Design of Hydraulic Door Open/Close System in Reheating Furnace

R.Mahendaran¹, S.Muthurathinam², L.Prakash², S.Suresh², M.Karthikeyan²

¹(Assistant professor, Mechanical Department, Jay Shriram Group of Institutions, Tirupur, India,mahendran2009@gmail.com)
²(UG Student, Mechanical Department, Jay Shriram Group of Institution, Tirupur, India, muthurathinamgpm@gmail.com, prakashnlp0699@gmail.com, vkspon@gmail.com, keyan2481@gmail.com)

ABSTRACT – In consideration of furnace, the door operation (open/close) is based on gear mechanism. During door operation stresses are developed and are acting on limited areas of the gear wheels, the maximum wear occurs at the gear tooth. Due to this wear, replacement of gearwheels and frequent maintenance is required and is more expansive. Our work is to overcome the problem by replacing of hydraulic system instead of gear wheel mechanism. This hydraulic system is more effective and smooth operation for opening and closing the door.

Keywords— Door, Gear wheel, Hydraulic

1. INTRODUCTION
Furnace is used to heat the object in the closed system. A door is provided to open and close the furnace for loading and unloading the object. Industrial furnaces have large size door. So it is not possible to operate by manually. Generally gear and sprocket is used to operate the door by chain. It is not efficient and frequent failure will happens. To overcome these demerits, we are using the hydraulic system for operating furnace door.

2. COMPONENTS USED
A. Reservoirs
Reservoir is equipment usually designed for performing a number of functions. The reservoir also provides a place for separate out of the fluid and permit contaminants to settle out. A well-designed reservoir will helps to dissipate any heat that is generated in the system.

Reservoir Construction
An industrial reservoir is conforming to industry standard. The tank is constructed of welded steel plate with extension of the end plates supporting the unit on the floor. The entire inside surface of the tank is painted for reduce rust. The reservoir is designed for fluid maintenance. The bottom of the tank has a drain plug at the lowest point. So the tank can be drained completely. The filter hose provided with a fine mesh screen to keep our contamination which the fluid is replenished.

B. Filter
The primary function of filter is to retention by some porous medium of insoluble contaminations in the fluid.

C. Strainer
Strainer function is to trap contaminans from fluid flowing through it.

D. Hydraulic Cylinders
Cylinders are linear actuators that convert the fluid energy to linear output motion or force.

Cylinder Construction
The parts of a cylinder are barrel, piston rod, caps and suitable seals. Barrels usually made up of seamless steel tubing, the inside of the barrel is finished by honing operation. The piston usually cast irons or steels. Piston rings are used where some leakages can be controlled. A very low rate T-rings or 0-rings with two heavy duty backup rings is often used. Ports are attached directly to each end of barrel.

E. Directional Control Valves
Directional valves as the name impulse are used to control the direction of flow. Directional valves vary considerably in construction and operation.

Four - Way and Three Position Valves
The two ways and four way valves direct inlet flow to one of the two outlet ports. In case of four way valve, there is an alternate port and it is connected to the reservoir and the remaining oil moves into the reservoir. Almost all these valves are sliding spool type and there are rotary valves which are mostly used in pilot control. There are three positions – for extraction, retraction and neutral position.

FIGURE-2.1 4/3 VALVES
Pressure Controls
Pressure controls are of different types such as relief valve, sequence valve, braking valve based on their primary function.

3. WORKING PRINCIPLE
The fluid from the reservoir is sucked out by the pump and supplied to the cylinder. The direction control valve directs the fluid from the pump into the cylinder. The pressure control valve is used in between direction control valve and the pump to maintain a constant pressure of the fluid.

In the forward stroke, the fluid is supplied to the cylinder through one of the inlet ports of the direction control valve and the piston moves up. This causes the furnace door to lift up. In the reverse stroke, the fluid is supplied through the other inlet valve and the piston moves downward causing the door to close.

4. DESIGN DIAGRAM

5. DESIGN CALCULATION
A. Design of Cylinder
Total load of the door = 35000 N
Total stroke length = 1m

Required cylinder dimension
Piston diameter = 100mm
Piston rod diameter = 56mm

Required piston velocity
Velocity = (stroke require length of piston)/ time
\[ \text{Velocity} = \frac{1}{5} \text{m/s} \]

B. Required Pressure
During Extension Stroke
Total pressure (p_c) = Force / Area of the cylinder
\[ \text{Total pressure} = \frac{35000}{\pi/4 \times 10^{-3}} \approx 44.5 \text{ bar} \]

During Return Stroke
Total pressure (p_t) = Force / Area of the piston - Area of the piston rod
\[ \text{Total pressure} = \frac{3500}{\pi/4 \times (0.1 \times 2) - (0.056 \times 2)} \approx 64.92 \text{ bar} \]

C. Required Flow Rate
Flow rate (q) = Velocity \times Area of the cylinder
\[ \text{Flow rate} = 0.2 \times 7.853 \times 10^{-3} \text{ m}^3/\text{s} \approx 1.5707 \times 10^{-3} \text{ m}^3/\text{s} \]

Required Velocity For During Forward Stroke
\[ \text{Velocity} = \frac{\text{Flow rate}}{\text{Area of piston}} \approx 0.2\text{m/s} \]

Required Velocity For During Return Stroke
\[ \text{Velocity} (V_{re}) = \frac{\text{Flow rate}}{\text{Area of Piston - area of the piston rod}} \]

Volume: 02 Issue: 03 2015 www.ijmtes.com
= \frac{(1.5707 \times 10^{-3})}{(5.39039 \times 10^{-3})} = 0.29 \text{m/s}

\text{Required Total Stroke} = \text{Dynamic force} + \text{Frictional force}
= \frac{w}{g} \times a + \mu w
= 142.71 + 3500
= 3642.71 \text{ N}

\text{D. Required Dynamic Force}
\text{Dynamic force} = 0.9 \times \text{Total pressure} \times \text{Area of the cylinder}
= 0.9 \times 64 \times 7.853 \times 10^{-3}
= 45888 \text{ N}

\text{Maximum pressure} = \frac{\text{Total force}}{\text{Area}}
= 45888 \times 7.535 \times 10^{-3}
= 58 \text{ bar}

\text{E. Check for Buckling Load}
\text{Total load} = 35000 \text{ N}
\text{Modulus of elasticity} = 2.06 \times 10^{11} \text{ N/m}
\text{Equivalent buckling length} = \text{Cylinder stroke} \times \sqrt{2}
= 1 \times \sqrt{2}
= 0.707 \text{ m}
\text{Consider the factor of safety} = 2
\text{Buckling load} = \text{factor of safety} \times \text{force}
= 2 \times 35000
= 70000 \text{ N}

\text{Buckling load} = \frac{\pi 2E I}{L^2}
\text{Where} \quad I = \frac{\pi d^4}{32}
\text{d}^4 = \frac{(64 \times 0.707^2 \times 70000)}{(\pi^3 \times 2.06 \times 10^{11})}
= 0.024 \text{ m}
= 24 \text{ mm}

\text{Even through the standard piston rod diameter is 28 mm. We have selected 56 mm for safety purpose.}

\text{CYLINDER 1}
\text{Piston diameter} = 100 \text{ mm}
\text{Piston rod diameter} = 56 \text{ mm}
\text{Pressure} = 44 \text{ bar}

\text{CYLINDER 2}
\text{Piston diameter} = 100 \text{ mm}
\text{Piston rod diameter} = 56 \text{ mm}
\text{Pressure} = 44 \text{ bar}

\text{F. Design of Pressure Relief Valve}
\text{Pressure control valve are used in hydraulic circuits to maintain the desired pressure levels. The rule thumb for the main relief valve in a circuit is to be at 10\% -20\% above the maximum required working pressure.}
\text{Working pressure} = 64 \text{ bar}
\text{Max Working pressure} = 64 + 64 \times (20/100)
\text{Pressure} = 78 \text{ bar}

\text{G. Design of Directional Valve}
\text{Directional control valve are used to control the direction of flow in hydraulic circuits. These are two types of DCV}
1. Sliding spool type
2. Rotary spool type

\text{Based on our requirement we are selecting the sliding spool type DCV (4/3 solenoid spring cantered DCV).}

\text{H. Design of Pump}
The main parameters affecting the selection of particular type of pump are discussed here.
- Maximum operating pressure.
- Maximum delivery
- Pump drive speed
- Type of fluid
- Fluid contamination

\text{Consider These Factors We Are Select the External Gear Pump}
\text{Maximum pressure} = 40-300 \text{ bar}
\text{Maximum delivery} = 0.25-760 \text{ lit/min}
\text{Speed} = 500-3000 \text{ rpm}
\text{Efficiency} = 70-90\% (refer fro table SAE J 517)
I. Calculation of Pressure Losses

- Directional control valve
- Filter
- Pipe line

**Direction Control Valve**

**During Extension Stroke**

Pressure drop over DCV

- P to A = 2 bar
- B to T = 2 bar
- Pressure drop over filter = 1 bar

Total losses = 2 + 2 + 1 = 5 bar

Pressure required at pump during the extend stroke = 44 + 5 = 49 bar

**During Retraction Stroke**

Pressure drop over DCV

- P to B = 4 bar
- A to T = 2 bar

Pressure drop over filter = 1 bar

Total losses = 4 + 2 + 1 = 7 bar

Pressure required at pump during the retract stroke = 64 + 7 = 71 bar

**Pressure Drop in Pipe Line**

Pressure drop = \( \gamma \) Hl

Where

- \( \gamma \) = oil specific gravity
- Hl = Head loss

**J. Calculation of Head Loss**

Head loss = \( f \times \frac{L}{d} \times 2g \)

Friction factor \( f \) = \( \frac{64}{Re} \)

\( Re = \frac{V \times d}{\nu} \) = 625

\( \frac{0.2 \times 0.1}{0.32 \times 10^4} \) = 0.1024

Head loss = \( \frac{0.1024 \times 5 \times 0.2}{2 \times 1 \times 2 \times 9.81} \) = 0.01043 m

Pressure drop = \( \gamma \) Hl

Pressure required during retract stroke = 64 + 7 = 71 bar

J. Design of Reservoir

The fluid reservoir is the storage tank which contains the hydraulic fluid. They are usually made of steel sheets. The empirical rules for sizing reservoirs are:

A. If there is no volume changes in system, the minimum reservoir capacity should be twice the pump delivery per min.

B. For high pressure system, the reservoir capacity should be 2-15 per installed horse power.

**Reservoir Model**

Normal air circulation round the fluid reservoir doubles the cooling. The fluid reservoir is square section of side a length of 2a.

**Calculation**

The total surface area of vertical plate (A) = 2(a*a) + 2(2a*a) = 6a²

Height of the vertical plate (L) = a

Temperature in reservoir = 70°C

Ambient temperature = 20°C

Operating pressure = 64 bar

Pump delivery = 1.57071 it/min

Heat transfer coefficient for vertical plate \( h = 1.42(\frac{\Delta T}{L})^{0.25} \)

Where

- H - Heat transferred in W
- \( h \) - Heat transfer coefficient in W/ M² °C
- A - Surface area in M²
AT - Temperature difference in °C

Heat transfer co-efficient for vertical plate \( H_v = 1.42 \left( \frac{50}{A} \right)^{0.25} \)

\[ = 3.77A^{-0.25} \]

Heat dissipation from vertical plate

\[ = H_v A \Delta T \times 3.6 \]

\[ = 3.77A^{-0.25} \times 6A^2 \times 50 \times 3.6 \]

\[ = 4071.6A^{1.75} \]

Air circulation doubles the cooling so

Net Heat Dissipation

\[ = 2 \times 4071.6A^{1.75} \]

\[ = 8143.2A^{1.75} \]

But the pump efficiency is only 90\% working

\[ = 0.9 \times 3.5 \]

\[ = 3.5Kw \]

This energy is dissipated as heat

Therefore \( 8143.2A^{1.75} \)

\[ = 3150k \]

Side A

\[ = 0.20M \]

Length 2a

\[ = 0.40M \]

DISADVANTAGES IN GEAR MECHANISM

- Due to fatigue load, breakdown occurs in gear box.
- It requires more time to repair.
- Frequent lubrication is required.
- Maximum wear and tear takes place in gear box.

ADVANTAGES IN HYDRAULIC SYSTEM

- It provides smooth and speed operational function.
- The stroke length attains at the exact time.
- Construction of the hydraulic system is simple.
- No wear and tear occur compare to the gear & chain mechanism.
- Easy to operate.
- It is very compact to open & close the door in reheating furnace.
- Noiseless operation.
- Maintenance cost is less.

CONCLUSION

We have studied the operation of the furnace door and the frequency of its failure throughout the year. By discussing with the furnace operators, we propose the hydraulic system for the door operation to avoid the failures.

REFERENCES