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DESIGN AND DEVELOPMENT OF THE JIG AND AUTOMATED SYSTEM FOR DRILLING OPERATION ON SLACK ADJUSTER

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ABSTRACT

The project is related to a cycle time optimization for the drilling operations on slack adjuster. Slack Adjuster is part of air brake assembly. After forging operation various drilling operations are to be performed on it. Presently, with manual setup more time & human effort is required for alignment purpose and to perform operation, also it does not meet the tolerance requirement. So, there is need to develop a system which can help in improving the accuracy of operation, productivity and reduce the cycle time and human efforts. The main aim or objective of this project is to design a jig & automated system so that the operations will be done with proper alignment to meet the desired tolerances and reduced human effort. Jig reduces operation time and increase productivity and high quality of operation is possible. As this operation required more pressure and human efforts combination of hydraulics and electronics system is to be implemented for automation purpose.

Keywords: Alignment , Automation, Fixture, Jig, Slack Adjuster.

I. INTRODUCTION

The project is related to a cycle time optimization for the drilling operations on slack adjuster. Slack Adjuster is part of air brake assembly. After forging operation various drilling operations are to be performed on it (Fig.No.1). Presently, with manual setup more time & human effort is required for alignment purpose and to perform operation, also it does not meet the tolerance requirement. So, there is need to develop a system which can help in improving the accuracy of operation, productivity and reduce the cycle time and human efforts.

The main aim or objective of this project is to design a jig & automated system so that the Operations will be done with proper alignment to meet the desired tolerances and reduced human effort. Jig reduces operation time and increase productivity and high quality of operation is possible. As this operation required more pressure and human efforts combination of hydraulics and electronics system is to be implemented for automation purpose.

1.1 Problem Statement

Slack Adjuster is part of air brake assembly. After forging operation various drilling operations are to be performed on it [Fig.No.1]. Presently, with manual setup more time & human effort is required for alignment purpose and to perform operation, also it does not meet the tolerance requirement. So, there is need to develop a system which can help in improving the accuracy of operation, productivity and reduce the cycle time and human efforts.

Fig.1 Drilling operation

1.2 Objective

- To achieve required tolerances.
- To reduce the human efforts.
- To reduce the cycle time required for operation.
- To achieve Line-balancing in gang drilling set up.
- To increase productivity by Automatic operations.

1.3 Scope

- Use of Jig or Fixture to achieve required tolerances.
- Use of hydraulic system to reduce the human efforts.
- Use of hydraulic clamps to reduce the cycle time required for operation.
- Perform Time-study to achieve Line-balancing in gang drilling setup.
- Use of Automatic operations to increase productivity.

II. TIME STUDY OPERATION ON SLACK ADJUSTER

2.1 Time Study for Operation Carry on Slack Adjuster

Problem: Line - Unbalancing

The following Table shows the sequence of operation to be performed on slack adjuster and average time required for each operation.

Operation	Machine /Instrument	Time (Avg.),Sec.
Spot Facing	Drilling Machine	6.4
Cross Hole	Drilling Machine	23.63
Drilling , D	Drilling Machine	61 .10
Reaming	Drilling Machine	18.43
Drilling , d	Drilling Machine	43.7
Counter Bore	Drilling Machine	12.59
Tapping	Tapping Machine	21.34
Burr removal	Hand Grinder	8.23
Inspection	Go , NO-GO Gauges , Dial indicator	145.4
Total Time Required		340.82 (5.680 min.)

Table1. Time Study for Operation Carry on Slack Adjuster

Solution: By making automated system for drilling operation we can reduce the time required for drilling operation and simultaneously person can perform Reaming operation on next setup.

2.2 Drilling Calculation

1) Speed,

   n = 600 RPM
2) Drill Diameter, Dc = 13.5 mm
3) No. of Flutes, z = 2
4) Cutting Speed,

   $Vc = (Dc*\pi*n)/(1000) = (13.5*\pi*600)/(1000) = 25.449$ m/min
5) Feed, f = 0.2 mm
6) Feed rate,

   $Vf = f*n = (0.2*600) = 120$ mm/min
7) Metal Removal Rate,

   $Q = (Vf*\pi*Dc^2)/(4*1000)= (120*\pi*13.5^2)/(4*1000)= 17.17665$ cm^3/min
8) Specific cutting force,

   Kc = 2000 N/mm^2
9) Torque,

   $Mc = (Dc^2*Kc*f)/(8000)= (13.5^2*2000*0.2)/(8000) = 9.1125$ N-m
10) Feed force / Axial force,

   $Ff = (0.63*f*Dc*Kc)/(2) = (0.63*0.2*13.5*2000)/(2)=2000$ N

2.3 Drilling Parameters

Drilling Parameters		Values	Units
Speed	n	600	RPM
Drill Diameter	Dc	13.5	MM
Number of fluets	z	2	
Cutting Speed	Vc	25.449	M/MIN
Feed	f	0.2	MM
Feed rate	Vf	120	MM/MIN
Metal removal rate	Q	17176.65783	CM^3/MIN
Torque	Mc	9.1125	N-M
Axial force	Ff	2160	N
Specific cutting force	Kc	2000	N/MM^2

Table 2. Drilling Parameters

III. DESIGN OF JIG[1]

3.1 Introduction

Presently, company manufacturing three types of slack adjusters with same features and different dimensions. For this purpose two to three jigs/fixtures with different configurations are in use. For new job order of slack adjuster new jig/fixtures needs to be design .This will increase accuracy and productivity of operations.

3.2 Design of jig (Calculation)

- Top Plate

  Dimensions = 100mm*45mm
- Middle Plate

  Dimensions = 120mm*100mm

  Material = Mild Steel (Ref. Design data page 1.10)

  Syt =400 N/mm2 (Ref. Design data page 1.11)

  Factor of Safety = Nf = 1.5

Shear Stress = (0.5*Syt/ Nf) = (0.5*400/ 1.5) τ =133.33 N/mm^2

Calculating Thickness

τ = (P/2*b*t) 133.33= (2160/ 2*100*t) t= 12.34 mm ~ 15mm

Checking for Bending

M= P*e = 2160*38 = 82080 N-mm

$Ixx=(1/12)*bt^3$

$= (1/12)* 100* 15^3 = 28125\ mm^4$

6b = (M*x/ Ixx)

= (82080*38/ 28125)

$=145.92\ N/mm^2$ < 6b Required

Hence design is safe against bending

- Bottom Plate

  Dimensions = 100mm*120mm

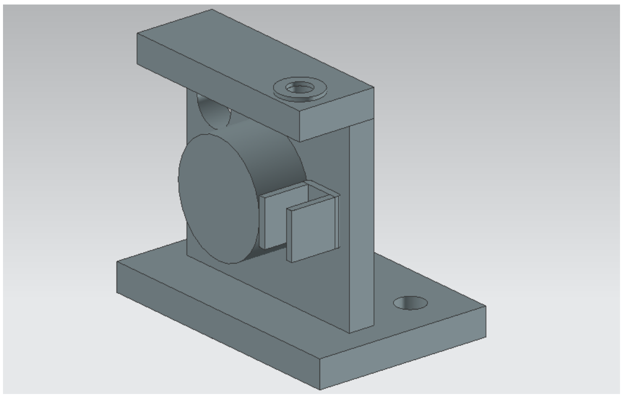

Fig.2 3-D Model of Jig

3.3 Design Drawing of Jig

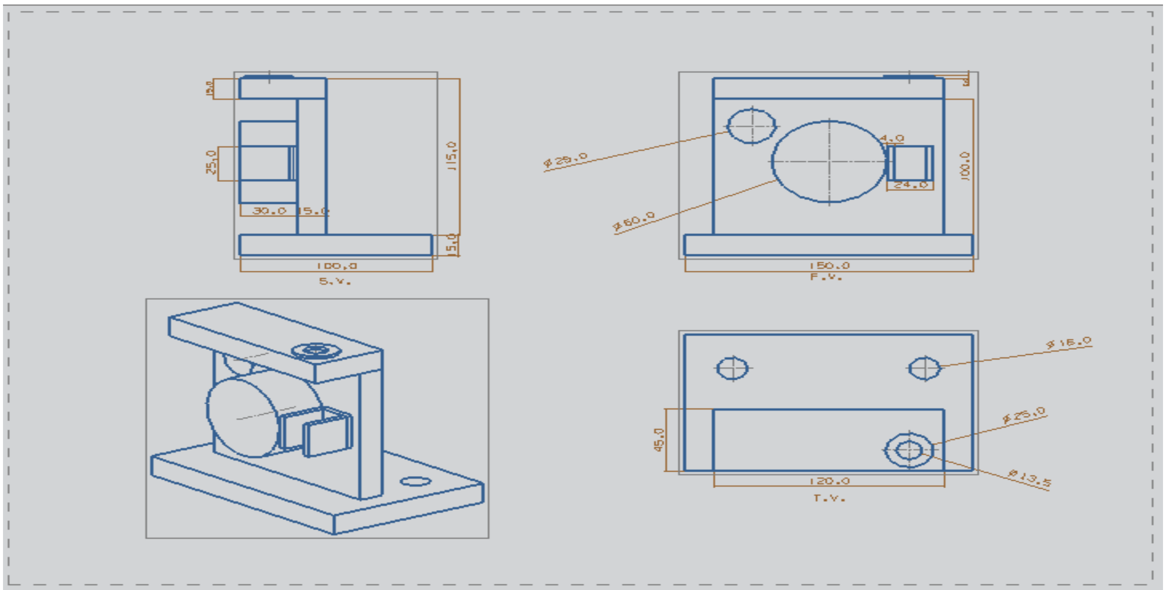

Fig. 3 2-D Drawing of Jig

IV.AUTOMATION OF DRILLING OPERATION

For Automation of Drilling Operation we designed General Hydraulic circuit for drilling operation.

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4.1 Hydraulic Circuit

In Hydraulic Circuit Sequence of operation is as follws:

a) Clamping of workpiece

b) Downward motion of drill

c) Upward motion of drill

d) Unclamping of workpiece

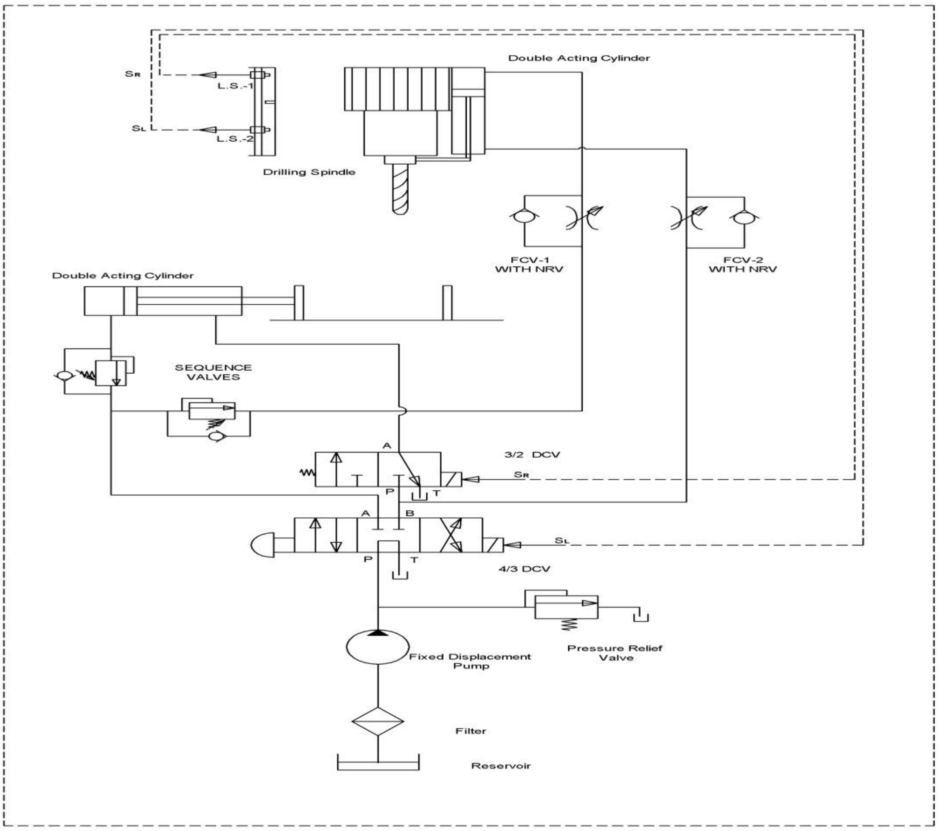

Fig4. Hydraulic Circuit for Drilling Automation

Explanation of Circuit

1) Actuated position

- In this circuit, as the push button is operated the oil flows from tank to the pump inlet through the filter. Pump gives pressurized oil to 4/3 D.C. Valve.
- In this position of DCV , the port P is connected to port A and port B is connected to port T.
- The oil will flows from DCV to inlet port of clamping cylinder throw sequence valve1. The oil in cylinder pushes the piston from face side and clamping of job takes place. Oil present at rod end sends to tank throw port B.`
- As pressure starts building in cylinder it actuate sequence valve2 and oil starts flowing throw it and passes from flow control valve to inlet port of double acting cylinder it pushes piston in downward direction and drill starts moving downward this motion continues till it reaches to limit switch2 position.
- Oil present at rod end side of cylinder directly send to reservoir.

2) Return Position

As the drill reaches to limit switch2 position it actuates 4/3 DCV in third position and connection of port becomes reverse.

- Oil starts flowing from DCV to rod end side of cylinder and starts moving drill in upward motion this motion of drill continues till it reaches to limit switch1 position.
- As it reaches to limit switch1 position it actuates 3/2 DCV in first position and oil starts flowing to rod end side of clamping cylinder, which pushes the piston back and this action tends to unclamping of job.
- Oil present at other end of clamping cylinder is directly send to reservoir.
- In this manner cycle repeats.

4.2 Design for Hydraulic system (Calculation) [4] [6]

- Selection of the cylinder

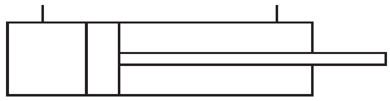

Fig.5 Symbol of Hydraulic Cylinder

Q= A*V P= F/ A

Maximum working pressure= 210 bar

$210*10^5$= [2160/ (π/4)*d^2]

d= 11.44 mm

Model	Bore diameter	Rod diameter
A1	25	12.5
A2	40	16
A3	50	35
A4	75	45
A5	100	50

Table 3. Selection of the cylinder

From Table, A1 model is selected.

Bore diameter, d= 12.5mm

Rod diameter, D= 25mm

- Selection of Pump

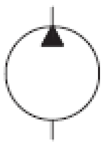

Fig.6 Symbol of Pump

Since total stroke of cylinder = 150mm

Full bore area =$A = \pi r^2$ = (π*12.5^2) = 490.87 mm^2

Anulus area = (π/4)*(D^2-d^2) = (π/4)*(25^2-12.5^2) = 368.15 mm^2

Max. working pressure = (load/area) = (2160/4.90*10^{-4}) = 44.08 bar

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Velocity of piston = (150/20) = 7.5 mm/s

Flow required = Area*velocity = (490.87*7.5) = 0.02205 lit/min

Model	Pressure (Bar)	Delivery (m^3/s)
P1	65	$12*10^{-3}$
P2	75	$2*10^{-3}$
P3	75	$6*10^{-3}$

Table 4. Selection of the pump

Pump P1 is selected

Pressure= 65 bar

Delivery= $12*10^{-3}$ m^3/s

- Selection of DCV

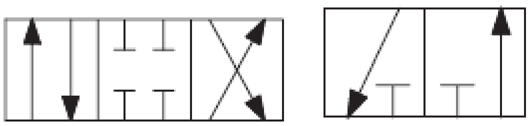

Fig.7 Symbol of DCV

Model	Pressure (Bar)	Delivery (m^3/s)
D1	100	$12*10^{-3}$
D2	90	$2*10^{-3}$
D3	85	$6*10^{-3}$

Table 5. Selection of the DCV

DCV D2 is selected

Pressure= 90 bar

Delivery= $2*10^{-3}$ m^3/s

- Selection of check valve

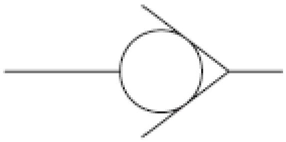

Fig.8 Symbol of Check Valve

Model	Pressure (Bar)	Delivery (lpm)
C1	85	12
C2	100	2
C3	80	6

Table 6. Selection of the check valve

Check valve C2 is selected

Pressure= 100 bar

Delivery= 2 lpm

- Selection of Relief valve

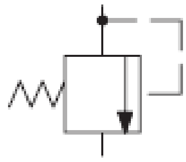

Fig.9 Symbol of Relief Valve

Model	Pressure (Bar)	Delivery (lpm)
R1	100	12
R2	110	2
R3	105	6

Table 7. Selection of Relief valve

Relief valve R2 is selected

Pressure =110 bar

Delivery = 2 lpm

- Selection of Flow control valve

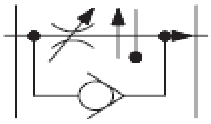

Fig.10 Symbol of Flow control valve

Q = Annulus Area* Velocity = $(3.6815*10^{-4}*0.105) = 3.8655*10^{-2}$lpm

Model	Pressure (Bar)	Flow Range (lpm)
F1	70	0-4.1
F2	105	0-4.9
F3	105	0-16.3
F4	70	0-24.6

Table 8. Selection of Flow control valve

Flow control valve F1 is selected

Pressure = 70 bar ; Flow Range = 0-4.1 lpm

- Selection of Reservoir

Fig.11 Symbol of Reservoir

Displacement of the cylinder = $(\pi/4)*D^{2*}stroke = (4.90*10^{-4}*0.150) = 7.35*10^{-2}$ lit of oil

Model	**Capacity (lit)**
T1	40
T2	100
T3	250
T4	400
T5	600

Table 9. Selection of Reservoir

Oil Reservoir T1 is selected

Capacity = 40 lit

4.3 Selection of Hydraulic Components

Component	Model	Specifications	Qty.
DA Cylinder	A1	Bore Dia.:25 mm Rod Dia.:12.5 mm	2
Pump	P1	Pressure= 65 bar Delivery= $12*10^{-3}$ m^3/s	1
DCV	D2	Pressure= 90 bar Delivery= 2*10-3 m3/s (4/3 & 3/2)	2
Check valve	C2	Pressure= 100 bar Delivery= 2 lpm	2
Relief valve	R2	Pressure =110 bar Delivery = 2 lpm	1
Flow control valve	F1	Pressure = 70 bar Flow Range = 0-4.1 lpm	2
Sequence Valve	S2	Pressure =70 bar Delivery = 2 lpm	2
Oil Reservoir	T1	Capacity = 40 lit	1

Table 10. Selection of Hydraulic Components

V. CONCLUSION

With manual setup more time & human effort was required for alignment purpose and to perform operation, also it did not meet the tolerance requirement. Due to this company was not able to take more job orders of Slack Adjuster. After studying manual system it was observed that unbalanced lines , inaccuracy in mounting of fixtures , vibrations , heavy human efforts affecting the accuracy and productivity of production line.

After implementation of Automated system it is observed that there is reduction in human efforts. Also, accuracy is improved by using proper jig/fixture design and mounting. Productivity is increased by proper time study and line balancing. After successful implementation of above, company is now able to take more job orders of slack adjuster. There is much reduction in cycle time with improved accuracy and productivity. Now one person can handle two machines due to this there is reduction in labour cost and the overall effect of this is nothing but increase in profit of company.

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