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Design and Manufacturing of Rubber-Metal Bond Testing Machine for Silent Bush Block

An Experimental Study

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***Abstract* — Now-a-days, the synthetic rubber parts like silent bush block are used frequently in the automotive & industrial area as they tend to offer equivalent level of sophistication in the various aspects like strength, maneuverability, & cost as compared to other industrial products. The synthetic rubber, when bonded with the metal is observed to have produced significant positive results in their areas of application. Primarily, in the automobile sector the bonded rubber-metal product is used as a part of the vehicle & also there are other areas like textile industries, medical field etc. in which they are used often. Most of the times, these products are subjected to very high loads, stresses, vibrations & noise in their corresponding application, hence under some specific physical conditions like increased load, stress & force, failure of such products may occur. The unknown condition like this will be very harmful for the personnel working nearby & should properly be taken care beforehand. Pertaining to the condition stated above, it becomes obligatory to test the bond between rubber & metal to make sure that the designed or manufactured product lies in the margin of safety. Therefore, this prescriptive paper serves a brief overview on the design and manufacturing of a machine used to test that bond.**

Keywords* — *Rubber-Metal components, Bond Test, Silent Bush Block, Special purpose machine

I. INTRODUCTION

The industrial or synthetic rubber can be molded & adhered to the metal component with the help of a suitable bonding agent. Generally, selection of rubber & its bonding agent is decided with the help of the required application of the component. As it is used in industrial areas, the manufacturing condition is that the rubber should easily flow into the mold without developing a significant level of cross-linking, so that the required bond can be created by using any rubber compound. It is also advised to avoid the substances that may bleed the surface of the uncured stock very rapidly. Before the molding takes place, the metal is made completely free from rust and some other impurities by degreasing, sandblasting or shot blasting processes. The bonding agent comprises of polymer/solvent solutions, having a primary coat of primer pertaining to phenol-style resins & a finish coat of polymer & some other reagents. [1]

However, the strength of rubber-metal component depends upon some properties. The expected value of strength, if observed to be lesser than the required value, then the whole component may result in a failure. The situation can be proven very dangerous & sometimes fatal to the operator if not taken care properly. Hence, it becomes very essential to check whether the component has achieved required strength or not. The method of theoretical calculations may be used but it may take large amount of time depending upon the quantities of components to be tested. [5]

Therefore a Special Purpose Machine called as 'Bond Testing Machine' is solely developed for the very same problem as described above for the component named as Silent Bush Block as shown in fig 1.1. The machine offers a flexible & quality assured solution along with the reduced requirement of time & operator fatigue. Various parameters like dimensions of the part, application, required pressure & force acting on the part, orientation of applied load, vibrations of the machine etc. are considered as the required input for the design of the machine.

Fig 1.1 Silent Bush Blocks

II. CONSTRUCTION OF THE MACHINE

The bond testing machine comprises of following main components as shown in fig. 2.1 –

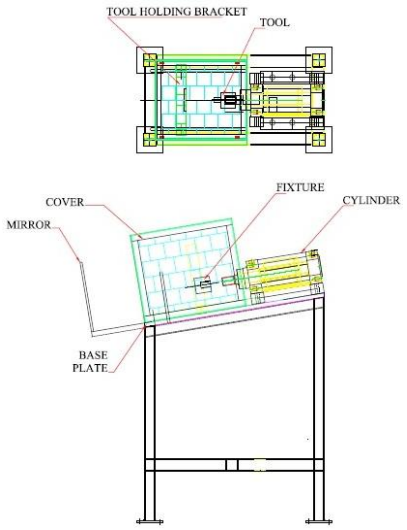

Fig 2.1 Constructional Layout of Machine

1. Structure & Base Plate –

The structure is made by hollow square pipes of varying sizes and having the thickness as per the dimensions of the machine & is tapered at the top as shown in fig 2.1. The base plate is used o top of the structure to bolster the sub-assemblies. The hollow pipes & the base plate are used of Mild Steel.

2. Pneumatic Air Cylinder –

Technical specifications of the pneumatic cylinder used are based on the application & customer's demand.

Cylinder (mm)	Dia. 50 mm to Dia. 150 mm
Standard Stroke (mm)	50, 75, 80, 100, 125, 160, 200, 250
Medium	Filtered & Lubricated Compressed Air
Working Pressure	0.5 to 10 bar
Medium Temperature	5 to 80 ^{0}C

Table 2.1 Specifications of Pneumatic Cylinder

3. Job Housing -

It is used as a fixture to hold the job. The specifications of the job are provided by the third party and then the housing is manufactured. Along with providing proper grip to hold the job, it also contributes in sharing a partial load on the job as well.

4. L-Brackets –

L-brackets are used for holding & supporting the pneumatic cylinder and are made by two square plates by welding together in right angle. The purpose of these brackets is to compensate for any deflection of the cylinder.

5. Pressure Gauges & Air Regulator –

The pressure gauges used in this machine are generally having the capacity of 5-10 bars. One pressure gauge is used to show the amount of pressure exerted by the air compressor at the outlet & one is used to determine the amount of air pressure in the cylinder. The flow of air pressure can be controlled with the help of air regulator & the flow control valve. 5/2 single acting solenoid operated DCV is basically used for the entire pneumatic circuit control.

6. Mirror Mounting Assembly –

Main objective of mirror mounting assembly is to provide the easy view of the tested object. It is installed on the machine base plate to reduce the operator fatigue which may have resulted if the operator would have to observe the jobs by bending down every time. The adjustable mirror thus eliminates the fatigue.

III. WORKING OF THE MACHINE

The principle on which the machine works is that, if tensile or compressive force is acting on any component then the various stresses are developed pertaining to it & some elongation of the component is occurred. With the help of this principle, the machine is designed.

The machine consists of the vertical structure in a tapered form as shown in the figure. The pneumatic cylinder is mounted on top of the base plate with the upper side of the tapered table and at the other side; the job housing is fixed along with the mirror mounting assembly. The testing tool is mounted on the shaft of the cylinder which actually exerts the required pressure on the grasped job. The job housing in which the job is fixed is then inserted into the bracket. The required pressure is then set with the help of flow control valve & pressure gauges. The operator then operates the entire machine by the means of the 5/2 single acting solenoid operated DCV and observes the physical condition of the job via mirror.

The pressure of the air from the compressor is used on the job with the help of the actuator or job testing component. The testing tool is mounted on the piston shaft which delivers the required stroke. When a particular distance is travelled by the piston shaft, the tool then comes in contact with the job to be tested. Some part of the tool is inserted inside the job & rest of the part remains outside on the collar. The fit between the two is maintained as the transition fit. The force acting on the job is calibrated according to the pressure developed at the intake of the cylinder.

Internal stresses are resulted inside the job after the application of subsequent force on it. If the bond between the rubber-metal is deemed weak, if the it fails in allowable load & then it will display physical failure. Some margin of safety is kept while testing the job i.e. applied force is always greater by some extent than actual application. With the application of force, minor displacement in the inner metal part is occurred which is clearly observed in the mirror by the operator.

IV. DESIGN CALCULATIONS

Designing the concept for the assumed inputs given by the customer -

Given Data:

1. Application of Force Acting on the Job to be tested = 80 Kg.

2. Pressure exerted on the part = 5 bar.

To Find:

1. Bore Diameter (d) & Stroke (l) for the selection of pneumatic cylinder.
2. Volume of the pneumatic Cylinder (V).
3. Load & Pressure Chart

Now,

1. Bore Diameter (d) & Stroke (l), mm -
   As force acting & pressure are known,

   Force = Pressure x Area (1)
   $80 = 5 \times \pi/4 \times d^2$

   ∴ By calculations,
   d = 4.51 cm = 45.10 mm.

Selecting standard size of the cylinder from the obtained data, i.e. cylinder having bore diameter, d = 50 mm.

Hence, for d = 50 mm, stroke of the cylinder, l = 100 mm.
Now,

To find out how much pressure is exerted by the cylinder having d = 50 mm.

We know that,

Pressure = Force/Area
But, $A = \pi/4 \times 50^2 = 1962.5\ cm^2$ (2)

∴ $P = 80/19.63 = 4.076\ kg/mm^2$

2. Volume of the Cylinder (V) –
   Volume is given by,

   V = Area x Stroke Length (3)
   $V = \pi/4 \times 50^2 \times 100$

   ∴ $V = 196.34 \times 10^3\ mm^2$

3. Load & Pressure Chart –

   The chart below shows the values of pressure (kg/cm^2) obtained for the corresponding value of load (kg)

Load (kg)	Pressure (kg/cm^2)
10	0.51
20	1.01
30	1.52
40	2.03
50	2.54
60	3.05
70	3.56
80	4.07
90	4.58
100	5.09

Table 4.1 Load-Pressure Chart

V. PNEUMATIC CIRCUIT

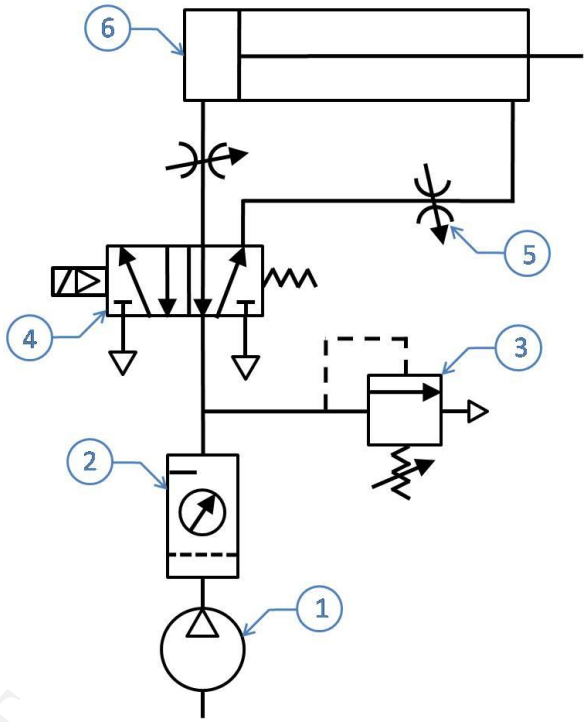

Fig 5.1 Pneumatic Circuit of the Machine

As shown in the figure 5.1, the primary elements of the pneumatic circuit are indicated are as explained below –

1. Pneumatic Compressor – Used specifically for compression of the air to achieve the required pressure & also acts as a reservoir of compressed air.
2. FRL Unit – This is the acronym for 'Filter-Regulator-Lubricator' unit. As the names suggest, filter is used to separate any contaminants from the incoming air in the circuit, regulator is used to control the pressure of the incoming air & finally the lubricator is used to lubricate the incoming air by spraying a fine mist of oil. They are generally used at the beginning of the air supply line.
3. Pressure Relief Valve – These valves are used to limit the maximum pressure in the system at any point or a region.
4. 5/2 Solenoid actuated DCV – DCVs are used for distribution of energy to various actuators by controlling the direction of flow of pressurized air in the system. A solenoid valve is an electromechanically operated valve. The valve is controlled by an electric current through a solenoid hence the name. 5/2 indicates 5-position-2-way valve.
5. Flow Control Valve – These valves are used to control the flow rate of the working fluid. Since the fluid energy contained in the fluid is in the form of pressure energy, flow control valves also control the rate of energy transfer in the fluid power system.
6. Pneumatic Cylinder – Pneumatic cylinders (sometimes known as air cylinders or air actuators) are mechanical devices which use the power of compressed gas to produce a force in a reciprocating linear motion

VI. ADVANTAGES & LIMITATIONS

1. Advantages –
   - Machine is extremely easy to operate.
   - Unskilled operators can also work.
   - Time required is very less.
   - Machine is versatile in operation.
   - Wide pressure range can be used.
   - Operator fatigue is abated.
   - Any component can be tested.
   - Maintenance is very less.
   - Cost of the machine is very low.

2. Limitations –
   - Any components can be used provided it has suitable job holding fixture.
   - Cost is high according to the design.
   - Can't be used economically for batch production.
   - The testing to be done is of destructive type.
   - Entire design of the machine is subjected to change if the component size is to be changed drastically.

VII. FUTURE SCOPE

Being the simplest machine, it has a wide future scope in rubber-metal industries. Some of them have been listed as follows –

1. The bond testing machine can be system integrated & automated to achieve entire automation of the corresponding line.
2. The machine can be used for varieties of jobs with the help of flexible fixture.
3. Machine can be used as a demonstrator in educational field.
4. It can be effectively used for batch as well as mass production with the help of proper resources.

VIII. RESULT & CONCLUSION

After the experimental study, it was observed that for the specified input conditions, the cycle time for one job comes out to be about 15-20 seconds and the overall cost may go up to INR 14,000 which is considerably low as compared to other testing machines.

Being a destructive testing machine, it obviously offers a complete assurance of the quality of bond as the failed job will be rejected otherwise automatically.

In conclusion, this versatile machine can be used in industrial as well as educational field with optimum efficiency, high reliability & lesser cost and also offer a wide scope for development.

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