International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 04 Issue: 07 | July -2017 www.irjet.net p-ISSN: 2395-0072

Dual Stage Hydropneumatic Pressure Intensifier

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Abstract - *In high pressure metal hydro-forming, fluid pressure commonly exceeds 20000 psi/1379 bar. This high intensity of pressure cannot be achieved by a pump alone. It can be provided by introducing a hydraulic pressure intensifier (HPI) between pump and the machine. In this work a pressure intensifying machine was designed and constructed. The machine consisted of pistons working in a separate cylinder of different diameters. The design of the pressure intensifier was based on diameter ratio of piston and maximum pressure at inlet allowed to 8 bars. Maximum input and output pressure was controlled by an air regulator. The test performed on the intensifier showed maximum oil pressure at outlet of 90 bars for the input pressure of 8 bars. Maximum intensification of pressure was found to be 11 times of the input pressure and efficiency achieved was 78.88 %.*

***Key Words*: Hydraulic, Pneumatic, Intensification, Hydropneumatic Pressure Intensification, Pressure Booster.**

1. INTRODUCTION

A hydraulic intensifier is a machine for transforming hydraulic power at low pressure into a reduced volume at higher pressure. Hydro-pneumatic products are widely appreciated for their dimensional accuracy, high performance, easy installation, resistance to corrosion and long service life. These products find their applicability in various medical, automotive and aviation industries [1].

A Hydropneumatic intensifier is a device which is used to increase the intensity of pressure of any hydraulic fluid or water, with the help of the pneumatic energy available from a huge quantity of air in the compressor at a low pressure. Hydraulic cylinder is a very important hydraulic product. There are various types of hydraulic cylinders such as Clevis Rod End Hydraulic Cylinder, Tie Rod Hydraulic Cylinder, Industrial Hydraulic Cylinder, Custom Stainless Steel Cylinders, Short Stroke Cylinder and Welded Hydraulic Cylinder [3].

In most of the hydraulic machinery used, the usual pressure of 80 to 100-psi may not be sufficient to operate certain spool valves and other mechanisms. To cater to the need for a high pressure requirement for a comparatively short period of time, pumps and accessories are definitely not the solution. But the substitute *can be* hydraulic intensifiers which can increase the pressure from 50 bars to 1000 bars, using small volumes of fluid. There are different types based on the medium of hydraulic fluids used and the number of strokes used to intensify to the desired pressure. Some of them are single-stroke, differential cylinder intensifiers, oil-oil intensifiers, air-air intensifiers, and oil-air intensifiers [9].

2. DESIGN AND MATERIALS USED

We have used mild steel for the cylinder, ram, tie rods and cover head. Piston and seal boxes are made up of cast iron. The design stress for the mild steel is 73.33MPa at factor of safety 3.

The thickness of cylinder is calculated by using the Lame's general equation considering the design of thick cylinder. The thickness of cylinder obtained at first and second chamber was 2.14mm and 5.53mm respectively. [14]

$\sigma_r=(a-b)/r^2$

$\sigma_t=(a+b)/r^2$

where,

σ_r is radial stress in MPa.

σ_t is tangential stress in MPa.

a,b are Lame's constants.

r is radius of cylinder.

The thickness of 2.45mm was obtained for the cover head using the equation,

$t = CD\sqrt{P/S}$

C=0.42= Flange plate is bolted

D=50mm= Internal Diameter

P=Maximum pressure

S=Design stress

The maximum tangential stress of 59.88MPa was obtained at the inner surface of the cylinder which was less than design stress(73.33MPa).Hence design is safe.

$\sigma_{t\,max} = p_i[(do^2+di^2)/(do^2-di^2)]$

Specification:

Inner diameter of the cylinder(d_1)= 50mm
Outer diameter of the cylinder(d_2)= 62mm
Piston diameter= 50mm

Stepped ram; Diameter at first chamber =45mm

Diameter at second chamber =43mm

Fig -1: Parts required for this intensifier.

Parts needed- Hone tubes, Piston, Ram, Flange cover, Seal boxes, Tie-Rods, Pressure Gauges, Seals, O-Rings.[7]

2.1 2-D Assembly Drawing

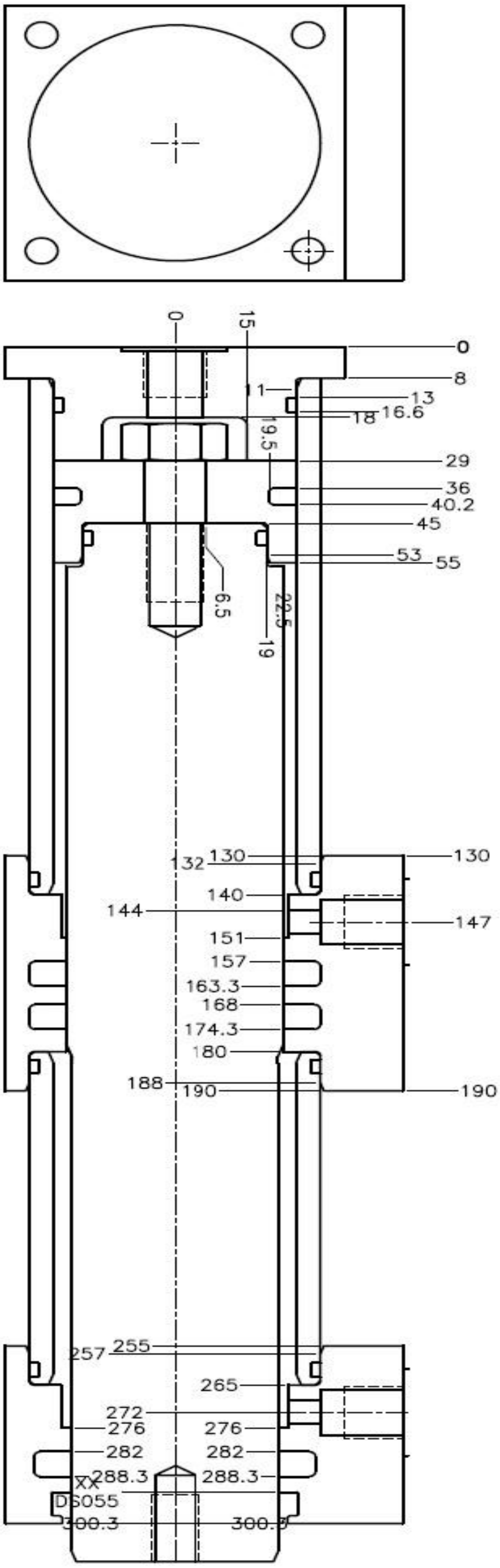

Fig -2: Assembly Drawing 2D

2.2 3-D Model of Intensifier

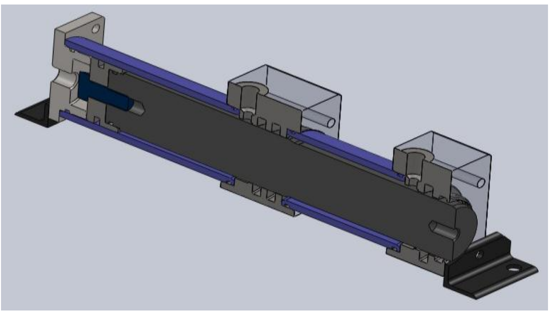

Fig -3: Cut-Section of Hydro-Pneumatic Intensifier Assembly (3D)

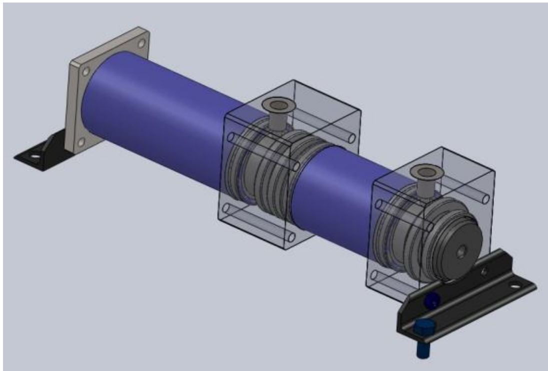

Fig -4: Hydro-Pneumatic Intensifier Assembly (3D)

3. WORKING

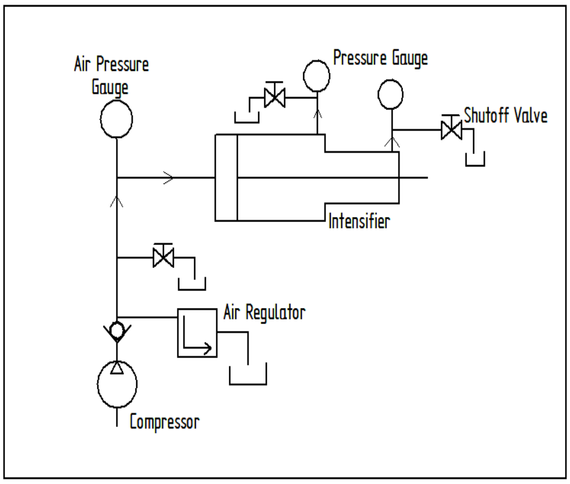

Fig -5: Single Acting Hydraulic Circuit

A low pneumatic pressure varying from 1-8 bars was provided at the inlet. The force exerted on piston and ram remain same across the intensifier. There was reduction in the cross section area of both the chambers due to stepping of the ram. The hydraulic oil gets compressed in the closed chambers and high pressure is obtained at two stages alternatively [10].

4. RESULTS & DISCUSSIONS

According to Pascal's Law, the theoretical intensification ratio obtained at first and second stage of intensifier was 1:5 and 1:14 respectively.

Actual output obtained during testing is shown in Table 1

Table -1: Pressure readings obtained at two stages for variation in the input air pressure.

S No	Air Pressure P_1 bar	Oil Pressure P_2 bar	Oil Pressure P_3 bar
1	2	1	7
2	3	5	20
3	4	9	35
4	5	14	45
5	6	18	56
6	7	22	68
7	8	26	78

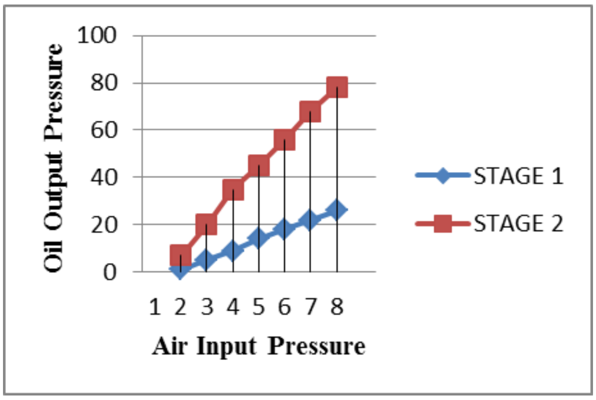

Chart -1: Variation of oil output pressure with air input pressure for two stages.

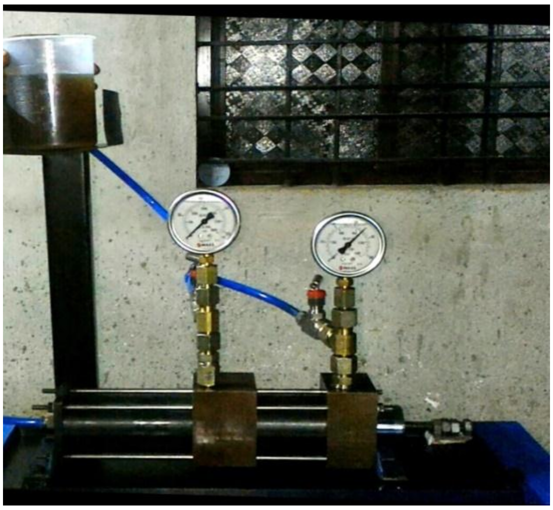

Fig -6: Hydro-Pneumatic Intensifier

This intensifier uses compressed air as the power source resulting in reliable, inexpensive components and piping and also completely eliminates the use of expensive hydraulic components and a large oil tank to be filled with a large quantity of expensive hydraulic oil. The fast response is because of the use of compressed air for rapid approach. It saves up to 50 % in energy input over fully pneumatic and hydraulic systems and 70% in cost compared to hydraulic systems.

It is easy to maintain because of simple pneumatic elements and sealing components. Since pressure and direction control valves are located in air portion, few fittings and usually no valves are required. The ram or piston stroke is constant. Since all dimensions are fixed, the intensification ratio cannot be changed. The return stroke should be carried manually as it is single acting unit. Hydro-pneumatic suspension systems can be expensive to repair or replace, if poorly maintained or contaminated with incompatible fluids.

5. CONCLUSION

The theoretical intensification ratio is 5.26 at first stage and 14.2 at second stage. The actual intensification ratio obtained from the graph was 4.21 at first stage and 11.79 at second stage. Thus static friction varies between 1.25 bars and 1.75 bars. Obtaining high hydraulic pressure by using moderate pneumatic pressure, the Pressure Intensification and application of Pascal's law can be studied and proved.

This hydro-pneumatic pressure intensifier can be used to develop test rig to check the flow control valve for process industries. It is an ideal replacement for expensive hydraulic presses for varied applications such as Riveting, Forming, Clamping, Bending, Straightening, Marking, Punching etc.

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