NOVATEUR PUBLICATIONS
International Journal of Research Publications in Engineering and Technology [IJRPET]
ISSN: 2454-7875
VOLUME 3, ISSUE 6, Jun.-2017

DESIGN AND CONTROL OF THE THREE POSITION PNEUMATIC CYLINDER ACTUATORFOR PRECISION POSITIONING UNDER VERTICAL LOADING

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ABSTRACT:

Pneumatic actuators offer several advantages over electromechanical and hydraulic actuators for positioning applications. However, pneumatic actuators subjected to high frictional forces, dead zone and dead time, making it difficult to achieve fast and precise position control. This research paper presents the process of identifying design, modeling, and controllers for the pneumatic actuator control system. Three-position pneumatic cylinder is the solution to all problems that occur because of two pneumatic two-position slides. Different external loads are added to investigate the effectiveness of the controllers designed in the system in real time. The performance monitoring of the closed circuit system is satisfied and offers considerable resistance even at a slight increase in load.

INDEX TERMS: Three Position Pneumatic Cylinder Actuator, Pneumatic actuator system, etc.

I. INTRODUCTION:

Pneumatic control systems play an important role in industrial automation equipment due to the following advantages: low cost, clean working environment, easy energy transfer, etc. In recent years, high-precision and the high-speed system have been growing rapidly, and they play an important role in technology. However, precise control of the pneumatic cylinder position is very difficult due to air compressibility, nonlinear airflow through the servo valve, the frictional force between the cylinder and piston and the effect of the system Low slip speed. Traditional pneumatic systems only work under supervision to perform a simple on-off position control and PLC speed. High precision control cannot be achieved with a logic controller on/off switch for modern management strategies are important.

Today existing technology to achieve 3 Pneumatic positions is to use two dual energy pneumatic cylinders. It means two different compressed air slides controlled by two pneumatic cylinders. This makes the system more complex and, due to its complexity, maintenance is required during operation. Since the two position pneumatic systems, the space required for installation is. If the user wants to install the system in a limited area of the space, the user must change the other line relative sub-system layout to make space for this system. To overcome the cost, area, service, performance problems Tires 3 position is a new revolution in the spiritual era. The three position pneumatic cylinder is the solution to all the problems caused by air moving two positions. A simple pneumatic cylinder can achieve the desired results of three different requirements for the reason.

II. LITERATURE SURVEY:

(Markov et al, 2009)ever mentioned that the classic PID control law is not modest adequate for a nonlinear application system that requires ominously higher positioning accuracy and drives stiffness under various external loads. Nevertheless, the Linear Neural Model Based Predictive Controller (LNMBPC)is synthesized with the combination of Model-Based Predictive Control (MBPC) and Artificial Neutral Network (ANN)to experimentally advance the system response compared to the classical PID model within the cycle pneumatic drive control system Management.

(Jihonget al., 1999) proposed a accurate position control approach for servo pneumatic actuator systems. This control approach has been applied in combination with an improved PID controller to a pusher mechanism in the packaging of confectionery products. Both the positioning and the time accuracy required by the manufacturing chore were achieved using such a control approach.

To boost the dynamic characteristic of pneumatic servo drives (Nagarajanet al., 1985) defined methodology based on an outer decision loop, which varies the command issued to an existing closed loop drive. Experimental results are offered which exhibit that the scheme can improve the quality of response with the respect of positioning time as well as overshoot.

In another research, (SyNajibet al)improved the PID controller with the adding nonlinear gain (NPID). Nonlinear gains are accustomed automatically based on the engendered errors feedback to the controller. (SyNajibet al) proved that the performance of the system is significantly boosted with the respect of system toughness against the load changes.

Cause of inadequacy of conventional PID controller to nonlinear systems, (Amin et al,2011) recommended, LQR is a control scheme that offers the best possible performance with respect to some given measure of performance. The LQR design problem is to design a state feedback controller K, is able to be reduced. Feedback gain matrix is formed which diminished the objective role with the purpose to attain several conciliation between the use of control effort, the magnitude, and the speed of response that will promise a stable system.

(Jian-Bo, He et al, 1998) stated that LQR has a very nice heftiness property. If the process is of the single-input and single-output (SISO), then the control system has at least the phase margin of 60 degrees and the phase margin of infinity. In his paper, (Jian- Bo, He et al, 1998) added that LQR solution is apposite to develop an optimal regulation algorithm for processes with time delay.

III. METHODOLOGY:

A) CONSTRUCTION OF 3 POSITION CYLINDER:

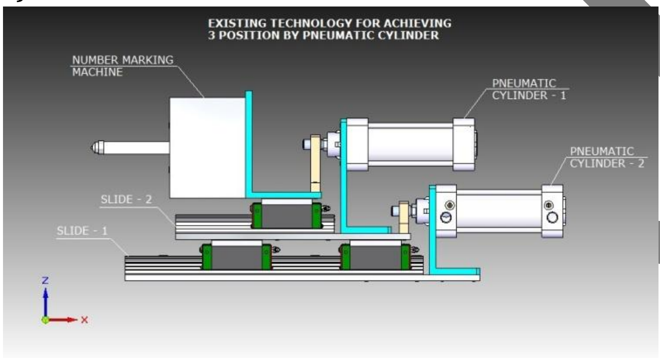

Fig.1: Existing Technology

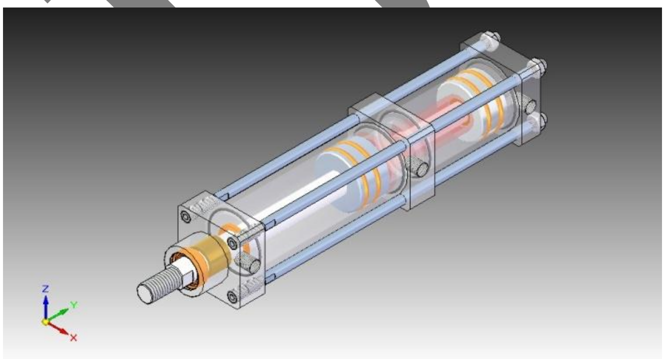

Fig.2: Three Position Pneumatic Cylinder

Fig.1 shows existing technology in pneumatic cylinder. Fig.2 shows Three-position pneumatic cylinder which comprises of two drums having two different turns. In this two-barrel comprises two pistons. The front plunger is attached to the front plunger rod whose length is equal to two strokes addition. The rear piston is guided into the rear piston rod which is stationery. Component sleeves used in this cylinder are a key element in the design, which gives three positions taken from two pistons. The main component of the 3-position is a front end of the cylinder cover, a rear end cap, an intermediate cap, the front of the piston plunger, the piston sleeve rear piston, the front piston, a rear piston and a tie.

B) APPLICATIONS OF 3 POSITIONS PNEUMATIC ACTUATOR:

(1) NUMBER MARKING MACHINE:

The three-sided pneumatic drive allows the placement of the marking unit in 2 operating positions and 1 initial position while retaining the element, is fixed in one position. Therefore, there is no need for the second component. This function is not available in the conventional 2 positions pneumatic actuator.

In addition, if we use 2 conventional pneumatic position actuators, we need two different slides for the working position, which also lead to increased costs.

EXAMPLE:

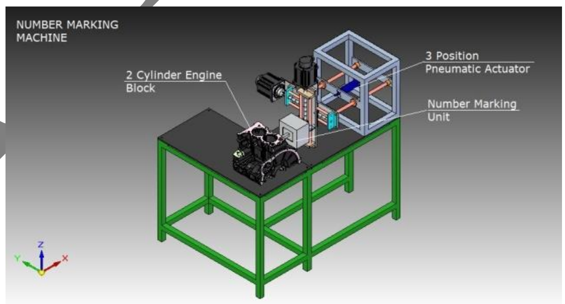

Fig.3: Three Positions Pneumatic Actuator for Number Marking Machine

(2) STUD WELDING MACHINE FOR GENERATOR LOCK :

Three Positions pneumatic actuator is used to position the Generator Lock at preferred position at which studs to be welded. Many welding applications demand the multiple positions to be welded with the same system. To achieve these positions, we can use many positioning technologies like servo drive system with ball screws, hydraulic power driven systems with LM guides, Pneumatic power driven system with LM guides.

Among all these, pneumatic driven system is most popular for industrial use. Advantages of using pneumatic system are safe operation, low maintenance cost, low running cost as air is available free of cost.

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Three position pneumatic actuator allows us the placement of Generator Lock in 2 working position and 1 home position by keeping the Welding Gun steady in one position. Hence no need of 2nd fixture to locate the Welding Gun for 2nd position of stud to be welded. This feature is not available in conventional 2 position pneumatic actuator

Also if we use conventional 2 position pneumatic actuator, we need 2 different slides for 2 working position which also increases the complexity of system which also results in increase in cost.

EXAMPLE:

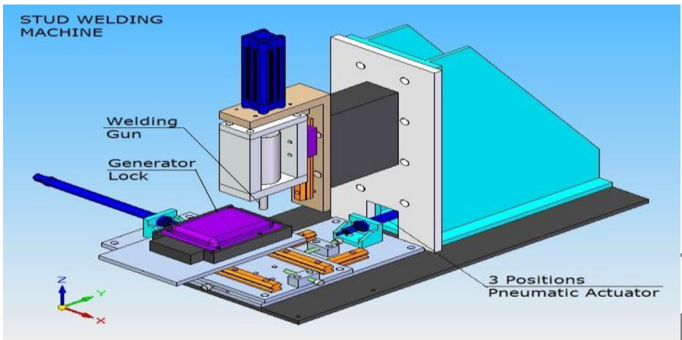

Fig.4: Three Positions Pneumatic Actuator for Stud Welding Machine

DESIGN AND CALCULATIONS:

(1) ACTUATOR BARREL DESIGN:

(A) DESIGN OF LONG STROKE BARREL - BARREL 'A

Input Parameter	Value	Unit
Internal Pressure (Pi)	10	bar
Inner Diameter of Barrel 'A' (Di)	50	mm
Wall Thickness of Barrel 'A' (t)	4	mm
Length of Barrel A (L)	147	mm
Material of Construction	Aluminum 1060	
UTS of MOC (σuts)	68.948	Mpa
Factor of Safety (Nf)	4	

Output Parameter	Value	Unit
Allowable Stress (σall.)	17.237	Mpa
Circumferential Stress (σt)	6.25	Mpa

(A2) Design Calculation for Longitudinal Stress (or Axial Stress)

Input Parameter	Value	Unit
Internal Pressure	10	bar
Inner Diameter of Barrel 'A'	50	mm
Wall Thickness of Barrel 'A'	4	mm
Length of Barrel A	147	mm
Material of Construction	Aluminum 1060	
UTS of MOC	68.948	Mpa
Factor of Safety	4	

Output Parameter	Value	Unit
Allowable Stress (σall.)	17.237	Mpa
Longitudinal Stress (σl)	3.125	Mpa

(B) DESIGN OF LONG STROKE BARREL - BARREL 'B':

(B1) Design Calculation for Circumferential Stress (or Tangential or Hoop Stress)

Input Parameter	Value	Unit
Internal Pressure (Pi)	10	bar
Inner Diameter of Barrel 'A' (Di)	50	mm
Wall Thickness of Barrel 'A' (t)	4	mm
Length of Barrel A (L)	88	mm
Material of Construction	Aluminum 1060	
UTS of MOC (σuts)	68.948	Mpa
Factor of Safety (Nf)	4	

Output Parameter	Value	Unit
Allowable Stress (σall.)	17.237	Mpa
Circumferential Stress (σt)	6.25	Mpa

(B2) Design Calculation for Longitudinal Stress (or Axial Stress)

Input Parameter	Value	Unit
Internal Pressure	10	bar
Inner Diameter of Barrel 'A'	50	mm
Wall Thickness of Barrel 'A'	4	mm
Length of Barrel A	88	mm
Material of Construction	Aluminum 1060	
UTS of MOC	68.948	Mpa
Factor of Safety	4	

Output Parameter	Value	Unit
Allowable Stress (σall.)	17.237	Mpa
Longitudinal Stress (σl)	3.125	Mpa

As σl < σall., Barrel 'B' is safe for Longitudinal Stress. Actual Factor of Safety on Longitudinal Stress = 22.06 Hence from Table B1 & B2, Barrel 'B' i.e. Short Stroke Barrel is safe for Circumferential Stress & Longitudinal Stress.

(2) ACTUATOR PISTON ROD DESIGN:

The piston rod is circular in shape & has length of 208 mm. The piston rod is made up of Stainless steel Grade 304. The compressive stress of SS:304 steel is

310 MPa. Since the compressed air concentrates in the cylinder when sent from compressor; This compressed air creates pressure in the cylinder and as the piston is free to move in the cylinder, the whole pressure acts on the cross sections of the piston. In order to design Pneumatic cylinder, we should know the load bearing capacity of the pneumatic cylinder & it depends upon Load bearing capacity of piston rod. Design Calculation of Load Bearing Capacity of Piston Rod –

Input Parameter	Value	Unit
Diameter of Piston Rod	20	mm
Material of Construction	SS:304	
Compressive Stress of MOC	310	Mpa
Factor of Safety (Nf)	2	

Output Parameter	Value	Unit
Allowable Stress (σall.)	155	Mpa
Max Force on Piston Rod (F)	48701	N
Max Force on Piston Rod (F)	4964.424057	Kg
Max Force on Piston Rod (F)	4.964424057	Tones

This means that 4.96 tones with FOS 2 is the last limit of our piston rod but our aim is to design the pneumatic cylinder working at 10 bar and which can easily withstand 200 Kg Load Hence our piston rod is safe under compressive strength.

(3) TIE ROD DESIGN

Tie Rod is an element of pneumatic actuator which keeps the end caps and barrel at desired design locations. While working of pneumatic actuator, tie rod undergoes tensile load Hence tie rod has to be design for tensile load Design Calculation of Load Bearing Capacity of Piston Rod –

Input Parameter	Value	Unit
Working Pressure of Cylinder	10	bar
ID of Barrel	50	mm
Diameter of Tie Rod	6	mm
Thread size of Tie Rod	6	mm
No. of Tie Rods	4	Nos.
Material of Construction	MS	
Tensile Stress of MOC	350	Mpa
Factor of Safety (Nf)	2	

Output Parameter	Value	Unit
Allowable Stress (σall.)	175	Mpa
Force to be sustained due to pneumatic pressure (Fi)	196.375	Kg
Force to be sustained due to pneumatic pressure (Fi)	1926.439	N
Max allowable Tensile Force on one Tie Rod (Grade 8.8)	16098	N
Total Force carrying capacity of 4 Tie Rod	64392	N

As Force carrying capacity of 4 Tie Rod is greater than that to be sustained. Hence Tie rod is safe under tensile loading with actual Factor of safety = 33.43

CONCLUSION:

Three positions pneumatic actuator is used to position the Number marking unit at desired position of marking. Many marking applications demand the multiple positions to be marked with the same setup. To achieve these positions, we can use many positioning technologies like servo drive system with ball screws, hydraulic power driven systems with LM guides, Pneumatic power driven system with LM guides. Among all these, pneumatic driven system is most popular for industrial use. Advantages of using pneumatic system are safe operation, low maintenance cost, low running cost as air is available free of cost.

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