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Analysis of Vibration Characteristics on Wa-350 Wheel Loader Heavy Equipment Machine Based on Capacity Comparison with 2000 Rpm Rotation in Horizontal, Vertical and Longitudinal Areas

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ABSTRACT

Wheel loader is a tool that facilitates the work of moving materials from one place to another using hydraulic energy. Wheel loader machine testing is carried out by looking for vibration data arising in the engine block. There are several stages that must be done, the first step is preparation of a Handheld Vibrometer as a vibration detection device. Next, examine the vibration level read on the Handheld Vibrometer with ideal, medium, and maximum rotation. Based on the ISO 2372 standard, vibration response results are obtained where the power capacity of a diesel motor is 350 kW where the highest speed is 62.7 mm / s with a horizontal direction at 90 seconds, categorized in Zone D in red, vibration from the engine is within dangerous limits and can be damaged at any time.

INTRODUCTION

Machine vibration is the movement of machine parts moving forward and backward or back and forth from rest or neutral, and a simple example to show vibration is the work of a spring (Sunarko, 2010). A comparison of rotation and capacity on a machine can usually explain the level of vibration produced by the machine, so that it can be seen whether the machine still has a level of comfort to operate (Sihombing, 2021 and Simatupang, 2024)

Vibration in machines can be in several forms, such as machine vibrations in the categories of heavy capacity machines, medium machines or light capacity machines. A machine component can vibrate strongly, slightly, quickly or slowly, or audibly and generate heat. Machine vibrations cannot always cause damage, but there are some machine vibrations that are designed for special purposes such as vibration screens and compactors (Naibaho, 2021).

Heavy equipment is a tool used to simplify the work process so that it becomes faster, easier and the results meet expectations. The use of heavy equipment must be truly appropriate and adapted to the conditions and situation in the field (Masdiana, 2023). Where a wheel loader is a type of heavy equipment that is similar to a shovel dozer but with rubber wheels (tires) so that its capabilities and uses are slightly different. Wheel loaders are only capable of operating in hard and flat areas, dry and non-slip (Kulo, 2017), (Setiawati, 2013), (Raynonto, 2023).

This wheel loader heavy equipment is generally used to handle project materials, especially materials from excavations or to create piles of material. Vibration measurements are an effective, non-intrusive method for monitoring machine conditions during start-up, shutdown and normal operation

(Munsil, 2018). Vibration analysis is used primarily in rotating equipment such as steam and gas turbines, pumps, motors, compressors, paper machines, rolling mills, machine tools and gearboxes. And it is also used to determine the operating and mechanical conditions of equipment (Saleh, 2018). The main advantage is that vibration analysis can identify developing problems before they become too serious and cause unscheduled downtime. This can be achieved by carrying out regular monitoring of machine vibrations either continuously or periodically (Arifin, 2019).

Analysis of vibration and noise in the engine room and passenger deck of aluminum fast boats which was previously studied by researchers obtained the results of system vibration amplitude values in the engine room and passenger deck of aluminum fast boats which were obtained from the results of analysis calculations of 250 mode shapes which obtained varying results with a value range of 3.273x10 -7 to 2.703x10-6. Then the standard vibration values obtained are in the range of 0.253 to 2.093. Therefore, all vibration values in 250 shape modes meet the vibration standards (Wulandari, 2021).

Case study of machine damage based on vibration signals in the frequency domain, at PT. FREEPORT Indonesia there was friction between the inner race and the pulley shaft which caused the vibration to be dampened and not provide correct information. This was discovered after checking that the vibration amplitude had decreased after the previous inspection, then the vibration amplitude suddenly decreased, and damage occurred suddenly without warning. Predictable (Hutahean, 2021).

Exposure to machine vibrations has an impact on fatigue and hand arm vibration syndrome (HAVS) in workers in the precast concrete industry. So the results of vibration measurements using a Vibration meter are as follows: Vibrator table UA (19.9 m/sec2), Vibrator table UB (19.3m/sec2), Impact wrench-A (19.9m/sec2), Impact wrench-B (21.0m/sec2), Vibrator table (20.3m/sec2) and Grinding wheel (19.9m/sec2). Statistical analysis with Spearman and Pearson correlation resulted in $p < 0.05$ (Pramudita, 2016).

By simulating the dampening of rotational machine vibrations using the Dynamic Vibration Absorber (DVA), which researchers studied previously, the spring and damper values in the main system have been determined to be 35,000 N/m and 2700 Ns/m, respectively. From the simulation results, it was found that the best DVA parameter values were able to reduce vibrations of this rotational machine, namely spring 10,000 N/m, damper 2000 Ns/m and mass 783.845 kg so that this DVA was able to reduce vibrations by 16.6% for max overshoot and 65.5%. for min overshoot (Fitri, 2013).

From the vibration analysis method in machine maintenance applications with mechanical loosening on the motor base plate and misalignment on the motor with good high vibration conditions. That after the next two months the high vibration was in an unacceptable condition because the inboard motor bearing on the SKF NU313 type BPFO (ball past frequency outer race) was damaged. This is caused by previous mechanical loosening and misalignment, even though the amplitude is good, if you don't check the bolts on the motor base plate they become loose, the motor can move thereby increasing the occurrence of misalignment which is the initial cause of bearing defects (Setiawan, 2013).

Based on previous research, it can be concluded that using a vibrometer can be used to measure the vibration of a machine. The use of a vibrometer is combined with simulating the dampening of rotational machine vibrations using a Dynamic Vibration Absorber (DVA). This is based on previous research which has produced the best DVA parameter values capable of dampening vibrations of this rotational machine, namely springs of 10,000 N/m, dampers of 2000 Ns/m and mass of 783,845 kg. This DVA is able to reduce vibrations by 16.6% for max overshoot and 65.5% for min overshoot. For this reason, researchers want to analyze the vibration characteristics of the WA-350 wheel loader machine based on capacity comparisons with 2000 rpm rotation in the horizontal, vertical and longitudinal areas.

METHOD

This research was carried out at PT. Mitra Engineering Group in Paku Village, Galang, North Sumatra, Indonesia. The method of this research is quantitative descriptive research. Quantitative research is defined as a broad term used to denote research designs and methods that produce numerical data. A quantitative research study collects numerical data that must be analyzed to help draw research conclusions[19].

The research method used in carrying out this research is as follows:

1. Determining Goals and Problem Limitations
2. Install the tool on the engine mount and mount on the engine block.
3. Installation and testing using a vibrometer on a stand.
4. Collection, processing and analysis of data.
5. Conclusions and Results.

In this research, the research subject is the WA-350 Wheel Loader heavy equipment machine as seen in the picture below.

Figure 1. Wa-350 Wheel Loader

Investigation of the vibration signals that arise due to the comparison of the rotation and capacity of the coral bucket with measurement points in the direction of the horizontal, vertical and longitudinal axes. Measurements are carried out at predetermined points by collecting data based on the time domain[20]. The measurement of the three axis directions is because the test system is assumed to have 3 degrees of freedom as shown in the figure below.

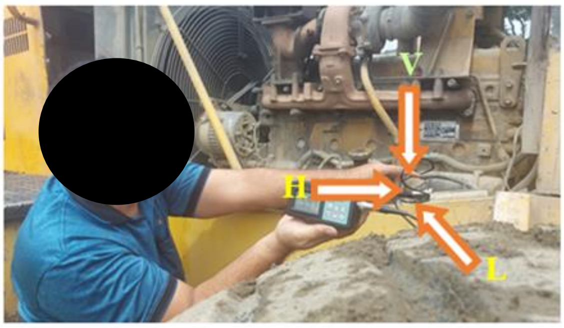

Figure 2. Observed variables from three measurement directions

RESULTS AND DISCUSSION

The results of this research were obtained by measuring vibrations on the engine chassis and engine block of the WA-350 Wheel Loader heavy equipment using a Handheld Vibrometer measuring instrument.[21]. And the results obtained by the vibration respondents in Table 1 are the sum of the average values obtained from direct measurements of deviation, speed and acceleration divided by the number of tests on the engine chassis mount when the engine is running.

Table 1. Measurement of vibration response results on heavy equipment wheel chassis mounts wa -350 loader when the engine is running.

No	Time(s)	Longitudinal			Vertical			Horizontal		
		Dis X (mm)	Vel$\dot{X}$(mm/s)	Acc$\ddot{X}$(m m/s^2)	Dis x (mm)	Vel$\dot{X}$(m m/s)	Acc$\ddot{X}$(m m/s^2)	Dis x (mm)	Vel$\dot{X}$ (mm/s)	Acc$\ddot{X}$(m m/s^2)
1	15	0.353	2.79	6.47	0.201	2.37	3.73	0.272	1.79	7,10
2	30	0,272	2.47	7.47	0.070	2.83	2.89	0.083	0.63	6.61
3	45	0.059	2.59	6,11	0.030	1.27	2.76	0.010	0.58	6.93
4	60	0.106	2.83	6.50	0.025	1.75	3.69	0.015	0.51	6.66
5	75	0.238	2.71	6.47	0.034	2.29	3.25	0.012	0.63	7.33
6	90	0.155	2.55	6.51	0.107	2.67	2.27	0.204	0.54	7.01
7	105	0.097	2.43	7.43	0.019	2.30	3.60	0.177	0.52	6.09
8	120	0.062	2.21	7.21	0.037	2.10	2.50	0.134	0.51	7.11
9	135	0.280	2.09	7.09	0.021	2.01	3.01	0.197	0.20	7.20
10	150	0.022	2.50	7.50	0.054	2.47	3.47	0.130	1.78	6.78
11	165	0.195	2.89	6.89	0.011	2.11	3.11	0.014	1.58	6.58
12	180	0.149	2.50	6.50	0.087	1.39	3.39	0.073	1.20	7.20
Average		0.156	2,456	6,845	0.058	2.13	3,139	0.110	0.872	6,883

Based on the analysis of vibration calculations from table 1 above, the values for each direction of vibration amplitude are obtained in table 2 below.

Table 2. Values for Each Amplitude Direction.

	Direction		
	Longitudinal	Horizontal	Vertical
ϖ (rad/s)	2163.4	1206.3	2919.7
ϖt (rad)	0.0030	0.0034	0.0017
t(s)	1.3867	2.8185	5.8225
A(m)	3.34875 x 12-6	8.60731 x 12-6	3.87357 x 12-6

From Table 2. above, the deviation, speed and acceleration can be obtained from the formula below:

Longitudinal direction:X= A Sin =3.34875 x 12-6 Sin 0.0030

=Aω Cos = 3.34875 x 12-6 Cos 0.0030

= Cos 0.0030

Vertical direction: X= A Sin = 3.87357 x 12-6Sin 0.0017

= Aω Cos = 3.87357 x 12-6 Sin Cos 0.0017

= 2919.7 Sin 0.0017

Horizontal direction: X = A Sin =8.60731 x 12-6 Sin 0.0034

= Aω Cos = 8.60731x 12-6 Sin 0.0034

= 1206.3 Sin 0.0034

And the results of the vibration respondents in Table 3. are the sum of the average values obtained from direct measurements of deviation, speed and acceleration divided by the number of tests on the WA -350 wheel loader machine block when the engine is running.

Table 3. Measurement of Vibration Response Results on the WA-350 Wheel Loader Heavy Equipment Engine Block when the engine is running.

No	Time(s)	Longitudinal			Vertical			Horizontal		
		Dis X (mm)	Vel X (mm/s)	Acc$\ddot{X}$(mm/s^2)	Dis x (mm)	Vel$\dot{X}$(mm/s)	Acc$\ddot{X}$(mm/s^2)	Dis x (mm)	Vel$\dot{X}$ (mm/s)	Acc$\ddot{X}$(mm/s^2)
1	15	0.073	34.9	172.2	0.175	57.7	113.5	0.363	59.7	128.7
2	30	0.093	32.1	158.7	0.120	51.2	116.3	0.121	61.0	122.8
3	45	0.072	33.5	172.7	0.144	50.1	117.9	0.089	59.5	124.5
4	60	0.073	34.9	177.5	0.142	51.5	131.6	0.109	60.1	112.3
5	75	0.056	32.7	169.5	0.139	52.8	112.3	0.094	62.1	175.3
6	90	0.071	33.5	165.2	0.138	54.7	114.6	0.102	58.0	134.7
7	105	0.081	31.9	191.1	0.104	55.5	116.0	0.096	57.5	155.5
8	120	0.061	32.9	154.3	0.137	55.7	120.2	0.097	56.3	165.7
9	135	0.206	33.5	179.5	0.121	50.3	120.4	0.086	57.1	150.3
10	150	0.245	31.7	151.7	0.154	59.4	124.6	0.088	59.4	129.4
11	165	0.205	35.5	149.7	0.111	56.2	118.4	0.074	60.7	136.2
12	180	0.281	33.4	197.2	0.187	59.4	119.2	0.090	58.9	159.4
Average		0.281	33,375	169.94	0.139	54,541	118.75	0.117	59.19	141.2

Based on the analysis of vibration calculations from table 3 above, the values for each direction of vibration amplitude are obtained in table 4 below.

Table 4. Values for Each Amplitude Direction.

	Direction		
	Longitudinal	Horizontal	Vertical
ϖ (rad/s)	1699.2	1810.4	1479.1
ϖt (rad)	0.0013	0.0070	0.0086
t(s)	7.6506	3.8665	5.8143
A(m)	1.899914 x 12-6	0.00209 x 12-6	1.829899x 12-6

From Table 4. above, the deviation, speed and acceleration can be obtained from the formula below:

Longitudinal Direction:X= A Sin = 1.899914 x 12-6 Sin 0.0013

=Aω Cos = 1.899914 x 12-6 Cos 0.0013

=1699.2 Cos 0.0013

Vertical direction: X= A Sin = 1.829899x 12-6 Sin 0.0086

= Aω Cos = 1.829899 x 12-6 Cos 0.0086

= 1810.4 Sin 0.0086

Horizontal direction: X = A Sin = 0.00209 x 12-6 Sin 0.0070

= Aω Cos = 0.00209x 12-6 Sin 0.0070

= 1810.4 Sin 0.0070

So you will get a combined graph of the vibration response results on the chassis and engine block of the WA-350 wheel loader heavy equipment in the graph below.

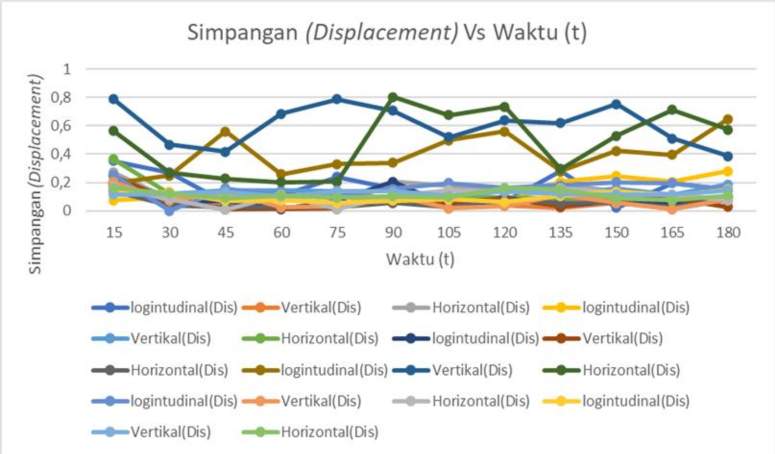

Figure 3. Combined graph of the relationship between displacement and time (t) on the chassis and engine block of the WA-350 wheel loader machine.

From Figure 3, the deviation relationship graph on the WA-350 Wheel Loader Heavy Equipment machine shows that the deviation in the horizontal direction is the highest direction with a value of 0.804 mm at 90 seconds, while the lowest deviation is in the vertical direction with a value of 0.011 mm at 45 seconds.

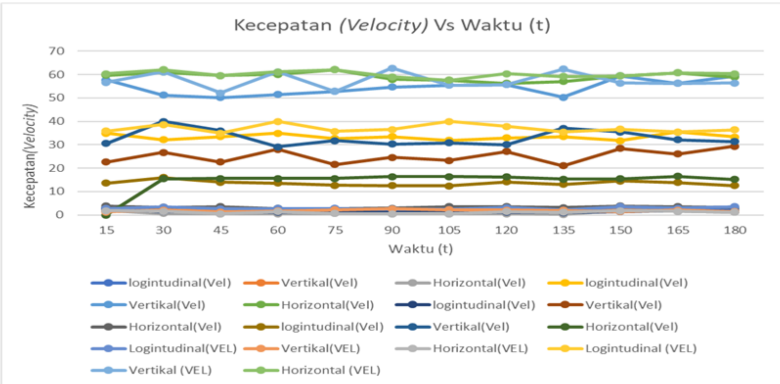

Figure 4. Combined Graph of the Relationship between Speed (Velocity) VS Time (t) on the Chassis and Engine Block of the WA-350 Wheel Loader Heavy Equipment Machine.

From Figure 4, the speed relationship graph on the WA-350 Wheel Loader Heavy Equipment machine shows that the speed in the horizontal direction is the highest with a value of 62.7 mm/s at 90 seconds, while the lowest speed is in the horizontal direction with a value of 0.20 mm/s. s at 135 seconds.

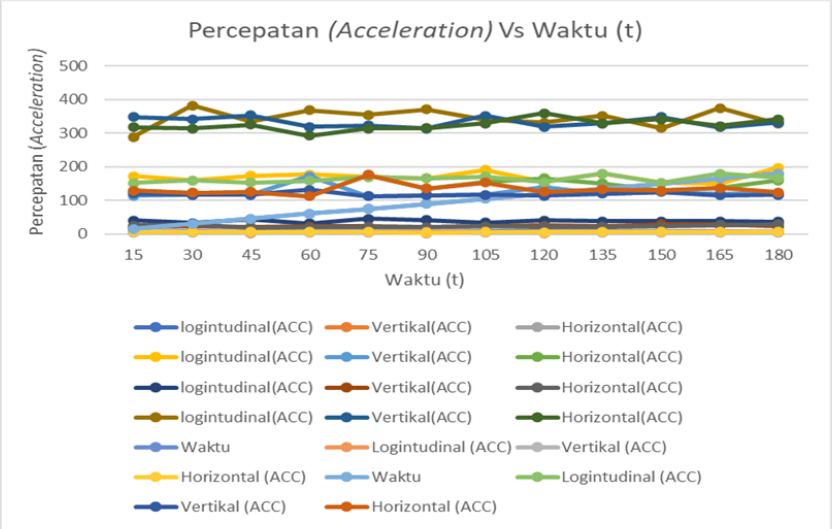

Figure 5. Graph of the relationship between acceleration and time (t) on the chassis and engine block of the WA-350 wheel loader machine.

From Figure 5, the graph of the acceleration relationship on the WA-350 Wheel Loader Heavy Equipment machine shows that the acceleration in the longitudinal direction is the highest with a value of 382.5 mm/s2 at 30 seconds, while the lowest acceleration is in the vertical direction with a value of 2.27 mm/s2. s2 at 90 seconds.

CONCLUSION

Based on the ISO 2372 standard, vibration response results were obtained where the power capacity of a 350 kW diesel motor with the highest speed was 62.7 mm/s in the horizontal direction at the 90th second, categorized in the yellow unacceptable zone, and higher vibrations could have an impact. on the WA-350 Wheel Loader Heavy Equipment machine when the vibration at the highest point can cause damage to the machine.

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