Development of Hydraulic System for Forging Press

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***Abstract* - Hydraulic presses are used in many industrial technologies. Press application include forging pressure with flat dies, used for hot work to break down ingot and shape them into roll, pressure vessel, forged bar, rods, plates and so on. Forging presses with closed dies, used to process preheated billet into various shapes. Upsetting presses, used for production of items with elongated shaft-long hollow bushings, pipes, vessel and so on.**

The paper describes the hydraulic system for the 15000-ton capacity with the selection of hydraulic component, development of hydraulic circuit and pumping requirement i.e., amount of fluid handled by the pumps and the size of accumulator etc.

Paper describes the complete process, principles, and component of the forging press with their arrangement in system by the hydraulic circuit diagram development from lower capacity to desired one. It is developed by considering requirement of the process. Further part of the paper contains the design procedure and calculation for the process and the analysis of main ram considering the given requirement and calculation results.

INTRODUCTION

Forging is a process used to form metal into large quantities of identical parts. It is often used in the manufacturing process of automobiles and to improve the properties of the metal being used. The products made by forging may be large or very small and can be made of steel or any other metal. Forging changes the shape and size, but not the volume, of a part.

Hydraulic presses, in which high-pressure fluid produced by hydraulic pumps drives a ram, are about 100 times slower than hammers. They are used for large or complex die forgings. Press Forging is more economical than hammer forging and closer tolerances can be obtained A greater proportion of the work done is transmitted to the work piece, differing from that of the hammer forging operation, where much of the work is absorbed by the machine and foundation. The basic difference between hydraulic press and other method is that pressure is applied in squeezing manner rather than by impact.

The paper presents a development of hydraulic system with their component. Hydraulic circuit is the main structure of whole system is developed by considering the requirement of the system. the selection of hydraulic components such as pump, pressure control valves and direction control valves in term of specification as per the requirements are given. These requirements are obtained from the hydraulic design of the press which contains the cylinder dimension, pumping requirement and accumulator size calculations.

Open die forging press:

In open die forging the dies are either flat or rounded. Large forgings can be formed by successive applications of force on different parts of the material. Hydraulic presses and forging machines are both employed in closed die forging.

Die forging is the best method, as far as tolerances that can be met, and also results in a finished part that is completely filled out and is produced with the least amount of flashing. The final shape and the improvement in metallurgical properties are dependent on the skill of the operator. Closer dimensional tolerances can be held with closed die forgings than with open die forgings and the operator requires less skill.

A the open die forging press as shown in fig 2.1, The application is characterized by huge flow demands and forces and also requires a dynamic performance in the critical decompression phase which is only achievable in open loop control. The process of open die forging is used for large steel bars. In order to achieve the required forging dimension, typically an iterative approximation algorithm is use.

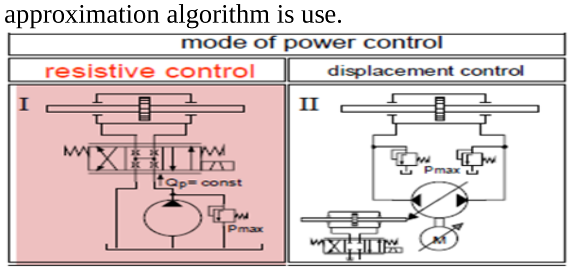

Fig 2.1 open die forging press power control

The actuation principle of the top die is depicted in the schematic of the actuation principle. Pumps supply flow into the upper chamber of the differential cylinder. Only the flow out of the cylinder is controlled via the forging valve.

Drawbacks of forging press for heavy application are

- Proportional increase in shock, pressure, and flow control valves.
- Step changes in flow and sudden ram stops and starts were accommodated with the large pressure spikes or droops.
- Enormous energy consumption occurred – electric power.
- Consumption increases more than 50 %.
- High level of noise.
- Selection of the hydraulic components, design of the system and the cooling type are not appropriate. Lack of cushion equipment, out-of-date the connection type of the system and the unreasonable pipelines mounting and fixation, lead to great vibration and big noise. The pump and the system glows greatly, which leads to the failure of the seal and leakage, furthermore big power was wasted.
- The collocation of the system is not well-designed, which lead to incommodity of service for the hydraulic components. The absence of oil level control and Alarming equipment also caused the heavy loss of hydraulic oil.

HYDRAULIC CIRCUIT FOR THE PRESS

Designing of hydraulic circuit is predicated on certain basic need and conditions such as,

- How much force is needed.
- How fast circuit must function.
- Sophistication of control required.
- Duty cycle
- Life cycle
- Reusability of components etc.

The first concern is force needed. An analysis of operation to be performed will yield some indication of force requirement. the amount of information available and degree of accuracy that can be expected in analyzing this information will determine the other circuit's requirement. After force requirement have been established, cylinder and motor size can be determined. The determination of component size may hinge heavily on the second factor –actuating speed. The simple ratio of pressure to area for force determination must be related to gallon per minute fluid flow that will determine the speed of movement of ram in cylinder.

The sophistication of control desired will determine the signal sources to create the cycle pattern of power transmission system.

The duty cycle may require high performance for limited time, as machine tool and construction machine circuit.

At the end of production cycle, the machine can be altered for new functional operation at much lower cost than would be possible with all new components.

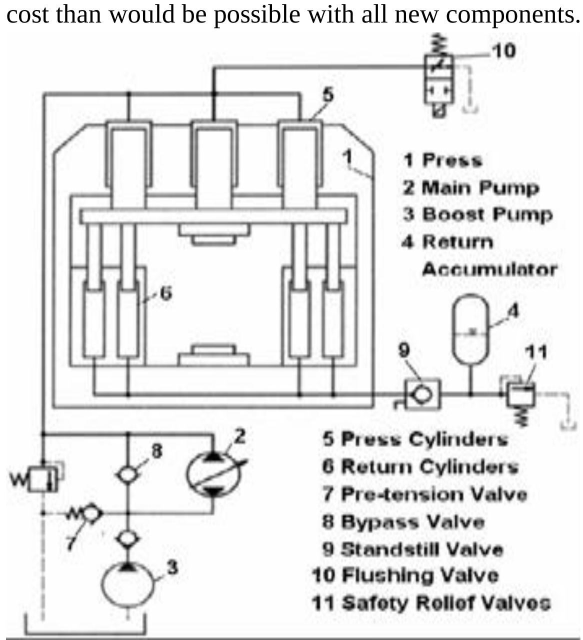

fig.401: low-capacity circuit

Figure shows the circuit diagram for higher capacity press. the circuit consist of pump, reservoir, pressure control valves, direction control valve, flow control valves and hydraulic actuators. The pressurized fluid from pump flows to the main and jack rams through direction control valve B which is solenoid hydraulically actuated valve operated by the pressure switch H. This pressurized fluid passes to the main ram after the jack rams counterbalance valve C through sequence valve D which is set at particular value.

The circuit does not provide the pump compensation; water hammer and accidental intensification may cause damage etc. to the press components due to the large tonnage of press.

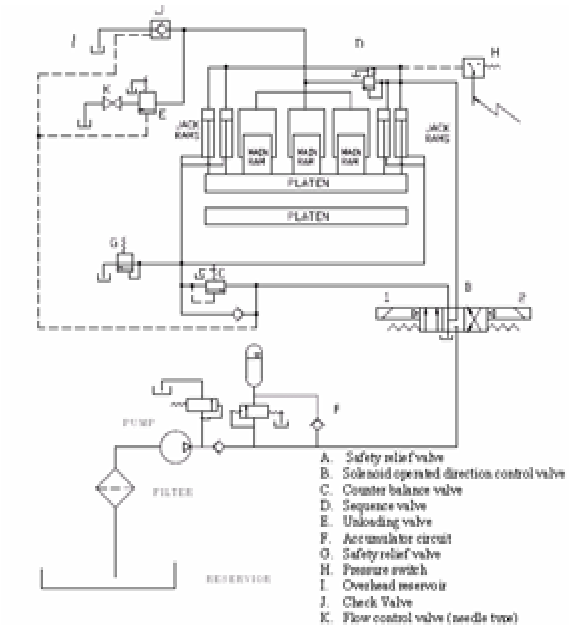

Fig.4.3 developed hydraulic circuit for press

To compensate above limitation in the circuit we added the accumulator circuit, safety valve G and check valve J with overhead reservoir I. so that circuit can work smoothly without with the required pressure to provide required capacity for pressing.

Figure shows the circuit diagram and working of hydraulic press with their components. counterbalance valve receives the signal from the main inlet line. this signal in normally taken from point within counterbalance valve structure. Valve c ins externally drained .it can be internally drained if there is to be no resistance on the cylinder line when the flow is diverted to the tank. but it is safest to provide an external drain.

Valve d is sequence valve. the signal from ahead of valve and is picked up within valve envelope. The drain in this is independently connected to tank because there will be pressure exerted on the discharge of the valve .an integral check valve may or may not be used in a sequence valve applied as indicated on the circuit. If valve E were not included in the circuit, the amount of fluid passing back through the check valve incorporated in valve D as an alternate circuit design might be used to assist in decompression of the press. Then the check valve would pass a certain part of the flow back through the four-way valve to the tank.

Valve E is used in the circuit as unloading valve .it will be externally piloted and externally drained if there is resistance in the return to the tank port. The needle valve K on the downstream side as shown, the spring pocket must be externally drained so that back pressure does not provide an additive pressure to the spring. The needle valve used in conjunction with the unloading valve, establishes the amount of flow necessary to decompress the press in proper time interval. The unloading valve receives the signal and starts and stops the fluid flow. Pilot check valve J is working as unloading valve during this portion of cycle.

A safety valve G is used at the rod end of the jack rams to prevent accidental intensification of pressure. The accumulator is used to hold the pressure when the desired maximum pressure is attained.

Valve A is safety valve it is adjusted to pressure higher than that of established by pumps for providing compensation when pump mechanism fails.

Valve B is the direction control valve. this valve is solenoid controlled, hydraulically actuated unit. When side 1 is actuated, it directs the fluid to the head end of the small pilot cylinder or jack rams. Valve D will prevent the fluid flow to the main ram until certain minimum pressure reached. As the fluid entering to the jack rams causes the platen to move downward, the main cylinder acts as a pump and the vacuum is thus created in the main cylinder is nullified by atmospheric pressure, causing fluid flow through valve .there is a reservoir above the main ram called as overhead reservoir, and valve J is in the bottom of the tank so that gravity also assist the fluid flow .when platen meets and resistance causes a rise in fluid pressure ,the flow from the pump is diverted through valve D at its set value , and the full pressure will be effective on the both jack ram and main ram. Full tonnage will then provide between the platens.

Pressure switch H creates a signal at pressure value somewhat less than the maximum value created by the pump control. the signal from the pressure switch H will start a timer that times out at pre-determined period. This denergizes side 1 of valve B and activates the side 2. fluid is then directed by the side 2 to the rod end of the jack rams through the check valve around valve C. This check valve may be built integral with valve C.

The pressure opens the valve E, relatively small two-way valve that allows all stresses in the press is to be relived and the pressure drop to a low value. After this decompression the pilot pressure opens the pilot check valve J and permits fluid flow to exhaust from the main ram. at this time the platen can rise and open the press, ready for unloading and reloading. when the reaches the upper level of travel, it contacts a limit switch, or some other sensing devices that cause the solenoid on the direction control valve to denergize .denergizing the solenoid causes the platen to stops its upward travel.

The press may not produce at its maximum rate because of the time necessary to move the ram. If the ram needs to be raised only halfway up to clear the workpiece, the moving time can be halved. The press can then function at more economical rate. When changing dies or clearing jams ups, automatic control may have to be blocked in order to raise the ram to its full travel. When the press opens the predetermined amount and the direction control has been returned to neutral position, the pump will be short stroked, holding pressure on other devices. The flow from the pump may also be used for other functional operation such as stock feeding or ejecting.

Design of hydraulic forging press for 15000 tonnage capacity:

Given data:

- Press rating T =15000 tons
- Pullback rating Tr=1500 tons
- Total stroke St =125 in (3.175 m)
- Maximum pressing stroke = 40 in (1.016m)
- Fast advance speed Va = 90 in (2.286 m)
- Fast return speed Vr = 90 in (2.286 m)
- Pressing speed Vp = 40 in/min (1.016 m/min)
- Fast advance = 15 in (0.381 m)
- Pressing = 25 in (0.635 m)
- Return = 25 in (0.635 m)
- Cycle time Tc = 12 sec
- Pressing time Tp = 4 sec
- Selected oil pressure in the system P = 5000 lb/in2 (34473.786 kN/m2)
- Determining the required effective pressing area of main plunger of the press.
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  A= T * 2000

  P=15000 *2000

  = 6000 in^2 =3.8712 m^2
- Step II:

  - select no.of cylinder = 3
  - each cylinder of capacity = 5000 tons
- Step III:

  - sub divide A in accordance with selected rating and determining the individual diameters:

    A1=A2=A3=1/3*6000

    = 200 in^2 (1.2903 m^2)

    D1=D2= D3= √ (2000/0.786) = 50.44 in

    ~ 51 in (1.29 m)

    - Adjusted area = 6130 in2 = 39.55 m

- Step IV:

  - geometric volume corresponding to stroke

    Vt = st *A

    =125 *6130 =766250 in3

    = (12.55 m^3)

  - for cogging Vpc = 4 * 6130

    = 24520 in^3

    (158.2 m^3)

- Step V:

- assuming hoop stress along the inner surface of cylinder barrel Sh =30000 lb/in^2

- cylinder expansion de will be

  de = (Sh /E) *D

  = 30000*51 / 30*10^3

  = 0.051 in

  (1.29*10^{-3} m)

- Step VI:

  - Compression of liquid takes place along the entire length of cylinder barrel assuming length of barrel = S+S/2

    = 125+125/2

    = 187.5 in (4.76 m)

- Volume of compressed liquid Vec:

Vec1 = Vec2 = Vec3 = 187.5(Π/4) (2D*30000*D) / 30*103

= 291 in3 (0.0048 m^3)

Vec = Vec1 *3 = 573 in^3 (0.088 m^3)

- Volume required for return stroke Vr = 6743 in^3
- Total additional volume

  = 6743 + 573

  = 7316 in^3 /stroke
- Total amount of liquid required /cogging stroke V

  = 24520 + 7316

  = 31836 in^3 (0.5217 m^3)

- Determining the pumping requirement for pump
  - without accumulator

$$Gpm = \frac{V * 60}{231*Tp}$$
$$= 2067\ (7.82545\ m^3/min)$$

  - With an accumulator

$$Gpm(acc) = \frac{Vtc * 60}{231* Tp}$$
$$= 835\ (3.16\ m^3/min)$$
$$= 3461\ lit/min$$

- Determining the size of accumulator to store the accumulator volume Vs of liquid

$$Vs = gpm(acc) * \frac{Tc-Tp-Vr}{60}$$
$$= 82.4\ gal$$
$$= 82.4/7.48$$
$$= 10.98\ ft^3\ (0.3109\ m^3)$$

- Air volume required

$$Vair = \frac{Vs}{1.11\ (1/n) -1}$$
$$= 10 * 82.14$$
$$= 821.4\ gal$$
$$= 109.81\ ft^3$$

- Total accumulator volume

$$= Vs + Vair$$
$$= 109.81 + 10.98$$
$$=120.8\ ft^3\ (3.42\ m^3)$$

CONCLUSION

Design of Hydraulic circuit is the most important part of development of the hydraulic system. The simple ratio of pressure to area for force determination must be related to gallon per minute fluid flow that will determine the speed of movement of ram in cylinder. The sophistication of control desired will determine the signal sources to create the cycle pattern of power transmission system. The design part of press provides the pumping requirement for the system on the basis of which decision on the number of pumps with capacity, piping requirement, number of different types of valves with requirement of the same and size of accumulator and reservoir can be determined. All this information about the requirement of different component will provide the basis for individual design of the same.

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