Dynamic Performance of Valve in Reciprocating Compressor Used Stepless Capacity Regulation System

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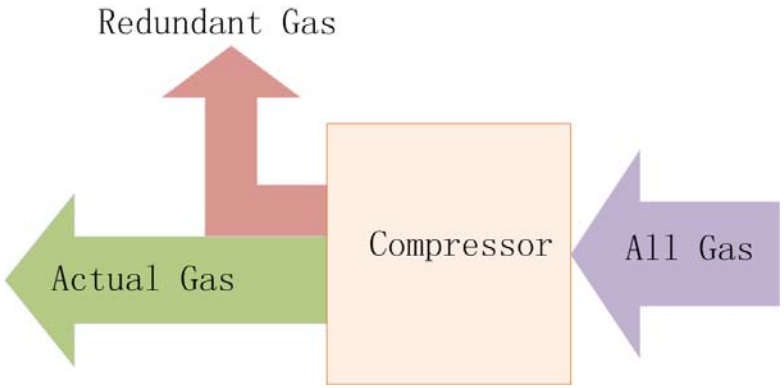
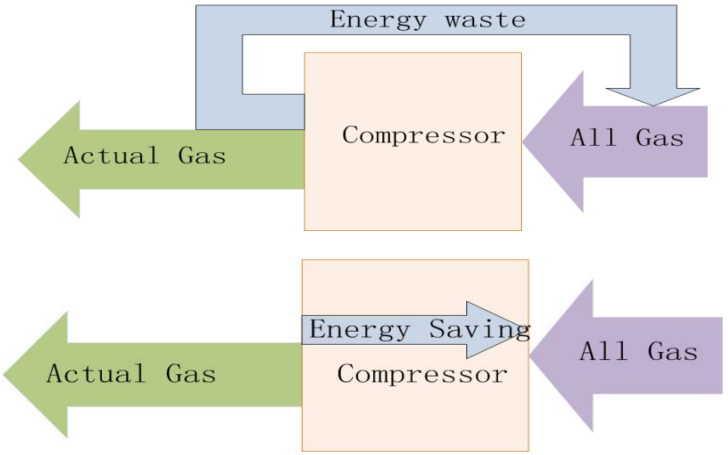
INTRODUCTION

- **Capacity Regulation**



- **Bypass throttle**
  - Energy waste
- **Clearance adjustment**
  - limited range
- **Suction valve adjustment**
  - Efficient and difficult

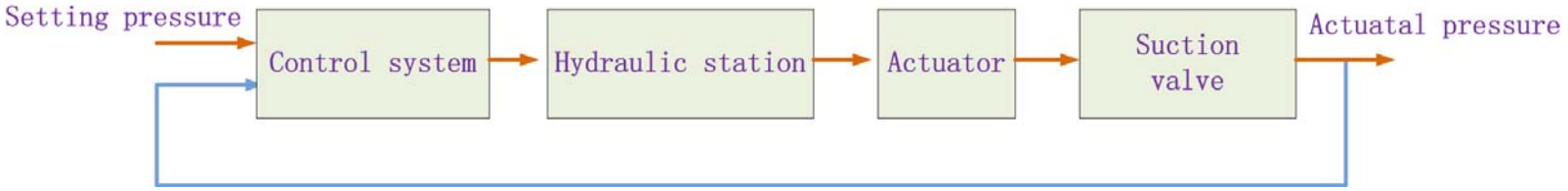


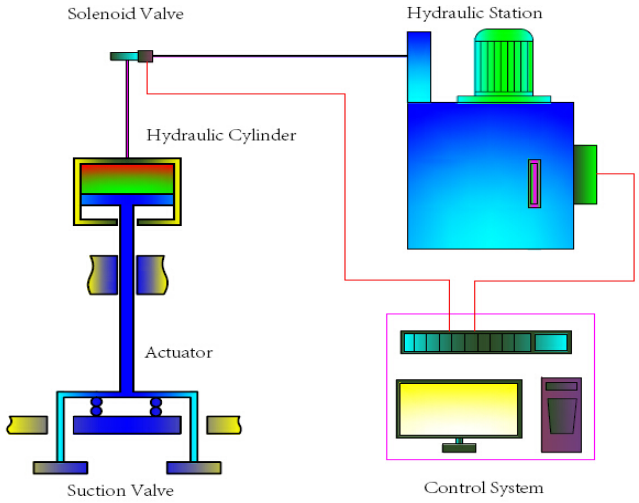
◆Adjusting capacity by controlling suction valve have good application prospect.

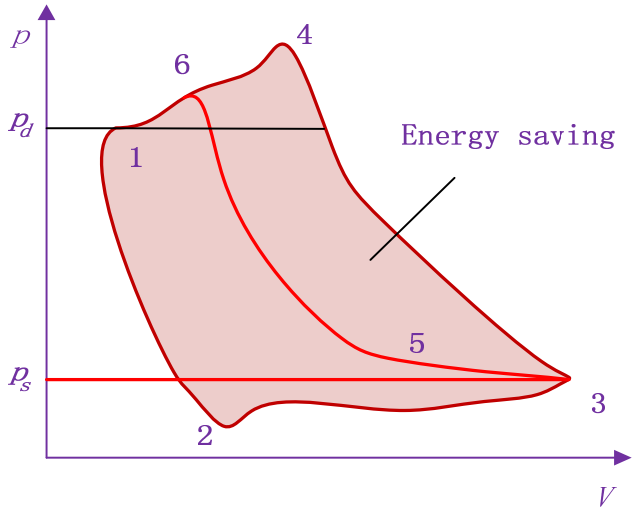
◆Power consumption can be reduced with the gas flow rate.

INTRODUCTION

- **Principle and component**







◆Only partial gas is compressed in the compressor

◆A complex system coupled with many equipments

THEORETICAL ANALYSIS

- **mathematical model**

•Flowing process of oil

$$\frac{dm_{oil}}{dt} = fA_{val}\sqrt{\frac{2(p_H - p_L)}{v_{val}}}$$

•Motion of actuator

$$\frac{dh_{act}}{dt} = \frac{4v_{oil}}{\pi D_{op}^{\ 2}}\frac{dm_{oil}}{dt}$$

•Motion of suction valve

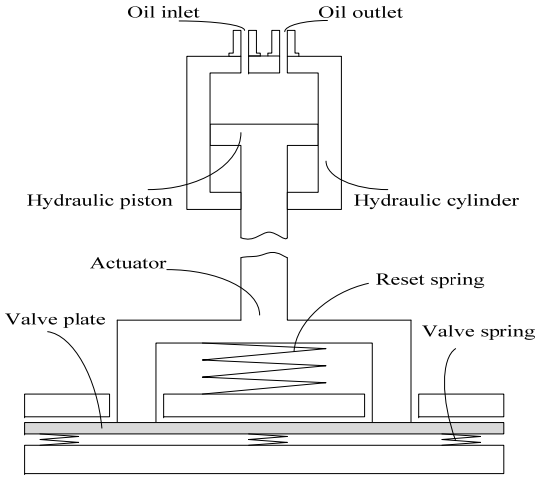
$$\frac{d^2h_{sv}}{d\theta^2} = \frac{\beta_{sv}A_{sv}\Delta p - zK_{sv}(h_{sv} + H_{sv})}{\omega^2 m_{sv}}$$

•Relationship of valve plate and actuator

$$\begin{cases} h_{vp} = h_{act} \\ u_{vp} = \alpha du \end{cases}$$

•Energy conservation

$$\frac{\partial T}{\partial \theta} = \frac{1}{mc_v}\left\{-T\left(\frac{\partial p}{\partial T}\right)_v\left[\frac{\partial V}{\partial \theta} - \frac{v}{\omega}(m_i - m_o)\right] - \sum\frac{m_i}{\omega}(h - h_i) + \frac{Q}{\omega}\right\}$$

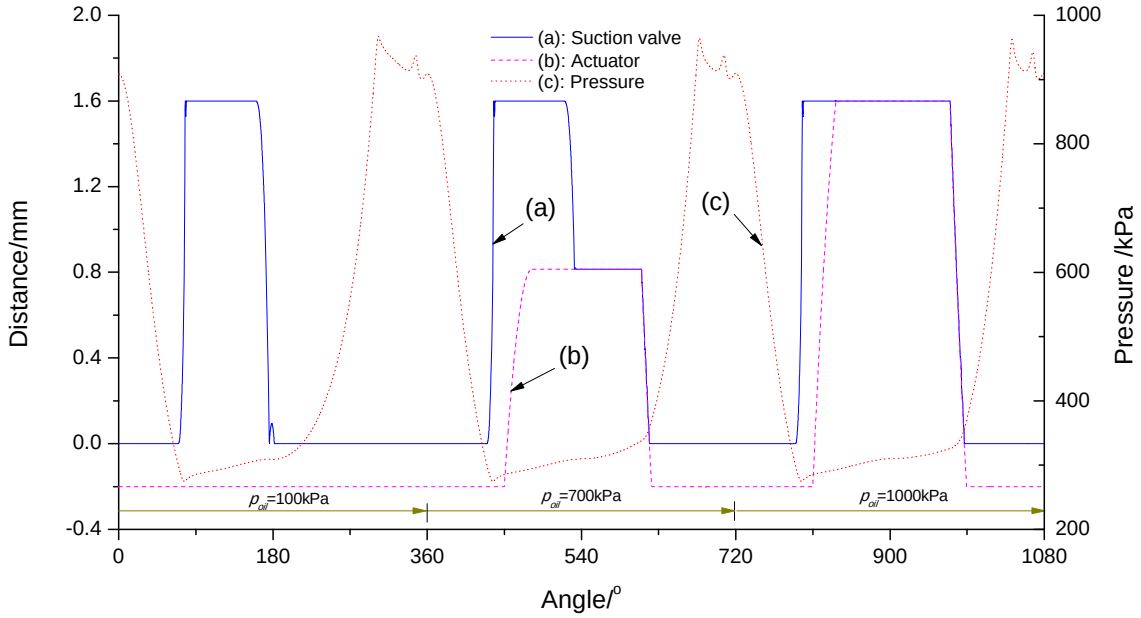


•Leakage process

$$\frac{dm}{d\theta} = \begin{cases} f\dfrac{A_i}{v_i \cdot \omega}\left[\dfrac{2k}{k-1}p_i v_i\left(\left(\dfrac{p_H}{p_L}\right)^{\frac{2}{k}} - \left(\dfrac{p_H}{p_L}\right)^{\frac{k+1}{k}}\right)\right]^{1/2} & if \quad \dfrac{p_H}{p_L} \geq \left(\dfrac{2}{k+1}\right)^{\frac{k}{k-1}} \\ f\dfrac{A_i}{v_i \cdot \omega}\left[\dfrac{2k}{k-1}p_i v_i\left(\left(\dfrac{2}{K+1}\right)^{\frac{2}{k-1}} - \left(\dfrac{2}{K+1}\right)^{\frac{k+1}{k-1}}\right)\right]^{1/2} & if \quad \dfrac{p_H}{p_L} < \left(\dfrac{2}{k+1}\right)^{\frac{k}{k-1}} \end{cases}$$

RESULTS AND DISCUSSTION

- **Influence of hydraulic oil pressure**



◆Providing the Driving force of actuator.

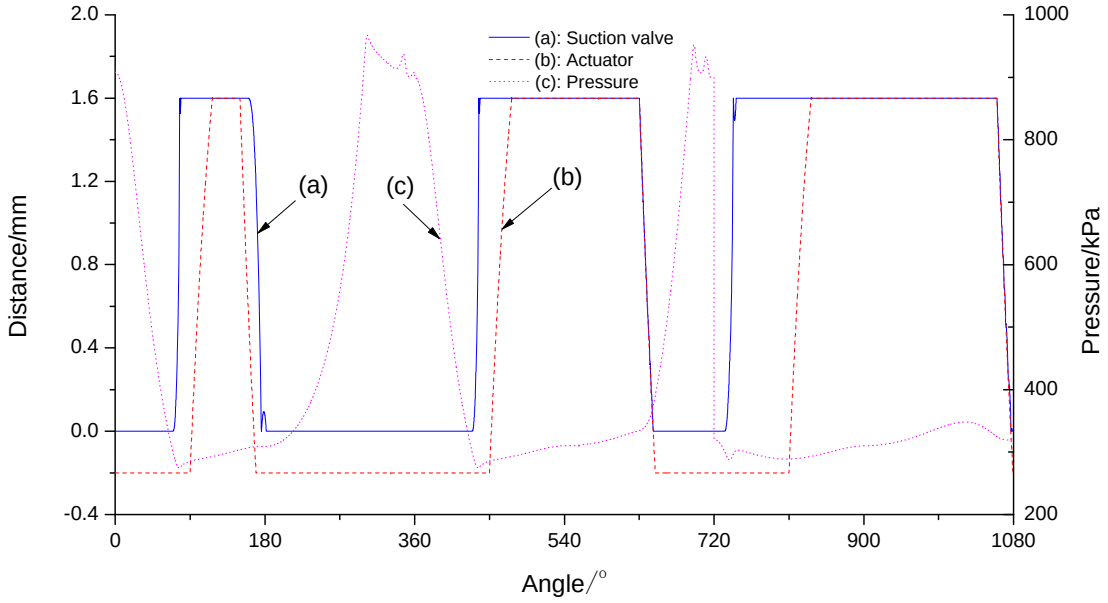
◆Larger engough pressure to overcome the force of reset spring

◆Opening process is uninfluenced by actuator

◆The displacement of actuator increases with the hydraulic oil pressure until the valve plate is keeped to be opened.

RESULTS AND DISCUSSTION

- **Hold time of actuator**

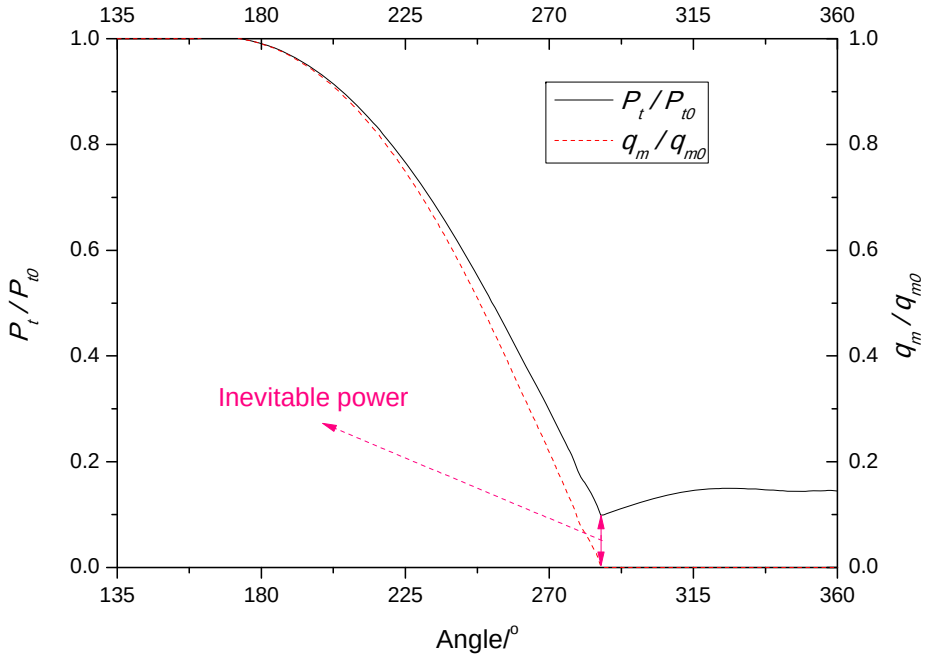


◆Actuator prevents the reset process of valve plate.
◆Compress process of gas is delayed.
◆There is no gas discharge if hold time is large engough.

◆The closing process of valve plate is delayed when the hold time of actuator is larger enough, and the larger hold time leads to more gas flowing back from suction valve.

RESULTS AND DISCUSSTION

- **Power consumption and mass flow rate**



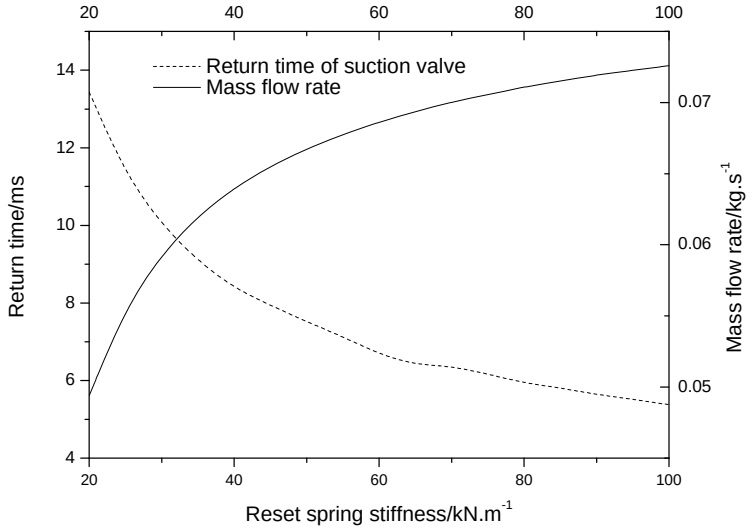
◆there is no gas outflow through the discharge valve when the relax angle is 287°.

◆power consumption is also above 10% of full load.

◆the power is also consumed when the gas is not discharged through the discharge valve.

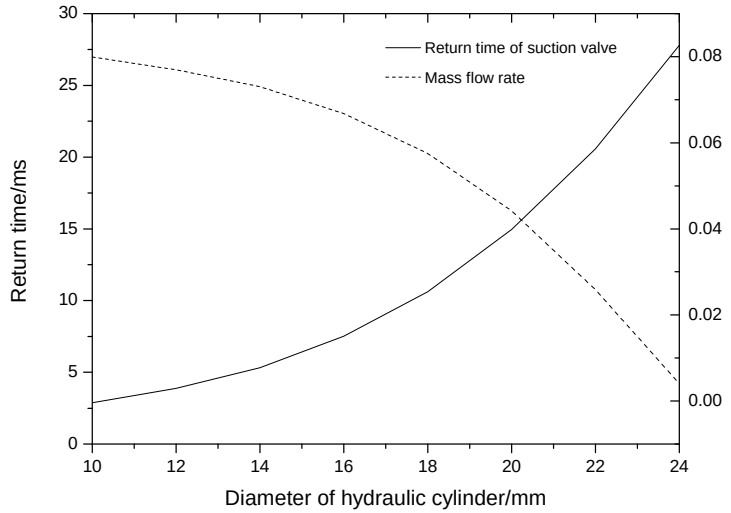
RESULTS AND DISCUSSTION

- **Influence of reset spring and diameter of hydraulic**



◆The closing time decreases with the reset spring stiffness but increases with the diameter of hydraulic.

◆The proper reset spring stiffness and diameter of hydraulic cylinder influence the response time of suction valve obviously.



CONCLUSION

- the displacement of actuator increases with the hydraulic oil pressure until the valve plate is keeped to be opened.
- The closing process of valve plate is delayed when the hold time of actuator is larger enough.
- Although the gas flow rate and power consumption of comressor decrease with the relax angle of actuator, the power is also consumed when the gas is not discharged through the discharge valve.
- The closing time decreases with the reset spring stiffness but increases with the diameter of hydraulic cylinder.