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Application of a Particle Damping Technique on Wind Turbine Rotor by Filling of 90 Percent Balls

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Abstract*: *Vibration of wind turbine blade is one of the major important obstacle to increase the capacity of electricity generation. Particle damping technique is introduced in wind turbine blade to check the vibration suppression. Damper is mounted on blade externally. RPM of blade, position of dampers, are the variable parameters used in this parametric study keeping particle size as 9 mm and percentage fill in damper is 90 %. Experimental test is conducted in all the research work. Without damping results are compared with with-damping results and find out the vibration suppression regions.

Keywords* : *wind turbine rotor, particle, damper, vibration

I. INTRODUCTION

Vibration in wind turbine brings major issues concerning to power generation. Many researchers studied by focusing on vibration of blade. Krenk [01] shows active struts located near the root of every blade for reducing blade vibrations. Duquette [2] investigated structural part is damage at nacelle cover and blades of wind turbine. Dapeng [3] shows edgewise vibration is the main issue in most of the wind turbine blades. Typhoon also creates problem in generating power, Ishizaki [4]. Giguere [5] gives dynamic characteristics of machine as it requires controlling vibration in blade which is necessary, as it adversely affect on electricity generation. Edgewise and flap wise modes of vibration is the main concern in blade according to Thomsen [6]. Khan [7] invented a tuned liquid column damper (TLCD) in a rotating blade. Active tuned mass damper in investigated by Fitzgerald [8] for mitigating edgewise vibrations. Saranyasoontorn [9] investigated extreme wind turbine load using different methods. Murtagh [10] shows the effect of passive damper inserted in turbine tower for suppressing vibration created by wind forces. Multiple tuned mass damper (MTMD) technique is introduced by Hussan [11] for multi-mode vibration suppression of offshore wind turbine considering seismic excitation. Mainly, load acting on the blade is wind load and many scientists have already worked by blade element momentum method (BEM) for calculating aerodynamic load of a blade Sandanshiv [12]. In this research work introducing particle damping technique on wind turbine blade.

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II. PARTICLE DAMPING TECHNIQUE

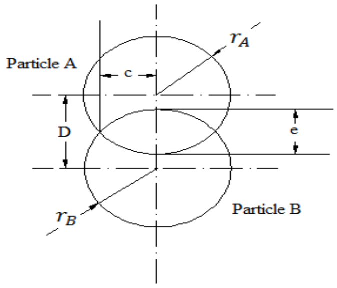
In particle damping technique, as many particles moves then collision of one particle to other takes place also collision of particle to container wall takes place. And due to this collision a lot of energy gets wasted and energy loss occurs. In this paper contains particle damping study included the damper which contains number of spherical balls. This dampers are mounted on blades, so as blades rotates at that time collision in balls takes place as well as collision in ball and container wall takes place resulting in energy loss and due to this energy loss vibrations reduces. And in this way achives suppression effect. Fig. 1. (b) Shows spring mass diagram of particle and container wall and Fig. 1 (c) shows spring mass diagram of particle and particle. Governing equations for this suppression shows as follows. Fig. 1 (a) shows two spherical particles A and B having radii r_A and r_B. Both particles centres are separated by a distance D. e is called as approach between two particles and c is the radius of circular area.

$$e = (r_A + r_B) - D$$

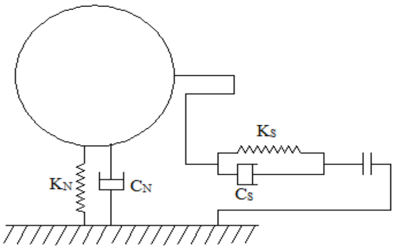
Contact forces between two colliding balls becomes

$$\vec{f} = f^n.\vec{N}^n + f^s.\vec{N}^s$$

Where, f^n = Normal force, f^s = Shear force, $\vec{N}^n$ = Unit vector in normal direction and $\vec{N}^s$ = unit vector in shear direction.



(a) Particle – Particle impact parameters



(b) Particle-wall spring mass diagram

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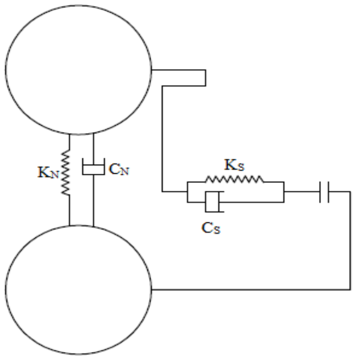

(c) ball-ball spring mass diagram
Fig. 1 spring mass diagram for different cases

III. EXPERIMENTAL SET-UP AND TESTING

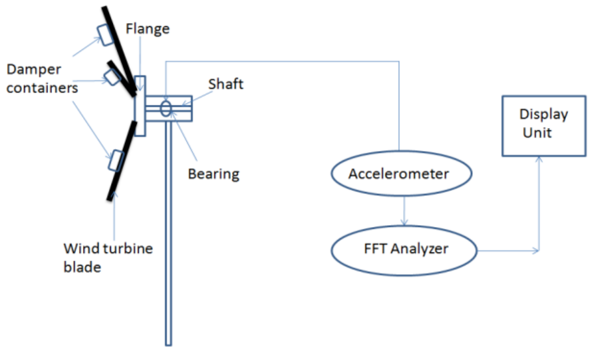

Fig.2. Block diagram of experiment set-up block diagram

Fig. 2. Shows block diagram of experimental set-up contains three blades attached with flange. Flange is connected with shaft which is mounted on bearing. On the top of bearing three directional accelerometers is mounted . Accelerometer sends the signals towards FFT analyzer. display unit shows the result graphs.

Fig.3. Experimental set-up

Fig.3. shows the actual experimental set-up seeing marking on each blade from the tip at the distance of 300 mm difference up to four positions. Power generation capacity of wind turbine test set-up is 1 kW. Container diameter is 48 mm, and height is 28 mm having material of Poly-propylene (PP). Considering the size of spherical particles as 9 mm for all tests, having material containing chemical compositions of 0.010 % Mo, 0.050% Ni ,0.98 % C, 0.33 % Mn, 0.25 % Si, 0.010 % S, 0.012 % P, and 1.40 % Cr.

A. Parameters for Testing

Different parameters are used for seeing the critical analysis for finding the suppression effect. Change in rpm and change in positions of dampers are the parameters consider to check the effects. In each case particle fill in damper is kept constant at 90 %.

1) **RPM of Blade:** Four different rpms as 60 rpm, 70 rpm, 80 rpm and 90 rpm are considered for this research work.

2) **Position of damper:** Fig. 4 (a) to (d) shows dampers mounted at different positions on blades.

(a) Damper at 300 mm

(b) Damper at 600 mm

(c) Damper at 900 mm

(d) Damper at 1200 mm

Fig. 4. Dampers at different positions

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Fig.4 (a) shows damper located at 300 mm, Fig. 4 (b) shows damper located at 600 mm. Fig. 4 (c) shows damper at 900 mm and Fig. 4 (d) damper at 1200 mm. All distances are marked from the tip of blade having overall length of 1525mm. Fig. 5. Shows 9 mm particle size damper which is mounted on each blades.

Fig. 5 Particle damper of spherical particles 9 mm

IV. RESULT AND DISCUSSION

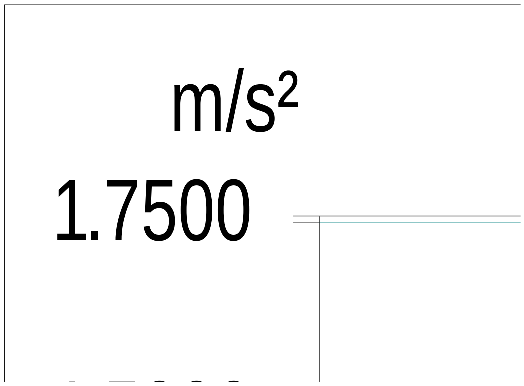
Table-I. Testing results of acceleration (m/s^2) for different rpms and positions

RPM	Modes	Damper Positions				Un-damp
		1200 mm	**900 mm**	**600 mm**	**300 mm**	
60 rpm	1st Mode	1.226	0.279	1.066	0.958	1.359
	2nd Mode	0.353	0.145	0.335	0.349	0.177
70 rpm	1st Mode	0.772	0.49	0.511	0.617	0.583
	2nd Mode	0.427	0.281	0.479	0.317	0.243
80 rpm	1st Mode	1.02	0.632	1.035	1.015	0.853
	2nd Mode	0.275	0.109	0.577	0.4	0.629
90 rpm	1st Mode	0.616	0.644	0.77	0.974	1.66
	2nd Mode	0.241	0.199	0.304	0.48	0.264

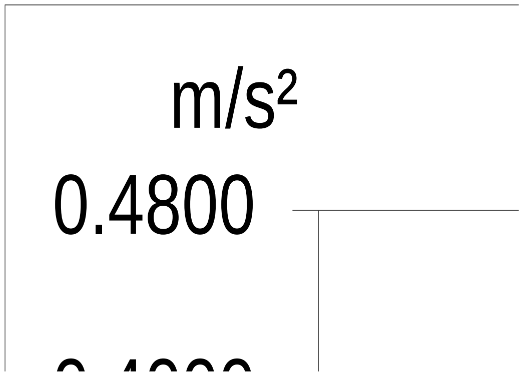
Table-I shows all testing results of damp and un-damp conditions. Accelerations of damper are found at four different positions alternately i.e. 1200mm, 900 mm, 600 mm and 300 mm, with considering 60 rpm, 70 rpm, 80rpm and 90 rpm respectively as shown in Fig (6-9).

A. 60 rpm

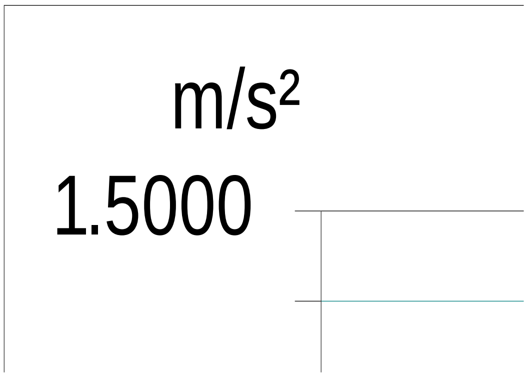
Fig. 6 (a)-(d) shows results of 60 rpm with damper located at 1200mm, 900 mm, 600 mm, 300 mm respectively. At un-damp condition of 60 rpm gives 1.359 (m/s^2) acceleration at 1st mode and 0.177(m/s^2) acceleration of 2nd mode. Table-I shows the results of 60 rpm. Comparing all acceleration of 1st mode at 0.279 (m/s^2) at 900 mm damper position gives good vibration suppression effect. At 300 mm damper location gives acceleration of 0.958 (m/s^2), this value is also lower than undamped value. At 1200 mm damper position it gives 1.226 (m/s^2) which is higher of all four damper positions. In overall at first two modes at 900 mm position gives optimum suppression effect.



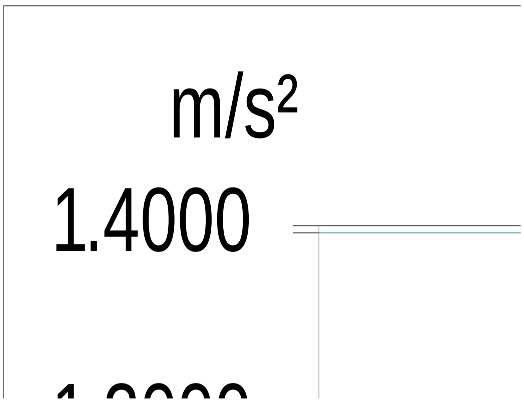
(a) 90% fill, 60 rpm, 1200 mm position



(b) 90% fill, 60 rpm, 900 mm position



(c) 90% fill, 60 rpm, 600 mm position



(d) 90% fill, 60 rpm, 300 mm position

Fig. 6 rpm at 60 with 1200mm, 900mm, 600 mm, 300 mm damper locations

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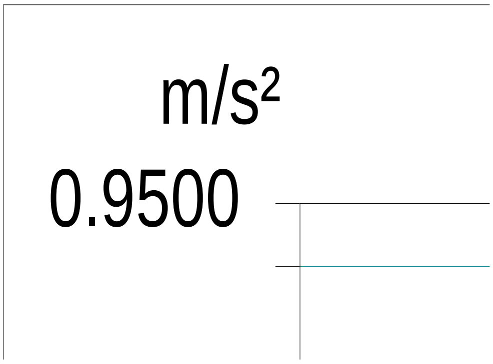
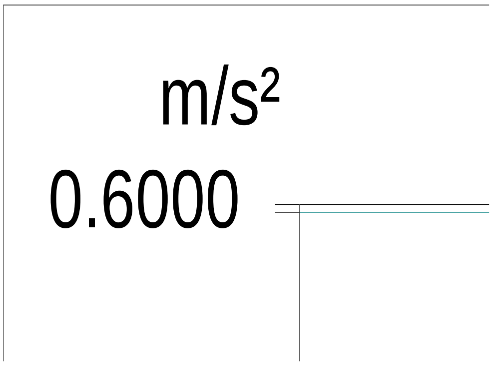
B. 70 rpm

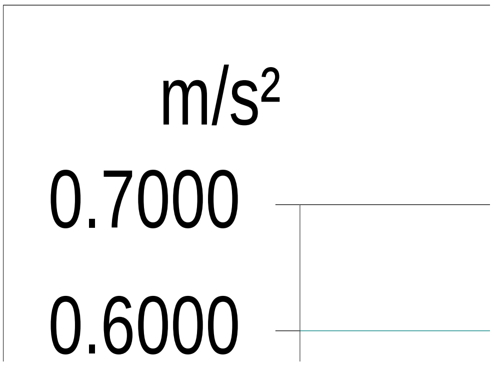
At un-damped case 0.583(m/s^2) and 0.243 (m/s^2) are the acceleration values. Here at 70 rpm receives suppression at 900 mm and 600 mm positions at 1st mode. But, 2nd mode not shown suppression effect. In overall at 900 mm position receives better suppression effect. Fig.7 (a) – (d) shows results at 70 rpm with damper located at 1200 mm , 900 mm, 600 mm, 300 mm position respectively.



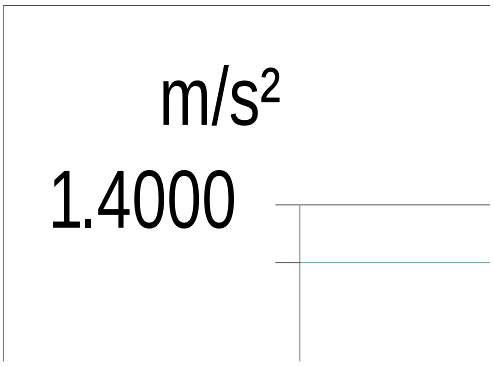
(a) 90% fill, 70 rpm, 1200 mm position



(b) 90% fill, 70 rpm, 900 mm position



(c) 90% fill, 70 rpm, 600 mm position

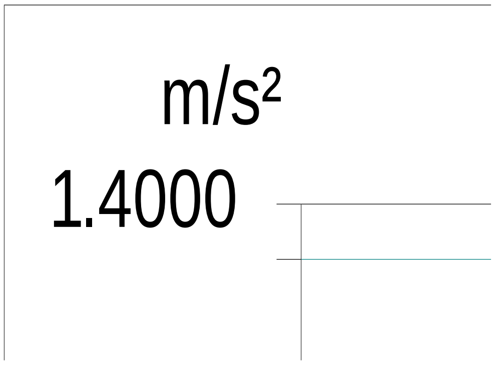


(d) 90% fill, 70 rpm, 300 mm position

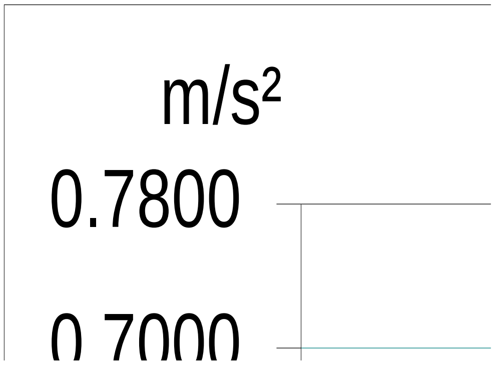
Fig. 7 rpm at 70 with 1200mm, 900mm, 600 mm, 300 mm damper locations

C. 80 rpm

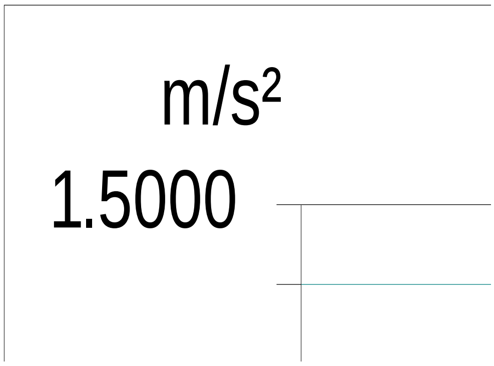
Fig.7. (a)-(d) gives results of 80 rpm at all four positions. Comparing all four position results, good results receives at 900 mm damper location in both modes. i.e. at 0.632 (m/s^2) at 1st mode and 0.109 (m/s^2) at 2nd mode. Remaining three



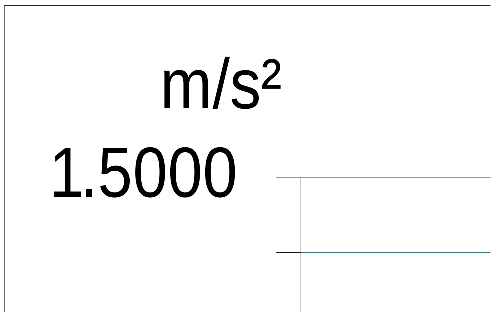
(a) 90% fill, 80 rpm, 1200 mm position



(b) 90% fill, 80 rpm, 900 mm position



(c) 90% fill, 80 rpm, 600 mm position



(d) 90% fill, 80 rpm, 300 mm position

Fig. 7 rpm at 70 with 1200mm, 900mm, 600 mm, 300 mm damper locations

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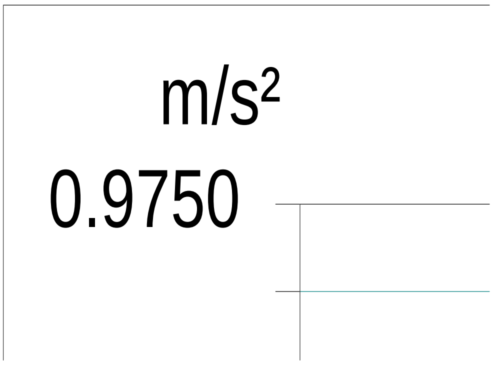
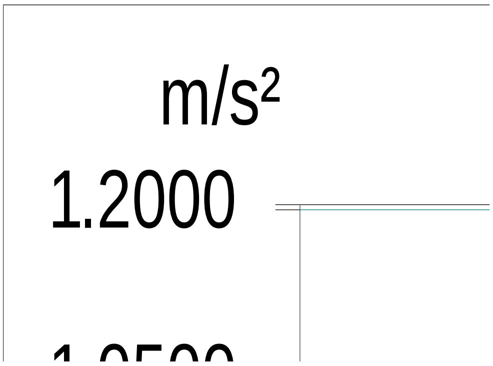
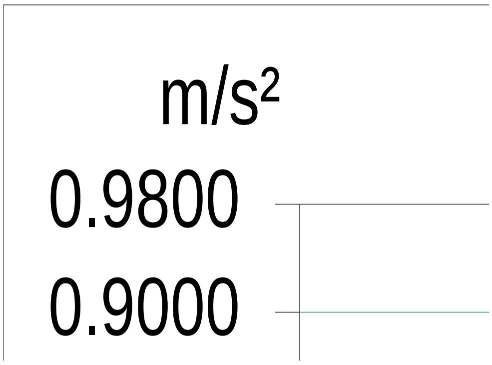
results are shown acceleration values are greater than un-damped conditions. So, here vibration suppression is not achieved at 1200 mm, 600 mm and 300 mm positions.



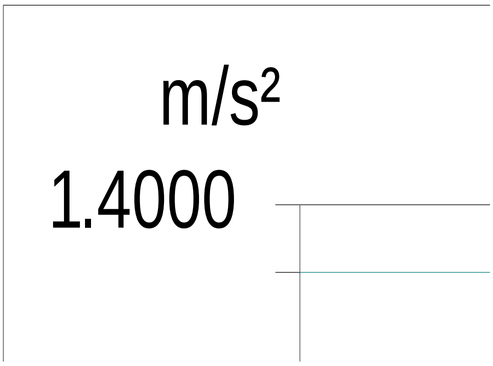
(a) 90% fill, 90 rpm, 1200 mm position



(b)90% fill, 90 rpm, 900 mm position



(c)90% fill, 90 rpm, 600 mm position



(d) 90% fill, 90 rpm, 300 mm position

Fig. 8. rpm at 90 with 1200mm, 900mm, 600 mm, 300 mm damper locations

D. 90 rpm

Fig. 8 (a)-(d) shows results of 90 rpm at four positions. In 90 rpm at 1200 mm and 900 mm position achieving vibration suppression effect. In 1200 mm position at 1st mode gives 0.616 (m/s^2) and at 2nd mode gives 0.241 (m/s^2). In 900 mm position at 1st mode gives 0.644 (m/s^2) and 2nd mode gives 0.199 (m/s^2). Un-damped values are 1.66 (m/s^2) and 0.264 (m/s^2) at 1st mode and 2nd mode respectively are high acceleration values as compare to 1200 mm and 900 mm Positions. Fig. 9 shows all results combined damp and un-damp conditions.

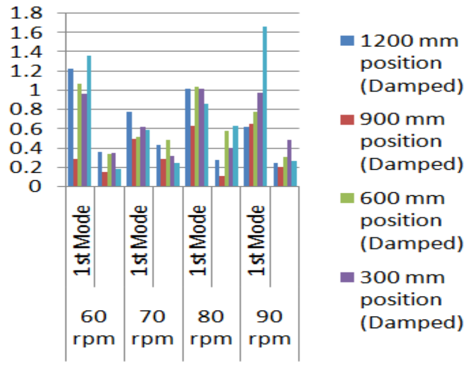


Fig. 9. Combined results of all cases

V. CONCLUSION

Damper location at 900 position gives better vibration suppression effect in 60 rpm case. At 70 rpm case no damper position shows overall vibration suppression effect at 1st and 2nd mode. Only at 1st mode case at 900 mm and 600 mm position give suppression. In 80 rpm condition 900 mm position gives good vibration suppression, remaining three positions are not shown both modes of suppression. In 90 rpm case shows two positions 1200 mm and 900 mm respectively shows suppression at both modes. In overall comparisons of results if want to find damper position on blade then 900 mm position is suitable for vibration suppression.

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