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Experimental Investigation on Natural Frequency of Poly Propylene Beam with Crack

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***Abstract*- Poly Propylene is one of the materials which is used in several applications like home appliances, car bodies, agriculture, home construction, etc. Cracks may be occurring at time of manufacturing, assembly or usage, thus results in reduced stiffness. So, there is a need to recognize damage which may be affecting other parts of the system also. There are various methods to recognize cracks. Natural frequency analysis is one of the better method to analyze cracks because frequency dependent on stiffness of the material. In this article, natural frequency of Poly Propylene beam is analyzed in cantilever condition with two cracks of different depth to width ratios using ANSYS-14.5 and then the results are compared with experiment. Effect of Nano Clay is analyzed with different percentages of Nano Clay. It is observed that addition of Nano Clay improves stiffness of the material.**

***Keywords*— Poly Propylene Beam, Natural frequency analysis, Experimental work, Nano Clay.**

I. INTRODUCTION

Poly Propylene is a semi-crystalline thermo plastic that is used extensively due to its unique combination of properties, cost and ease of fabrication. All grades consist of polymer, a neutralizer and antioxidants. Other additives like clarifiers, nucleates, slip additives, UV stabilizers, silica, talc, and calcium carbonate are added to impart specific functionality. The polymer may be a pure homo polymer made by polymerizing propylene, a random copolymer made from propylene and another monomer (like ethylene), or an impact copolymer made by dispersing rubber in polypropylene matrix. The main advantages of Poly Propylene are, high chemical and corrosion resistance, light weight and rigid, high tensile strength, excellent abrasion resistance, low moisture absorption, easily machined and cut, easy to maintain and clean, excellent thermal insulating properties, excellent dielectric properties, long life span. So, these are mostly used in home appliances, car bodies, chemical industries, agriculture, home construction etc. Damages may be occurring at time of manufacturing or assembly or usage, thus resulting in reduced stiffness and then component would become useless.

They are many non destructive tastings are there like acoustic emission testing, blue etch anodize, dye penetrate inspection, liquid penetrate testing, electromagnetic testing, ultrasonic testing, vibration analysis, visual inspection etc. to detect crack. Vibration analysis is mostly better and suitable technique among all of techniques. In this method, impact hammer is used to create vibration of the beam and laser vibro meter is used to receive output frequency of the beam. Dimensions are taken as, 0.8X0.05X0.006 m^3 and followed by standard in [19].

The introduction of nanofiller in the polymer nano composites had proved a significant improvement in the mechanical properties. The addition of small amounts of clay (0 to 15% wt) in a polymer matrix leads to improved mechanical, thermal and barrier properties. The addition of Nano Clay in a polymer matrix may result in the formation of two types of Nano Composite Structures, namely, intercalated and exfoliated nanostructures. In an intercalated structure, the host polymer matrix enters into the interlayer spacing of the Nano Clay and increases the interlayer spacing but maintains the parallel arrangement of the nano layers of clay in the matrix. In practice, exfoliated structures provide enhanced and improved properties due to their excellent dispersions and improved aspect ratio.
In this paper, efforts have been going made through PP beam for cracked with different crack to depth ratios by simulation and experimental basis.

Material properties of PP material as, E=1.35X10^9 N/m^2, poison's ratio=0.4,Density=905 Kg/m^3 and Nano Clay as, E=7.016X10^9 N/m^2 , poison's ratio =0.017, Density= 163.6 Kg/m^3

Steps involved in extrcting frequencies of cracked beam main steps involved to detect frequencies of cracked beam are,

1) Natural frequency of un-cracked beam for Poly Propylene material is determined theoretically.
2) Natural frequency of un-cracked beam for Poly Propylene material is estimated in ANSYS and is compared with theoretical results.

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3) Natural frequencies of Poly Propylene material are estimated for different crack depths by using ANSYS.
4) Natural frequencies of Poly Propylene material are estimated experimentally for different crack depths and compared with ANSYS results.
5) Effect of Nano Clay was analyzed by using ANSYS for different crack depths for different percentages of NC by following same steps 1, 2 and 3.

II. THEORETICAL CALCULATIONS FOR UN-CRACKED PP BEAM

Theoretical formulae were obtained from [20] for four modes of natural frequencies. Results obtained by the formulas as,

Natural frequency of 1st mode=1.85Hz.
Natural frequency of 2nd mode=11.57Hz
Natural frequency of 3rd mode=32.45Hz
Natural frequency of 4th mode=63.65Hz

III. FINITE ELEMENT MODELING FOR UN-CRACKED PP BEAM

The ANSYS finite element software is used for free vibration of the cracked beams. A 20-node three-dimensional structural solid element under SOLID 186 is selected to model the beam. The beam is discredited into 1045 elements with 2318 nodes. Geometrical shape of the beam is shown in figure 1.Cantilever boundary condition is considered by constraining all degrees of freedoms of the nodes located on the left end of the beam. The subspace mode extraction method is used to calculate the natural frequencies of the beam and mode shapes are shown in figure 2.

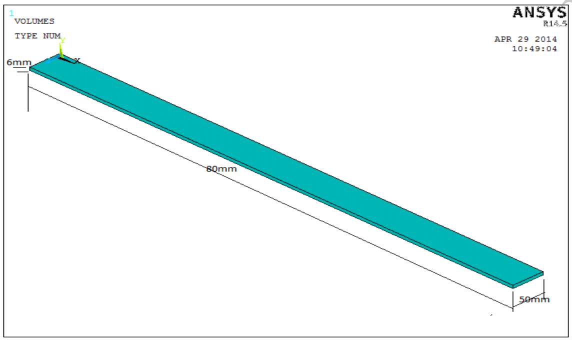
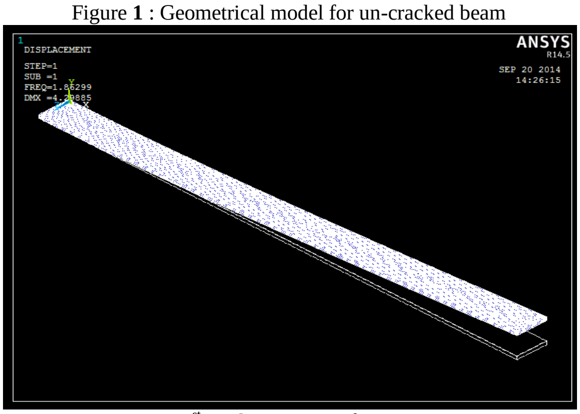
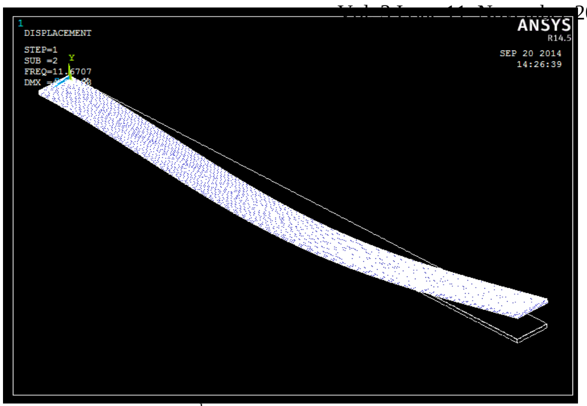


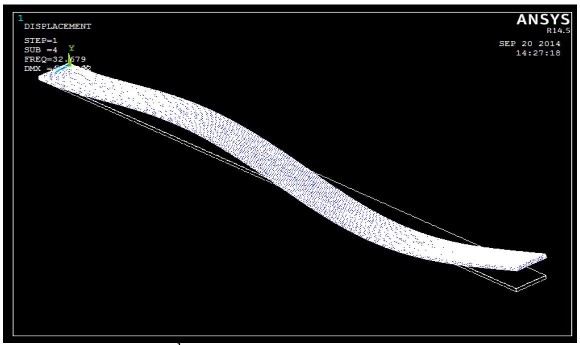
Figure **1** : Geometrical model for un-cracked beam



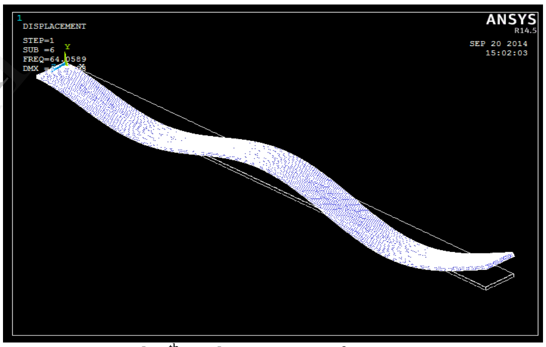
2-a: 1st mode-1.8629Hz frequency



2-b: 2nd mode-11.607Hz frequency



2-c: 3rd mode-32.629Hz frequency



2-d: 4th mode-64.0589Hz frequency

Figure 2: Mode Shapes of un-Cracked PP Beam

IV . COMPARISON OF THEORETICAL RESULTS WITH ANSYS 14.5 RESULTS

After comparison of both theoretical and ANSYS results, the difference between both results is negligible and comparison of frequency is shown in figure 3. Hence, the analysis of cracked beam is extended in ANSYS package.

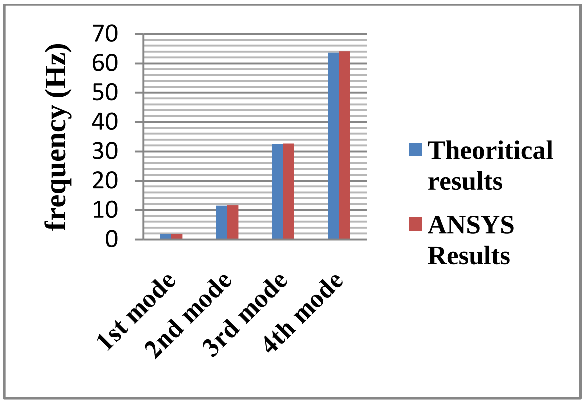


Figure 3: Comparision of theoritical frequency with ANSYS

V. Results for PP Beam with Crack

After comparison of the both theoretical and ANSYS results, Procedure could be verified in ANSYS [19] for Aluminum material. Same results were obtained from that procedure. Hence, the same procedure is adopted for extracting natural frequencies and % of decrees in frequency of cracked beam as shown in figure 4 and 5 and obtained results are listed in table 4.The percentage of variation for different mode frequencies with varying crack depth is shown in figure 6.

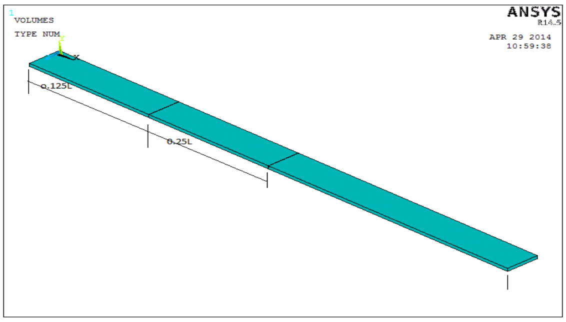


Figure 4: Location of cracks on composite beam

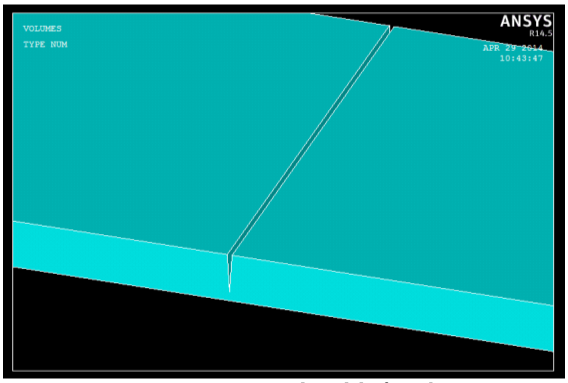


Figure 5: Geometrical model of crack.

Table 4: Natural frequencies and percentage of decrease in frequency of beam for different cracks depths

	frequency(Hz)				% of variation of frequency			
	1st mode	2nd mode	3rd mode	4th mode	1st mode	2nd mode	3rd mode	4th mode
0	1.8629	11.6707	32.679	64.0589	--	--	--	--
0.25	1.84721	11.6545	32.5997	63.849	0.842235	0.138809	0.242663	0.327667
0.5	1.78451	11.5851	32.2618	63.027	4.207955	0.733461	1.276661	1.610861
0.75	1.53245	11.266	30.7274	60.206	17.73847	3.467658	5.972031	6.014621

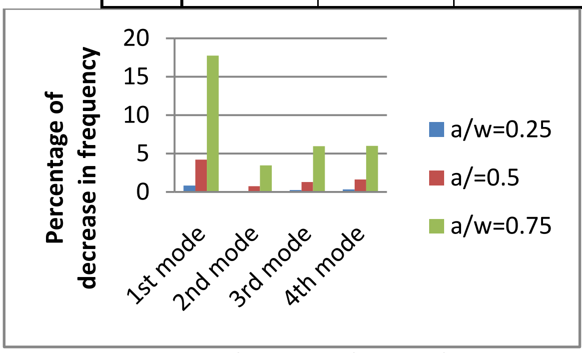


Figure 6: percentage of variation in frequency for crack depth

VI. EXPERIMENTAL RESULTS

The poly propylene material is imported from Polyester polymers, Mumbai. Specimens were prepared by using different operations as, cutting, finishing. And cracks were created by using mini hack saw blade. Vibration testing was done by using Impact Hammer, Laser Vibro meter and Data acquisition System. The schematic diagram for experimental set up is shown in figure 7 and experimental setup is shown in figure 8,9.

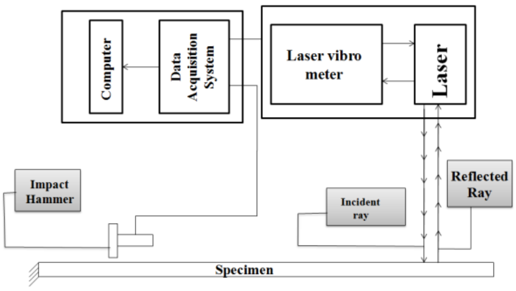


Figure 7: Schematic diagram for experimental setup.

Figure 8: Experimental setup.

Figure 9-a: Fixed boundary condition

Figure 9-b: Impact action Figure 9-c: Leaser incidence

Figure 9: Experimental work.

The experimental results are correlated with ANSYS results as shown in figure 10.

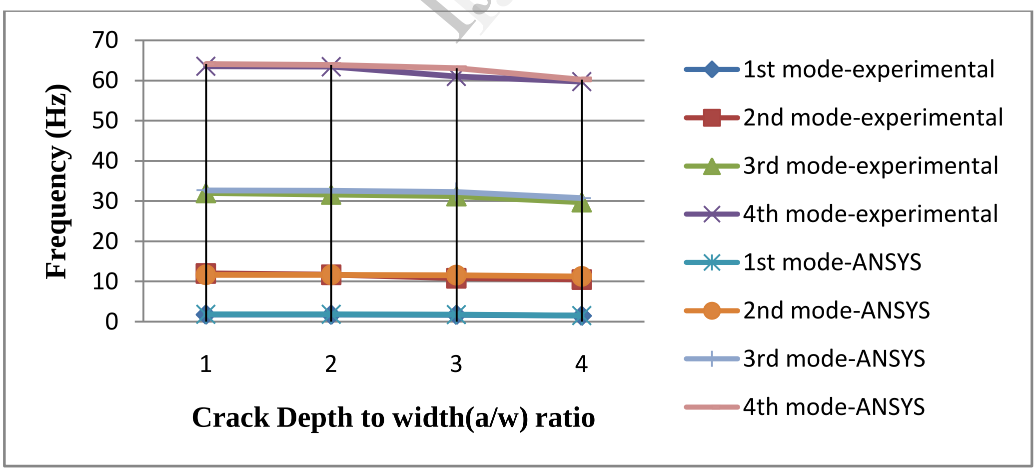


Figure 10: Comparison Of Experimental Results With ANSYS Results Effect Of NC

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VII. Analysis of Effect of Nano Clay

The mechanical properties of Poly Propylene-Nano Clay are listed in table 5. The material properties of Poly Propylene with Nano Clay addition is obtained through *rule of mixtures*. Frequency response results of different crack depths for different compositions of Nano Clay are obtained and are listed in table 6. Comparison of results is shown in figure 11.

Table 5 : Properties of PP-NC Composite Material By Rule of Mixes

S.No	**% 0f NC**	***E* for *composite (N/m2)***	***poisons ratio* for *composite***	**Dennsity of mixtre (Kg/m3)**
1	0	1.35E+09	0.4	905
2	3	1.52E+09	0.322	882.758
3	7	1.74E+09	0.333	853.102
4	11	1.96E+09	0.403	823.446
5	15	2.18E+09	0.369	793.79

Table 6 : Results of PP-NC Composite material for different crack depths

% of NC	**a/w**	**Frequency(Hz)**			
		1st mode	**2nd mode**	**3rd mode**	**4th mode**
0	**0**	1.863	11.67	32.68	64.06
	0.25	1.847	11.65	32.6	63.85
	0.5	1.785	11.59	32.26	63.03
	0.75	1.532	11.27	30.73	60.21
3	**0**	1.996	12.61	35.02	68.62
	0.25	1.979	12.49	34.93	68.39
	0.5	1.908	12.41	34.64	67.46
	0.75	1.607	12.06	32.81	64.84
7	**0**	2.173	13.62	38.12	74.71
	0.25	2.155	13.6	38.03	74.47
	0.5	2.09	13.53	37.67	73.7
	0.75	1.774	13.13	35.74	70.01
11	**0**	2.354	14.74	41.29	80.93
	0.25	2.335	14.72	41.19	80.67
	0.5	2.255	14.64	40.76	79.63
	0.75	1.937	14.23	38.82	76.06
15	**0**	2.525	15.82	44.29	86.81
	0.25	2.501	15.8	44.18	86.53
	0.5	2.416	15.7	43.71	85.38
	0.75	2.068	15.26	41.58	81.5

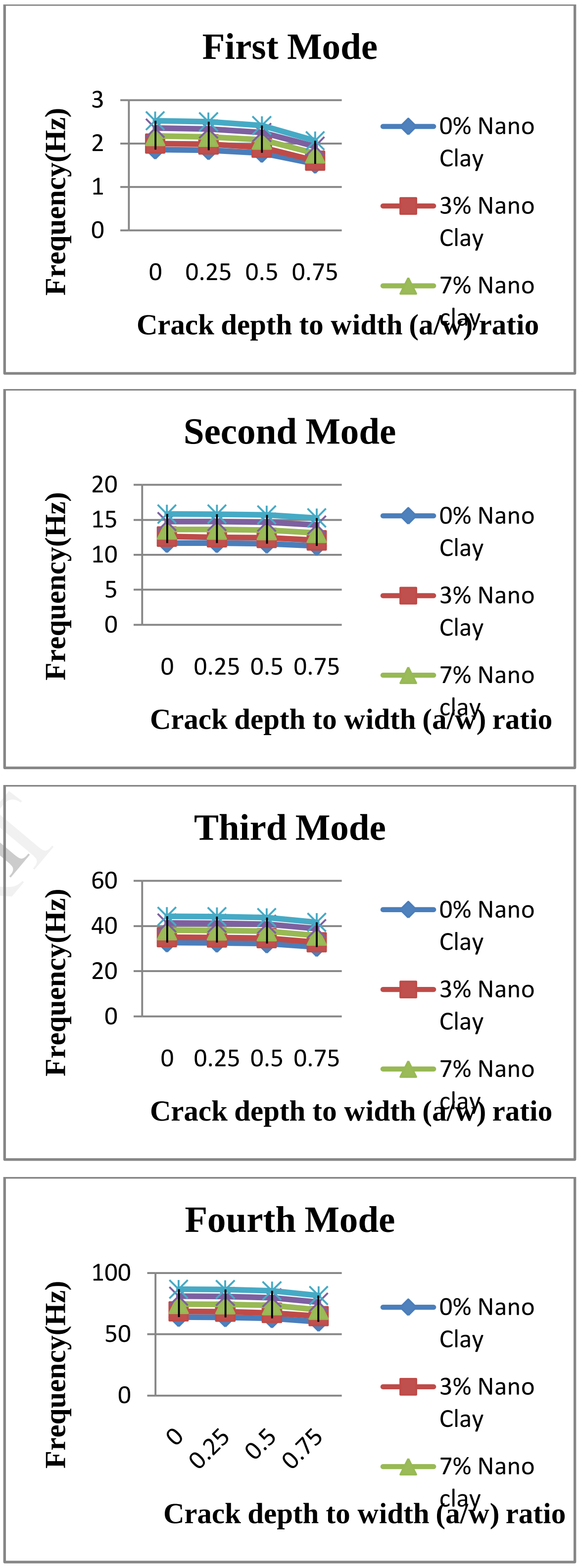

Figure 11: Comparisons of frequency with change in Nano Clay and crack depth ratio

VIII. CONCLUSIONS

After analyzing the natural frequencies of Poly Propylene beam and effect of Nano Clay, following conclusions are made.

- Frequency response of beam decreases with increase in crack depth Because of decrease in stiffness.
- Percentage of decrease in frequency is too high for 0.75 crack depth to width ratio indicates very lagging in stiffness of the beam. Finally that may be become useless.
- Frequency response of beam increases with increase in Nano Clay percentage indicates Nano Clay could be improved stiffness of material according to frequency analysis.
- Decrease of frequency is all most same for same any combination of poly Propylene-Nano Clay material for same crack depth to width ratio.

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