VIBRATION CONTROL OF A HAND BLENDER WITH THE TUNED VIBRATION ABSORBER

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Abstract: *Hand Arm Vibrations (HAV) an acute problem with the human operated tools. The prolonged use of such vibrating instrument may cause serious injuries to the sensitive organs of human body. Tuned Vibration Absorbers (TVA) are the secondary device attached to the primary system to control its vibrations. Here an attempt has been made to design and simulate the Tuned vibration absorber for a Hand blender. The natural frequencies are obtained by the Modal analysis in ANSYS ® and the results are simulated in MATLAB®. The response of the hand blender is determined experimentally before attaching and after attaching TVA, a 27% reduction in Displacement RMS is obtained.*

Keywords: *Tuned Vibration Absorber, Hand blender, Hand Arm Vibration, Mass Ratio Tuning, Dual Mass Tuned Vibration absorber.*

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I. INTRODUCTION

The Hand blender is the daily use tool in the kitchen. HAV is one of the reasons of the post process fatigue. The same may cause serious injuries to the nervous system and the sensitive organs of the operator thus, it is required to search for a suitable means to reduce the vibration. Different concepts had been developed and employed in the vibration control area. These concepts are vibration damping, isolation, and vibration absorption. Dampers dissipate system energy, and vibration isolations prevent vibration transmission, while vibration absorbers transmit the vibration energy to a secondary system and then dissipate energy.

The idea of the vibration absorber was pioneered by Watts [1] in 1983 and Frahm [2] in 1909. The secondary system with mass-spring was considered as vibration absorber. Tuning of absorber i.e. adjusting either of the m,c,k parameters of the absorber such that natural frequency of the absorber becomes equal to the excitation force frequency. TVA for the electric grass trimmer have attenuated the vibration by 67% [4]. TVA for the control of HAV of the motorcycle handles had given remarkable results [5]. The lightly weighted TVA attached to the handle of the percussive machine allow suppression of the dominating harmonics of machine accelerations [6].

Here a Dual mass TVA is developed to avoid the resonance condition of a Hand blender and shifting the frequency away from the resonating frequency.

II. HAND BLENDER RESPONSE BEFORE ATTACHING TVA

In Figure 1 hand blender in as it is condition presented. When we are using it we feel heavy vibration. The causes may be heavy clearance in bearings, motor shaft etc.

By attaching the sensor of the FFT analyzer on the handle, the response that we are getting is as shown in Figure 2. The Vibration response shows that, the RMS displacement is 54.002 µm, and the maximum displacement of 9.716 µm resulted at the frequency 225.5 Hz. And at the frequency 100 Hz the displacement value is found below 1 µm.

Figure 1: Hand blender without TVA

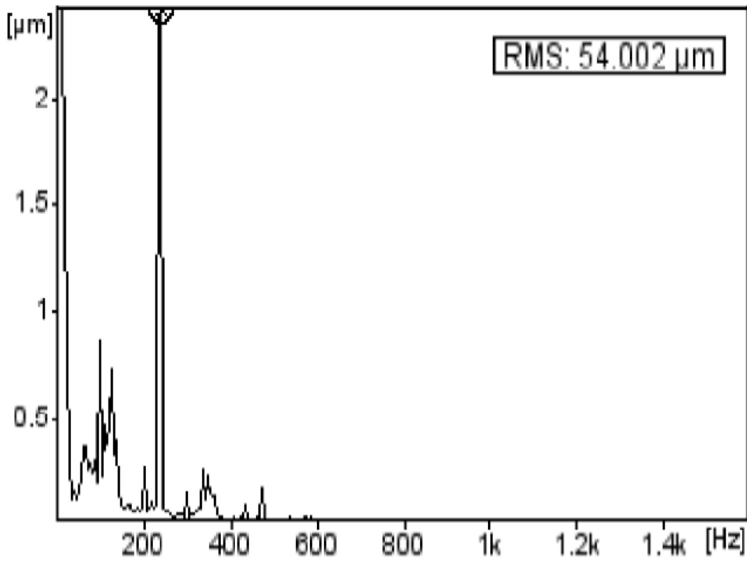

Figure 2: Vibration response of handle without TVA, Xaxis: Frequency in Hz, Yaxis: Displacement in μm

III. DESIGNING DUAL MASS TVA

The TVA is designed as a Dual mass so to nullify the bending moment effect due to TVA self weight.

Here two 50 gm mass is there on each threaded horizental beam so, one can move the mass to change the stiffness and thus the natural frequency of TVA. The natural frequency were determined by the numerical method FE Modal analysis

Figure 3: Dual mass TVA

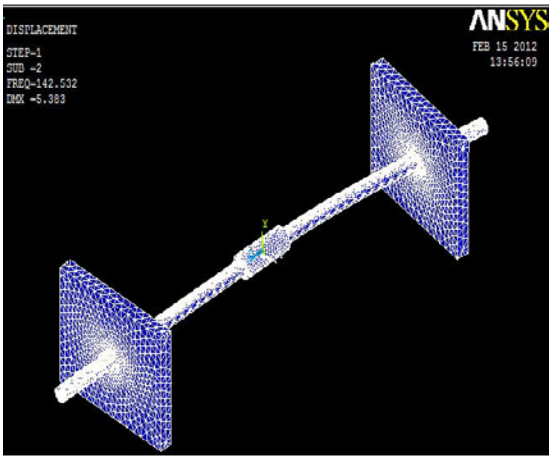

Figure 4: Mode shape for the TVA mass at 7 cm from center

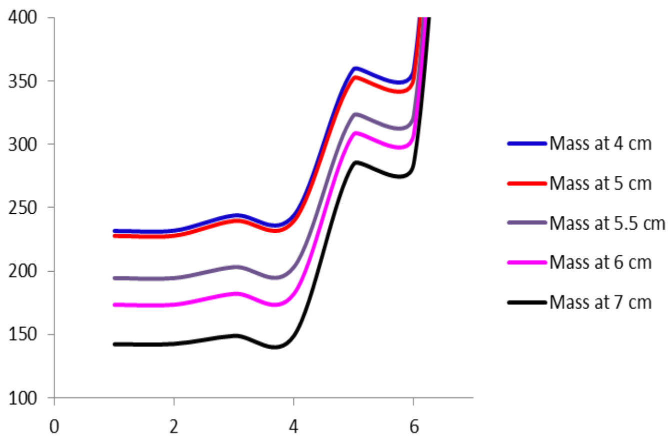

Figure 5: Natural frequency by FE Modal analysis for various mass locations on the beam. Xaxis: nthMode, Yaxis: Frequency in Hz

In Figure 5, we can see that for the mass location 5 cm from the TVA center for the first 2 modes we are nearer the disturbing frequency 225.5 Hz as found from the Figure 2. For the

5 cm location of mass the 1st and 2nd mode are giving frequencies 227.72 and 227.86 Hz respectively.

IV: OPERATIONAL MODAL ANALYSIS AND RESULTS OF THE HAND BLENDER WITH TVA

By moving the mass on the horizontal beam we are changing the stiffness and thus the natural frequency of the TVA. We have attached the TVA on the shaft at the location 1 i.e. just at the end of the handle and the beginning of the shaft.

Figure 6: Hand blender with TVA

The mass is moved turn by turn at 4, 4.8, 5, 5.5, 6, 6.5, 7, 8 cm on both the beam and handle vibrations are recorded.

Following are the results we are getting for various mass locations.

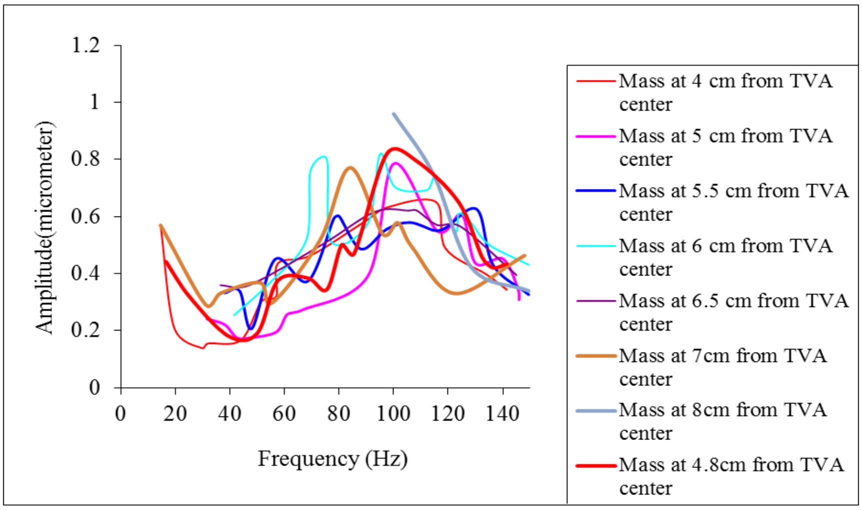

Figure 7: Displacement response of the handle for the frequency range 0-150 Hz

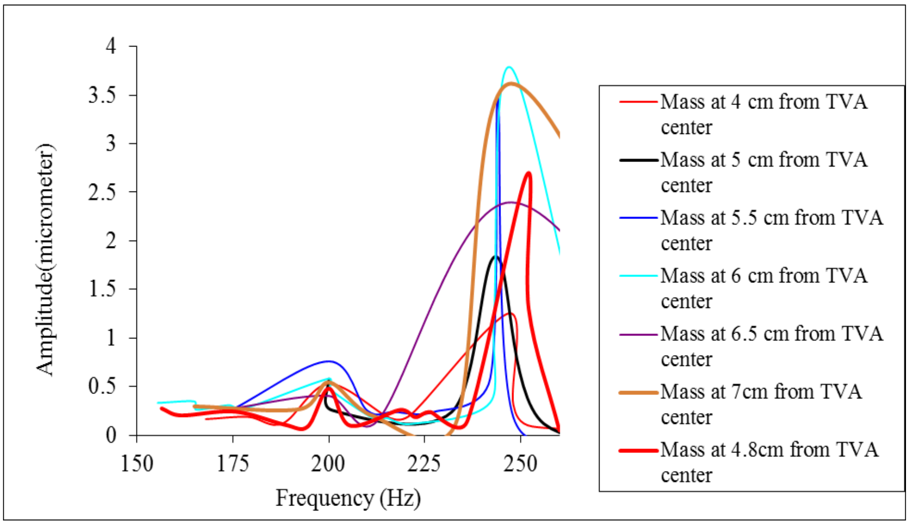

Figure 8: Displacement response of the handle for the frequency range 150-260 Hz

Here from the Figure 7 and 8, it is found that the mass location 4.8 cm and 5 cm from the TVA center are giving appreciable reduction in the displacement amplitude at the 100 Hz and 225.5 Hz. With the 4.8 cm location of TVA mass the displacement amplitude are 0.82 µm and 0.794 µm at frequencies 97.5 and 108.5 Hz respectively. And with the 5 cm location of the TVA mass the displacement amplitude are 0.785 µm, 0.549 µm, 0.39 µm for the frequencies 90.5, 100, 116 Hz respectively.

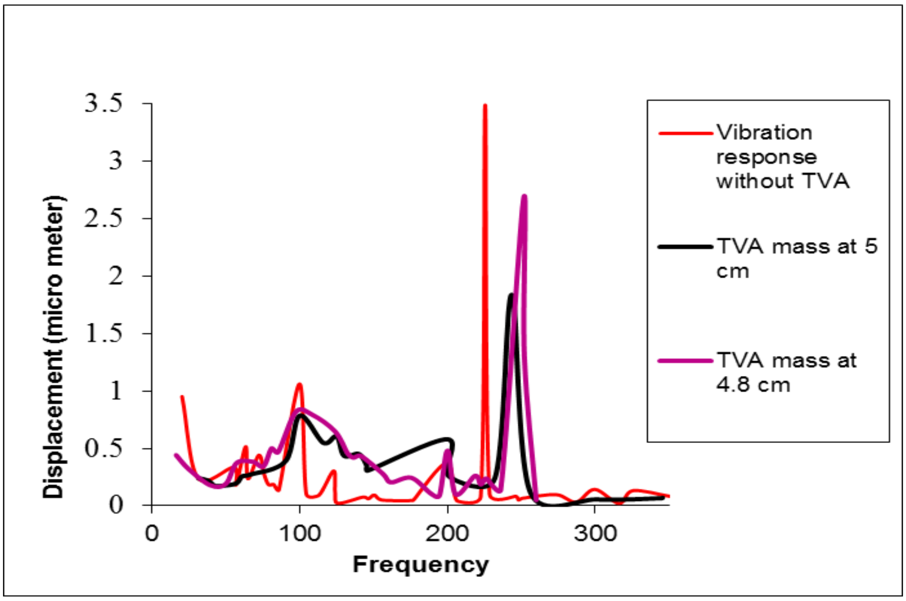

Figure 9: Hand blender response with and without TVA

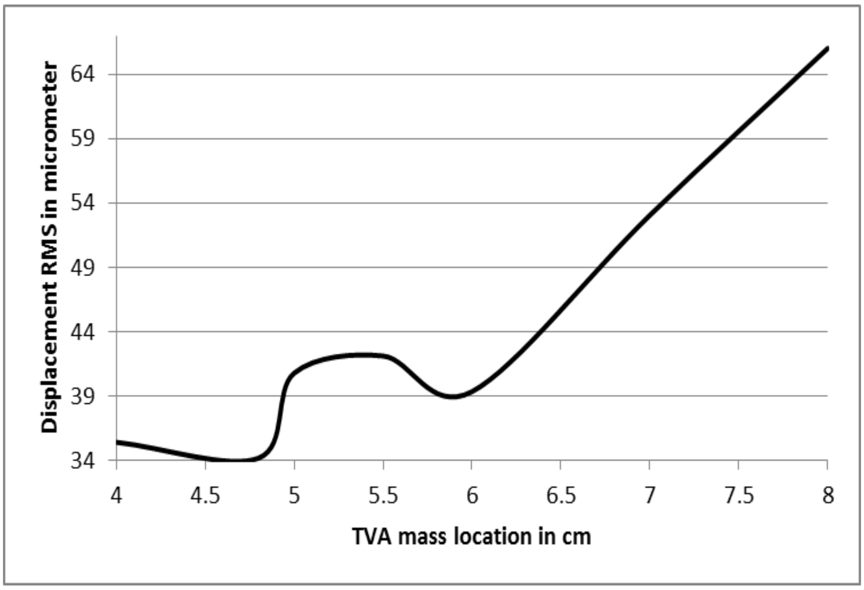

Figure 10: Displacement RMS of hand blender v/s TVA mass location

From the Figure 10, it is seen that, the distance 4.8 from the TVA center resulted in the minimum displacement RMS 34.182 µm.

V. THEORITICAL RESPONSE

For the determination of theoretical response the combined system is modeled as shown in Figure 11. The Hand blender is presented as lumped mass m_1 and TVA as mass m_2. The stiffness of the hand blender and TVA are k_1 and k_2 respectively. With the change of the location of the mass on the beam the k_2 is changing. The equation of motion by lagrange method are as follows,

$$m1\ddot{x}1 + k1x1 + k2(x1 - x2) = F\ sin\omega t$$

$$m2\ddot{x}2 + k2(x2 - x1) = 0$$

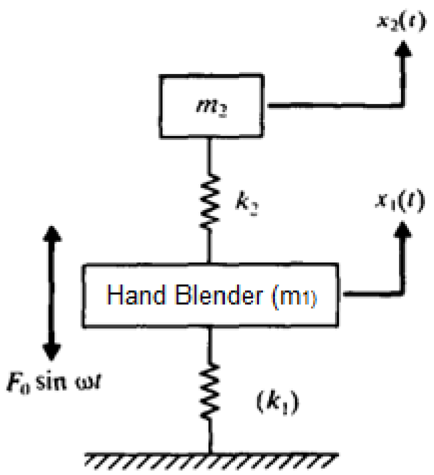

Figure 11: Hand blender with TVA

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The amplitude ratio equations are obtained by considering harmonic response x1 and x2[3].

$$\frac{X1}{Xst} = \frac{1-\frac{\omega^2}{q^2}}{\left(1+\frac{k_1}{K}-\frac{\omega^2}{p^2}\right)\left(1-\frac{\omega^2}{q^2}\right)-\frac{K_1}{K}} \quad \ldots \quad (1)$$

$$\frac{X2}{Xst} = \frac{1}{\left(1+\frac{k_1}{K}-\frac{\omega^2}{p^2}\right)\left(1-\frac{\omega^2}{q^2}\right)-\frac{K_1}{K}} \quad \ldots \quad (2)$$

With the attachment of the TVA the single degree of freedom system is converted to two degree of freedom system. Thus the resulting two new natural frequencies are obtained as follows [3].

$$\omega_{n1,2}^{2} = p^2\,[1+\mu/2 \pm \sqrt{\mu+\frac{\mu^2}{4}}] \quad \ldots \quad (3)$$

Here, µ is the mass ratio i.e. mass of the absorber to the mass of TVA. Mass of the hand blender is 0.818 Kg and of TVA is 0.174 Kg. thus the mass ratio µ is 0.2127.

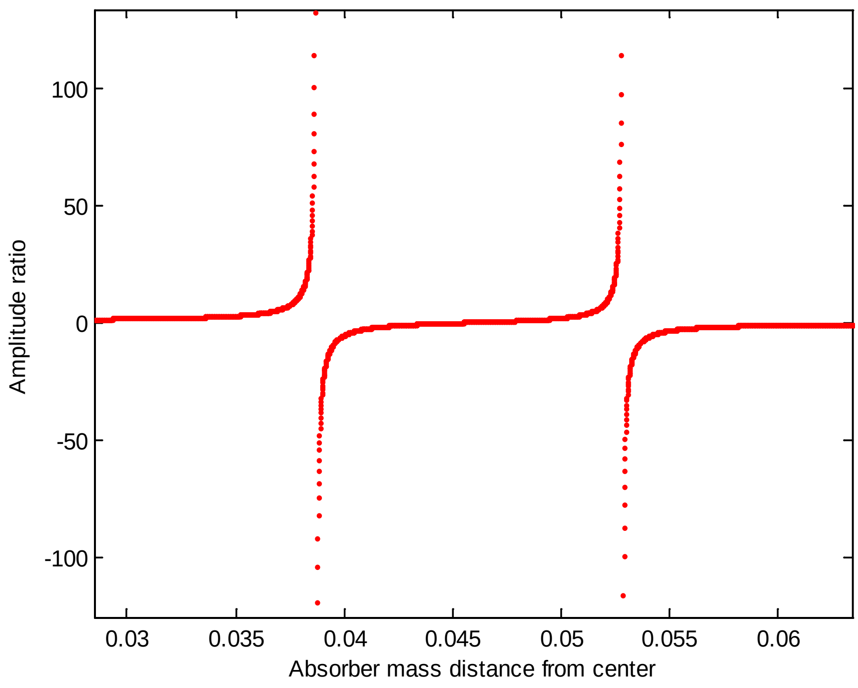

Figure 12: Amplitude ratio to TVA mass location from center

From the Figure 12 we found theoretically the safe operating range is with the TVA mass located between 4 and 5 cm from the center. From the equation (3) the resulting new frequency of the combined system are 180 and 283 Hz. From the Figure 9, experimentally we are getting new safe operating range as 200 and 251.5 Hz with the location 4.8 cm of TVA mass.

VI. VIBRATION RESPONSE OF THE SYSTEM WITH TVA MASS LOCATION 4.8 CM

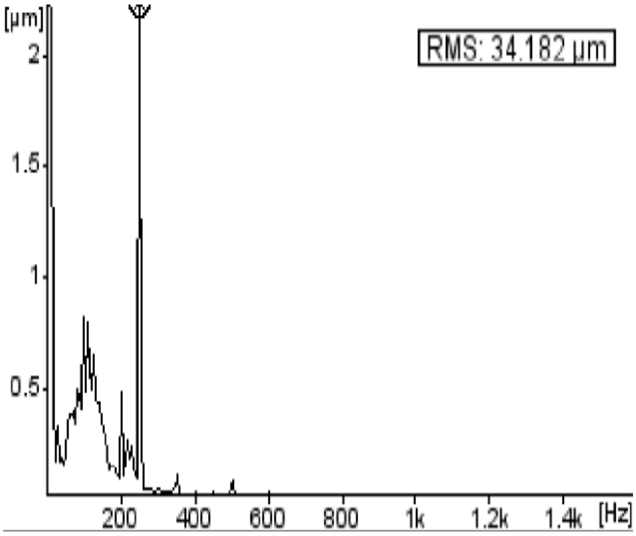

Figure 13: Vibration response of handle without TVA, Xaxis: Frequency in Hz, Yaxis: Displacement in µm

VII. CONCLUSION

TVA with mass located at 4.8 cm gives controlled response. The RMS displacement is reduced to 34.182 µm. which is 37% lesser than that without TVA. A deviation from this optimal mass location would result in higher displacement RMS.

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