- on/off operation
- compressor motor speed variation
- by-pass
- suction throttling

Internal Devices

- cylinder unloading
- fixed and variable clearance pocket
- reverse flow capacity control



Related to the compressor valves



Training Workshop

Clearance pocket control





Training Workshop

Clearance pocket control can be fixed or variable type.



- V1: maximum inlet volume
- V2: controlled inlet volume due to the additional clearance pocket volume

Cylinder unloading

Step control using suction valve unloaders



Kept open



50% load (only CE is loaded)

Single-stage compressor with two cylinders double effects can achieve 75%, 50%, 25%, 0%.



Intermediate steps can be obtained using a combination of unloaders and clearance pockets control.

Training Workshop



September 23/24 2015

Flow control

Reverse Flow Capacity Control

The capacity of the compressor is reduced proportionally to the amount of gas flowing back into the suction plenum when the suction valve is kept open beyond the bottom dead center.







Training Workshop

Flow control

Reverse Flow Capacity Control

The Reverse Flow principle allows to obtain a **<u>stepless capacity control</u>** adjusting the closure of the suction valve each compression cycle.





The suction valve can be controlled using special hydraulic or electric actuators

Stepless Control by Electric Actuator



Conclusion

- Cylinder valves are one of the most important wear components of the reciprocating compressors.
- Thanks to a proper valve design in accordance with the compressor data and operating conditions, adequate reliability and performances are achieved.

