Analysis of heat load in coffee bean drying oven room

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Abstract. Technology has an essential role in the production process which has a function to increase the quality and quantity of production results. Post-harvest coffee bean drying oven technology is needed to speed up the production process, which has been done manually—design and analysis of coffee bean oven machines to produce the effective performance of the oven machines. The method in this study uses the finite element method using ANSYS (Workbench) V 18.1 to analyze the strength of the material and the heat temperature generated from the combustion system. The results of the analysis obtained an average temperature value of 60ºC, with the highest temperature of 200ºC found in the engine furnace because of the initial heat source.

1. Introduction

The drying process of agricultural products makes it easy to store agricultural produce for proper distribution. The method of drying the granules aims to reduce the water content to a certain extent so that there is no damage due to metabolic activity by microorganisms [1]. The drying method, to remove most of the water from a material through the application of heat energy, is transferred to a system [2],[3]. The use of life to produce heat without realizing it by humans will increase the rate of environmental pollution, especially air pollution. As a result of burning these fuels, it is necessary to recycle CO2, so that CO2 emissions into the atmosphere are net zero [4],[5]. Burning biomass briquettes has several advantages, namely being able to provide a sustainable source of energy, user needs, environmental standards and economic conditions [6],[7]. One of the most commonly used seed drying processes is combustion technology. To ensure that the combustion process can run completely, combustion is carried out in excess air h (excess air). The amount of excess air depends on the type of fuel and the combustion/kitchen appliance [8]. The combustion process follows the character of the combustion system designed in the reactor unit by paying attention to the capacity of the combustion chamber, of course, it is also inseparable from the characteristics of the biomass itself, to get the expected combustion process [9]. To improve thermal efficiency in the use of solid fuels, combustion through the furnace is possible. Where the resulting temperature will be used thoroughly in a seed drying oven, it is necessary to analyze the extent of the required heat composition and the rate of heat propagation in the oven seed drying system.
2. Method
In designing a structure, it is necessary to establish a material selection procedure by the conditions of the application. Strength or material stiffness is not the only criterion that must be considered in structural design. Still, material strength is as important as other material properties such as hardness, toughness, which are criteria for determining material selection [10]. The strength of the structural material can be calculated and simulated through a tensile test experiment using a numerical approach [11]. The results are then compared with the yield strength of the material to obtain the material safety factor. In engineering and engineering, the software is generally used to help resolve cases that have been determined [12]. One of the software commonly used in designing is ANSYS [13]. Various analyzes can be done with the help of this software, such as structure analysis (global and local). Ansys program a finite element method is a numerical method suitable for solving engineering problems with geometry, loading and complex material properties. The finite element method approach uses the information at node points. In the process of determining the node point, which is called discretization, a system is divided into smaller parts. Then problem-solving is carried out in the parts and then recombined so that a comprehensive solution is obtained [14]. ANSYS is an effective finite element method program for solving engineering problems using the built-in simulation package. ANSYS (Workbench) V 18.1 is a multipurpose program that can be used to solve problems involving two different domains and design optimization. To analyze technical problems with the ANSYS program, steps are taken, namely; select the type of analysis, create the model, enter the material data, create a mesh, provide the load and boundary conditions, enter the desired results, request results, view and analyze the results [15]. The thermal-structural analysis was initially carried out by selecting thermal analysis (thermal transient), which was combined with structural (static structural) analysis in series by including thermal loads. The initial stage is carried out by completing the transient thermal simulation, and the analysis results will be the initial load (setup) of the structural simulation.

3. Result and discussion
The coffee bean oven machine in this study was made to produce even heating of the coffee beans. Knowing the heat transfer process that occurs in the coffee oven machine used needs to be researched to analyze the heat transfer that occurs during the coffee oven process. The machine design used in the study can be seen in Figure 1 as follows,
Research conducted on a coffee oven machine is a simulation study using ANSYS 18.1 steady-state thermal software. The objective is to determine the heat transfer from the engine furnace to the coffee oven filter. The temperature in the coffee filter during the coffee roasting process is 60 °C and the temperature at the furnace is 200 °C.

The process of making the components of a coffee oven machine in this study using the Autodesk Inventor 2018 software. The simulation process using the ANSYS 18.1 software to simulate a steady-state thermal requires a geometric format that can be read by the software used. Machine components that have been combined into one (assembly) are imported with geometry using STEP or STP format so that the geometry can be read during the simulation process using ANSYS 18.1 Steady-State Thermal software.

**Pre Processing**

This process describes the process of making geometry, determining the type of material, the geometric meshing process, and determining the boundary conditions in the coffee oven machine.

**Geometry Modeling.**

The geometry of the coffee oven is shown in Figure 2 below, in the design of the coffee oven machine, which has one burning stove, one coffee bean oven and a filter that rotates at a specified speed to produce evenly heated coffee beans. The filter drive of the coffee oven machine is an electric motor.

![Figure 2. The temperature of the coffee oven machine](image)

**Determining the Type of Material**

The material used by the coffee oven machine is SS grade 304, which is inputted manually. Description of the coffee oven component material data for the thermal steady-state simulation process includes the material properties of the oven frame, the furnace frame, the inside of the oven, the coffee filter, and the coffee oven machine cover using grade 304 stainless steel. Material properties for SS 304 can be seen in Table 1.

| Material                  | Value |
|---------------------------|-------|
| SS Grade 304 (UNS S30400) |       |
| Density (Kg/m$^3$)        | 8055  |
| Thermal Conductivity (W/m°C) | 13.8  |
| Specific Heat (J/kg°C)    | 480   |

*Table 1. Material properties stainless steel (SS) grade 304*
Meshing

Before carrying out the simulation process, the meshing process must be carried out first. In this meshing process, it is dividing this geometry into small parts that will form the object's geometry. The smaller the meshing size that is formed, the closer to the actual value, however, the finishing process will take longer.

Table 2. Total elements and nodes in the coffee oven geometric model

| Explanation                  | Elements | Nodes |
|------------------------------|----------|-------|
| Oven Frame                   | 456109   | 159645|
| Furnace Frame                | 72287    | 25608 |
| The inside of the oven part  | 225201   | 51310 |
| Coffee Filter                | 394299   | 136841|
| Engine Cover                 | 608268   | 195198|
| Total Number                 | 1756164  | 568602|

source: ANSYS Workbench – Steady-state thermal

Mesh sizing in this simulation uses the size with the number of elements and nodes as in Table 2, making a mesh is done using an element size of 0.005 in the software to produce a fine mesh.

![Image](image_url)

Figure 3. The results of the meshing process in the coffee oven machine

Determination of Boundary Conditions

Determination of these boundary conditions is the parameters used in the simulation based on the calculation results. The average temperature at the stainless steel pipe outlet after passing through the capacitor.

\[ T_{\text{furnace}} = 200^\circ\text{C} = 473.15^\circ\text{K} \]
\[ T_{\text{Filter}} = 60^\circ\text{C} = 333.15^\circ\text{K} \]

Then the average temperature:

\[ T_{\text{average}} = \frac{473.15^\circ\text{K} + 333.15^\circ\text{K}}{2} \]
\[ T_{\text{average}} = \frac{806,3^\circ K}{2} \]

\[ T_{\text{average}} = 403,15^\circ K = 130^\circ C \]

Then the temperature of the engine furnace to the engine oven produces an average temperature of 130 ° C. The 130 ° C temperature is the average temperature that will occur during the coffee oven simulation process. The problem that often occurs in heat transfer is determining the temperature distribution of the system. By using the finite element method, the amount of heat entering or leaving the system and thermal stress can be determined. Steady Conduction Equation on a single layer plate.

\[ q \frac{A}{dX} = -K \frac{dT}{dx} = -K \times \frac{(T_1 - T_2)}{(X_2 - X_1)} \]

It is known that the thermal steady-state simulation results for the maximum and minimum heat flux values that occur in a coffee oven have a maximum heat flux value of 0.021269 W / mm² and a minimum heat flux value of 4.7492 \times 10^{-19} W / mm². The equation for calculating the maximum heat flux that occurs on the SS 304 plate surface per coffee oven furnace area is described as follows,

\[ q/A = -K \times (dT/dx) \]

\[ dX = \frac{K \times dT}{q/A} = \frac{0.0138 W/mm^2 \times 200^\circ C}{0.021269 W/mm^2} = 129,766 mm = 0,1297 m \]

The equation for calculating the minimum heat flux that occurs on the SS 304 plate surface per coffee oven furnace area is described as follows,

\[ q/A = -K \times (dT/dx) \]

\[ dX = \frac{K \times dT}{q/A} = \frac{4,7492 \times 10^{-19} W/mm^2}{4,7492 \times 10^{-19} W/mm^2} = 1,743 \times 10^{18} = 1,74 \times 10^{18} m \]

Then the heat transfer rate distance on the surface and the thickness of the inner and outer plates for the maximum heat flux has a value of \(dX = 0.1297 m\) and the minimum heat flux has a value of \(dX = 1.74 \times 10^{18} m\).

Based on the calculation of the heat flux value in the coffee oven machine, it can be concluded that the higher the temperature, the smaller the plate area and the smaller the plate thickness, the smaller the heat flux value, while the lower the temperature, the larger the plate area and the larger the plate thickness. Produces a large heat flux value. In the furnace area, the coffee oven machine has a space volume smaller than the coffee oven area so that the location of each plate of the machine furnace has a smaller plate area than the coffee oven plate.

**Post Processing**

Post-processing is the final process of finishing finite elements. In post-processing, it explains the display of simulation results from finite element software. The simulation results in post-processing are temperature plots.
Based on Figures 4, it is known to have an average temperature value of 60 °C. Based on the figure, it is known that the coffee bean filter section has the lowest temperature value than other machine parts, because this section is far from the heat source of the heating furnace. A conclusion can be drawn from Figure 16 that the highest temperature of 200ºC is found in the engine furnace because the initial heat source occurs in that section, and the lowest or minimum temperature occurs in the coffee bean filter with a temperature of 60 °C.

4. Conclusion

Conclusions from the results of thermal analysis and structural analysis carried out simultaneously (thermal-structure) on a coffee bean oven machine obtained the distribution of temperature, heat flux, equivalent stress (Von-Mises), total deformation, and thermal strain. The temperature value decreases because when you move away from the heat source and the area of heat propagation becomes wider, the resulting temperature decreases during heat propagation.

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