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Automated-Combined valve oscillation testing machine for 4&6 Cylinders

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***Abstract*— Valves in an engine have numerous functions to perform and they experience enormous stress even in normal conditions. Hence testing of valves is very important. The present work is focused towards design of combined valve oscillation testing machine to check two and four valve cylinder heads. Also four as well as six cylinder engine heads can be tested on the same machine. Conventionally, valves are tested on two different assembly lines separate for two and four valves. This approach has been adapted to save space, cost and time of testing. This concept incorporates mechanical, automation and pneumatic principles. As a result, it improves efficiency and speed of operation, reduces manpower. The aim is to elaborate the concept with the aid of designing. The concept is simple and reliable. The design calculations have been obtained and found to be suitable for the application stated above.**
Keywords- valves, automation, analysis, ANSYS.

I. INTRODUCTION

The valves in an engine have numerous functions. First, they must permit the intake of fuel and air. Then they must seal compression. After the explosion the exhaust valve must permit the burned gases to leave the combustion chamber. Then there is one other function that valves must perform. They must streamline these gases and make it possible for them to move into and out of the combustion chamber as rapidly as possible, and, when the gases leave the combustion chamber, they must be so directed that they will not swirl or congest in a manner that will prevent the complete scavenging of the cylinder. Valves experience enormous stress even in normal conditions. Hence testing of valves is very important.

Nowadays, the world is moving towards optimization. Engineers are searching for new ways to reduce working time and cost without compromising efficiency and accuracy. The main motive behind this newly generated concept is to incorporate two cylinder head assembly lines into single line. The concept reduces cost and space in industries. Till date conventional machines test two and four valve cylinder heads on different assembly lines in which more manpower was required.

The concept presented uses automation and pneumatics to increase efficiency and reduce manual work. Due to decrease in manual interference the quality of work is improved. The problems associated with designing can be overcome with some brainstorming and inputs from various fields, combined together can lead to a more optimal solution than present today. Our concept incorporates pneumatics and automation along with basic mechanical principles.

Our design consists of basic mechanical components such as cam, shaft, roller, bearings, spring, gearbox, motor etc. which are partly same as conventional machine. Along with these, pneumatic cylinders, proximity sensors, PLC unit etc. are utilized for better performance. As height and width of two and four valve cylinder heads is different that forms the input to the sensor through PLC unit and differentiates among the two. It gives signal to the pneumatic cylinder and it gets actuated according to the input. Then the machine accordingly adjusts the working height.

The proposed report consists of one such innovative concept. It also includes project outcomes, design calculations and system layout.

II. LITERATURE REVIEW

Assembly lines are types of automated flow lines which consists of several machines or workstations linked together by work handling devices that transfer material between stations. Cylinder heads are designed to help improve the swirl or turbulence of the air fuel mixture, and prevent fuel droplets settling on the surfaces of the combustion chamber or cylinder walls. Thus testing of cylinder heads is very essential. Cylinder head testing consists of an assembly line of thirteen stations. Cylinder head undergoes various types of fitments and checking in this assembly line.

The valve oscillations testing machine is one of the stations in testing of cylinder head. Generally at the first station cylinder head will be loaded on the conveyor from where it is passed to the second station. At the second station of assembly line stem seal pressing takes places. The spring fitment occurs at the next station. Further stations consist of cotter pin fitment with lifter. The cylinder head is then placed on palette at the next station. Further it is passed over turn table. Any rejected cylinder head returns for rework from this station. Further the cylinder head is passed to the next station i.e. Valve oscillation testing station. At this station testing of valve oscillation is done. Rejected cylinder heads are returned to rework while the selected cylinder heads are further passed checking of valve seal with lifter.

Automation is a technology concerned with application of mechanical, electrical, electronic and computer-based systems to operate and control production.

Flexible automation is an extension of Programmable automation. As the name suggests, it is used for producing a variety of products, without requiring batch production. The main feature of this system is that no time lost during the changeover from one product to another. This system is generally used for medium production rates.

Material handling is an important, yet sometimes overlooked aspect of automation. The cost of the material handling is the significant portion of the total cost of production. Estimates of the handling cost are as high as two third of the total manufacturing costs. This fraction varies depending upon the type and quantity of production and the degree of automation in the material handling function.

Material handling uses the right method to provide the right amount of the right material at the right place, at right time, in right sequence, in right position, in right condition and at the right cost.

Roller conveyor consists of series of tubes (rollers) that are perpendicular to the direction of travel. Rollers are contained in a fixed frame which elevates the pathway above floor level from several inches to several feet. They can be either powered or gravity types. Roller conveyors are available in various versions and have no limitations in terms of length and shape. These are used for delivering loads between manufacturing operations, delivery to and from storage and distribution operations.

III. CONCEPT

Initially, the cylinder head (component) placed on the pallet is introduced to the roller conveyor. The pallet gets disengaged by the pop up pneumatic cylinder and the component rests on rigid structure. Then the sensors get actuated and measure width and height of the component. Sensors give signal to the PLC unit on linear motion slide which provides input to the slide vertical type pneumatic cylinder. The cylinder extends to give downward motion to the linear motion slide to obtain working height so that further testing of component can be done.

Testing is carried out with cam and follower in which motor gives power to the gearbox which gives speed reduction and rotates the camshaft. The camshaft consists of cams and is held in Plummer bearings and rests on vertical linear motion slide. Cam engages with the roller follower which is connected to the guide through the springs. The guide provides necessary force to the valves with proper displacement to check the oscillations and valve lift. A set of two cams operate at a time and sequentially test all the valves. Proximity sensors are placed on camshaft to check the maximum lift of cam in order to ensure specific required displacement of valves.

Finishing time of operation is set in PLC unit. Hence, when the testing is done it will give signal to the double acting slide vertical pneumatic cylinder to retract and lift the linear motion slide to its original position. The bottom pop up cylinder then lifts the roller conveyor and pallet along with component and moves it to the next station.

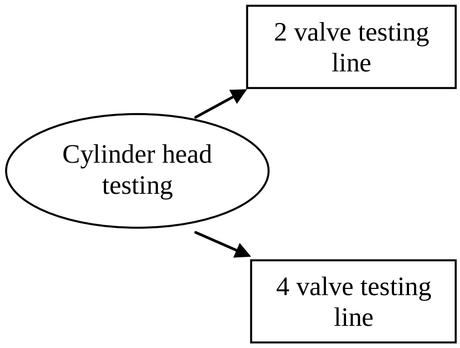


Figure 1.Conventional concept

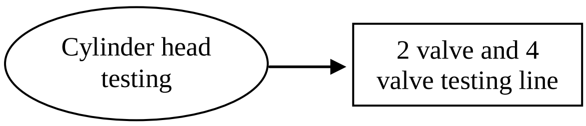
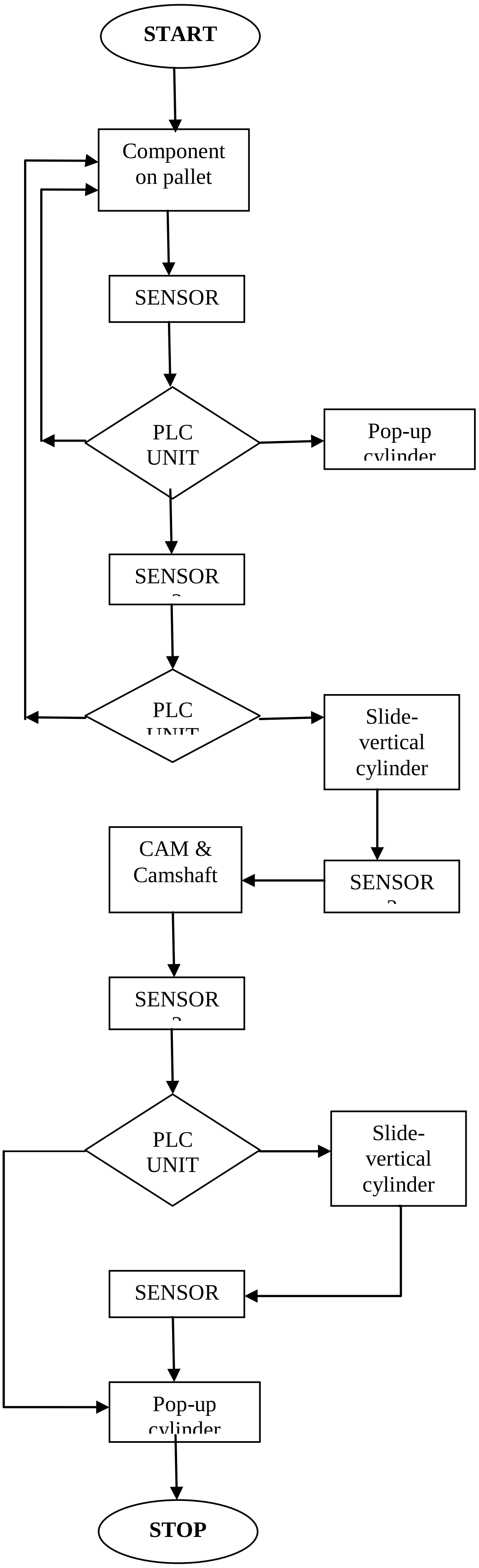


Figure 2.New concept



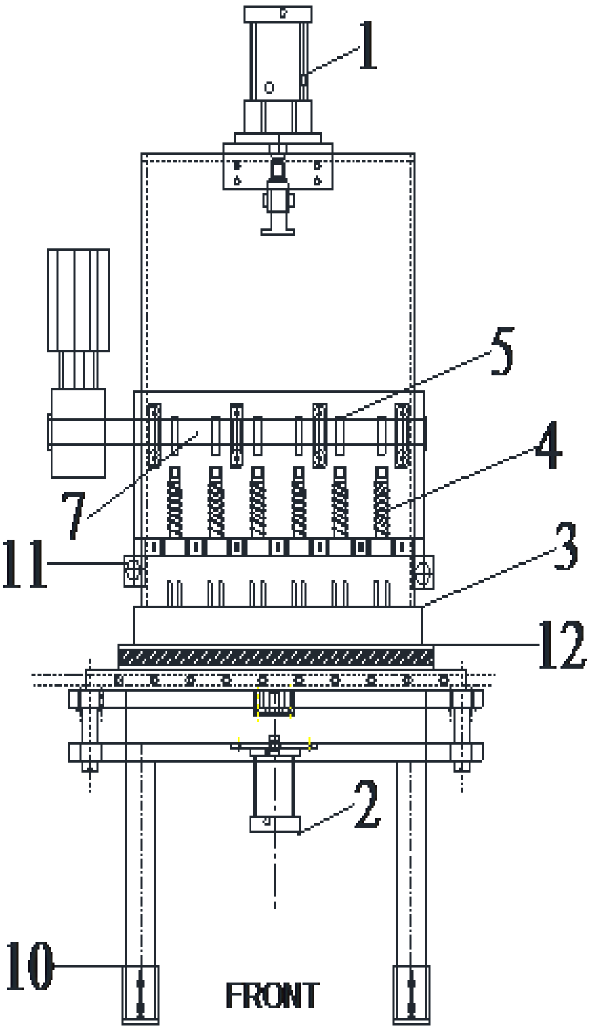


FIGURE 3.Front View

COMPONENT-

- **2 valve 4 Cylinders**
- **4 valve 4 Cylinders**
- **2 valve 6 cylinders**
- **4 valve 4 Cylinders**

1-slide-vertical pneumatic cylinder
2-pop-up cylinder
3-component
4-Spring & follower unit
5-cam
6-Linear-motion Slide
7-Camshaft
8-Guide & bush unit
9-Gear & motor unit
10-support structure
11-LM slide Stopper
12-Pallet & Roller Conveyor unit

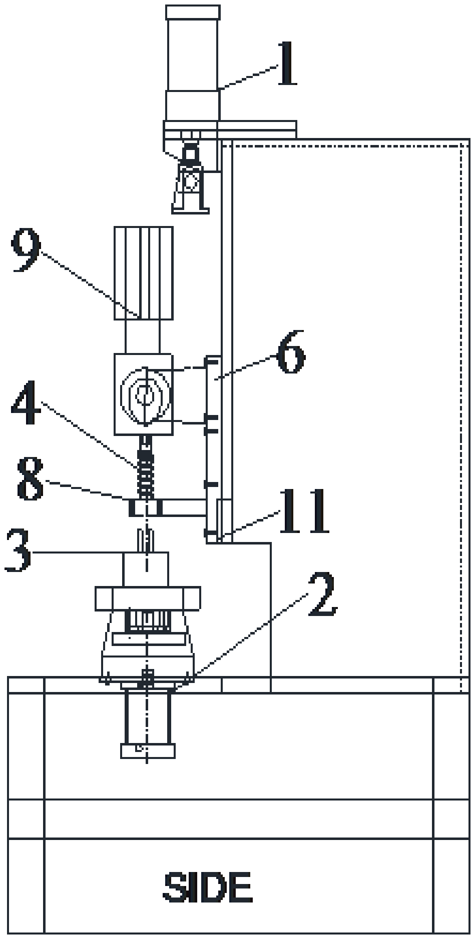


FIGURE 4. Side View

IV. DESIGN AND ANALYSIS

Purpose of designing is to prove that the generated concept can be used practically and obtain final result with same functioning accurately. Hence, before manufacturing all machine parts are designed as per mechanical procedure and are validated by using software to check safety of each part. Main parts designed are as follows and satisfactory results are obtained: Pneumatic Cylinders, spring, Camshaft, Cam and follower, Plummer Bearings, Linear motion slide concept.

Pneumatic cylinder is designed as per pneumatic design procedure and pressure vessel stress theory. Initially critical diameter and thickness is calculated by using Eq.1 and 2 respectively and from respective values actual part can be selected from available standard parts which is safer than calculated values on the basis of space and cost constraints.

$$A = \frac{F}{P}$$

$$L = 2 \times D \quad \text{....(1)}$$

$$t = \frac{P_i \times d_i}{2 \times \sigma_{all} \times \eta_t \times (-P_i)} \quad \text{....(2)}$$

Where, P_i=internal pressure, N/m^2

t= thickness of cylinder, m

L=length of cylinder, m

A=area of cylinder, m^2

σ_{all}=allowable stress, N/m^2

η_t =joint weld efficiency

Spring-

To design spring same mechanical design procedure is followed to find wire and coil diameter from Eq.3 and 4. Then safety of calculated spring dimensions is checked by using shear stress Eq.5 and is validated by analysis in software.

$$K = \frac{4C-1}{4C-4} + \frac{0.615}{C}$$

$$C = \frac{D}{d} \quad \text{....(3)}$$

$$\tau = K \times \frac{8 \times F \times C}{\pi \times d^2}$$

$$\tau > \tau_d \quad \text{....(4)}$$

Where, k=Wahl factor

C=spring index

D=mean coil diameter, mm

d=wire diameter, mm

τ=torsional shear stress, N/m^2

For analysis spring material considered is steel. Condition for safe design is stress computed in ansys result should be less than its material allowable stress value.

$$\sigma_{design} < \sigma_{allowable}$$

Computed stress	Allowable stress
1.142e+008 Pa	4.44e+008 Pa

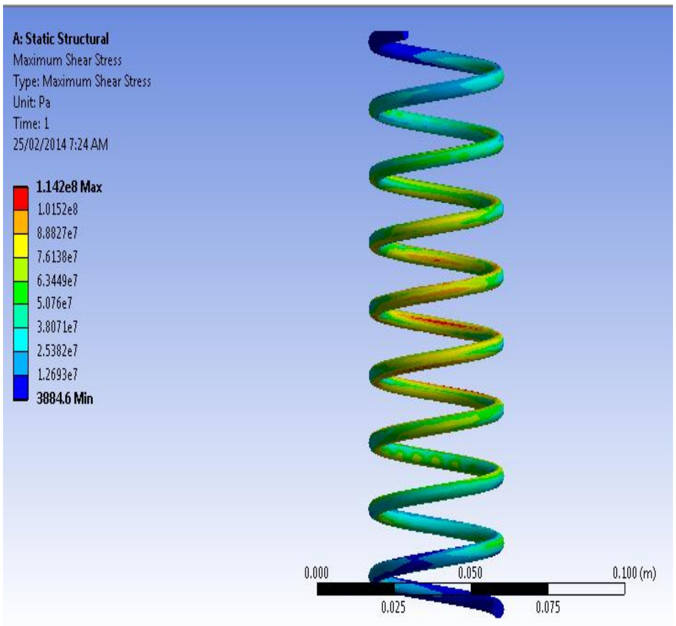


FIGURE 5
Model (A4) > Static Analysis (A5) > stresses

Static Structural (A5) > Solution (A6) > Results

Object Name	*Equivalent Stress*	*Maximum Shear Stress*
State	Solved	
Scope		
Scoping Method	Geometry Selection	
Geometry	All Bodies	
Definition		
Type	Equivalent (von-Mises) Stress	Maximum Shear Stress
By	Time	
Integration Point Results		
Display Option	Averaged	
Results		
Minimum	7229.4 Pa	3884.6 Pa
Maximum	2.2492e+008 Pa	1.142e+008 Pa
Information		
Time	1. s	
Load Step	1	
Substep	1	

TABLE. 1

Camshaft is designed by considering all failure modes and design consideration. After this critical diameter value is obtained from Eq.5 which is minimum limiting value. Above that any preferable value can be selected by considering space, material and size constraints.

$$\tau_{max} = \frac{16}{\pi d^3}\sqrt{(K_b M_b)^2 + (K_t M_t)^2} \quad \text{....(5)}$$

where, τ_{max} = principal shear stress, n/m^2

d=shaft diameter, m

K_b=combined shock and fatigue factor applied to bending moment

M_b =bending moment, N-m

K_t =combined shock and fatigue factor applied to torsional moment

M_t= torsional moment, N-m

For analysis shaft material considered is steel. Condition for safe design is stress computed in ansys result should be less than its material allowable stress value.

$$\sigma_{design} < \sigma_{allowable}$$

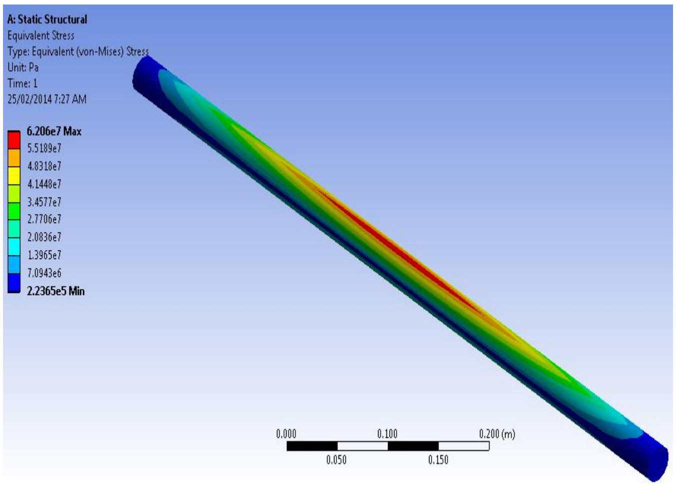


FIGURE 6
Model (A4) > Static Analysis (A5) > stresses

Computed stress	Allowable stress
6.3193e+007 Pa	6.5e+007 Pa

Static Structural (A5) > Solution (A6) > Results

Object Name	*Equivalent Stress*
State	Solved
Scope	
Scoping Method	Geometry Selection
Geometry	All Bodies
Definition	
Type	Equivalent (von-Mises) Stress
Integration Point Results	
Display Option	Averaged
Results	

Minimum	2.9059e+005 Pa
Maximum	6.3193e+007 Pa
Information	

TABLE. 2

For cam designing analytical and practical methods are used and are validated by camtrax and ansys software. For Roller follower Eq.6 and for cam geometry Eq.7 is used.

$$P_b = \frac{P_c}{d_1 \times l_1}$$

$$\tau = \frac{F}{A}$$

$$\tau < \tau_{all} \qquad \text{....(6)}$$

$$\tan \propto = \left(\frac{V}{R \times \omega}\right)$$

$$F_N = \frac{F}{\cos \propto}$$

$$\sigma_c = \sqrt[189.8]{\frac{F_N}{b} \times \left(\frac{1}{r_c} + \frac{1}{r_f}\right)}$$

$$\sigma < \sigma_{all} \qquad \text{....(7)}$$

Where, p_b = bearing pressure N/m^2
p_c = force on follower
d_1=diameter of roller pin, m
l_1= diameter of roller pin, m
τ= shear stress, N/m^2
F= force acting on follower, N
A= area of roller, m^2
τ_{all}= allowable shear stress, N/m^2
tan α = pressure angle, degree
V= velocity of follower, m/s
R= distance between cam centre and follower center, m
F_N = normal force between cam and follower, N
F = external force acting on follower, N
σ_c = contact stresses, N/m^2
r_c =radius of curvature of cam at the point of contact, m
r_f = radius of curvature of follower, m

To design Plummer bearings, conventional bearing design is followed and all important factors are calculated using Eq.8. Further actual part is selected from the catalogue having dimensions more than critical dimensions.

$$L_{10} = \frac{60 \times n \times L_{10h}}{10^6}$$

$$C = P \times (L_{10})^{\frac{1}{3}} \qquad \text{....(8)}$$

Where, L_{10} = rated bearing life in million revolutions
L_{10h}=rated bearing life in hours
n=speed of rotation, rpm
C=dynamic load capacity, N
P=equivalent dynamic load, N

An additional concept of linear motion slide is important hence it is designed by considering newly generated concept constraints.

A **Programmable Logic Controller**, **PLC** is used for automation processes, such as control of machinery on factory. PLCs solve the logic in a predictable and repeating sequence. The program is transferred from a personal computer to the PLC. A primary reason for this is that PLCs solve the logic in a predictable and repeating sequence, and ladder logic allows the programmer to see any issues with the timing of the logic sequence more easily than would be possible in other formats

A **proximity sensor** is a sensor able to detect the presence of nearby objects without any physical contact. A proximity sensor often emits an electromagnetic field or a beam of electromagnetic radiation, (infrared, for instance), and looks for changes in the field or return signal. Types of proximity sensors are capacitive and inductive photoelectric sensor.

In this system signals from proximity sensors are given to the PLC unit for automation process.

V.CONCLUSION

Following are the conclusions made after conceptual design and validation of calculations.

The newly generated concept saves space, cost and time of operation. It improves efficiency and accuracy. Due to automation, requirement of manpower is reduced. Pneumatic systems are clean and cost effective.

Conventional concept consists of two different assembly lines whereas our concept combines them into one. Manual fatigue is reduced due to automation and assembly line layout.

Due to use of sensors, accurate testing can be achieved.

Design calculations and results have been validated using analysis software and found to be suitable for the required application.

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