Vibration Analysis Vibro Fluidized Bed Dryer Using Finite Element Method

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Abstract - **Nowadays, the vibrating fluidized bed dryer is one of the most popular kinds of tea drying equipment available. The water content is lowered to 2.8–3.8 by applying the heat generated by the heater, which stops the enzyme-based oxidation process. The objective is to investigate how vibration affects a vibro-fluidized bed dryer's inherent frequency, structural integrity, and tea mass loading on the device. Tea powder is sprayed onto beds using vibro-fluidized bed dryers, which use an eccentric motor to create vibrations. Hot air flows from tiny holes in the bed into the tea powder that is circulating on it. After leaving the heating furnace, the hot air is directed through air ducts beneath the vibro-fluidized bed drier by the main fan. A cyclone extracts the tea powder and evaporates moisture, which is then released from the vibro-fluidized Bed dryer. Once disturbed, a system is allowed to vibrate on its own without external stimuli, oscillating at its natural frequency. As per the early analysis of the vibro-fluidized Bed Dryer, the dryer structure's normal frequency in the first three modes was 5.8876 Hz, followed by 9.5267 Hz and 10.512 Hz. The vibro-fluidized bed dryer structure's stress is within acceptable bounds when the safety factor for each loading variation is FS>1. The vibro-fluidization frequency of the bed dryer with a tea mass of 695 kg matches to the excitation frequency under real-world conditions. The tea mass supplied to the system increases with the natural frequency of the vibro-fluidized bed dryer. Static structure studies show that the von Misses stress of the vibro-fluid layer drying structure increases with the mass of tea added to the system. The largest von Mises stress was seen at a tea mass of 695 kg.**

Keywords: Fluidized bed dryer, CFD, Drying, Tea.

I. INTRODUCTION

Fluidized bed dryers find widespread application across various industries, including mining, pharmaceuticals, and more, primarily for solid object drying processes due to their high mass transfer and heat transfer rates, thus reducing drying time [1].Fluidized bed dryers operate by involving air entering a holding vessel, which causes particles to float within. The process via which solid particles change into a suspension is called fluidization. When air is blown into the containment vessel, there is a decrease in pressure due to friction. The particles are lifted and move like a fluid because the blown air exceeds the resisting force, causing the containment vessel to fluidize [2]. Under fluidization conditions, particles attain a minimum fluidization velocity (Vmf) to remain suspended [3].

These days, one popular kind of tea drying equipment is the vibro-fluidized bed dryer type tea dryer. The enzymatic oxidation process is stopped by the heater's heat, which also lowers the air content to about 2.8–3.8 percent. Vibro-fluidized bed dryers work by causing the tea powder that is dripping over the bed to vibrate through the use of vibrations generated by an eccentric motor. Hot air is blasted from a tiny bed aperture onto the tea powder. Hot air is drawn in by the heating furnace's primary fan and directed through the air duct beneath the vibro-fluidized bed dryer. The tea powder's moisture is extracted by the cyclone and released from the vibro-fluidized bed dryer [4].Fluidization is the process of contact between solid particles and gas or liquid, reaching a semi-fluid state. This contact is typically achieved by flowing gas from a porous column base, penetrating solid particles, and forming a spread. Hence, a certain fluid flow velocity is required for solid particles in the spread to suspend at low currents, where the fluid only passes through void spaces between stationary particles. This state is known as a fixed spread. When the current velocity is increased, solid particles move and vibrate, referred to as an expanded spread. The particles will move away from each other and rotate like the movement of highly viscous particles if the flow velocity reaches a certain point and the particles experience suspension for the first time. The fluid speed is known as the minimum fluidization speed (Umf), and this condition is known as the minimum fluidization condition [5].

II. RESEARCH METHODOLOGY

The vibro-fluidized bed dryer is a machine that employs heat to inhibit enzymatic oxidation and reduce moisture levels

by up to 2.8-3.8%.The specifications for the vibro-fluidized bed dryer used are shown in Table 1.

Table 1: Vibro-Fluidized Bed Dryer specification

Manufacture	:	Kilburn Engineering Limited
Model	:	Vibro-Fluid Bed Dryer EEC LFDC
Water evaporation rate (kg/hr)	:	550
Size of drying chmaber (L x W) (mm)	:	7550 X 1070
Heat requirement (hot air @ 120°C)	:	24000
Drying System (KW)	:	29,25
Dust Colln System (KW)	:	9,375
Type of fuel	:	Oil, Coal, Wood, Gas, or Steam
Expected steam consumption (8-10 bar) (kg/hr)	:	1400
1st Zone (°C)	:	110
2nd Zone (°C)	:	90-95

To measure vibrations, we use a vibration meter, which is a device employed to gauge vibrations generated by machinery during operation. Through the use of this vibration meter, results are obtained and compared against predetermined threshold values. Measuring the dimensions of the vibro-fluid bed dryer was one of the tasks of this research. Then, we evaluated the frequency that is generated when it vibrates. This is followed by an analysis using computational fluid dynamics (CFD) and the calculation of safety factors for three different designs. When a system experiences a disturbance and is allowed to vibrate independently without external forces, the system oscillates at its natural frequency. When there is forced vibration, the system vibrates, equivalent to the frequency of the stimulus received. If the excitation frequency equals its natural frequency, the system undergoes resonance. Resonance, a condition to be avoided during system operation, results in large amplitude values and may lead to structural failure. Mathematically, the natural frequency is expressed as [6].

The equation for Natural Frequency:

$$f_n = \frac{1}{2\pi}\sqrt{\frac{k}{m}} \tag{1}$$

$$\omega_n = \sqrt{\frac{k}{m}} \tag{2}$$

Free vibration without damping that has equal forces on the mass and spring. Mathematically expressed by :

$$m\ddot{x} + kx = 0 \tag{3}$$

The period equation:

$$\tau = \frac{2\pi}{\omega_n} \tag{4}$$

Natural frequency:

$$f_n = \frac{1}{\tau} = \frac{\omega_n}{2\pi} = \frac{1}{2\pi}\sqrt{\frac{k}{m}} = \frac{1}{2\pi}\sqrt{\frac{kg}{W}} \tag{5}$$

$$m\ddot{x} + c\dot{x} + kx = 0 \tag{6}$$

Critical damping coefficient :

$$c_c = 2\sqrt{km} = 2m\omega_n \tag{7}$$

The solution to the equation mentioned above varies depending on whether the damping coefficient matches, falls below, or exceeds the critical damping coefficient c_c. If the stress applied to a component is identified, and the permissible stress surpasses the actual stress, then structural failure will not occur. Nevertheless, in practical scenarios, design elements inevitably entail a degree of uncertainty, underscoring the necessity for safety margins.

$$FS = \frac{\sigma_y}{\sigma_{application}} \tag{8}$$

III. RESULTS AND DISCUSSION

3.1 Product Specification

During the geometric simulation, the containment vessel is represented as a plate with a mass matching its real weight, while the remaining components maintain their original dimensions. The geometry of the vibro-fluid bed dryer used in the simulation is shown in Figure 1. The main frame, base, leaf spring holder, and leaf spring are the constituent parts of the vibro-fluid bed dryer.
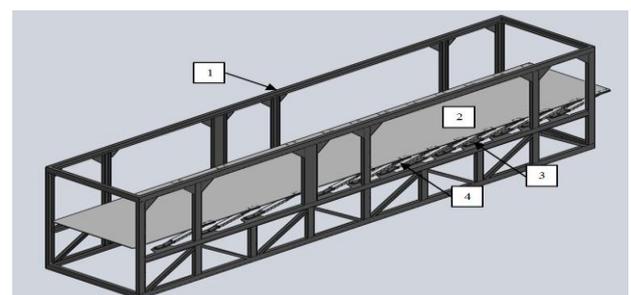

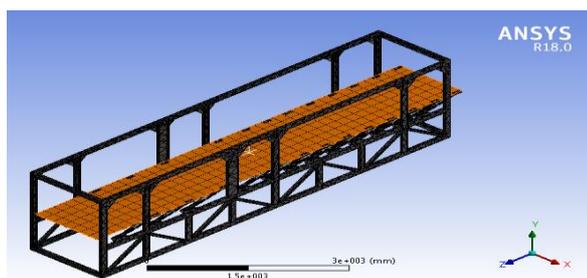**Figure 1: GeometryVibro-Fluid Bed Dryer**

Figure 2: Meshing Vibro-Fluid Bed Dryer

3.2 Meshing

The meshing process is completed once the stiffness characteristic and material type have been established. Face sizing with an element size of 195mm is used to mesh the geometry. Figure 1 shows the geometry of the vibro-fluidized bed dryer used for the simulation process. The parts of the vibro-fluidized bed dryer consist of the main frame, bed, leaf spring holder, and leaf spring. A total of 95,270 nodes and 38,610 elements are produced by this meshing. The mesh of the vibro-fluidized bed dryer geometry is shown in Figure 2.

3.3 Modal Analysis

During modal analysis, the system's initial three natural frequencies will be identified under a load of 450 kg of tea leaves. Structural design is within its strength or capacity limits by calculating material strength, safety factors, gravity, and other environmental influences that can influence design. In the material used, the stress tolerance used is 43.4 DaN. Detailed modal analysis settings used in the fluidized bed vibro dryer are shown in Table 2.

Table 2: Details of modal analysis setup

| Options	
Max Modes to Find	3
Limit Search to Range	No
Damped	No
Solver Type	Program Controlled
Coriolis Effect	Off
Campbell Diagram	Off

After configuring the modal analysis, as shown in Table 2, the next step is to determine the support point of the vibro-fluid bed dryer at its bottom. As shown in Figure 3, the first three modes of the vibro-fluidized bed drying system will be analyzed to produce the maximum displacement and natural frequency.
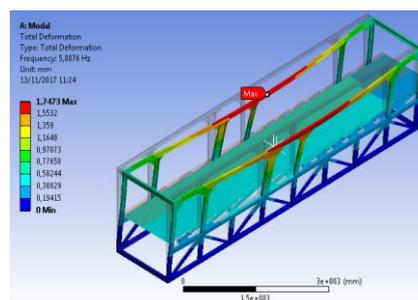
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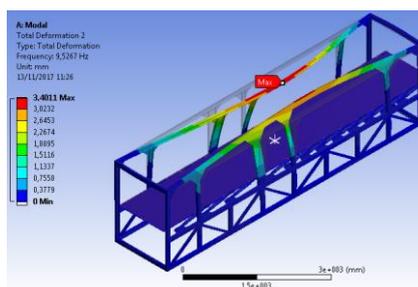
(2)
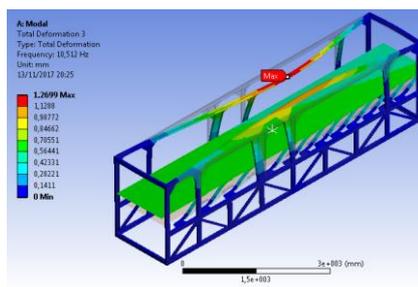
(3)

Figure 3: Mode shapes and natural frequencies for modes 1, 2, and 3

In Figure 3, the natural frequencies of modes 1, 2, and 3 for the vibro-fluidized bed dryer structure are as follows: 5.8876 Hz with a maximum displacement of 1.7473 mm for mode 1, 9.5267 Hz with a maximum displacement of 3.4011 mm for mode 2, and 10.512 Hz with a maximum displacement of 1.2699 mm for mode 3. The static structural analysis simulation yielded a von Mises stress of 5.838 MPa.

After obtaining the results from both modal analysis and static structural analysis using a load of 450 kg of tea leaves, a justification was conducted on the simulation results to determine whether the methods used were appropriate or not. This is done by changing the mass of the tea leaves to determine how much tea can be fed into the system, as well as the pressure generated in the vibro- fluidization dryer. In modal analysis with different loadings, the mass of tea leaves should not exceed 695 kilograms, as shown in Figure 4. This is due to the fact that the natural frequency of the vibro-fluidized dryer at a loading of 695 kilograms is the same as the

excitation frequency of the vibro-fluidized dryer, i.e. 5.7545Hz. As a result, structural failure due to resonance will occur.
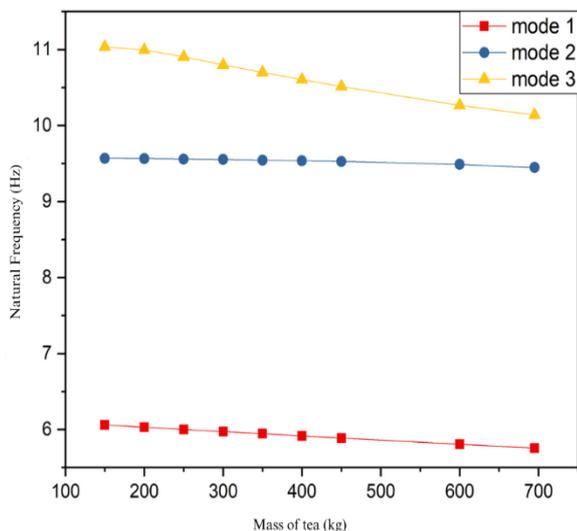

Figure 4: Comparison graph of natural frequencies for each vibration mode with varied loading

Figure 4 illustrates a comparison graph of the natural frequencies for each vibration mode with varied loading. From the graph above, it is evident that as the tea mass increases, the natural frequency values of the vibro-fluidized bed dryer structure decrease. This aligns with the mathematical equation stating that the natural frequency of a structure decreases as its mass increases [7].

3.4 Static Structural Analysis

Using 450 kilograms of tea leaves, the von Mises stress under static load will be calculated in the static structural analysis. Structural steel, with material properties listed in Table 3, will be used as the material for the vibro-fluidized bed dryer.

Table 3: Material Properties

Properties	Value
Density	7850 kg/m^3
Tensile Yield Strength	250 Mpa
Tensile Ultimate Strength	460 Mpa

The material properties listed in Table 3 serve as references in analyzing the strength of the Vibro-fluid bed dryer structure. Therefore, the safety factor value for the vibro-fluid bed dryer structure, based on the equation $\mathbf{Fs} = \frac{\sigma_y}{\sigma}$, should be greater than 1. From Figure 4, it is observed that the vibro-fluidized bed dryer structure is within the safe limits because its safety factor value is greater than 1, and it possesses a very high safety factor value.
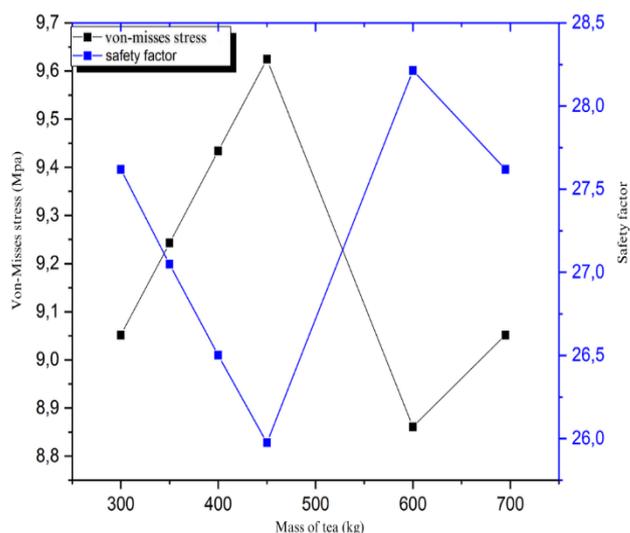

Figure 5: Comparison graph of von Mises stress and safety factor with varied loading

Figure 5 depicts a comparison graph of von Mises stress with varied loading. From the graph above, it is evident that as the tea mass increases, the von Mises stress also increases. Additionally, there is a comparison graph of the safety factor values with varied loading. From the graph above, it is observed that as the tea mass increases, the safety factor values decrease.

IV. CONCLUSION

The initial examination of the vibro-fluidized bed dryer indicated that the inherent frequencies of the structure are present in the first three modes, which are 5.8876 Hz, 9.5267 Hz, and 10.512 Hz. For all load fluctuations in this case, the safety factor value FS>1. This proves that the forces acting on the vibratory fluid bed drier's structure are within a reasonable risk range. When more tea is introduced to the system, the fluidized bed dryer's intrinsic frequency drops. In real-world conditions, the vibro-fluidized bed dryer's stimulation frequency and natural frequency match precisely at a tea mass of 695 kg. The fluidized bed vibro dryer is caused by the mass of tea introduced to the system, per the static structure analysis.

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