Vibration Analysis of Work Holding Devices in Composite Materials

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Abstract— Vibration is the most important criteria to be taken into account while designing and also important for considering the safety. In the vibration analysis various parameters like velocity, displacement, acceleration, and amplitude are taken into consideration. These parameters are finding out by using accelerometer, a vibration sensor. The output from accelerometer is interfaced to labview software by data acquisition system. Analogue to digital convertor is used for interfacing with computer. The accelerometer is interfaced to DAQ by software. The labview software vibrating force, amplitude and acceleration are observed. Labview is used for analysis of Mild Steel whereas Ansys Workbench is used for analysing Fe-TiC. The labview software is used to observe the data and calculating Magnification factor, force transmitted, Force at Resonance, and other parameters. The calculated values compared between the workholding device made of mild steel and Fe –TiC composite materials is done.

Key words: Fe-Tic Composites, Labview Software, Ansys Workbench

I. INTRODUCTION

Vibration analysis is one of the important factors to be considered while designing the machine.. It also affects the machine efficiency of working atmosphere. One must be careful while determining the parameter. In this vibration analysis the parameter included are displacement, velocity, acceleration, resonance, amplitude, vibrating force and transmissibility.[2] The metal matrix composites have focused in the research area which have high fatigue strength, high strength to weight ratio, thermal stability and good wear resistance . The Metal matrix composite iron based MMCs widely used because which has the excellent mechanical properties and reduces the manufacturing cost. The reinforcing material of TiC used as to fabricate the MMCs is attractive benefits of low density, high melting point, and hardness and wear resisting properties. [1] Accelerometer is a device that is used to sense the acceleration developed in a particle. It is used as a sensor in vibration analysis. When a load is subjected to a machine vibration is created while operating to measure this vibration we use sensors. In such a way that accelerometer is a sensor used to measure the vibration.[4] Data accusation system is used to interface the output from accelerometer to computer. Labview software is used to obtain the curve corresponding to the vibration [8]. The Output of the accelerometer is obtained by software and data are observed.

II. EXPERIMENTAL ANALYSIS

A. *Vibration Analysis of Vice Mild Steel Using Labview*

Labview is used for analysis of Mild Steel work holding device, whereas Ansys Workbench is used for analysing Fe-TiC. The labview software shows the curves which is used to observe the data. These vibrations are sensed by accelerometer and the output is feed to DAQ and output of DAQ is interfaced with the computer installed with labview and DAQ driver software

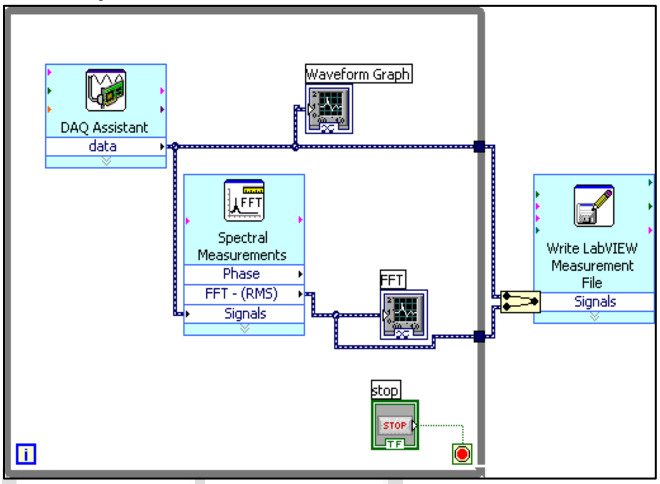

Fig. 1: Block diagram for amplitude-time and frequency-amplitude curve

The steps involved to find the observation are mount accelerometer to measuring system, wire the accelerometer to Data Acquisition system, and connect the DAQ to computer for visual output corresponding to accelerometer reading. Fig.1 shows that the block diagram for amplitude-time and frequency-amplitude curve. This analysis we found out the Acceleration-time curve, Amplitude-time curve and Frequency-amplitude curve.

B. *Waveform Graph*

This fig 2 shows the amplitude-time curve graph shows the amplitude of vibration for the workholding device made of mild steel is 0.0117mm.

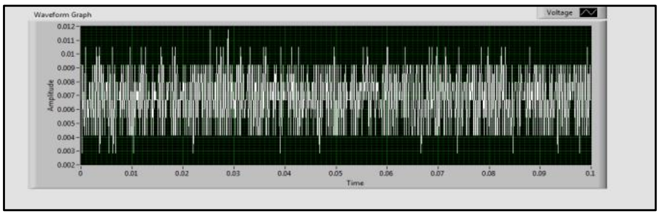

Fig. 2: Amplitude-time curve

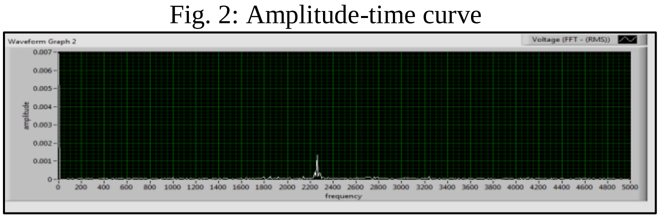

Fig. 3: frequency-amplitude curve

The fig 3 shows the frequency-amplitude curve the graph the Frequency of vibration for workholding deice made of mild steel is found to be 5000Hz

C. Acceleration-time curve:

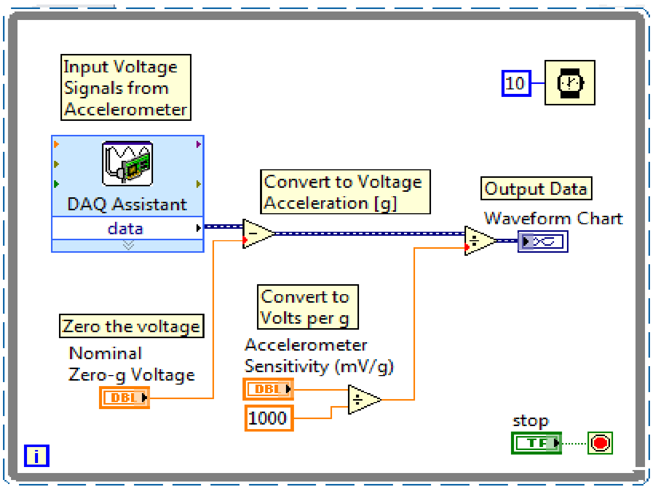

Fig. 4: Block diagram for acceleration-time

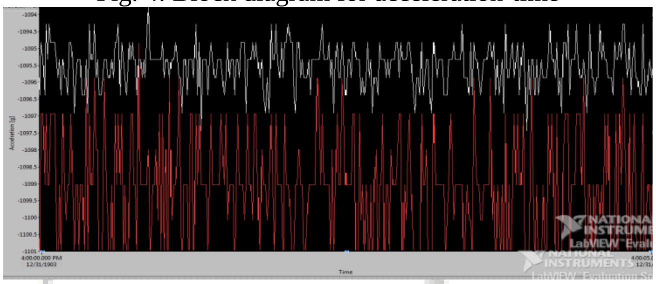

Fig. 5: Waveform graph for acceleration-time

The above fig 4 shows the block diagram for acceleration time curve circuit. fig 5 curve is used to found the acceleration of the workholding device made of mild steel is to be $1094 mm/s^2$ as maximum.

D. Mild Steel Properties

Frequency due to external force (f) = 5000Hz, Angular velocity (ω) = $2\pi*5000$ = 31415.92rad/s, Mass of the body (m) =17.81kg, Deflection of the body (δ) = 0.002075mm, The maximum amplitude is (x_{max}) = $0.012x10^{-2}$mm, Stiffness (s) = mg/δ = 17.81X9.81/0.002075 = $84.20x10^3$N/mm, Force acting on the work piece during milling (F) = 800N, Natural frequency of the system (ω_n) = 1943.28Hz

1) *Maximum amplitude*

$(x_{max}) = F/\sqrt{}\ (c^2\omega^2 + (s\text{-}m.\omega^2)^2$,Damping coefficient (c) =559.488N/mm/s

2) *Force at resonance* $F = x_{max.}*c*\omega_n = 1304.67N$
3) *Magnification factor* $(D) = x_{max} / x_0 = 6$
4) *Transmissibility* $(\varepsilon) = 1/\ ((f / f_n)^2\text{-}1),\ (\varepsilon) = 0.177$
5) *Force transmitted* $(F_T) = \varepsilon.F = 142.34N$

III. ANALYSIS OF VICE MADE OF FE-TIC

Ansys workbench is a analysis software used to measure the deformations, frequency, stress. Frequency is measured using Harmonic Analysis. It is a mode of analysis used to find generated frequency. Frequency-amplitude curve and Frequency-acceleration curve are generated using this platform. Stress produced due to Static force and cutting force is finding using this software. In this analysis vice

Length X	Length Y	Length Z	Volume	Mass	Centroid X	Centroid Y	Centroid Z	Moment of Inertia Ip1	Moment of Inertia Ip2	Moment of Inertia Ip3
244.18 mm	115.17 mm	425.25 mm	2.2695e+006 mm³	13.663 kg	55.542 mm	9.7856 mm	136.53 mm	1.0865e+005 kg·mm²	1.1603e+005 kg·mm²	28434 kg·mm²

Material is Fe-Tic Composite with a weight percentage of 60% of Fe and 40% of Tic. The reason behind choosing the above composite is to reduce the vibration the material should have high strength and fatigue strength.

A. Material Property Of Fe-Tic

1) *fibre volume fraction:*

$$V_f = \frac{\rho_m W_f}{\rho_f W_m + \rho_m W_f}$$

=(7950*0.480)/[(4650*0.72)+(7950*0.48)] = 0.532

2) *Matrix Volume Fraction* $V_m = 1 - V_f = 0.467$
3) *Youngs Modulus Of Composite Along Longitudinal Direction:*

$E_L = (V_f E_f + (1 - V_f) E_m)$ = ((0.532*440)+(0.469*210)) = 353.5GPa

4) *Youngs Modulus Of Composite Along Transverse Direction:*

$E_T = 1/ [(1 - V_f / E_m) + V_f / E_f]$ = 1/ [(0.467/210) + (0.532/440)] = 296.2Gpa

5) *Youngs Modulus Along X-Direction:*

$Ex=1/3E_L+2/3E_T$ = (353.5/3) + ((2*296.2)/3) = 333.85Gpa

6) *Youngs Modulus Along Y-Direction:*

$Ey=2/3\ E_L + 1/3\ E_T$ = ((2*353.5)/3 + (296.2/3) = 321.55Gpa

7) *Youngs Modulus Along Z-Direction:*

$E_Z = E_T$ = 296.2GPa

B. Poison Ratio Calculation:

Strain/ Poison Ratio	Force along X-direction	Force along Y-direction	Force along Z-direction
ϵ_x	1.66	0.16	0.16
ϵ_y	0.863	0.34	0.17
ϵ_z	0.937	0.18	0.37
Γ_{xy}	0.29	0.24	0.19

Table 1: Poison Ratio For X,Y & Z Direction

C. Property of Vice:

Table 2 Properties of composite vice

D. Meshed Body:

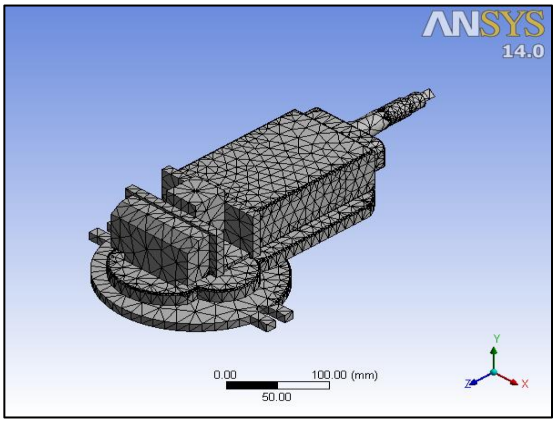

Fig. 6: Meshed component

The ansys workbench is used to mesh the composite vice of Fe-Tic. The fig 6 is the meshed component and type free mesh is used. The nodes are 25956, and elements are 14255.

E. Static Analysis:

Static analysis is a mode of analysis where deflection due to its own weight is found. In this analysis used to calculate the total deformation and Equivalent Von-mises stress. The fig 7 and 8 showed the deformation and stress generated due to own weight. The deformation results are load is 800N and maximum deformation 1.1693e-003 mm.

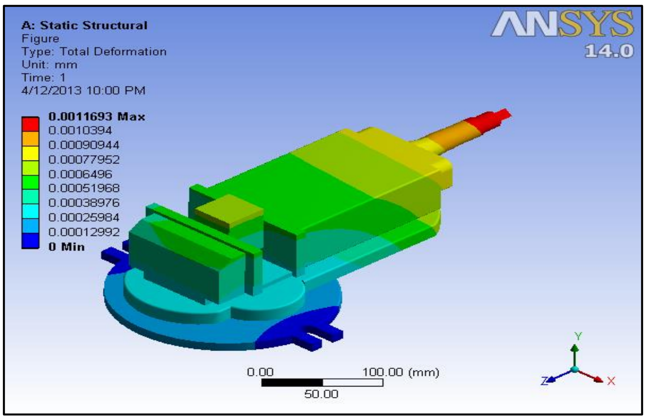

Fig. 7: Static analysis-Total deformation

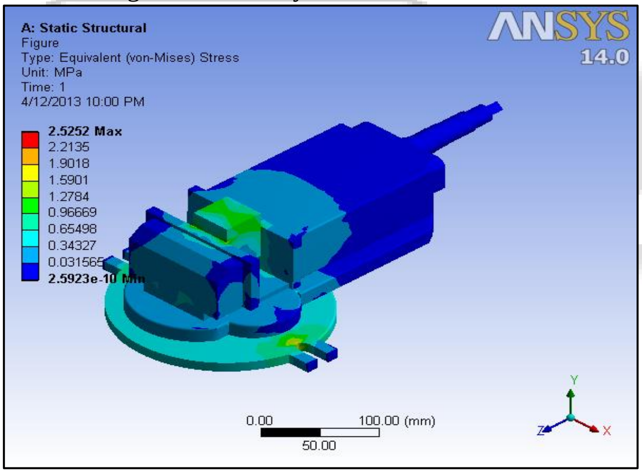

Fig. 8: Equivalent von-mises stress

F. Simple Harmonic Analysis:

In this analysis generated frequency, amplitude and acceleration can be found out. The frequency generated by the cutting force can be calculated. This analysis the frequency is divided into 30 intervals and amplitude, accelerations corresponding to the frequency can be taken.

Generated frequency for the cutting force of 800N is 3400Hz.

G. Amplitude-Frequency Curve & Acceleration-Frequency Curve:

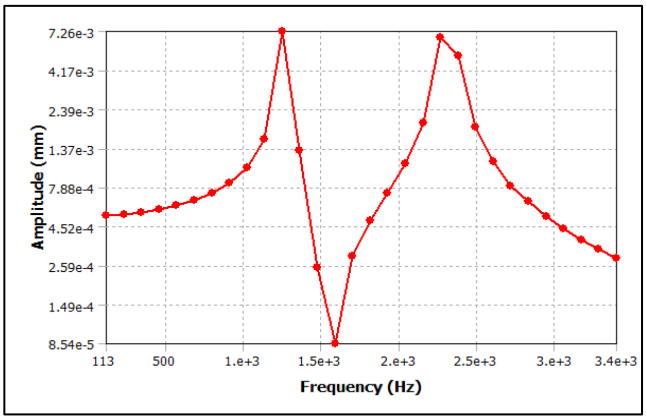

Fig. 9: Amplitude-Frequency curves

The above fig 9 is the Amplitude-Frequency curve is used to found the maximum amplitude at a frequency of 1246Hz. Amplitude at each intervals of frequency is shown in the curve.

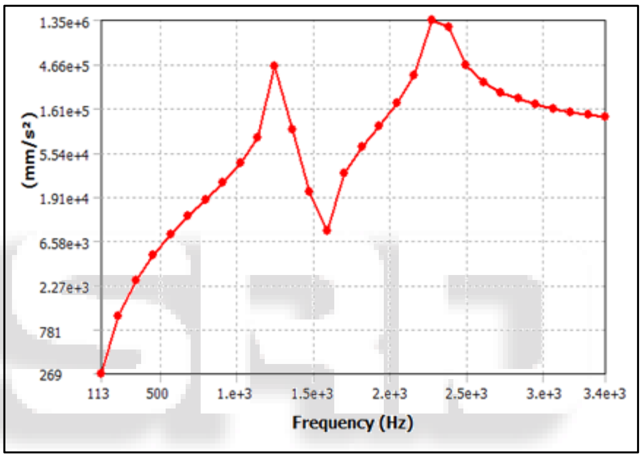

Fig. 10: Acceleration-amplitude curve

The above fig 10 Acceleration-amplitude curve showed that maximum acceleration can be obtained at a frequency of 2266.7Hz and the acceleration value is found to be 1.3522e+006 mm/s². Acceleration at respective intervals of frequency is shown in the curve.

H. Calculation for Fe-Tic:

Frequency due to external force (f) = 3400Hz, Angular velocity of periodic disturbing force (ω) = 2π*3400 = 21362.83rad/s, Mass of the body (m) =13.63kg, Deflection of the body (δ) = 0.0011mm, The maximum amplitude is (x_{max}) = 7.2639x10^{-3}mm, Stiffness (s) = mg/δ = 13.63X9.81/0.0011 = 121.554x10^{3}N/mm, Force acting on the work piece during milling (F) = 800N, Natural frequency of the system (ω_n) = 1263.3Hz

Damping coefficient (c) =285.43N/mm/s

The force at resonance: (F) = 2618.9N

Magnification factor (D) = 6.60

Transmissibility (ε) = = 0.160

Force transmitted (F_T) = 128.13N

IV. COMPARISION OF VIBRATION PARAMETER

A. Amplitude Comparison:

Amplitude of vibration for Fe-Tic reduction= (2075-1100) = 975mm

Percentage reduction in amplitude = (2075-1100)/2075
= 46.75%

B. Frequency Comparision:

Frequency reduction when comparing MS and Fe-Tic= 5000-3400 = 1600Hz
Percentage reduction in frequency = 1600/5000
= 32%
Generated Frequency reduces by 32% for Fe-TiC

C. Transmissibility Comparison:

Increase in Transmissibility Percentage= (0.17-0.16)/0.17
= 5.8%
The ability to transmit force decrease by 5.8% in Fe-TiC

D. Force Transmitted Comparison:

Percentage decrease in Force transmitted= (142.43-128.45)/142.43= 10%
MS material transmit force 10% more than Fe-TiC

E. Force at Resonance Comparison:

Percentage increase in force = (2619-1034)/2619= 60%
MS material will attain resonance earlier than Fe-TiC for same cutting force

F. Percentage Reduce In Weight of Vice:

Percentage reduction in weight= (17.81-13.63)/17.82
The weight of vice made of Fe-Tic is reduced by 23.46% when compared to vice made of Mild Steel.

G. Percentage Reduction In Weight of Machine:

Weight of the milling machine made of MS = 300kg
Weight of machine excluding the vice=282.19Kg
To arrest a 5000Hz vibration we need a mass of 282.19Kg

H. Considering Fe-Tic:

To arrest a 3400Hz vibration we need mass= (282.19/5000)*3400= 191.89Kg
Total weight of machine made of Fe-Tic=191.89+13.63= 205.52Kg
So, the percentage reduction in weight of machine = (300-205.52)/300= 31.49%
Weight of machine made of Fe-Tic is reduced by 31.49% when compared to weight of machine made of Mild Steel.

V. CONCLUSION

Comparing both the vibration parameters Generated Frequency reduces by 32% for Fe-TiC. The ability to transmit force decreases by 5.8% in Fe-TiC. Mild steel material transmits force 10% more than Fe-TiC. MS material will attain resonance earlier than Fe-TiC for same cutting force. The weight of vice made of Fe-Tic is reduced by 23.46% when compared to vice made of Mild Steel. Weight of machine made of Fe-Tic is reduced by 31.49% when compared to weight of machine made of Mild Steel. The amplitude reduced by 46.75%. Thus we conclude that vibration parameter for Fe-Tic is much better than Mild Steel.

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