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Modeling and simulation of hydraulic door in heat treatment furnace

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Abstract— **The basic working principle of the furnace is heat the object or substance to a certain temperature so the heated substance can be taken for further processes. This is done by passing the fuel which acts as the source for heating the substance. In this the hydraulic door plays an important role in allowing the steel bar for heating and discharging it for rolling process. The furnace door is lifted using the worm and worm wheel mechanism. The problem is the failure of the gear box due to repeated operation, fatigue and the radiation coming out of the furnace due to heating of the steel up to 1200c. To overcome this problem this furnace door is designed using hydraulic and analysis has been carried out on the parts of 6he furnace door. The circuit operation of the furnace door has been designed using automation studio and the circuit has been explained. The outcomes of the projects are improved operation furnace door, reduction in the operation cost, reduction in the maintenance cost incurred in operation of the furnace door.**

Keywords— Gear failure; Hydraulic door; Heat treatment; Rolling mill

I. INTRODUCTION

In the hot rolling mill the steel slabs are heated in the reheating furnace so that they become soft enough to roll. If the metal is too cold then it will be too hard and it will crack and stress the rolling equipment. The furnace door is open by means of gear arrangement. This door open/close by 1/4th rotation of the gear arrangement. Due to which the entire load is applied in the part of the gear and thus resulting is gear of the gear tooth. To overcome this failure we are using the hydraulic system, for using the hydraulic system the rate of production increases and reduce the production time. The company profit also increases.

Jinwa Kang et al (2004) the simulation of heat transfer in heat treatment furnace is of great importance for the production and control of the ultimate microstructure and properties of work piece, In this paper the hydraulic method based on numerical simulation and analytical equation are proposed to calculate the radiation convection and conduction heat transfer in heat treatment process. Yimingrung, (2005) the maximum difference is about 700C. But finally all the blades reach the soak temperature. There is about 1hr for phase transformation

of the slowest heated work piece which complies with the experience of 1hr per inch in heat treatment production. A hydraulic sub system is built around directional spool valves and load sensing hydraulic pump. The load sensing pump operates with variable flow and pressure both both being controlled by load pressure. A typical property of load sensing system is its relatively slow response compared to a system with constant system pressure.

B.-R. Ho'hn and K. Michaels states that typical gear failures like wear scuffing micro pitting and pitting are influenced by the oil temperature in the lubrication system. High temperature on gear failures is shown. High temperatures lead to low viscosity and thus thin lubrication films in the gear mesh with generally determined influence on failure performance of the lubricant. Last, but not least, at very high temperature even metallurgical change have been found with a reduction in material endurance limits.

David Marlow states that the door lifting operation and the door lifting time plays a significant role in the heat treatment of steel or any other product in the furnace. He states that door lifting time plays a significant role in the annealing of the steel and optimum lifting time would lead to improved and effective annealing thereby leading to improving efficiency of the furnace.

Wit old piekoszewski and Marian szczerek states that the effects of thermal radiation is a major factor in the upper areas of the furnace cracks at micro level gets developed. Due to the repeated operation and exposure of thermal radiation these cracks get developed which results in the failure of the gear box and ultimately the breakdown of the furnace.

The proposed system for this problem is the design of the furnace door using hydraulic system. Hydraulic system possess numerous advantages when compared to the conventional system of door lifting. Even though the implementation of the hydraulic system costs more, due to its reliability the hydraulic system is proposed for the lifting of the furnace door. Hydraulic system can withstand numerous loads and gives good protection against it is preferred. Power can be transmitted in limitless quantities. Hydraulic is well suited for automated application.

II. GEAR FAILURE MODES

2.1 Wear

Wear is a continuous failure under thin separating film conditions, typically at slow pitch line velocities, where asperity interaction can occur. This leads to material removal from the mating surfaces with each load cycle.

2.2. Scuffing

Scuffing is an instantaneous failure, where gear flanks are welded together under pressure and temperature, typically at medium or high speed conditions without any protecting layers between the surfaces protection of the surfaces can be provided by hydrodynamic lubrication through thick oil films, physically strong increase in scuffing capacity was found due to increased chemical activity of the additive system at higher temperature, which is able to over compensate the decrease in viscosity.

2.3. Micropitting

Micro pitting is a fatigue failure of the surface where predominantly in the areas of negative sliding below the pitch circle micro cracking leads to breaking out of material from the surface. Micro pitting is strongly influenced by the relative film thickness l as the relation of film thickness to surface roughness and thus by operating viscosity and additionally by the additive type.

2.4. Pitting

Pitting is a fatigue failure in the dedendum of the pinion, which often originates from surface cracks that propagate into the material and progress further under high subsurface shear stress levels. In some cases and especially for larger sizes the crack initiation can also be subsurface with crack propagation towards the surface Pitting is strongly influenced by the Hertzian stress, but also by surface shear stress and thus by lubricant film formation. It is well known that lubricants with higher operating nominal viscosity can provide higher pitting endurance limits.

III. DESIGN CALCULATION AND METHODOLOGY

3.1. Hydraulic Cylinder

Cylinders are linear actuators which convert hydraulic fluid power into mechanical force. Hydraulic cylinders are used at high pressures and produce large forces and precise moment. For this reason cylinders are made up of stronger materials like steel and designed to withstand large forces.

Hydraulic cylinder are preferred over pneumatics because gas is an compressible substance and the cylinder of pneumatics because gas is an compressible substance and the cylinder of pneumatics are made of lighter materials like brass, aluminum and the pressure is limited to 10 bar. Since gas is compressible substance it is hard to automate and control.

The type of the cylinder used in this design is the double acting cylinder. The working principle of the double acting cylinder is desired below. It consists of two ports for oil flow two piston for the linear moment. As the fluid moves in to another port pressure is built up on another side of the cylinder causing another piston to produce the linear motion while the fluid on the opposite side is moved to the reservoir.

3.2. Design of cylinder

Mass of the single door = 3000 kg
= 3000 x 9.81
= 29430 N

Total stroke length = 1 m

Cylinder dimension

Piston diameter (dp) = 0.125 m

Piston rod diameter (dr) = 0.90 m

Area of the piston (Ap) = 0.0123 m2

Area of the piston (Ar) = 6.35 x 10-3 m2

Required piston velocity

Velocity v = s/t

S= stroke in m

T= time in sec

V=1/10=0.1 m/sec

<u>Pressure calculation</u>

Total pressure (Pe) = force/ area of cylinder
= 29430/0.0123
= 23.9 bar

Pressure during retraction stroke = force/(Ap-Ar)
= 29430/(0.0123-0.00635)
= 49.4 bar

Flow rate (q) = velocity x area
= 0.1 x 0.0123 m3/sec

<u>Velocity calculation</u>

Velocity during the forward =flow rate / area of the piston
= 0.00123/0.0123
= 0.1 m/s

Velocity during retraction stroke = flow rate / (area of the piston – area of the rod)
=0.00123 / (0.0123-0.00635)
=0.2 m/s

<u>Calculation of head loss</u>

HL = f x (L/D) x (V2/2g)

F = 64 Re

Re = vd / µ
= (1000 x 0.2 x 125)/ 5
= 500

Since Re is 500 the flow is laminar

F = (64/500)
= 0.128

Head loss (hl) = 0.128 x (5/0.1) x (0.22/19.62)
= 0.013 m

Pressure drop = µhl
= 1000 x 9.81 x 0.95 x 0.013
= 1.21 bar

<u>Calculation of pressure losses using DCV</u>

During extension stroke

Pressure drop DCV P to A = 2 bar

Pressure drop DCV B to T = 2 bar

Pressure drop over the filter = 1 bar

Total losses occurred = 5 bar

Total pressure required = 23.9+5 = 28.9 bar

During retraction stroke

Pressure drop DCV P to B = 4 bar

Pressure drop DCV A to T = 2 bar

Pressure drop over the filter = 1 bar

Total losses occurred = 7 bar

Total pressure required = 56.4 bar

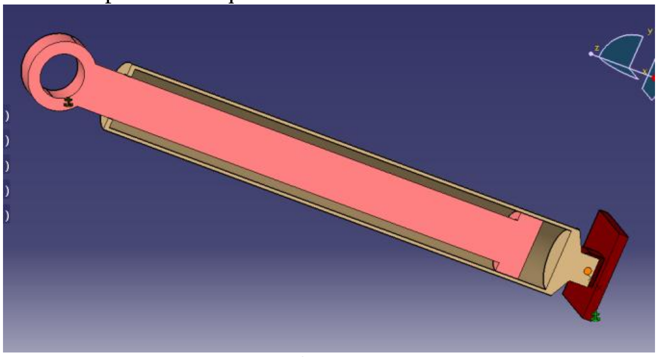

Fig.3.1 Design of cross section cylinder

3.3. Design of Pressure Relief Valve

Pressure control valve are used in the hydraulic circuit to maintain the desired pressure levels parts of the circuits. The rule thumb for the main relief valve in a circuit is to be at 10 – 20% above the maximum required pressure.

Working pressure =64 bar
Max working pressure = 64 + 64 x 20 /100
Pressure = 78 bar

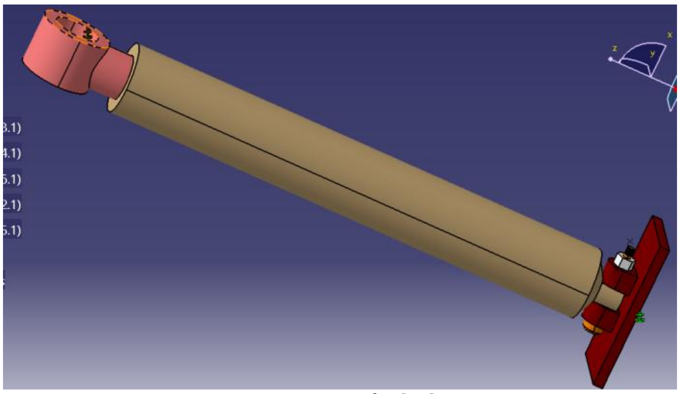

Fig.3.2 Design of cylinder

3.4. Design of Pump

The main parameters affecting the selections of particular type of pump are discussed here,

- Maximum operating pressure
- Maximum delivery
- Pump drive speed
- Types of fluid
- Fluid contamination
- Pump noise

3.5. Consider these Factors we are select the External Gear Pump

Maximum pressure = 40 – 300 bar
Maximum delivery = 0.25 – 760 lit/min
Speed = 500- 3000 rpm
Efficiency = 70- 90%

(Refer the table 3.1 SAE J 517)

3.6. Design of Reservoir

The fluid reservoir is the storage tank which the hydraulic fluid is contained. They are usually made of steel sheets. The empirical rules for the sizing reservoir. If there is no volume changes in system the maximum reservoir capacity should be twice a pump delivery per minute.

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

TABLE.3.1

Pump type	**Maximum pressure bar**		**Maximum delivery lit/min**		**Speed rpm**		**Noise level**	**Efficiency**
External gear pump	40	300	0.25	760	500	3000	90	70-90
Internal gear pump	100	210	0.6	740	3000	4000	85	75-90
Vane pump	50	140	6	360	500	3000	80	65-80
Axial piston pump	200	350	1	1450	200	2000	90	80-90
Radial piston pump	350	1750	0.3	1000	200	2000	90	80-90
Balanced Vane pump	140	175	2	620	500	3000	80	70-90

Reservoir Model

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

IV. CONCLUSION

Thus by this design process the door can be lifted using hydraulics very effectively and smoothly thus giving long life to the door. The problem occurring during the conventional lifting process like the gear box failure can be avoided and the reduction in the maintenance cost, operation cost of the company can be reduced thus leading to increased investment. Even though the implementation cost of the hydraulic system is costly the life of the hydraulic system is long thus leading to increased life.

The analysis process carried out identifies the critical parts and thereby indicating us that attention needs to paid to those parts for effective operation. The stress, strain, displacement values found would be much useful in determining the failure much before.

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