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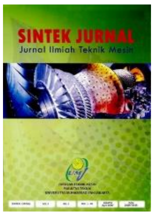

MODELING AND VIBRATION RESPONSE ANALYSIS OF PELLET MACHINE GRINDER AND GEARBOX

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ABSTRACT

Pellet machine is a machine used to print feed in the form of pellets. In this machine, if it operates, it can experience excessive vibration and the force acting on the machine is close to its natural frequency and can cause damage, so it needs to be reduced. In this study, the objective of this research is to model and simulate vibrations in the gearbox and grinder to determine the results of the displacement and acceleration vibration responses on the pellet machine. In this study, an electric motor is used as a source of rotation and an input clutch as a connection between the shaft of the electric motor and the gearbox as a transmission to reduce the speed of the electric motor, where the rotation produced by the electric motor contains vibrations, the output coupling is the connecting shaft between the gearbox shaft and the shaft grinder and miller as a tool used to print pellets. From the existing physical form, mathematical equations and simulation blocks are constructed. In this research, it is found that the vibration response generated from the gearbox and grinder can be modeled with the x and z axes as the center of the system. The higher the vibration response, the higher the given frequency, the greater the amplitude and rms of the displacement and acceleration responses in each part, namely the motor, clutch in, gearbox gearbox, coupling out, and grinder will be greater. The result of displacement vibration response yields an rms of 1.956. The worm gear in the gearbox produces a displacement vibration of 1.0585 m and an acceleration of 6.8485 m/s^2. The mill produces a displacement vibration of 1.0891 m and an acceleration of 5.1095 m/s^2.

Keywords: *pellet machine, vibration, modeling.*

1. INTRODUCTION

A pellet machine is a machine used to make fish feed in the form of pellets. In this machine, if it operates, it can experience excessive vibration and the force acting on the machine is close to its natural frequency and can cause damage, so it needs to be reduced [1]. In the process of making and designing a pellet machine, simulations are needed to make it easier to select components, as well as to find out the value of the working force and mass. The pellet machine has components such as motor, gearbox and grinder, from these components when operating, it causes vibrations due to the rotational force [2]. The occurrence of vibrations in the pellet machine can be beneficial or detrimental, if the vibration received by the pellet machine is excessive it can cause damage [3].

The vibrations that occur in the engine are due to the torsional force of the rotating motor, so that the engine components interact with each other and through the structure in the form of vibrations. While the force that causes vibrations can be generated from the contact between rotating components such as the rotation of an unbalanced mass and bearing damage [4]. One of the studies conducted shows torsional vibrations in the test structure that have the dominant active frequency is a one-turn signal component and the torsional vibration level that occurs depends on the type of flexible coupling used [5].

In this research, modeling and simulating the vibration response of the gearbox and pellet machine grinder was carried out. Basically, this research starts from modeling the free body diagram of a pellet machine where mathematical equations will be solved and then simulated to produce a response from the pellet machine so that it makes it easier to analyze the resulting vibration response.

2. METHODS

This research begins with a literature study to obtain information related to existing problems. The following is the physical form of the pellet machine being analyzed.

Basically this machine is a system that is connected to each other such as an electric motor as a driving source, the input coupling as the connector between the electric motor shaft and the gearbox shaft, the gearbox as a transmission to reduce the speed of the electric motor, the output clutch as a connector between the gearbox shaft and the grinder shaft and the grinder as a tool used to make pellets.

The following is the flowchart of this research.

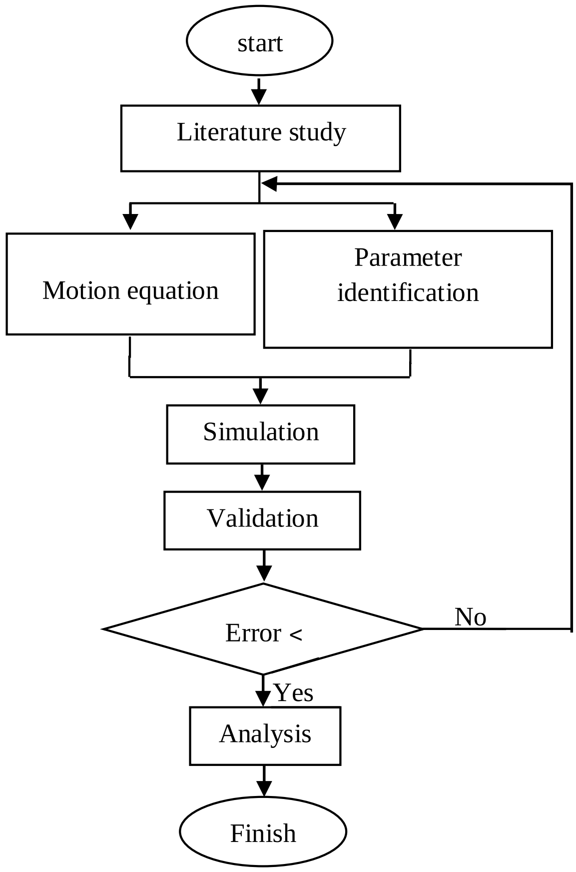


Figure 1. Research flowchart.

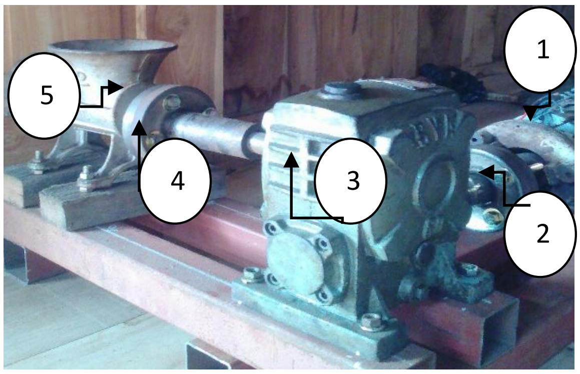
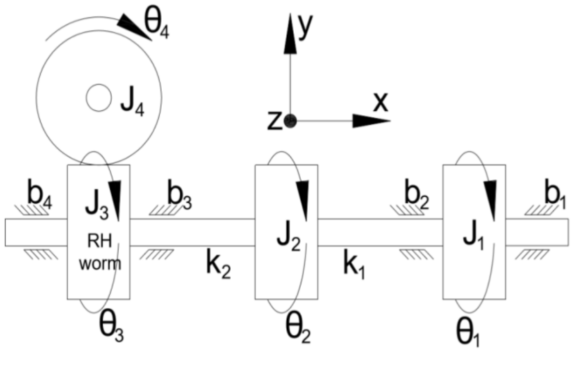
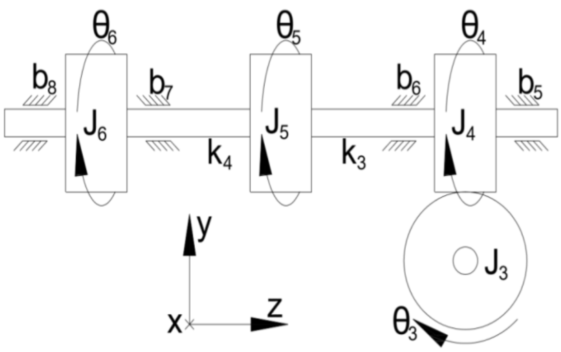


Figure 2. Pellet machine, (1) electric motor, (2) input coupling, (3) gearbox, (4) output coupling, (5) grinder.

Furthermore, the free body diagram modeling of the pellet machine is carried out using three DOF as in Figure 3.



(a)



(b)

Figure 3. (a) & (b) Model configuration in y-z plane.

B_1 = Motor bearing

B_2 = Motor bearing

B_3 = Input shaft bearing

B_4 = Input shaft bearing

B_5 = Output shaft bearing

B_6 = Output shaft bearing

B_7 = Grinder bearing

B_8 = Grinder bearing

k_1 = Motor shaft

k_2 = Input gear shaft

k_3 = Output gear shaft

k_4 = Grinder shaft

θ_1 = Motor angular displacement

θ_2 = Input coupling angular displacement

θ_3 = Input gear angular displacement

θ_4 = Output gear angular displacement

θ_5 = Output coupling angular displacement

θ_6 = Screw angular displacement

J_1 = Inertia of motor

J_2 = Inertia of input coupling

J_3 = Inertia of input gear

J_4 = Inertia of output gear

J_5 = Inertia of output coupling

J_6 = Inertia of screw

The excitation force exerted by an electric motor is a force with a sine function using the equation $\mathrm{F} = \mathrm{m}.\omega^2.\mathrm{R}.\sin(\omega.\mathrm{t})$. From the free body model system diagram in Figure 3, the state variable equations will be programmed into the Matlab simulink in the form of a simulation block diagram as follows. The state variable equation method is also used on some researches [6,7].

Motor motion equation

$$\dot{\omega}_1 = \frac{1}{J_1}[-B_1\omega_1 - B_2\omega_1 - k_1\theta_1 + k_1\theta_2 + \tau_a] \quad (1)$$

Input coupling motion equation

$$\dot{\omega}_2 = \frac{1}{J_2}[k_1\theta_1 + k_2\theta_3 - (k_1 + k_2)\theta_2] \quad (2)$$

Gear motion equation

$$\dot{\omega}_4 = \frac{1}{J_3\frac{r_4^2}{r_3^2} + J_4}\left[-\left((B_3 + B_4)\frac{r_4^2}{r_3^2} + (B_5 + B_6)\right)\omega_4 + \left(k_2\frac{r_4^2}{r_3^2} + k_3\right)\theta_4 - k_3\theta_5 + k_2\theta_2\right] \quad (3)$$

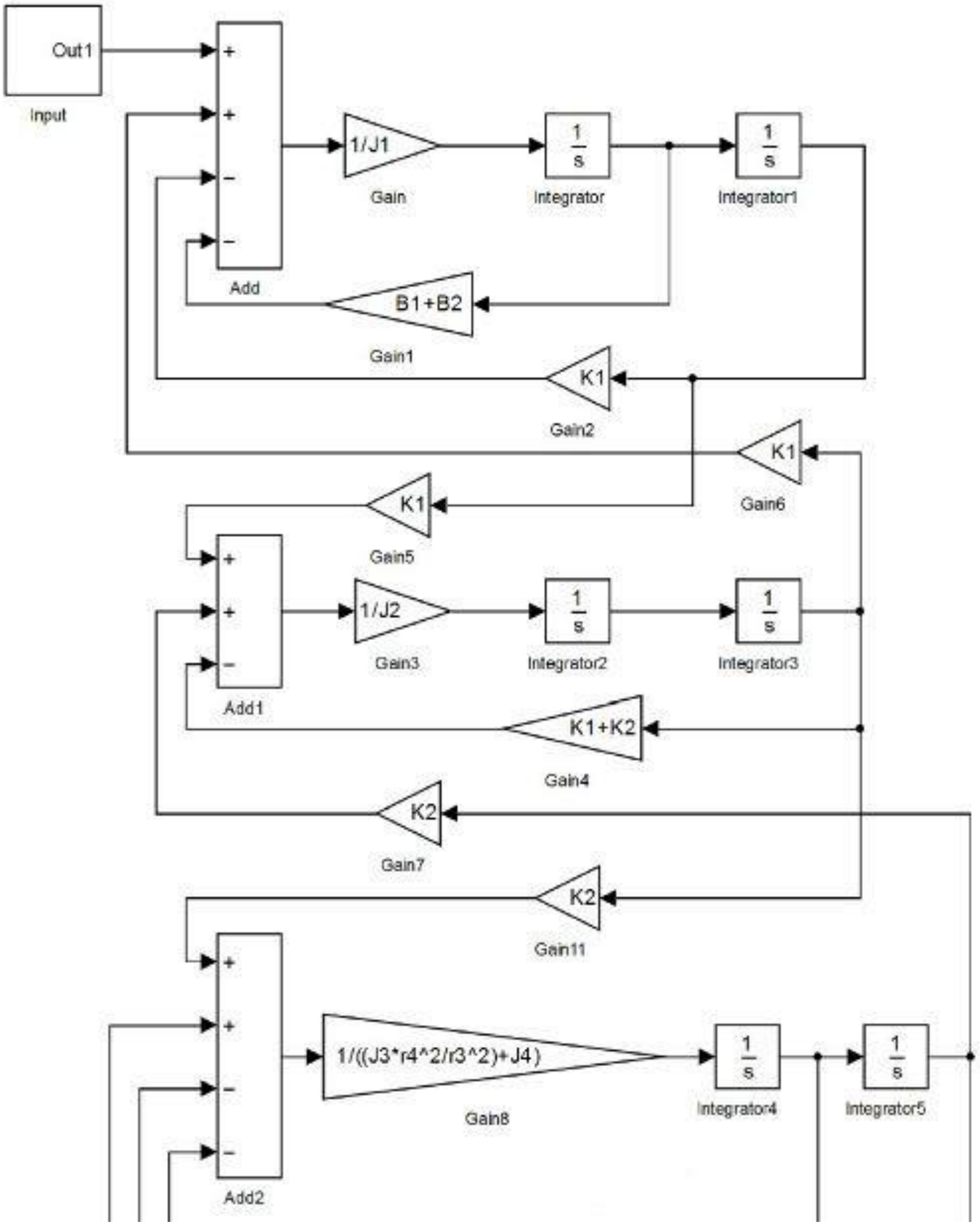
Screw motion equation

$$\dot{\omega}_6 = \frac{1}{J_6}\left[-(B_7 + B_8)\dot{\theta}_6 + k_4\theta_5 - k_4\theta_6\right] \quad (4)$$

Where:

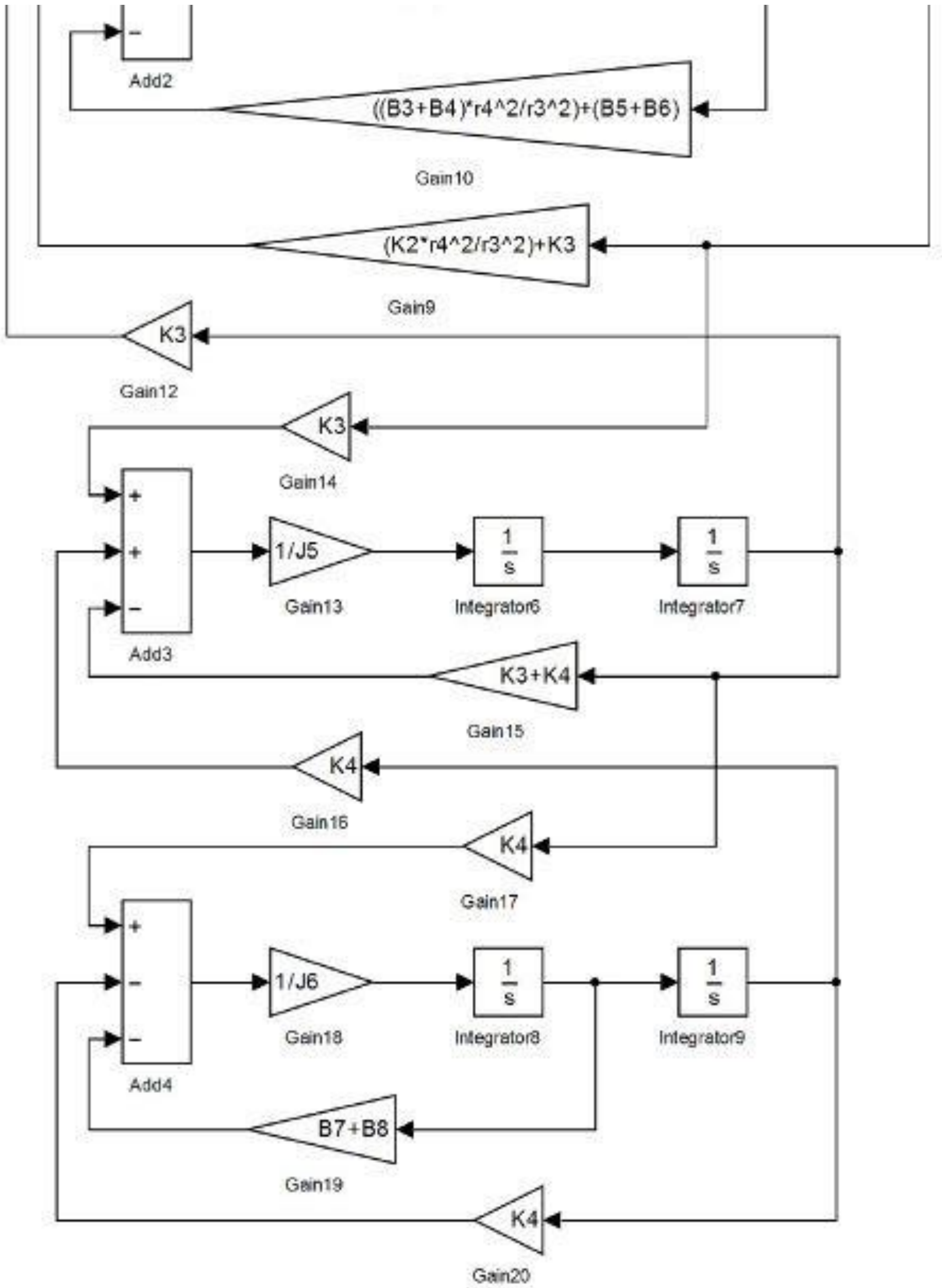
$\dot{\omega}_1$, $\dot{\omega}_2$, $\dot{\omega}_4$, $\dot{\omega}_6$ = Angular velocity

The following picture is the simulation block diagram.



Out1
Input
Add
1/J1
Gain
1
s
Integrator
Integrator1
B1+B2
Gain1
K1
Gain2
Gain6
Gain5
Add1
1/J2
Gain3
Integrator2
Integrator3
K1+K2
Gain4
K2
Gain7
Gain11
Add2
1/((J3*r4^2/r3^2)+J4)
Gain8
Integrator4
Integrator5

(a)



(b)

Figure 4. (a) & (b) Block Diagram.

The simulation is carried out to determine the vibration response of the gearbox and the pellet machine grinder. From the simulation process, the displacement and acceleration rms graphs are obtained from the pellet system. The simulation parameters used are shown in the table 1.

Table 1. Simulation parameters.

No	Symbol (unit)	Value	No	Symbol (unit)	Value
1.	T (kg.m)	2.525	11.	B1 (N.s.m)	17.23 x 10^{-3}
2.	JI (kg.m^2)	1.47x10^{-2}	12.	B2 (N.s.m)	17.23 x 10^{-3}
3.	J2 (kg.m^2)	6.2 x 10^{-4}	13.	B3 (N.s.m)	3.4037 x 10^{-7}
4.	J3 (kg.m^2)	4.0837 x 10^{-4}	14.	B4 (N.s.m)	3.4037 x 10^{-7}
5.	J4(kg.m^2)	4.46 x 10^{-4}	15.	B5 (N.s.m)	1.9484 x 10^{-5}
6.	J5 (kg.m^2)	1.5 x 10^{-4}	16.	B6 (N.s.m)	1.9484 x 10^{-5}
7.	J6 (kg.m^2)	4.4306 x 10^{-4}	17.	B7 (N.s.m)	6.2 x 10^{-6}
8.	k1 (Nm^{-2})	66.314	18.	B8 (N.s.m)	6.2 x 10^{-6}
9.	k2 (Nm^{-2})	266.354	19.	R3 (m)	0.0032
10.	k3 (Nm^{-2})	145.2583	20.	R4 (m)	0.05148

3. RESULTS AND DISCUSSION

In the simulation, the vibration response is obtained due to the excitation force. The vibration response is in the form of displacement and acceleration rms generated by the system. The excitation used in the time response modeling is period excitation with a phase difference of 0. The pellet machine simulation is done by simulating a mathematical equation that is built when the mass of the damper is neglected. In this condition, the system only has one degree of freedom, namely in the direction of translation and displacement and acceleration responses with the excitation frequency variation given to the system. The higher the vibration response, the higher the given frequency, the greater the amplitude and rms of the displacement and acceleration response in each part, namely the motor, input coupling, gearbox, output coupling, and the grinder will be greater. The following is a graph of the displacement vibration response in Figure 5.

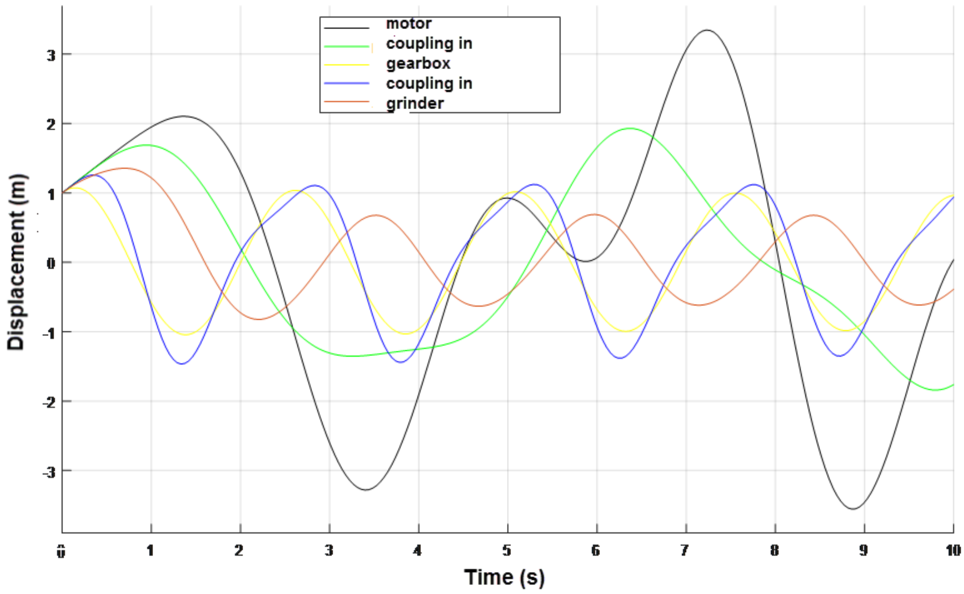


Figure 5. Displacement Response.

Figure 5 shows the vibration response of the motor from the pellet machine system produces an rms of 1.956, an initial peak point of 2.092 m and a vibration valley point of 3.277 m. The displacement vibration response on the input coupling of the pellet machine system produces an rms of 1.2, the initial peak point of 1.69 m and the valley point of 1.355 m. The displacement vibration response on the gearbox of the pellet engine system produces rms of 0.7277, an initial peak point of 1.086 m and a valley point of 1.048 m. The displacement vibration response on the output coupling of the pellet engine system produces an rms of 0.8716, an initial peak point of 1.274 m and a valley point of 1.454 m. Meanwhile, the response of the displacement vibration of the grinding screw from the pellet machine system produces an rms of 0.6308, an initial peak point of 1.364 m and a valley point of 0.827 m. It can be seen that the greater the mass, the smaller the displacement rms, so as to reduce excess vibrations. Furthermore, the results of the acceleration response from the pellet machine are shown in Figure 6.

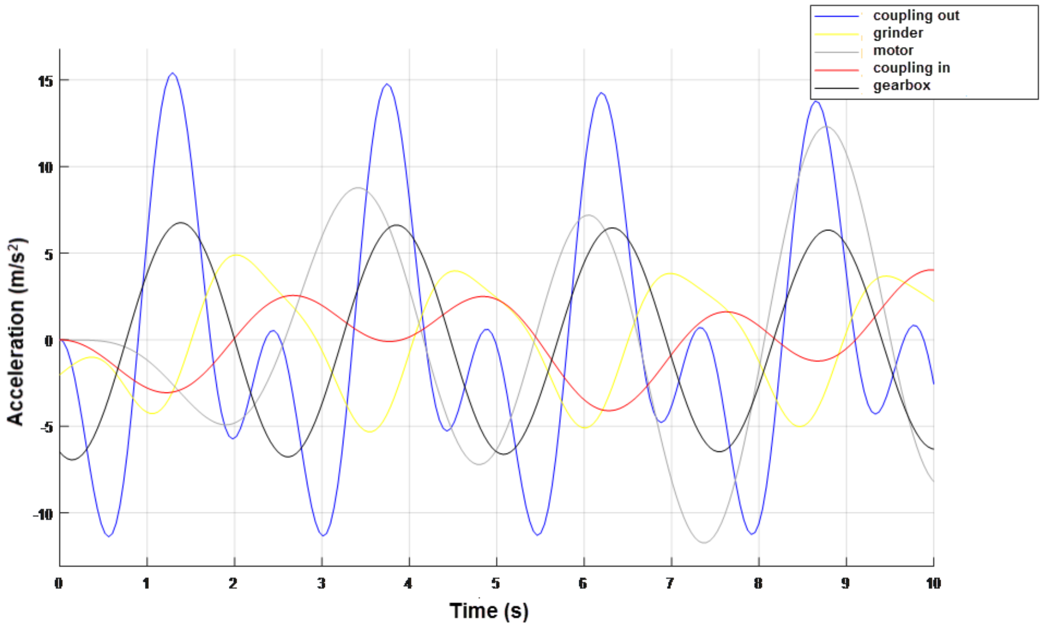


Figure 6. Acceleration Response.

Figure 6 shows that the acceleration vibration response of the pellet machine in the response of the motor rms of 8.756 m/s^2, the valley point of 4.879 m/s^2, the peak point of 7,235 m/s^2. The acceleration response of input coupling is rms value of 2.558 m/s^2, the valley point of 3.053 m/s^2, and the peak value of 2.498 m/s^2. Meanwhile, the acceleration response on the gearbox is rms value of 6.76 m/s^2, the valley point of 6.902 m/s^2, and the peak value of 6.619 m/s^2. The acceleration vibration response on the output coupling is the rms value of 1.542 m/s^2, the initial peak of 1.542 m/s^2, the valley point of 11.258 m/s^2, and the peak value of 1.478 m/s^2. The response of the acceleration vibration on the grinding screw is rms value of 0.961 m/s^2, valley point of 4.236 m/s^2, and peak value of 4.902 m/s^2.

4. CONCLUSION

The greater frequency the greater vibration response amplitude of each component. The amplitude and RMS of displacement and acceleration responses of each component, such as motor, input coupling, gear, output coupling, and grinder, will be greater. Displacement vibration response result has RMS value of 1.956. *Worm gear* in gearbox has displacement vibration response of 1.0585 m and acceleration response of 6.8485 m/s^2. The grinder has displacement vibration response of 1.0891 m and acceleration response of 5.1095 m/s^2.

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