Study of Electronic Direct Digital Control (DDC) Panel using Mechanical Vibration Exciter

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Abstract - *Main purpose of this paper was to study the effect of vibration on electronic Direct Digital Control (DDC) panel. During transportation these panels get damaged due to vibrations. So under this work a vibration exciter was design to vibrate the electronic DDC panel with different frequencies. Mechanical vibration exciter is used to generate these vibrations. The maximum dimension of panel was 400 x 210 x 180 mm. For finding the natural frequencies of panel modal analysis was done in ANSYS WORKBENCH 16.0. After that Fixture was design which was used to mount the DDC on it for testing. Natural frequency of fixture should be greater than DDC panel so that resonance doesn't occurs in it. The force required to produce vibration was depend on mass of DDC panel and fixture so mass of fixture should be optimized. After the design vibration table was manufactured and test were taken. Variable Frequency Drive (VFD) was used to control speed of vibratory motor. After testing the location of damages found out and appropriate remedies were found to minimize its damages.*

Key Words: Mechanical Vibration Exciter, DDC panel, Fixture, Modal analysis, VFD.

1. INTRODUCTION

A vibration exciter is a machine which produces mechanical vibrations which are used in our case to test the object. The vibration exciter is being designed to produce a required range of harmonic or time dependent excitation force and displacement through a given range of frequencies. This machine or a system can be mechanical, electro hydraulic or electro-dynamic in nature. Different types of vibration exciters are available in the market which was too costly for small scale applications, so there was a need to design a relatively low cost exciter which can be used for low frequency range and fulfils the need of project. This can be used for experimentation purpose and testing product at different frequencies to achieve the goal of project.

During transportation of DDC panel some damages occur in the panel due to vibration in transport vehicle. In order to find out location and frequency at which damage occurs a mechanical vibration exciter is designed. Fixture was design on the basis of natural frequency of DDC panel so that no resonance occurs in it during testing. Using modal analysis in ANSYS Workbench 16.0 natural frequencies were found. Its value should be more than the testing object. After manufacturing the test was conducted and results were obtained as amplitude of test object at natural frequencies. As in case of its working, the natural frequency should be in lower range for the proper excitation which the project needs to achieve so as to use it for small parts.

1.1Failure Modes of Electronic Devices

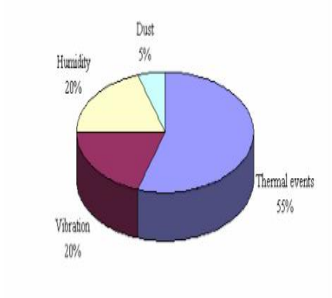

Fig. 1- Failure percentage of electronic components

Electronic devices which are used in control, guidance and communication systems are one of the most important parts of modern control systems. Electronic systems are composed of many different materials and interfaces which make system very complex. In addition to complexity, systems are subjected to various environmental conditions during storage, handling, transportation and operation. Therefore, various failure modes such as mechanical, thermal and electrical are encountered in electronic systems. Fig1.1 shows the percentage of failure of electronic control system.

1.2 The Objective of Present Work

- The Vibration Exciter should Work between the designs frequency zone.
- Generated forced vibration frequency should not match with Natural frequency of fixture.
- To develop physically smaller, simpler, more reliable and less costly.
- It fulfills the requirements of company. So that to focus on the DDC panel remedies.

2. EXPERIMENTAL SETUP

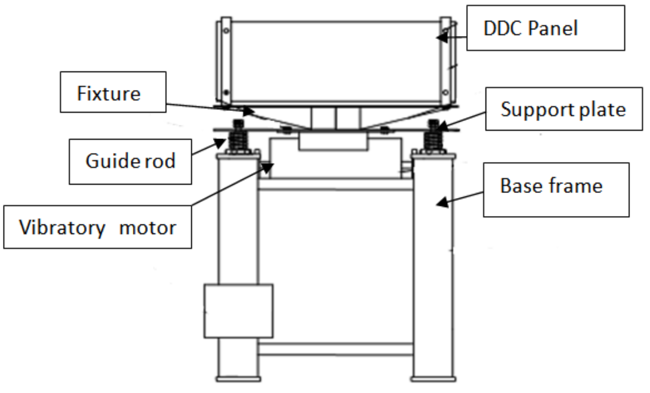

Fig. 2 – Schematic diagram of vibration exciter

Direct Digital Control (DDC) panel in control system of Dynamometer test rig is shows the different parameters value like Torque, Speed, Temperature, and Power. It has number of PCBs attach for functioning it. There is Soldering on these PCBs during transportation due to vibration these soldering get damage or loose contact occurs. So in order to find this problem vibration test is done.DDC panel and Test Setup is shown in below figures.

Fig. 3 – DDC panel (Test Object)

For testing First of all on main switch then by pressing push button increase the frequency of Variable Frequency Drive (VFD) by operating knob. VFD is use for controlling speed of vibration motor. First operating frequency should be low (15 Hz). Then increase by step by step (up to 26 Hz). Displacement and velocity measure by Magnetic Sensor Vibrometer.

Fig. 4 – Actual Test Setup

2.1 Fixture

Fixture is used as intermediate between testing part and vibration exciter. It should be stiff so it's natural frequency more than natural frequency of testing part. It should be so strong to take weight of testing part and other mountings. Also its weight will be as low as possible.

Fig. 5 - Fixture

2.2 Calculations

2.2.1 Design of Fixture

Main Plate

According to Rayleigh-Ritz Criteria

(From Bruel and Kjaer)

$\omega^2 = (\pi^4 \text{ x } D/b^4 \text{x} \rho \text{x} h) \text{ x } \lambda^2$

Where

h = Thickness of plate

λ = Mode const.
= (0.39+0.96x (b/l) ^{2} +0.36x (b/l) ^{4})$^{1/2}$
By simplifying the equation
F =23.5x10^4x (h/b^2) x λ 1)
OR
F =23.5x10^4x (h/l^2) x λ {h, l = Dimension in cm.}
F_{min} ⇔ Max (b,l)
For design of fixture we take safe natural frequency as 1000 Hz.
h = (F xl^2)/(4x23.5x10^4x λ) 2)
= (1000x196.46^2) / (4x23.5x10^4x1.31)
= 3.11 ~ 3.5 mm.
By considering Manufacturing Allowances
h = 6 mm
Side braces (small side)
(b/l) = 50/50 = 1
λ = 1.31
By putting this value in equation 1 we get
h_1 = 0.81 ~ 1 mm.
By considering Manufacturing Allowances
h = 3 mm
Side braces (large side)
(b/l) = 190/50 = 3.8
λ = 5.88
h_2 = 2.48 ~ 2.5mm.
By considering Manufacturing Allowances
h = 3mm

2.2.2 Design of Helical Spring

Total Weight = 40 kg = 400 N.
Total No of Spring = Therefore force on each spring = 100 N
τ_{max}=0.3x S_{ut}
{Harden and Tempered (C65) Grade1 S_{ut}=1050 Mpa and C=8}
(From design data book by PSG)
= 03x1050
= 315 Mpa
τ_{max} = Ks x (8xpxc/πxd^2)
Where,
P = load in N
Ks = Wahl factor
C = Spring Index

$$k_s = \frac{4xc-1}{4xc-4} + \frac{0.615}{c}$$

$$k_s = \frac{4x8-1}{4x8-4} + \frac{0.615}{8}$$

k_s = 1.226
315 = (1.226x8x100x8)/(πxd^2)
d =2.81~3.2mm
D = C x d = 8x3.2 =25.6 mm ~ 25 mm
Now assume maximum deflection will be considered as 15 mm.
Therefore,
K= P/δ
= 100/15 = 6.67N/mm ~ 6.7 N/mm.
No of coil turns
δ = (8xpxD^{3}xN)/ (Gxd^4)
Where
G = Torsional Rigidity
G = 81370 N/mm^2
15 = (8x100x32^{3}xN)/(81370x4^4)
N = 10.23+2 =12.23 ~ 12 mm.
Solid Length = N x d = 12x3.2 = 38.4 mm
Total Length = Solid Length+ δ
= 38.4 + 15
= 55 mm
Pitch of spring
Pitch = (L- 3xd)/N
= (55-3x3.2)/10.23
= 4.44 mm.

2.3 Vibratory Motor

Vibratory motor use for generating the vibration and VFD is used for controlling the speed of motor. Below Table shows the Characteristics of motor.

Table 1 – Specification of vibratory Motor

Power	0.16 Kw
Centrifugal Force	1940 N
Weight	11.8 Kg
RPM	1440

Fig. 6 - Vibratory Motor

2.4 Experimental Results

By taking test on DDC panel the amplitude and velocity occur at different frequency and RPM as given in Table 2

Table 2- Experimental Analysis Frequency and Amplitude

Sr. No.	Speed (RPM)	Frequency(Hz)	Amplitude(mm)	Velocity(mm/s)
01	480	16	0.7	16.9
02	540	18	0.78	19.1
03	600	20	0.9	20.25
04	660	22	1.15	22.65
05	720	24	1.47	24.6
06	780	26	1.532	29.2

3. NUMERICAL METHOD

3.1 Modal Analysis

Modal analysis was done in ANSYS WORKBENCH 16.0 to find out natural frequency of Fixture as well as DDC panel so it's easy to understand the range of natural frequency to avoid resonance in fixture.

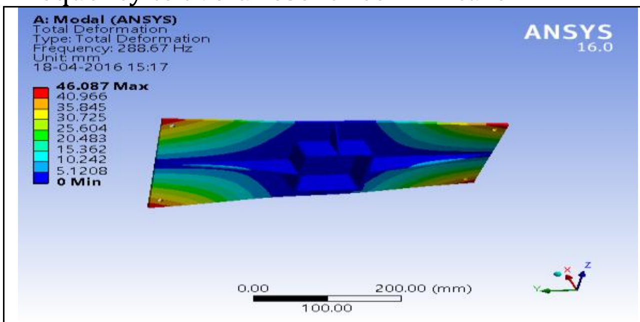

Fig. 7 – Modal analysis of fixture

Table 3– Natural frequency and amplitude of fixture

Mode Shape no.	Frequency(Hz)	Amplitude(mm)
1	288.67	46.05
2	289.65	46.19
3	382.96	41.87
4	399	42.402
5	892.71	41.147
6	902.36	41.857

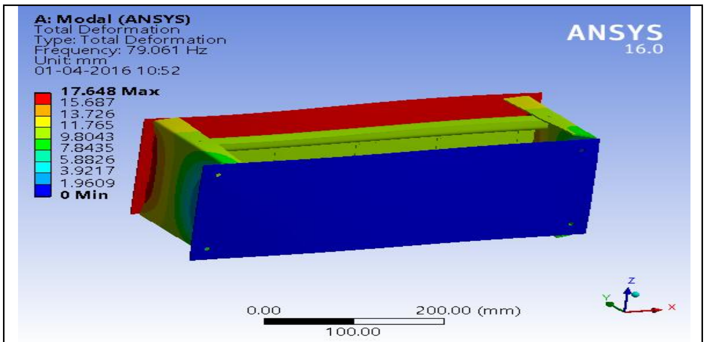

Fig. 8 – Modal analysis of Test object (DDC)

Table 4 – Natural frequency and amplitude of test object (DDC).

Mode Shape No.	Frequency (Hz)	Maximum Amplitude(mm)
1	52.345	39.81
2	64.182	41.28
3	79.061	17.65
4	110.42	63.11
5	124.36	66.42
6	139.4	39.51

3.2 Harmonic Response Analysis

Harmonic response analysis requires boundary conditions as Frequency range and load as force, displacement, acceleration. This gives output as stress, strain, displacement, and phase.

Boundary conditions

Frequency range –10 to 200 Hz.

Load as force – 1940 N.

Table 5- Harmonic Analysis Frequency and Amplitude

Sr. No.	Frequency(Hz)	Amplitude(mm)
01	16	0.96
02	18	1.02
03	20	1.135
04	22	1.26
05	24	1.28
06	26	1.375

4. RESULTS AND DISCUSSION

Table 6- Comparison between Harmonic analysis V/s. Experimental Analysis

Sr. No.	Harmonic Analysis Frequency Amplitude		Experimental Analysis Frequency Amplitude	
1	16	0.96	16	0.7
2	18	1.02	18	0.78
3	20	1.135	20	0.9
4	22	1.26	22	1.15
5	24	1.28	24	1.47
6	26	1.375	26	1.532

As the frequency or speed increases the amplitude of vibration also increases. As at high frequency more amplitude of vibration produces so initial it keep at low frequency then increases it slowly. The deviation occurs in results due to measurement of amplitude on vibrometer during testing.

5. CONCLUSIONS

From Table 3 it seems that, the natural frequency of fixture is more than DDC panel. After testing DDC panel at different speeds, next step was to check the DDC panel for proper working. Then proper remedies are found to solve this problem, like increase in the stiffness or strong the soldering on PCBs. Mechanical unbalanced vibration exciter is used as low frequency vibration exciter. Maximum frequency obtained is 50 Hz. So it is used for small parts and low frequency range.

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