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Design and Development of Low Cost Compact Vibration Stimulator - An Experimental Approach

Nawaz Multani[1], Bhumit Pandav[2], Yashkumar Parmar[3], Rajath Shetty[4], Mihir Vaktana[5], Prof. Mayur S. Modi[6]
[1, 2, 3, 4, 5]Student, [6]Assistant Professor, Mechanical Department, SSASIT, Surat

Abstract: In today's era quality is a crucial factor for any product and customers are very concerned about their product. So, it's very important for a company to supply defect-free products. Although from the external look of a product we can't say whether the product is free from defect or not because some defect is not visible by naked eyes so some kind of special testing is required to determine the internal defect (minor crack, internal shrinkage, crack in parent material, root undercutting, surface crack, etc.) of the components. One such testing is vibration testing popular among many manufacturing industries. A device named a vibration exciter which produces forced vibration of varied frequency is used to vibrate the test specimen and therefore the detailed analysis is obtained by an FFT analyzer.
Keywords: Mechanical mechanism, forced vibration, cam follower, testing vibration, vibration apparatus.

I. AIM & OBJECTIVE

To design and fabricate a device titled as vibration exciter for providing several types of motion. Vibration exciter is an important device that is used for testing of specimens, that are subjected to cyclic loading. It acts as an external source of vibration, to simulate conditions during which the specimen under test will be working. Vibration Stimulator are of lower cost than other types and can be utilized for laboratory experiments in college or in research lab.

II. INTRODUCTION

To determine their limits and tolerances of a components they are tested under vibration. Every component is unsafe to vibration loads and breakage or failure. That includes tiny objects like a microchip, circuit boards right up to giant structures like rockets and skyscrapers. It allows manufacturers, designer, engineer to know what stress limits their product can withstand. Testing through vibrations ensures the product is qualified according to the norms purpose and meets safety and regulatory standards. Nowadays many different manufacturing industries use vibration testing as part of their manufacturing process. Leading industries want to ensure product reliability as well as safety. These are some of the industries using vibration testing during product development:

1) The aviation industry avoids parts and system failures like wing movements and engine pressures by vibration testing. Also, the aerospace industry inspects highly sensitive components which will withstand high force during take-off as well as in outer space.
2) Electronic industry tests their complex parts for potential breaking by testing prototypes through vibration testing.
3) Marine manufacturers reduce driveline wear and hull fatigue by having vibration testing wiped out controlled facilities.
4) Defense departments employ vibration testing in equipment and weapons systems to form sure they will be safely transported and utilized in the sector of battle.
5) Oil and gas manufacturers believe vibration testing stops production problems during a highly volatile industry.
6) High-voltage equipment are operating safely or not is checked in power plant using vibration.
7) Consumer goods manufacturers involve vibration testing to make sure products withstand everyday rigors in household use.

A vibration stimulator is a device that produces forced vibration, shock, or modal excitation source for testing and analysis produces mechanical vibratory motion to test object with the help of cam and follower which is attached to the motor via a shaft. Although these machines can be mechanical, electro-hydraulic, or electro-dynamic. It is used to measure the internal defect of the object and also studying the effects of the vibration found in different sectors like aerospace, agriculture, manufacturing, automobile, education sector.

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A. *Types Of Vibrating Testing Equipment's*

Controlled vibration testing involves three different kinds of shakers or vibrating machines. All three designs have featured so the operator or vibration testing specialist controls the speed, frequency, and other testing variables the test specimen goes through.

1) *Mechanical Vibration Shakers:* This is a very common and cheap device compare to others. They are easy to operate and very reliable. But it has one limitation that it has only a limited range of speed and oscillation.
2) *Electro-Hydraulic Shakers:* The vibration table starts vibrating hydraulically via some sort of electric power source. Although it is expensive compare to mechanical shakers but it has a wide range of adjustments.
3) *Electromagnetic Shakers:* For advanced work such as in the aviation and aerospace industries, electromagnetic (EM) shakers are preferred by vibration experts.

B. *Main Components of Vibration Stimulator*

1) *Cam and Follower:* The cam and follower mechanism are used for creating the vibrations. Two cam are used for different outputs i.e. S.H.M profile and Snail/Drop profile. One will provide uniform motion while the other will provide sudden jerk.

(Fig. 1 Cam)

(Fig. 2 Follower)

2) *Shaft:* The shaft is connected with the motor and key ways is provided on shaft so it will mount cams on it.

(Fig. 3 Shaft)

3) *Plate:* A metal plate with holes in it to insert a follower with the help of an internal thread. Test specimen will be kept over this plate which is to be tested.

(Fig. 4 Plate)

4) *Bearing:* Two types of bearing will be used. One is roller bearing used in follower and another one is pedestal bearing used to provide support to the shaft.

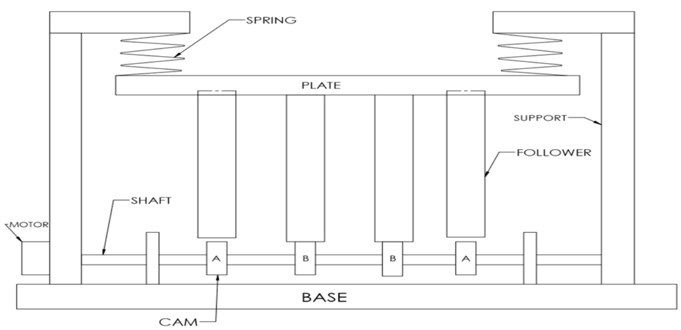
(Fig.5 Bearing)

5) *Motor:* 1 HP motor is used which is connected with shaft via coupling.

(Fig.6 Motor)

III. DESCRIPTION OF PROJECT / INVENTION

In Engineering testing is one among the foremost important field. Testing is done for finding defects whether it is internal or external. For finding external defects there are several methods which does not requires breaking the object for finding defects but for finding internal defects some methods require breaking object or using of chemical, powder etc. on the object. But we have made a testing apparatus / equipment named vibration stimulator by which we will test the object for internal defects with the means of forced vibration. vibration exciter Consist of a base plate and upper. On base plate on which the entire equipment is mounted. On the base plate there are 4 column which houses four spring, and a shaft is also mounted on the base which have 4 cams, one motor is also there. There are 4 followers mounted on the upper plate. the upper plate is supported by two column which are mounted on base plate. The motor is connected with shaft so when we will start the motor the shaft will start rotating on which four cams are mounted so they will start rotating to and the followers in contact with cams will start moving up and down and this will force the plate to vibrate and as the plate is provided with spring damping it will create a forced vibration. and on the upper plate an object is placed and then it is analyzed by FFT analyzer for the exact location of the internal defect.



(Fig. 7)

IV. MODEL CALCULATION

A. Design of shaft

1) Power for shaft is taken as 1 KW considering FOS
2) Motor speed is taken to be 500 rpm

Data: P = 1 kw N = 500 rpm

a) Torque acting on the shaft

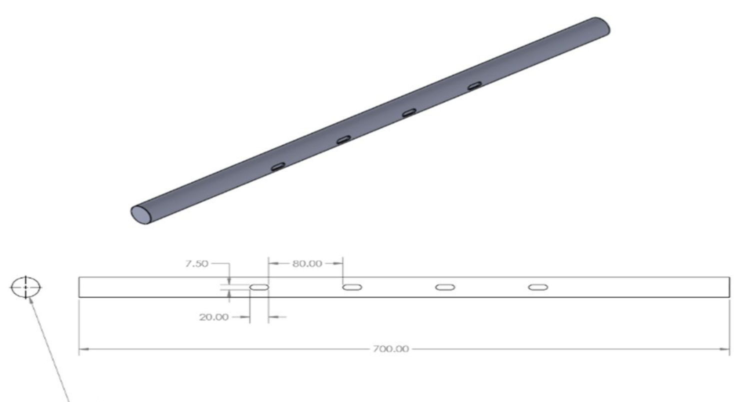
$T = \frac{P}{(\frac{2\pi N}{60})} = \frac{1000}{\frac{(2\times\pi\times500)}{60}} = 19.09$ N.m

$T = 19.09\times10^3$ N.mm

Ra + Rb = 800N [Assume Pc = 400N & Pd = 400N]

Taking moment at point A

(400×160) + (400×240) = (Rb×400)



(Fig. 8 Shaft)

Rb = 400N

Ra = 400N

b) Bending moment diagram (BMD)

Ma = 0

Mb = 0

Mc = 400×160 = 64000 N.mm

Md = 400×160 = 64000 N.mm

c) The given shaft is subjected to both twisting and bending.

d) Here the shaft will be design based on twisting moment and bending moment.

$T = 19.09 \times 10^3$ N.mm

Bending moment at point C

Mc = 400 × 160 = 64000 N.mm

Equivalent twisting moment is given by

$T_{eq} = \sqrt{(K_t \times T)^2 + (K_b \times m)^2}$

Where,

K_b = combined shock and fatigue factor applied to bending moment

K_t = combined shock and fatigue factor applied to torsional moment

Take $K_b = 2$, $K_t = 2$

$T_{eq} = \sqrt{(2 \times 19.09 \times 10^3)^2 + (2 \times 64000)^2}$

$T_{eq} = 133.57 \times 10^3$ N.mm

For diameter

$\tau = \frac{T_{eq}}{\frac{\pi}{16} \times d^3}$

$d^3 = \frac{T_{eq}}{\frac{\pi}{16} \times \tau}$

From material property

$\tau = 78.67$ N/mm^2

$d^3 = \frac{133.57 \times 10^3}{\frac{\pi}{16} \times 78.67}$

d = 20.52 = 30mm

(We are considering shaft diameter d = 30mm with factor of safety)

B. Design of Simple Harmonic Motion Cam (SHM)

h_m = 10mm σ_{yt} = 400N/mm^2

r_b = 40mm θ_r = 150

b = 16mm θ_d = 30

N = 500rpm θ_f = 150

F = 400N/mm^2 θ_d = 30

1) During accent

2) Angular velocity of cam

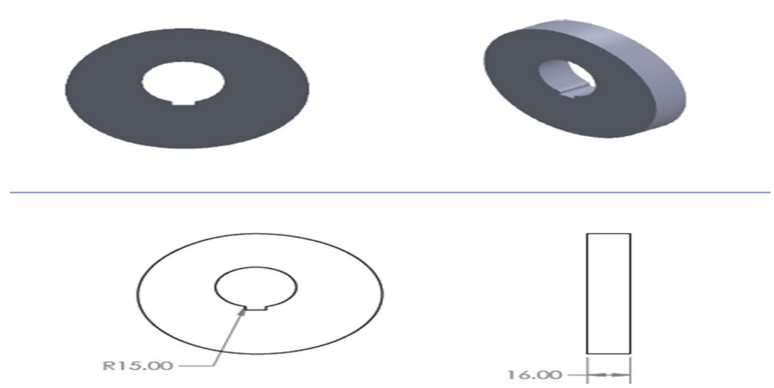
$\omega = \frac{2\pi N}{60} = \frac{2 \times \pi \times 500}{60} = 52.35$ rad/s

3) Velocity of cam

$V_{max} = \frac{h}{2} \times \frac{\pi\omega}{\theta_r}$

$= \frac{10}{2} \times \frac{\pi \times 52.35}{150 \times \frac{\pi}{180}}$

= 314.1 mm/s



(Fig.9 SHM Cam)

Acceleration of cam

$a_{\max} = \frac{h}{2}\left(\frac{\pi\omega}{\theta_r}\right)^2$

$a_{\max} = \frac{10}{2}\left(\frac{\pi \times 52.35}{150 \times \frac{\pi}{180}}\right)^2$

$a_{\max} = 19.73 \times 10^3$ mm/s^2

$a_{\max} = 19.73$ m/s^2

4) During descent

- Velocity of cam

$V_{max} = \frac{h}{2} \times \frac{\pi\omega}{\theta_F}$

$V_{max} = \frac{10}{2} \times \frac{\pi \times 52.35}{150 \times \frac{\pi}{180}}$

$V_{max} = 314.1$ mm/s

Acceleration of cam

$a_{\max} = \frac{h}{2}\left(\frac{\pi\omega}{\theta_F}\right)^2$

$a_{\max} = \frac{10}{2}\left(\frac{\pi \times 52.35}{150 \times \frac{\pi}{180}}\right)^2$

$a_{\max} = 19.73 \times 10^3$ mm/s^2

$a_{\max} = 19.73$ m/s^2

C. Design of snail cam

$h_m = 10$mm

$r_b = 40$mm

$b = 16$mm

$N = 500$rpm

$F = 400$N

$\sigma_{yt} = 400$N/mm^2

$\theta_r = 270$

$\theta_F = 0$

$\theta_d = 90$

Angular velocity of cam

$\omega = \frac{2\pi N}{60} = \frac{2 \times \pi \times 500}{60} = 52.35$ rad/s

Linear Velocity of cam

$V_{max} = \frac{h}{2} \times \frac{\pi\omega}{\theta_r}$

$= \frac{10}{2} \times \frac{\pi \times 52.35}{270 \times \frac{\pi}{180}}$

$= 174.5$ mm/s

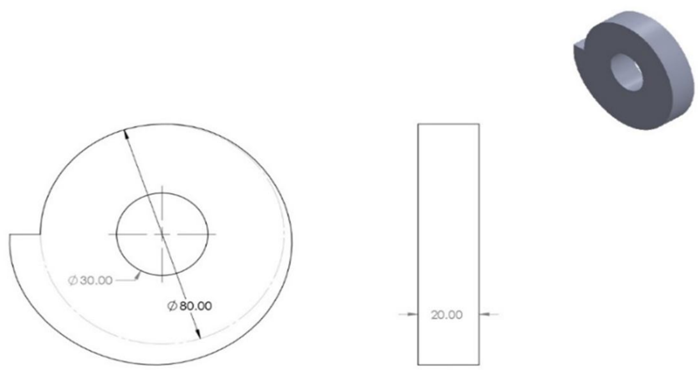
Acceleration of cam

$a_{\max} = \frac{h}{2}\left(\frac{\pi\omega}{\theta_r}\right)^2$

$a_{\max} = \frac{10}{2}\left(\frac{\pi \times 52.35}{270 \times \frac{\pi}{180}}\right)^2$

$a_{\max} = 6090.05 \times 10^3$ mm/s^2

$a_{\max} = 6.09$ m/s^2



(Fig.10 Snail Cam)

D. Design of roller follower

$d_r = 30$mm (diameter of roller)

b = 14mm (width of roller)

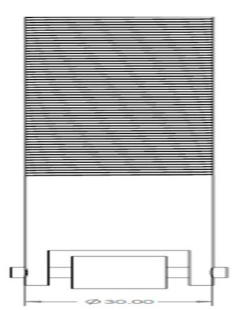
Diameter = 30mm

Thread = M30×2

1) Design of roller pin

$\tau = 45$N/mm^2

$F_{max} = 2\pi\left(\frac{d_p^2}{4}\right)(\tau)$



(Fig.11 Roller)

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$400 = 2\pi\,(\frac{d_p{}^2}{4})\,(45)$

d_p = 2.37mm = 4mm

(so we are considering d_p = 8mm with FOS=2)

Table I
Part List With Dimension

Sr.no	Component	Dimension	Material	Quantity
1	Shaft	Diameter: 30 mm Length: 700 mm	Mild steel	1
2	SHM Cam	Base circle radius: 40mm Maximum rise: 10mm Width: 16mm	High carbon steel	2
3	Snail Cam	Base circle radius: 40mm Maximum rise: 10mm Width: 16mm	High Carbon steel	2
4	Roller Follower	Roller radius: 30 mm Roller width: 14 mm Roller pin diameter: 4mm Body diameter: 30 mm Body length: 150 mm	Mild steel	4
5	Spring	Wire diameter: 4mm mean coil diameter: 24mm no. of coil: 7 solid length: 28mm Free length: 44mm	Stainless Steel	4
6	Plate	Length: 600 mm Width: 600 mm Thickness: 5 mm	Mild steel	1

(Fig.12 Vibration Stimulator)

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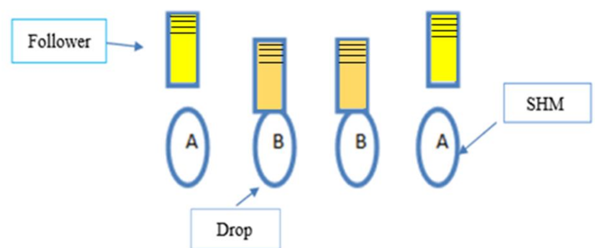
V. RESULT

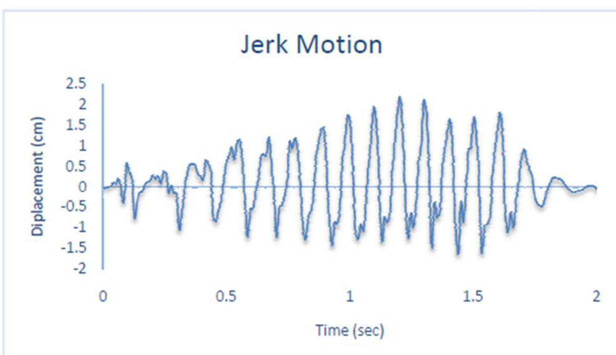
To obtain different kind of output we are using 2 different types of cam profile i.e. one is SHM cam which will provide uniform motion and other one is snail cam which will provide sudden drop motion means not uniform motion. By this we will get 2 different kind of variation in output which will be very helpful in observing defect. As you can see fig.13 & fig.14 which shows the setup for drop cam and SHM cam respectively. To measure this output, we used FFT analyzer which show the result in displacement vs time graph form. As you can see fig.15 & fig.16 which shows the graph of output of vibration stimulator.

In this experiment, we provided 1 cm as an input in jerk setup with which it tends the periodic up and down movement, but the result recorded in graph as shown in fig.15 acts as 2 cm maximum in upward direction & -1.4 cm minimum in downward direction. Same we done with SHM setup we provided 1cm amplitude, a peak of 1.16 cm is recorded in upward direction & 1.29 cm is recorded in downward direction as shown in fig.16. the obtained graph is to be compared with the standard one and from that we can say whether the product is defect free or not.

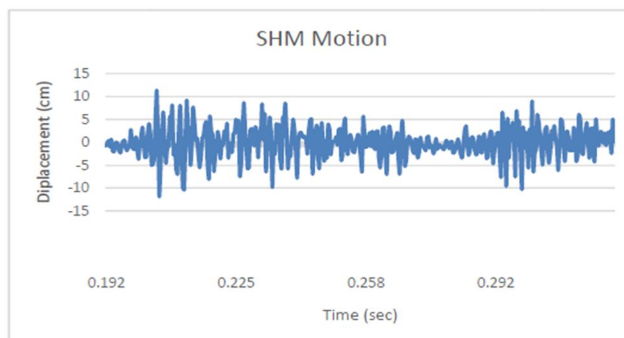
(Fig.13 Jerk Motion)



(Fig.14 SHM Motion.)



(Fig.15 O/P of jerk motion)



(Fig.16 O/P of SHM motion)

VI. ANALYSIS

The graphs obtained by FFT analyzer with the assistance of accelerometer are slightly out of range due to following reasons:

A. Insufficient damping because the setup isn't fixed to the bottom.
B. Required contact stresses between follower bearing and cams can't be measured.
C. Friction between roller and roller bearing is causing slight slipping of the roller initially.

VII. CONCLUSION

The stimulator can be used for the rpm value of the motor up to 500 rpm or we can say up to 1000 rpm. The variation observed in graph indicate us the damping provided to the setup was not up to the mark means more weight is to be added. By properly grounding the base of system or by using vibration dampening pads, sufficient damping is can be provided, which can give better accuracy. the utilization of a ball bearing as a roller within the roller follower will reduce the friction between the roller and cams and also reduce the strain on the roller bearing. this might increase the lifetime of both the roller and therefore the cams.

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