Development of 300 mesh Soy Bean Crusher for Tofu Material Processing

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Abstract. A machine such as bean crusher machine is subjected to different loads and vibration. Due to this vibration there will be certain deformations which affect the performance of the machine in adverse manner. This paper proposed a vibration analysis of bean crusher machine using ANSYS. The effect of vibration on the structure was studied in order to ensure the safety using finite element analysis. This research supports the machine designer to create a better product with lower cost and faster development time. To do this, firstly, using Inventor, a CAD model is prepared. Secondly, the analysis is to be carried out using ANSYS 15. The modal analysis and random vibration analysis of the structure was conducted. The analysis shows that the proposed design was successfully shows the minimum deformation when the vibration was applied in normal condition.

1. Introduction

Soybean is important for agriculture since it is one of the main food sources of nutrition for human. It is contains high quality protein, phytic acid, dietary minerals, and B vitamins. One of the most common food products made from soybean is tofu. The making process of tofu includes soaking of beans in the water, grinding the bean, filtering the grinded bean, boiling the bean extract, coagulating the extracted bean and finally moulding the tofu [1]. During tofu making process, inextricable dreg or soy pulp called okara is remained. In common, every 1 kilogram of dry beans makes into tofu produce about 1.1 kilogram of okara with around 80% moisture. It consists of high percentage of fiber and significant amounts of high quality oil and protein. However, until now okara is generally used as feed or fertilizer. Since the awareness of the dietary fiber importance in human health are growing, the utilization of whole beans as an alternative solution are increased [2]. Moreover, more than 90% of the water used during tofu making is wasted [3]. This waste water including coagulant recently has caused severe environmental issues. Some issues that caused by wastewater from tofu production are ecosystem contamination, certain organisms elimination, and decreased of water quality. Therefore wasted coagulant should be avoided. To produce whole beans tofu, the bean powder size should be less than 300 mesh. Conventional soybean pulverizer can only produce bean powder more than 100 mesh. Liquefied nitrogen is used to prevent the generation of oil in the pulverizer soybean during the pulverization. The surface hardening causes the wear of the pulverizer blade and the durability of the pulverizer.

In this research a bean crusher machine to produce the bean powder with size less than 300 mesh to produce high quality tofu. Furthermore, the temperature can be kept at 40 ℃ or less to prevent spoiling the beverage. A bean crusher machine is a mill used to grind hard soybean between two rotating abrasive surfaces. These surfaces are separated by some distance. When these two abrasive surfaces are far apart, the output material is bigger, and when the two abrasive surfaces are set closer together, the output material is smaller. According to the market demand, in this research a high speed bean crusher machine was developed. The structural analysis is one of important step in the development process such as in [4]. During operation, uneven load inside the crushing machine will lead the machine to the forced vibration. If the excitation vibration frequency and the resonance natural frequency of the frame structure are closed, the mechanical structure will produce local resonance and deformation [5]. Therefore, the simulation related to the vibration analysis is needed in development process.

2. System Design

The developed bean crusher machine is shown in Figure 1. The dimension of the machine was calculated optimally to maximize the capacity and the material strength. This machine powered by 220V 3.75KW induction motor. The nominal angular velocity of the crusher machine is 3000 rpm. Power transfer box transfer the energy generated by motor to the crush box through belt system. The belt conversion ratio is 1:2. The crush box is the most important part of bean crusher. It was made of steel. Three Nano inner crush tool inside the crush box rotate in different direction to crush the bean. The hopper was used as inlet for the crusher machine. Powder box was used to collect the bean powder processed by crush tool. The suction pipe then transports the bean powder to collector tank. Figure 2 shows the horizontal cut off schematics of the crusher machine. Since it consist of inner shaft and outer shaft, the Nano crush tool can rotate in two directions simultaneously. To reduce the noise occurred during operation, vibration proof rubber was attached to the base of each corner. To prevent degeneration of soybean grains with high oil content, a special cooling system was developed to maintain a low temperature of 40 degrees or less.


Figure 1. Developed system.

Figure 2. Schematics diagram of soy bean crusher machine.
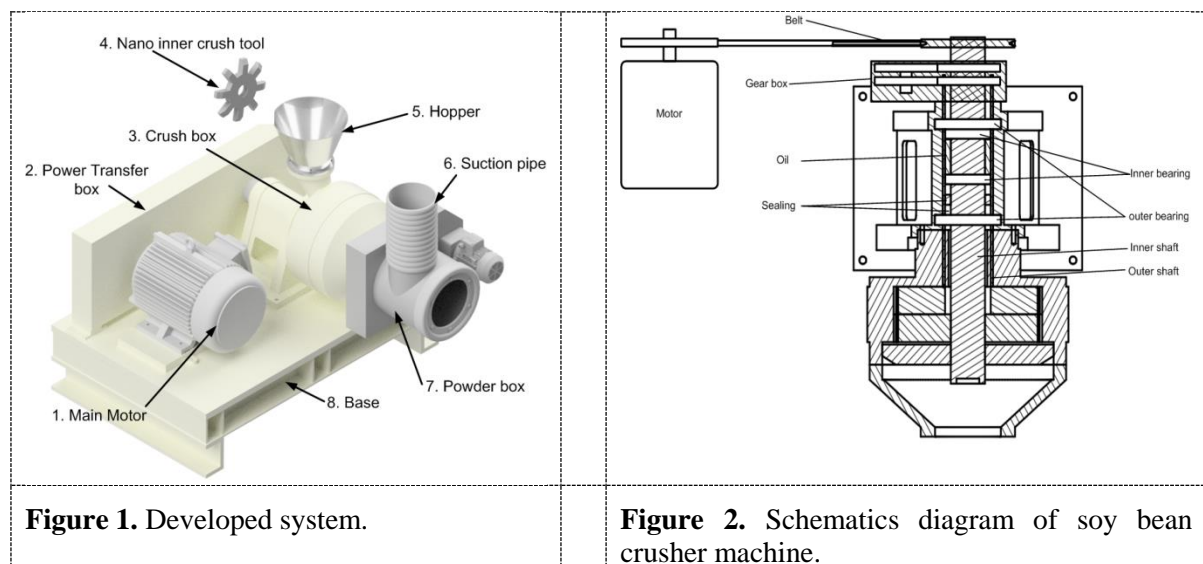
3. Method

In this research the stress and modal analysis was done to evaluate the reduction gear performance. Stress analysis was done to clarify the design of reduction gear can withstand a specified load, using the specified amount of material or that satisfies some other optimality criterion. Modal analysis is a study of dynamics properties in frequency domain used to determine the natural frequency and vibration mode of a structure.

The static analysis and modal analysis process are consists of several steps. Firstly, the 3D model of important component was created. In this research focused on the crush box since this part affected by the operation condition. Secondly, the model was simplified to obtained geometry model. Thirdly, the mesh of the model was generated. Fourthly, the materials properties were defined. In this research the crush box is made of steel. Fifthly, the boundary condition was defined. Finally, solve the problem, visualized and read the results. In this research the 3D model was build using inventor software. The stress analysis was done using EDEM 2017 and modal analysis was done using ANSYS 15.

4. Result and Discussion

The calculation result of modal analysis is shown in figure 3. Modal analysis results in Table 1 shows the frames of 1 ~ 6 orders of natural frequency are between 338.55 ~ 1437.1 Hz range. Figure 3a~e shows the deformation effect on the frame when the natural frequency occurred. The scale is 1.
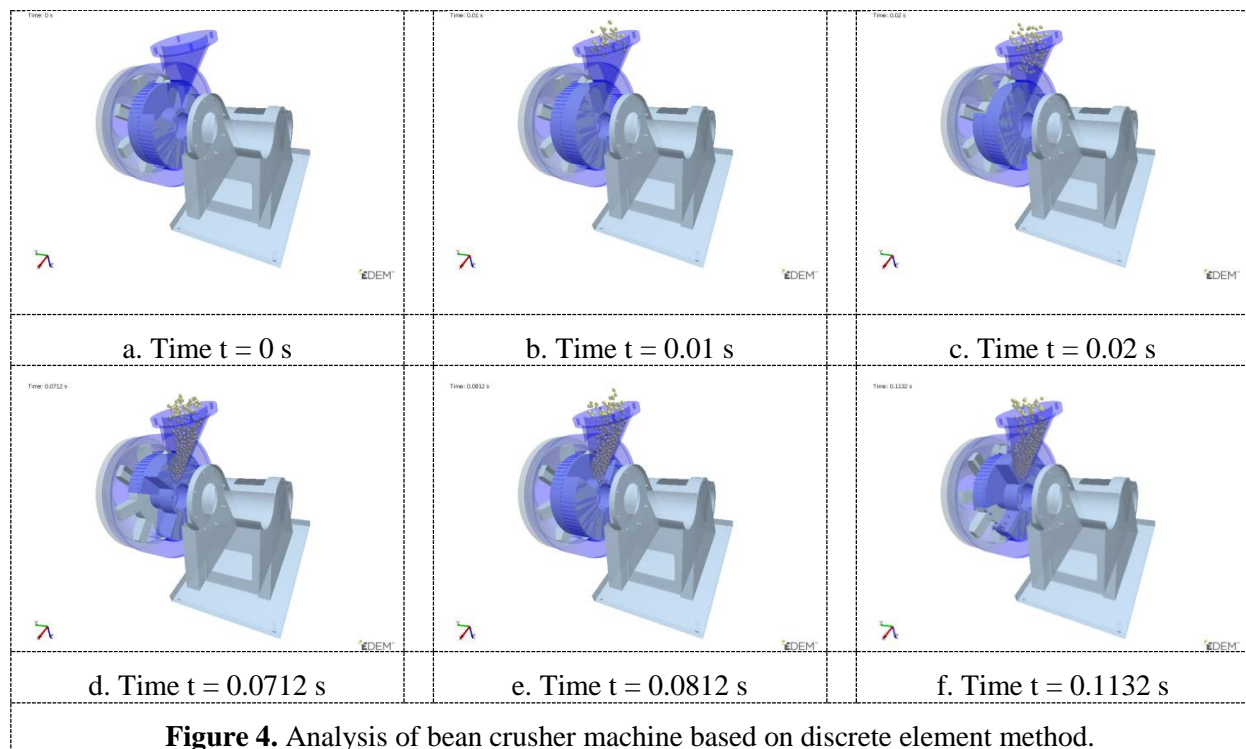

a. F = 236 Hz	b. F = 251 Hz	c. F = 477 Hz
d. F = 547 Hz	e. F = 1055 Hz	f. F = 1080 Hz
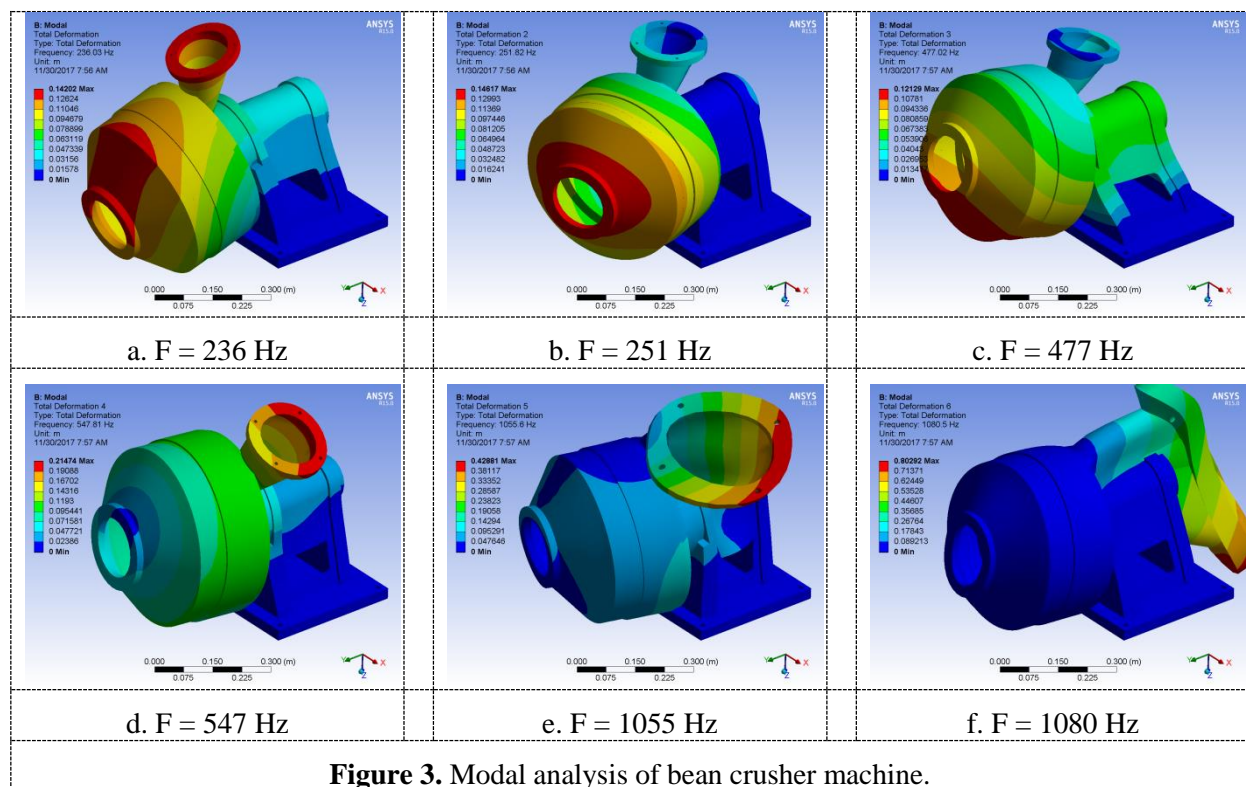
Figure 3. Modal analysis of bean crusher machine.

Table 1. Natural frequency and vibration mode.

No	Frequency	Characteristics of modal
1	236	Vertical across the Z axis at the front side
2	251	Horizontal across the X axis at the front side
3	477	Vertical across the Z axis at the front side
4	547	Horizontal across the X axis at the top side
5	1055	Horizontal across the X axis at the top side
6	1080	Vertical across the X axis at the top side

The bean crusher analysis based on discrete element method (DEM) using EDEM software is shown in figure 4. This figure shows the bean flow through the crusher machine at 1500 rpm motor speed. In this simulation the bean diameter size is 5 mm.

a. Time t = 0 s   b. Time t = 0.01 s   c. Time t = 0.02 s

d. Time t = 0.0712 s   e. Time t = 0.0812 s   f. Time t = 0.1132 s

Figure 4. Analysis of bean crusher machine based on discrete element method.

5. Conclusion
In this research, natural frequency analysis and random vibration analysis was done to the bean crusher machine. The simulation results show that the first order and second order natural frequency can be obtained from proposed modal analysis simulation. Modal analysis results show that the machine 1 ~ 6 orders modal natural frequencies range are 338.55 ~ 1437.1 Hz. This value should be considered during design process to avoid resonance condition. The behaviour of beans inside the bean crusher machine was investigated using discrete element method. The simulation shows that the bean flow the hopper inlet to the crush box.

Acknowledgments

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