Dynamic Response of Composite Beam Structure to a Moving Mass Using FEA and Theoretical approach

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Abstract- **The dynamic response of a composite beam subjected to a moving mass is of very much importance in the designing process of roadway bridges and railway bridges. This moving load problem finds several applications in the field of bridges, Transportation, guide ways, road ways, overhead crane, cable ways, pipe lines and tunnels. These structural elements are designed to support moving masses. Composite materials are gradually becoming more popular for many reason, the main advantage over metal components is the resistance to weight ratio which is important for many applications. In the present work the equation of motion in matrix form for an Euler beam subjected to a concentrated moving mass at a constant speed is formulated by Krylov's function approach. The solution of the declared problem for the case of cantilever beam is evaluated using Krylov's function. The effect of moving mass and its speed on the dynamic response of a cantilever beam for different compositions have been investigated using FEA analysis to support theoretical results, in this the beam is divided into twenty divisions and the deflection of the beam at each point is recorded while a mass moves at a steady velocity over different points. The results are obtained is plotted in the form of graphs.**

Index Terms— **Euler-Bernoulli beam, Krylov's function, Cantilever beam, Composite materials, FEA, Transient analysis.**

I. INTRODUCTION

Rapid technology advances in engineering brought the engineers to a point, where the ability of traditional materials became limited with the limits of capabilities the material failed to solve the requirements of engineer. Researchers in material technology are constantly searching for answers to provide stronger, durable material which will provide solution for the need of engineers. Composite materials are one of the most favorite solutions to this problem in the field by combining the stronger properties of traditional materials and eliminating the disadvantages they contain, it provides limitations like thermal resistance, structural strength and heavy weight are being solved. Due to high specific strength and stiffness, composite materials are used in many engineering applications. Metal Matrix Composite (MMC) is material consisting of a metallic matrix combined with a ceramic (oxides, carbides) or metallic (lead, tungsten, molybdenum) dispersed phase. E.g. Aluminum, Titanium, Magnesium, Steel, Nickel, Copper, lead. The most important problem facing by the design engineers is dynamic behavior of bridges subjected to moving mass that is the dynamic behavior of bridges subjected to moving mass. This involves moving load problem, evaluation of natural frequency and modes of vibration. It is the oldest problem in the structural dynamics but now a day the mass and speed of the vehicles have been increased. There have been investigations of potential hazards caused by moving mass on structures for several years. The importance of moving mass lies in many applications such as transportation, Tunnel, Highway Bridge, railway track, cable ways and pipe lines and these are needed to be designed to support moving load. Moving load has substantial effect on the dynamic behavior of engineering structure. Dynamic loads are time dependent forces. These forces are applied on the structure either by natural way like earth quake or by human activity like machine vibration, structures affected by the dynamic forces can be simple as beams. In the design and analysis of the structure the time dependent initial force is considered. During its response to dynamic loads, a structure offers resistance to these loads in the form of internal forces some of which related to velocities and displacement these resistance forces also considered in the analysis.

II. MATERIAL AND METHODOLOGY

Usually the Cantilever beam is made of Aluminum or Stainless steel for the construction of Railway bridge and Roadway bridge and dynamic analysis is done on these materials. In this paper the material chosen is composite material which is combination of Alluminum6061 and Silicon nitride[1], Analysis done on different percentage of Silicon nitride. The beam is divided into 20 divisions that is 21 points and the Modal analysis and Transient analysis is done on each point on the beam to obtain better results.

Table 2: Engineering Properties of the composite Material

PROPERTY	UNIT	0% OF Si_3N_4	6% OF Si_3N_4	10% OF Si_3N_4
DENSITY	Kg/m^3	2700	2744.4	2774
MODULUS OF ELASTICITY	GPa	70.8	85.152	94.72
POISSIONS RATIO	--	0.33	0.324	0.32

1.Modeling using solidworks 11.Software
2.Model is imported to ANSYS WORKBENCH
3.Boundry conditions and loads to be applied
4.Analysis and comparison of the results
5.Opimization of results obtained by analysis beams with different structural materials

III. RESULTS AND TABLES

By using krylov's function approach considering the boundary conditions we get the following equations

wi (*x*)=*AiS* (*kix*) + *Bi*T (*kix*) + *Ci*U (*kix*) + *Di*V (*kix*),

where

S(*kix*)=(cosh *kix*+cos *kix*)/2,

T(*kix*)=(sinh *kix*+sin *kix*)/2,

U(*kix*)=(cosh *kix* - cos *kix*)/2,

V(*kix*)=(sinh *kix* - sin *kix*)/2

Where S,t,U,V are the Krylov's function

1) Then considering the 1st boundary condition

Ai=0 (a)

2)Now considering 2nd boundary condition

Bi= 0 (b)

3)Now considering 3rd boundary condition

i.e. M*i*(L) = EI∂2*wi* (L)/∂x2 = I*m* ω*i*2 ∂ *wi*(L)/∂x

takind 2nd derivative of all kryloves function

M*i*(L)/EI=-*ki2[Ci*(cosh *kix* - cos *kix*)/2] + *ki* 2[D*i*(sinh *kix* - sin *kix*)/2] (c)

4)Now considering the 4th boundary condition

or 2*Qi*(L)/EI *ki* 3= C*i*(sinh *kix* - sin *kix*)- *Di*(cosh *kix* + cos *kix*) (d)

taking equation (c) and (d) and by multiplication of coefficient of *Di* and adding

Ci[(cosh *kix* - cos *kix*)2 +(sinh *kix* - sin *kix*)2]= 2*Qi*(L)/EI *ki* 3×(sinh *kix* - sin *kix*)

-2M*i*(L)/EI *ki2*×(cosh *kix* - cos *kix*) *(e)*

AS Qi(L) is the transverse force at the end at the end of the end of the cantilever hence

the bending moment will be

M(L)= Qi(L).L3/3EI

Hence equation (e) becomes

Ci=2*Qi*(L)/EI *ki2[*(sinh *kix* - sin *kix*) / *ki* -L3(cosh *kix* - cos *kix*) */3EI] /*(cosh *kix* - cos
kix)2 +(sinh *kix* - sin *kix*)2
(A)

Similarly by cross multiplication by coefficient of *Ci* and substracting

Di=-2*Qi*(L)/EI *ki* 2×[(cosh *kix* - cos *kix*)/ *ki* + L3(sinh *kix* - sin *kix*)/3EI] (B)

From all these boundary conditions and their subsequences we can get a 4×4 matrix as
follow

By simplifying the equation we will get

-*ki* /2×2*Qi*(L)/EI *ki* 2×[(cosh *kix* - cos *kix*) (sinh *kix* - sin *kix*)/ *ki*-L3(cosh *kix* - cos*kix*)2
/3EI]/
(cosh *kix* - cos*kix*)2 +(sinh *kix* - sin *kix*)2
=2Qi(0).L3/3E2I2

ki=0 (C)

For ki=0 R.H.S = L.H.S

Ki= π R.H.S = L.H.S

Hence Ki= nπ, where n= 1,2,3,4,5………..

Since Ki^4= ωi2ρA/EI

Where Ki= Stiffness coefficient

ωi=natural frequency

ωi2= Ki2√(EI/ρA)

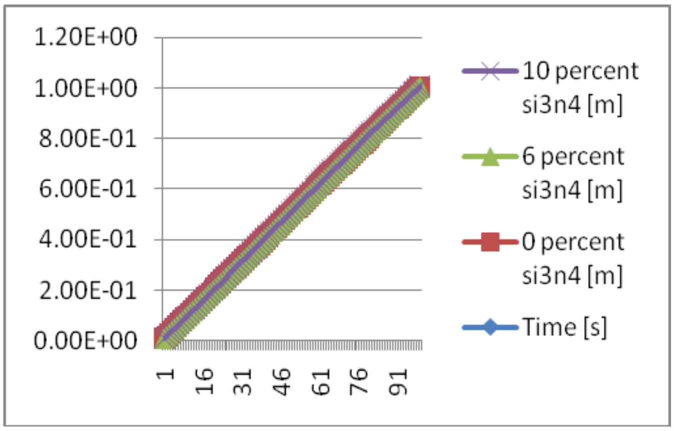
now taking all the given values and calculated values

for Al6061 + 0% si3n4

for Ki= π
ωi=0.69853 Hz
for Ki=2π
ωi=0.69949 Hz
for Ki=3π
ωi=4.3606 Hz
for Ki=4π
ωi=4.3645Hz

for Al6061 + 6% si3n4
for Ki= π
ωi=0.66579 Hz
for Ki=2π
ωi=0.66686 Hz
for Ki=3π
ωi=4.1566 Hz
for Ki=4π
ωi=4.1601Hz
for Al6061 + 0% si3n4
for Ki= π
ωi=0.61194 Hz
for Ki=2π
ωi=0.61314 Hz
for Ki=3π
ωi=3.8212 Hz
for Ki=4π
ωi=3.8238Hz
and so on

Fig 3: Graph showing deformation v/s time



Time [s]	0 percent si3n4 [m]	6 percent si3n4 [m]	10 percent si3n4 [m]
1.00E-02	1.18E-07	3.25E-07	3.16E-07
2.00E-02	4.92E-07	1.36E-06	1.33E-06
3.00E-02	1.17E-06	3.24E-06	3.16E-06
4.00E-02	2.21E-06	6.24E-06	6.18E-06
5.00E-02	4.26E-06	1.26E-05	1.26E-05
6.00E-02	7.52E-06	2.19E-05	2.18E-05
7.00E-02	1.19E-05	3.43E-05	3.40E-05
8.00E-02	1.75E-05	5.01E-05	4.96E-05
9.00E-02	2.44E-05	6.95E-05	6.86E-05
1.00E-01	3.27E-05	9.27E-05	9.12E-05
0.11	4.24E-05	1.20E-04	1.17E-04
0.12	5.34E-05	1.50E-04	1.48E-04
0.13	6.59E-05	1.86E-04	1.82E-04
0.14	7.99E-05	2.25E-04	2.21E-04
0.15	9.56E-05	2.70E-04	2.65E-04
0.16	1.13E-04	3.18E-04	3.12E-04
0.17	1.32E-04	3.71E-04	3.63E-04
0.18	1.52E-04	4.27E-04	4.18E-04
0.19	1.74E-04	4.87E-04	4.76E-04
0.2	1.98E-04	5.52E-04	5.39E-04

Table 3.1: Total deformation

%Si3N4	total deformation
0 percent	0.0054927
6 percent	0.0036553
10 percent	0.0027002

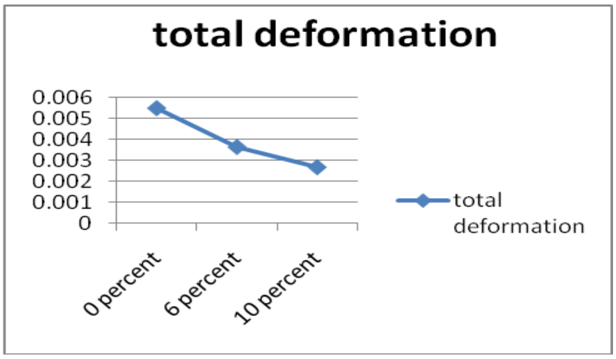


Fig 3.1:Graph showing deformation v/s %Silicon nitride

The above graph shows that the combination of 10%Silicon nitride with aluminum exhibits lesser deformation compared to 0% and 6% Silicon nitride

Table 3.2: Total stress

%Si3N4	von mises stress in pa
10 percent	4.90E+05
6 percent	3.99E+05
0 percent	3.22E+05

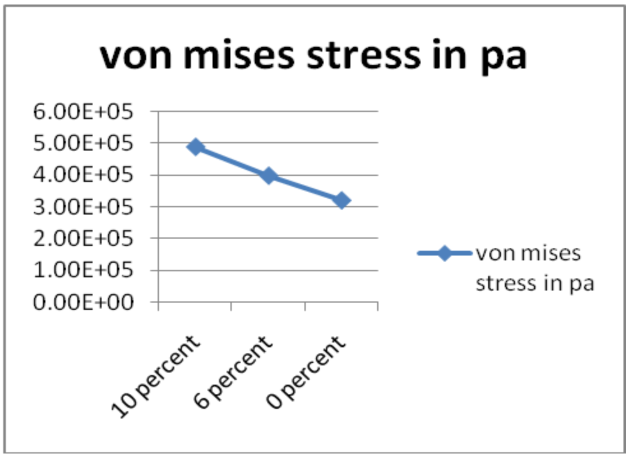


Fig 3.2: Graph showing stress v/s %Silicon nitride

By observing the above graph we can come to the conclusion that the combination of 10%Silicon nitride and aluminum shows more stress compared to other two

Table 3.3:Total Elastic Strain

%Si3N4	Elastic strain
10 percent	6.93E-06
6 percent	4.70E-06
0 percent	3.41E-06

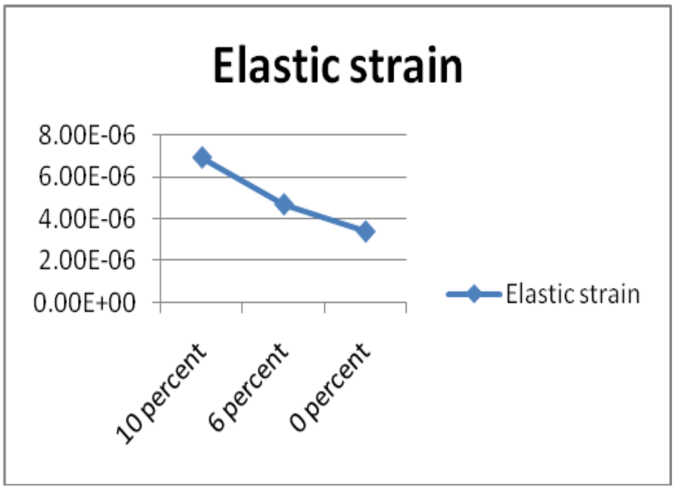


Fig 3.3: Graph showing strain v/s %Silicon nitride

By the above graph we can come to the conclusion that The Elastic strain is more for the combination of 10%Silicon nitride compared to other two

IV. CONCLUSION

- The natural frequency obtained for 6% composition of Silicon nitride at 21 positions for 6 modes is relatively lesser when compared 0% Silicon nitride.
- For 10% composition of silicon nitride the natural frequency decreases as compared to 0% and 6% silicon nitride.
- The above result shows that when the percentage of Silicon nitride is increased the natural frequency decreases that is the vibration produced is less i.e. percentage of silicon nitride is inversely proportional to the natural frequency.
- As the Silicon nitride percentage increases Deformation decreases, The value of equivalent stress and elastic strain increases.

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