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SCIENCE BEHIND THE MULTI-PURPOSE STRENGTH-BASED SET-UP FOR VIBRATION TESTING OF MACHINE ELEMENTS – A STATE OF ART

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ABSTRACT
The science of vibration analysis of any machine element is very vital. This analysis not only defines the health of the element but also determines the effect of various parameters on the modal analysis of the element. To perform the vibration analysis experimental, the first and most important step is to have strong and sturdy vibration test set-up. This set-up is helpful in determining natural frequencies using any kind of measurement devices like Fast Fourier Transform. The literature survey has helped in technical aspects of design of the set-up. The material selection, various functions, purposes, dimensions, manufacturing processes in the development of set-up are discussed in the paper. It is the requirement to produce very strong and sturdy set-up to avoid its self-vibrations. Accordingly, the material has been selected. Also, the for the robust construction, best manufacturing processes and practices have been deployed.

Keywords: science, vibration, set-up, strength, machine elements.

I. Introduction

To execute the steps of project which are said in problem definition, the first step is to arrange an accurate test rig to conduct experimental trials. The different types of set-ups shown in the literature papers had studied thoroughly. The guidelines from many authors are also considered such as Dr. S. K. Maiti [4], [5] from IIT Bombay. Main constraints required for design of set-up are:

1) It should be strong, sturdy that it should not add its own vibrations during experimental trials.
2) Different boundary conditions can be accurately achieved on it.

Hence it has been decided to design such a set-up on which following facilities can be provided.

a) Variations of boundary conditions like cantilever, simply-supported, fix-fix, overhanging etc.
b) Variations in shape like beams, shafts, plates etc.
c) Variations in cross-section like square, rectangular, circular etc.
d) Variations in the length and width etc.

II. Components of Set-up

A) Table Legs

Obviously, the construction of set up starts from foundation. According to the guidelines from the experts like Dr. S. K. Maiti, Dr. D. W. Panday, the strong and sturdy set up will give more accurate results. Hence, before starting the thought process of set-up, it has been decided that all components should be of larger strength, weight, volume so that it will not have its own vibrations.

The hollow pipe or round bar may impact over testing results. Instead of that thick angles will be suitable. The standard angles available in market are 40 x 40 x 4 mm. and 50 x 50 x 5 mm. (PSG Design Data Book) [16]. Hence the L-shape standard angles are selected for making the legs structure of set-up. These legs are strongly welded to thick rectangular plates so that in future, these legs and plates can be bolted to concrete foundations. These foundation plates are having size of 125 x 75 x 10 mm. these plates are having drilled holes of diameter 15 mm at a distance between them of around 100 mm.

The extreme length of beam to be tested is kept at around 1000 mm. Hence the length of table should be more than 1 meter. The distance between two legs is decided to be 1450 mm. As the length is sufficiently high, instead of having only four legs, one more pair of legs should be placed along the length, which will act as middle support. Hence, total six legs (i.e. three legs pair) should be used.

The height of legs should not be much high or much smaller, otherwise the testing with FFT analyzer for beams and plates become cumbersome. Hence the height of 700 mm is decided by studying some actual existing test set-ups. The figures drawn with CADian Mech 2006® are shown at the end of this chapter.

B) Table Top Frame

Once we attach all the angles of legs together and weld them, we get a frame for next assembly part which is table top frame. This table top frame is also made up of standard angles of size 50 x 50 x 5 mm. Total four angles are used and they are welded together as shown in figures attached at the end of this chapter. This frame, after welding, is kept over the table legs and again welded strongly. The length of this frame is also 1450 mm and width are 400 mm.

As on this frame the thick metal plate is to be welded, we have kept the angles in inverted way. It means that flat L-shape arm of angles are facing on top side, while the hollow portion i.e. corner of L-shape is facing on floor side. At this position, it becomes easier to keep the top plate and weld it. But at the same time, it also gives the strength to plate as well as weld and hence will not cause for more vibration.

C) Table Top Plate

This is 10 mm thick plate, mounted and welded on table top frame. This is continuous metal plate and it does not have any joint or gap. As already stated above, the angles of top frame are kept inverted. Hence on the flat portion of angles, top plate can be easily joined. A continuous welding confirms a strong assembly of base and top plate. Now it is ready for mounting of other components on it.

To hold the testing objects like beams, plates, rods etc., heavy steel jaws need to be prepared. For holding these objects and also to get accurate vibration results, these holding jaws should also be very strong. Hence, we have to think about their arrangement during designing of top plate.

On this top plate, on one side we keep one block fixed and on other side the block is in moving position. The reason behind moving block is to adjust the beams of varying length and to achieve different boundary conditions. Now when we want to fix the moving block at one particular location, then we have to bolt it to the top plate tightly. Hence, we have to provide holes to this top plate at regular intervals.

The maximum length of beam for testing is maintained at 1000 mm but in future, we should follow the practice on short beams also. Hence, the steps 100 mm are decided for shorter beams such as 900 mm, 800 mm, 700 mm and so on. For accommodating such short lengths, the moving block should also move in same steps. Hence, the holes for moving block fixation are drilled at the regular interval of 100 mm and such 11 rows are made drilled on top plate. The center-to-center distance between holes should maintain accurately so that moving block can be exactly placed at desired location. On one side of this plate, some distance has been kept for placing the fixed block, while from back side again some space has been left for the fixture of free-free beams. These all details can be revealed in the diagrams attached at the end of this chapter.

D) Blocks and Jaw Plates

Blocks are simply the supports for jaw plates which are used to hold the beams firmly under testing. These blocks are made up of thick heavy metal plates joined together in square shape and then bounded by bottom and top plates.

The plates of block are 10 mm thick and are of height300 mm. Four plates are used to form one a single block. These four plates are joined by continuous welding. Then, a plate of 150 x 150 mm and thickness 10 mm is welded at the bottom of the block and then this whole assembly is fixed to the open space on one side of table top plate. This block will be treated as fixed block to hold the beam firmly from one side. At the top of this block, a same plate i.e. 150 x 150 x 10 mm is welded. Four holes are drilled to this top plate so as to fix the heavy jaw plate. The two blocks are of same size and height. The only difference is that one is fixed while other is detachable.

Jaw plates are heavy plates of size 150 x 150 x 10 mm and are having four holes for bolting purpose. Such six plates are made, out of that four are welded to blocks and two are free for holding the beams to blocks. Thus, the beams under study are sandwiched between these plates and hence called as jaw plates. The centre-to-centre distance between the holes are same as that of holes provided on table top plate and free jaw plates.

E) Fixture and Hooks for Free-Free Beams

The experimental set- up is designed to make it more generalized so that various boundary conditions can be achieved. Hence previously explained set-up is having extension at top side for free-free condition.

This fixture is made up of 50 x 50 x 5 mm standard angles. Its height is about 600 mm. the 100 mm extension is provided to this fixture so that hooks can be provided to this fixture. The hooks are required to attach the strings with which we can hang the beams and can achieve free-free boundary condition. Total 10 hooks provision is given to this fixture at a distance of 100 mm so as to achieve different beam lengths.

III. Manufacturing Details of Experimental Set-up

Following table shows a quick review of set-up dimensions, material, and manufacturing process.

Table 1 : Manufacturing and dimensional details of experimental set-up

Sr. No.	Part Name	Material	Dimensional Details	Manufacturing Processes Involved
1	Table Legs (10 nos.)	Cast iron	Angle : 50 x 50 x 5 mm. Angle : 40 x 40 x <u>Overall size</u> Length : 1450 mm. Width : 400 mm. Height : 700 mm.	Gas cutting, hand grinding, continuous welding, finishing.
2	Foundation plates	Cast iron	Length : 150 mm. Width : 75 mm. Thickness : 10 mm.	Gas cutting, welding, drilling, hand grinding, finishing.
3	Table top frame	Cast iron	Angle : 50 x 50 x 5 mm. <u>Overall size</u> Length : 1450 mm. Width : 400 mm.	Gas cutting, hand grinding, continuous welding, finishing.
4	Table top plate with holes	Cast iron	Length : 1450 mm. Width : 400 mm. Thickness : 10 mm.	Gas cutting, hand grinding, drilling, finishing.
5	Blocks (2 nos.)	Cast iron	Plate thickness : 10 mm. Square shape : 100 mm x 100 mm. Height : 300 mm.	Gas cutting, continuous welding, hand grinding, finishing.
6	Jaw plates (6 nos.)	Cast iron	Square shape : 150 mm x 150 mm. Thickness : 15 mm.	Gas cutting, drilling, continuous welding, hand grinding, finishing.
7	Fixture and hook arrangement	Cast iron	Total length of fixture : 1450 mm. Height of fixture above table top plate : 600 mm.	Gas cutting, welding, hand grinding, finishing.

			Angle : 50 x 50 x 5 mm. (5 nos.) Fixture protruded for distance of 100 mm. Hooks spread over distance of 1020 mm for total 10 nos.	
8	Over – all cost of experimental test set-up : - Rs. 11,000/-			

IV. Assembly Details

First of all, all the components are produced as per above said dimensions using above manufacturing operations. Then fabrication started from welding of table legs and angles with utmost care. The foundation plates are welded to legs considering straightness as important factor. This is followed by welding the table plate on the top of table. Then, one block is welded permanently on one side of table. The other is bolted on other side which can be moved any time along the length or it can be kept separately. Angles are welded to table for hook arrangement. Then by taking nut and bolt we can fix the beam on blocks using fixing plates. The experimental set-up is now ready for trials. Following figure shows actual photograph of set-up.

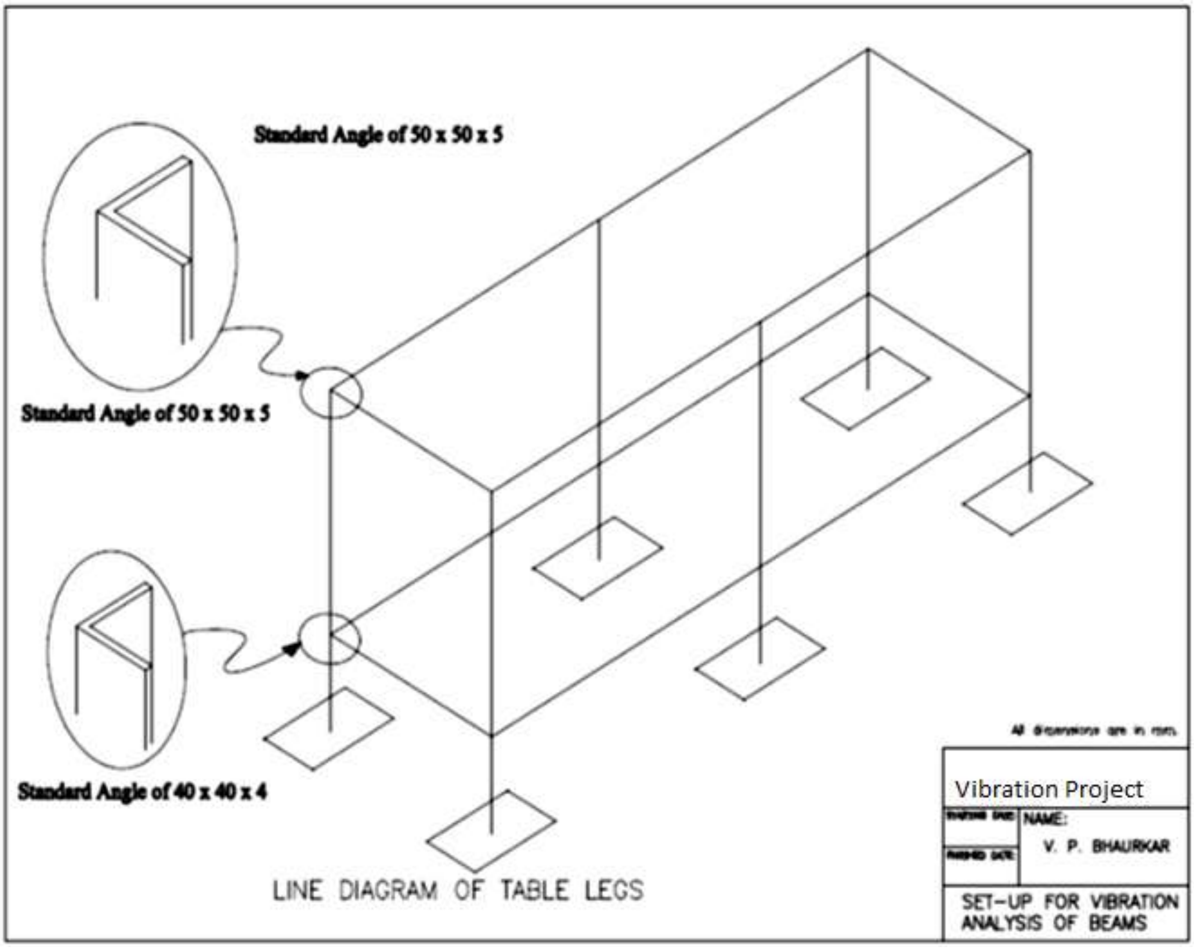

Figure 1: Experimental set-up of table legs (3-D presentation)

Figure 2: Actual experimental set-up for vibration analysis and crack detection

III. Conclusion

It is studied during this research, that the design and development of set-up is equally important to the study of vibration of machine element. It is an art of designing the set-up considering all constraints from the literature. Also, it is a science of applying basic knowledge of vibration, manufacturing processes, drafting softwares to design and develop the overall set-up. After complete assembly of set-up, it has been observed that whatever the precaution taken during design stage, was worthwhile. The natural frequencies of a beam obtained from experiments on this set-up, was found agreed to that of mathematical output. It shows that, the set-up presented in this paper is now helpful and correct for further vibration study of any machine element.

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