Structural Analysis of *Keropok Keping* Drying Machine

Mohamad Syazwan Zafwan Mohamad Suffian[1(✉)], Muhammad Naim Leman[2], Shahrol Mohamaddan[1], and Abang Mohamad Aizuddin Abang Mohamad Mohtar[1]

[1] Universiti Malaysia Sarawak (UNIMAS), 94300 Kota Samarahan, Sarawak, Malaysia
msmsyazwan@unimas.my
[2] Institut Latihan Perindustrian (ILP), 94300 Kota Samarahan, Sarawak, Malaysia

Abstract. In *keropok keping* industries, most of the production processes are implemented by semi-automated machines. However, the drying process is still conducted using a traditional method where the *keropok* is arranged under the sunlight. To improve the drying process, a new rotary type of *keropok keping* drying machine was invented. The new machine will undergo structural analysis via static analysis. The static analysis is only focusing on the vital parts of the new design machine.

Keywords: Static analysis · *Keropok keping* drying machine · Semi-automated machine · Rotating machine

1 Introduction

Keropok keping is a dried crispy food product relatively popular in South-east Asian countries [1]. Currently, its manufacturing is the mostly practised in small scale industry [4]. In Malaysia, the *keropok keping* industries are widely operated in the coastal areas in the state of Terengganu, Kelantan, Johor, Kedah and some parts of Pahang due to the high seafood supply, high temperature and windy area that contributed to the sustainability of the industries [2]. Ingredients for making the *keropok keping* are fillet fish, squid, prawn and shrimp as protein ingredients and seasonings such as pepper, garlic, salt, sugar and monosodium glutamate (MSG) as flavour to the *keropok*. The protein ingredients normally give its distinction to the name of the *keropok keping*. Flour is a principle ingredient for making *keropok keping* and technically the protein components can be altogether skipped and a less tasty puffed *keropok keping* is created.

In *keropok keping* making process, the flour is mixed with grinded fillet fish, squid or prawn and all the ingredients by using a mixer to obtain a dough. Typically, the diameter of dough formed is around 5 to 10 cm. The dough then is shaped into round, oblique, stick or longitudinal forms and gelatinized by boiling or steaming [5]. The gelatinized dough is then cooled, drained and cut into the thin slices with thickness around 3 mm and finally, the slices are dried under the sunlight until the moisture

M.S. Mohamed Ali et al. (Eds.): AsiaSim 2017, Part II, CCIS 752, pp. 12–25, 2017.
DOI: 10.1007/978-981-10-6502-6_2

content reaches around 10%. The dried *keropok keping* obtained is considered as the half-finished product or intermediate product. The *keropok* is typically fried in hot oil to obtain the edible puffed cracker before eaten as a snack food or together with rice and other daily dishes [3].

In *keropok keping* industries, most of the production process activities are conducted by the semi-automated or automated machines such as grinding, mixing and slicing machine [2]. However, the drying process is still implemented using a traditional method as in Fig. 1. In this method, the slices of *keropok* are spread and arranged on the ground or a drying board called *pemidai* under the sunlight so that the *keropok* is exposed to the surrounding heating temperature and wind to be dried. At the moment, this method is considered the most convenient, suitable and practical due to the operating cost is considered much cheaper than the other method. However, this method is exposed to low level of hygiene and bad weather which can limit the potential of the *keropok keping* to be manufactured in high volume [2]. By using the *pemidai*, the keropok may be contaminated by surrounding dust and dirt from air pollution. Besides, it is also exposed to the animals and insects such as birds, mice, and flies [2]. From this situation, the quality level of the *keropo*k product will decrease, caused by the products are dirty, cracked, failure and unattractive shape. Besides, contaminated the *keropok* can cause illness to the consumers and the product demand may be decrease affected by these problems. In order to meet the market demands which is tremendously increased, entrepreneurs need to increase the total amount of output. In furtherance of that, an enormous change needs to be done such as, extending the operating hours of production, and at the same time, the number of manpower also needs to be increased. Besides, entrepreneurs also need to find more space for drying process neither using their own property nor lending from others.

Fig. 1. Drying the keropok keping by using the traditional method

By recruiting more manpower and lending more space for the drying process, it will be incurring a more overhead cost to the entrepreneur. As a result, entrepreneurs need to increase the price of their products as they have to contra with the increasing of their overhead. Thus, entrepreneurs will be facing big business issues whereby the demand of the products in a market will definitely be decreased. Therefore, finding the drying process alternative is needed in order to solve the entire problems. The suitable method is to develop the drying machine for the *keropok keping* in order to improve the drying process in the *keropok keping* industries.

2 Design and Fabrication of *Keropok Kep*ing Drying Machine

A *keropok keping* drying machine was designed and fabricated. It consists of six main parts namely drying chamber, moving tray, transmission system, heating element, cooling fan, and control system. The no–load testing with two level of air velocity with 1.5 m/s and 2.0 m/s were experimented to the machine. The evaluation was conducted to determine the maximum temperature, the lowest of air humidity and the pattern of air velocity above the tray inside the drying chamber. Based on the results, the maximum temperature can be reached in the chamber is 39.8 °C and the trend shows, the highest air velocity blown inside the chamber, the lower temperature of the drying air. The lowest humidity is recorded in the chamber is around 47.6% and the pattern of the humidity shows, when the air velocity increases the humidity inside the chamber is slowly decreased. The pattern of air velocity above the tray is highest when the tray rotates nearly to the fan inlet with angle of rotation 135º. The air velocity recorded at this position is 0.29 m/s and 0.36 m/s with air inlet velocity 1.5 m/s and 2.0 m/s respectively. The machine is expected to improve the hygiene of drying process in the *keropok keping* industries.

2.1 Idea Generation and Conceptual Design

The critical solution designs for the machine can be determined into five elements are drying chamber, type of tray design, transmission system, air source, and heat source design. The solution for each problem is identified into sub problem as in Table 1. The number of possible combination ideas concepts can be calculated as 2 × 2 × 1 × 1 1 = 4 (based on the number of table row and column) that means four ideas concepts can be generated through this table.

Table 1. Morphological chart for *keropok keping* drying machine

Subproblems solution concept				
Drying chamber	Tray	Transmission system	Air source	Heat source
Drum type	Stationary tray	Roller chain type with sprocket	Fan	Heating element
Cabinet type	Moving tray			

The best idea concept for the *keropok keping* drying machine is selected by using Pugh selection matrix. The computer aided design software is utilized to develop 3D model for the selected idea. The machine design architecture is also developed in this stage. The machine is made up of six main parts namely drying chamber, moving tray, transmission system, heating element, cooling fan and control system. The CAD model and design architecture for the machine can be illustrated as in Figs. 2 and 3.

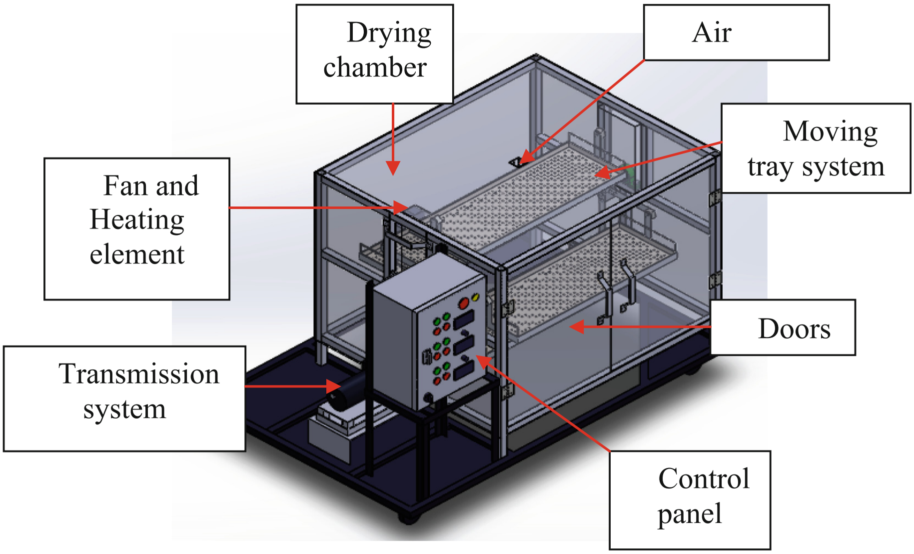

Fig. 2. 3D modelling of *keropok keping* drying machine

2.2 Structure Frame and Wall Design

The size of the structure frame is 95.08 cm length, 80.08 cm width, and 77 cm height. The main material used in the frame design is 2.54 cm × 2.54 cm hollow aluminum square steel because this type of material is a light weight and anti-corrosion. The machine structure plays an important role in supporting and withstanding all static and dynamic load condition in the machine and to investigate the Von-Mises stress and deformation on the frame. The machine is also covered with five side walls are top, left, right, back and a bottom wall. A pair of the door is also provided to ease the users to load and unload the trays in the drying chamber. The transparent polycarbonate sheet is selected as the main material for the dryer walls and door. The advantages of this material are it is not brittle, resists in high temperature, lightweight, low thermal conductivity and can trap the heat in a certain time. The structure and wall design for the machine can be illustrated in Fig. 4.

2.3 Structure Frame Analysis

The material properties and technical condition applied in the machine frame structure can be shown in Table 2. Tetrahedron mesh with refinement and structured hex-dominant mesh are applied to the geometry of the frame and shaft respectively and generated by FEA software. The mesh generated can be illustrated as in Figs. 5 and 6.

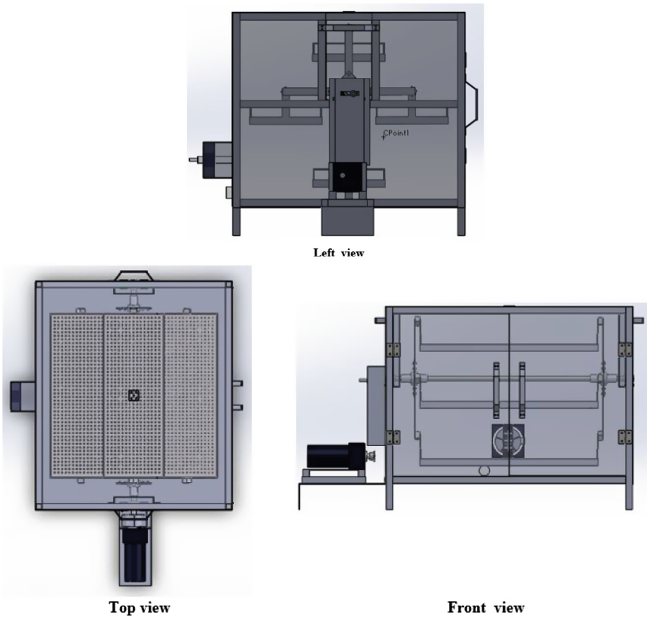

Fig. 3. Front, top and left view of the new drying machine

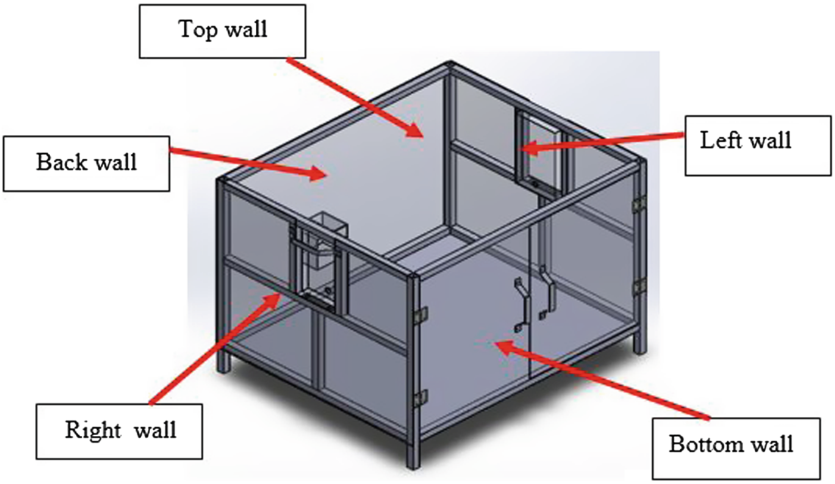

Fig. 4. Structure frame and wall design

Table 2. Material properties and technical condition of the structure frame

Material properties	Technical condition
Material	Aluminium alloy
Mass density	2770 kg/m^3
Elastic modulus	7.1e + 10 Pa
Poisson's ratio	0.33
Yield limit	2.8e + 08 Pa

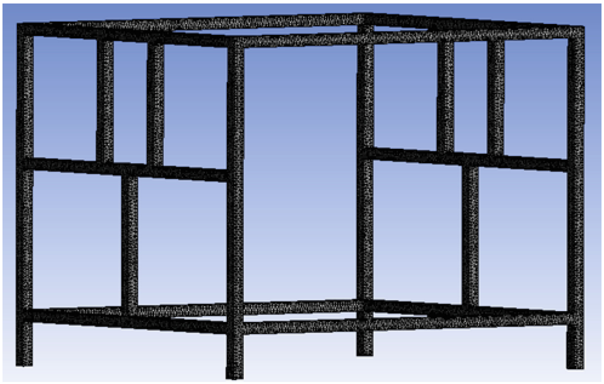

Fig. 5. Mesh generation with refinement for the structure frame

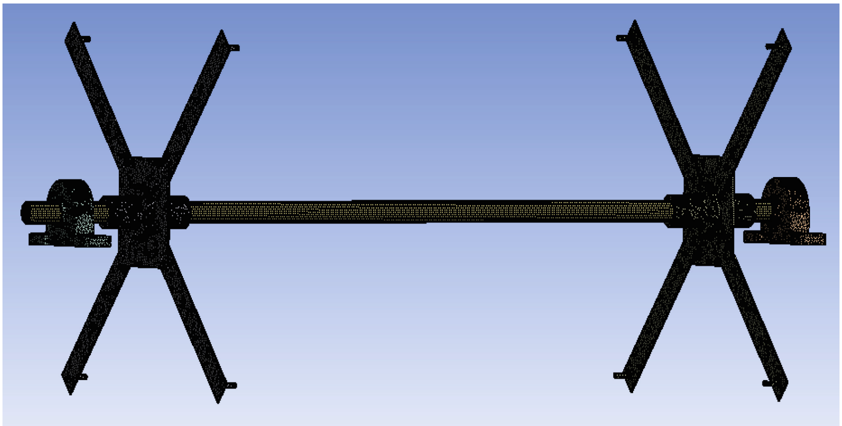

Fig. 6. Mesh generation of shaft

3 Static Analysis

The structural frame and shaft in the moving tray design can be considered as the critical parts in the machine. The frame and shaft play an important role to win stands all loads of bucket and tray during static condition. Therefore, the static analysis is carried out in order to understand the stress, deformation and dynamic characteristic of each part. In this study, the finite element analysis (FEA) software is utilized by using static structural and modal analysis. The static structure and modal analysis procedure can be shown in the flow chart as in Fig. 7.

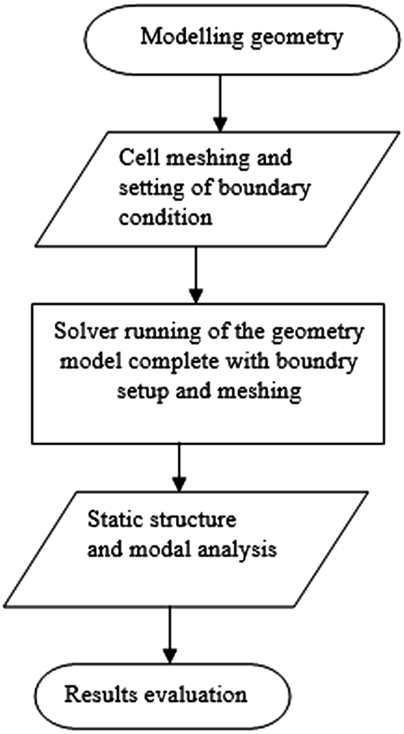

Fig. 7. Static structural and modal analysis procedure

3.1 3D Modelling of the Structural Frame

The frame and shaft model are developed by using computer aided design. The material properties and technical condition used in the frame and shaft design are as follows: Material: Aluminium alloy, Mass density: 2770 kg/m^3, Elastic modulus: 7.1e + 10 Pa, Poisson's ratio: 0.33 and Yield limit: 2.8e + 08 Pa.

3.2 Boundary Condition

The boundary condition set up for both structure frame and shaft can be shown in Figs. 8 and 9.

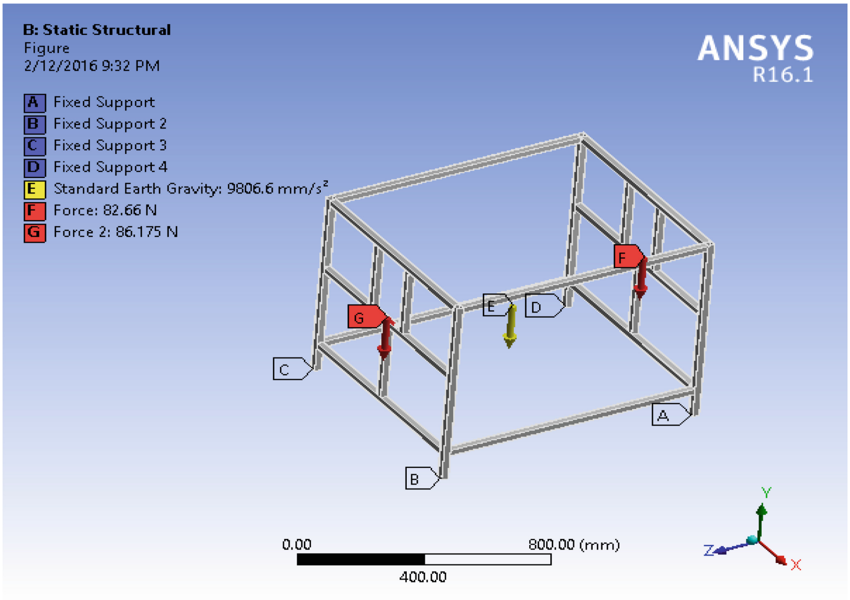

Fig. 8. Boundary condition for structure frame

Structure frame boundary condition

- Points A, B, C, and D are assumed fixed support.
- Standard earth gravity at point E is 9.81 m/s^2 in y-direction.
- Force at point G and F.

Force at Point G = Reaction force of the moving tray at point G + ½ weight of shaft + bearing self-weight

$$= 78.18\,\text{N} + 1.52\,\text{N} + 6.475\,\text{N} = 86.175\,\text{N}$$

Force at Point E = Reaction of the moving tray at point E + ½ weight of shaft + bearing self-weight

$$= 74.66\,\text{N} + 1.52\,\text{N} + 6.475\,\text{N} = 82.655\,\text{N}$$

Shaft boundary condition

- The bearing at point A and B are assumed as fixed support
- Standard earth gravity at point C is 9.81 m/s^2 in y-direction

- The force at point D, E, F, G, H, I, J and K is assumed as the half weight of bucket and tray is 17.85 N.

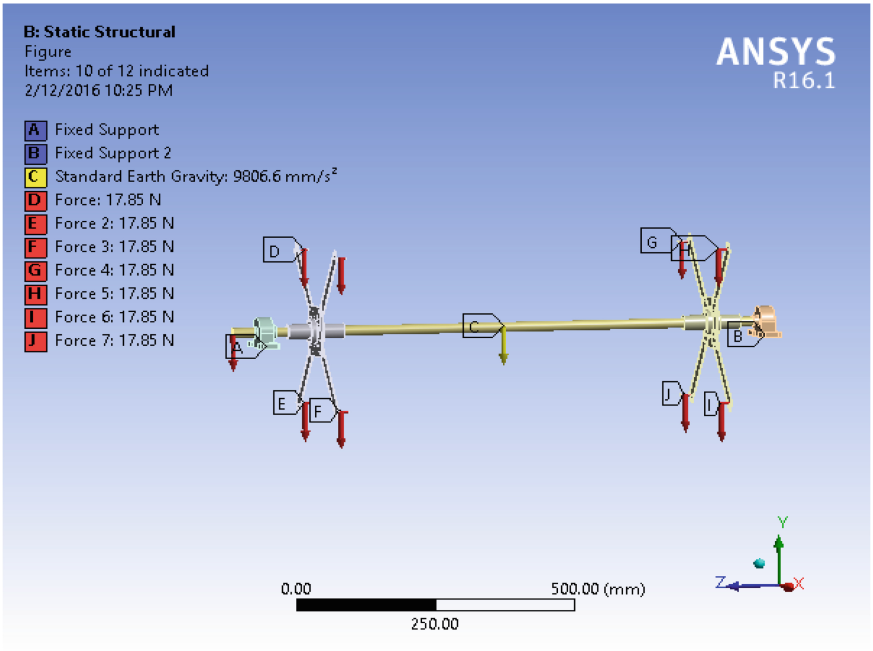

Fig. 9. Boundary condition for shaft

3.3 Static Analysis

Based on the structural frame analysis, the maximum convergence of Von-Mises stress occurs in the frame structure is 4.8177 MPa and the total deformation is 0.072055 mm in the y-direction with the number of elements is 645127. The results can be shown in Fig. 10.

In the frame structure design, the highest Von-Mises stress can be observed at the left and right of the structure frame. This is because both location need to support the distribution load of the moving tray system via pillow block bearing during the static condition. The total load of the moving tray system will be transferred from the bearing to the structure. In term of the structure deformation, the highest deformation can be observed at the same location with the deformation value is 0.072 mm in the y direction. The deformation result can be shown as in Fig. 11.

All the results are obtained after conducting the validation by convergence study to the structure. The study is done by tested the structure with difference size of element. The convergence graph for both results can be shown as in Figs. 12 and 13.

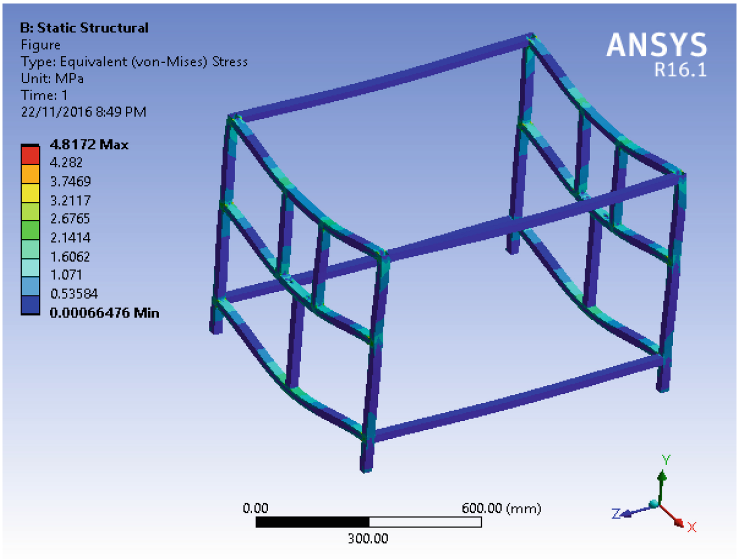

Fig. 10. Structure frame Von-Mises stress

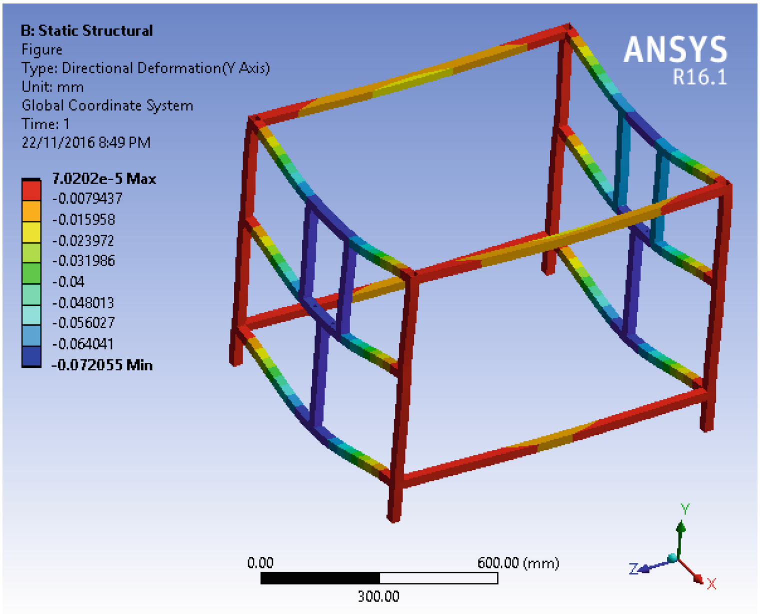

Fig. 11. Deformation of the structure frame

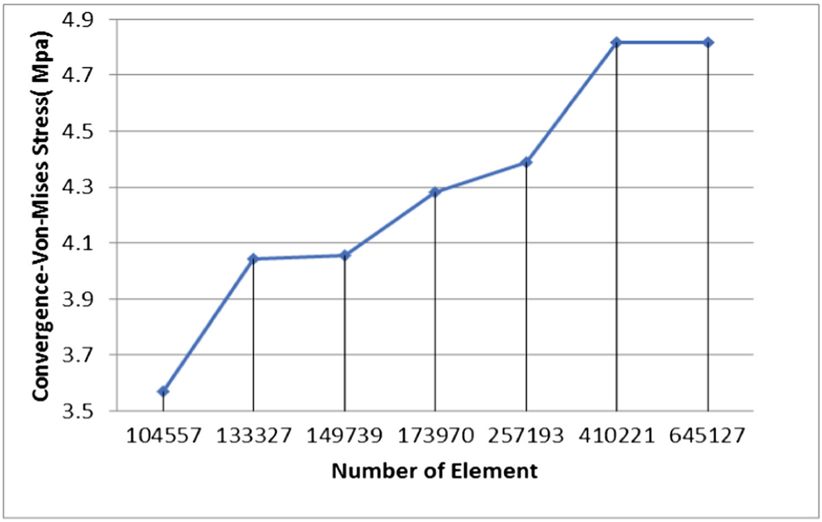

Fig. 12. Graph Von-Mises of the structure frame versus number of elements

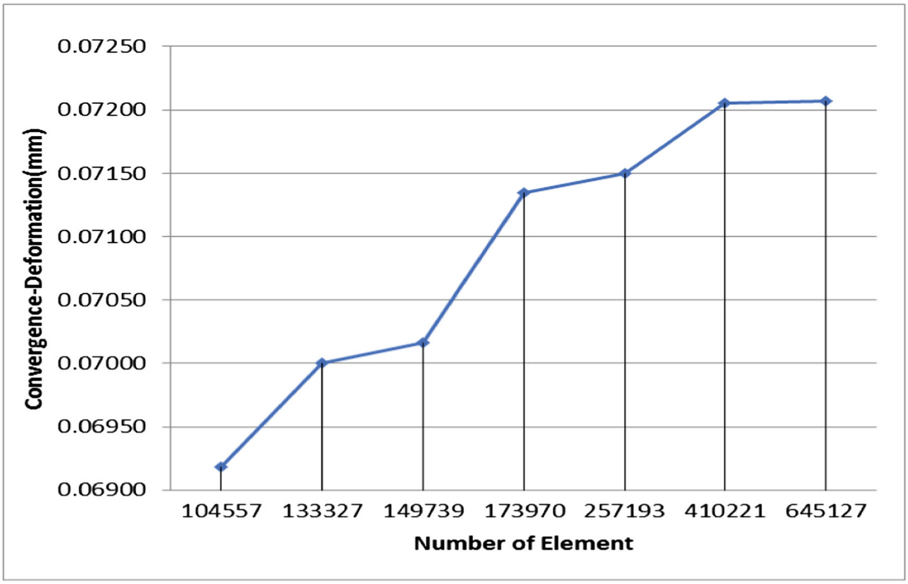

Fig. 13. Graph convergence deformation of structure frame verses number of elements

It can be concluded that the Von-Mises stress of the structure can be considered below the allowable stress of the material, which is approximately 200 MPa. The deformation of the structure from the simulation result is below 1 mm.

For the shaft, the maximum convergence Von-Mises stress is 11.892 MPa and the total deformation is 0.10765 mm in the y-direction with the number of elements is 211489. The results can be illustrated in Figs. 14, 15, 16 and 17.

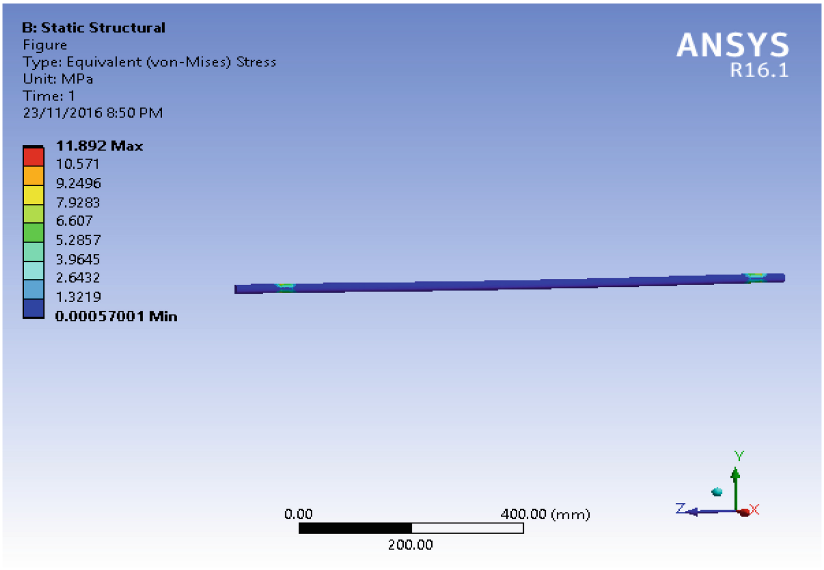

Fig. 14. Von-Mises stress of the shaft

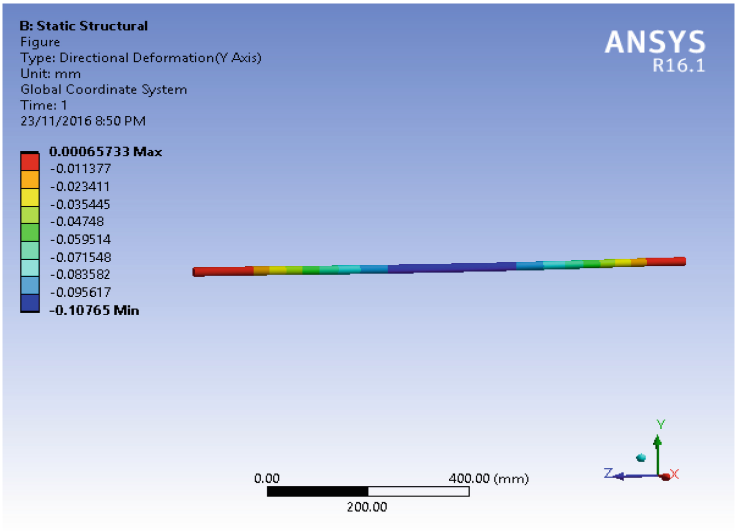

Fig. 15. Deformation of shaft (Color figure online)

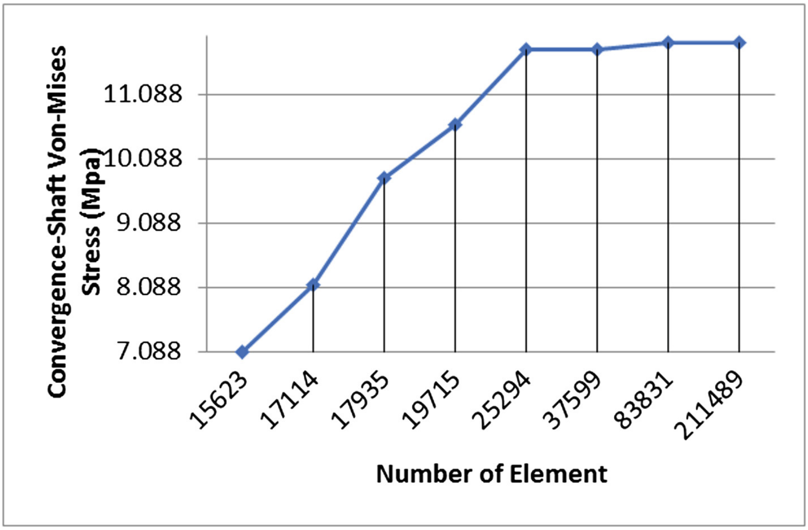

Fig. 16. Graph convergence of the shaft's stress versus number of elem**ents**

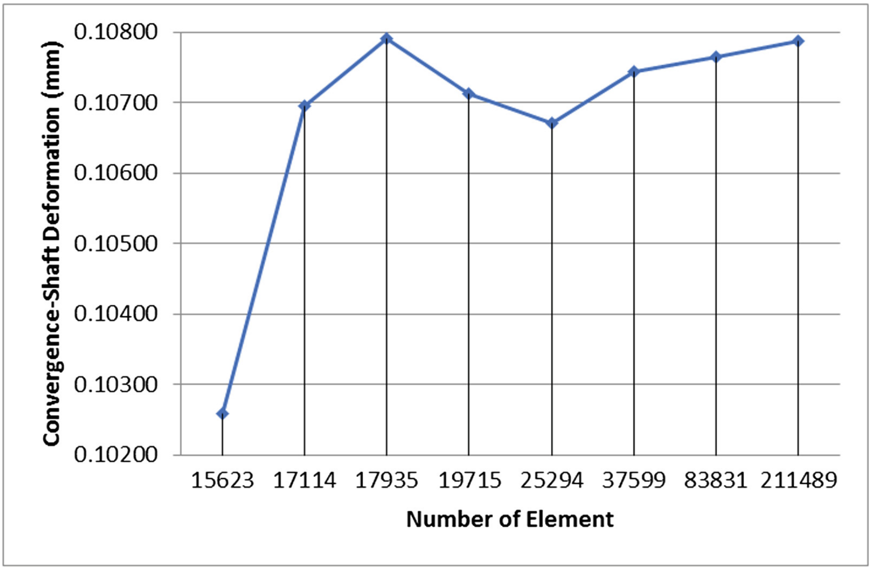

Fig. 17. Graph convergence of the shaft's deformation versus number of elements

The maximum deformation of the shaft can be observed at the center of the shaft (blue coloured) with value recorded at this position is 0.10765 mm at y-direction. The deformation result can be illustrated in Fig. 15 with the number of elements is 211489.

The convergence study is conducted to validate both results. The analysis result can be shown as in Figs. 16 and 17. The shaft is also tested with different size and number of element. The number of converge element is 211489.

The Von-Mises stress of the shaft is lower than the allowable stress of the material which is approximately 200 MPa. This shows that the strength of shaft meets the design requirement. The maximum deformation of the shaft is below than 1 mm. This shows that the stiffness of the shaft meets the design requirement. The shaft can be considered safe from the static load.

4 Conclusion

Based on both analysis, it can be concluded that the Von-Mises stress of the whole structure can be considered below the allowable stress of the material, which is approximately 200 MPa. The structure can be considered safe for assembly and operation as the deformation of the structure from the simulation result is below than 1 mm.

References

1. Kyaw, Z.Y., Yu, S.Y., Cheow, C.S., Dzulkifly, M.H., Howell, N.K.: Effect of fish to starch ratio on viscoelastic properties and microstructure of fish cracker ('keropok') dough. Int. J. Food Sci. Technol. **36**(7), 741–747 (2001)
2. Mohamaddan, S., Aizuddin, A.M., Mohtadzar, N.A.A., Mohamad Suffian, M.S.Z., Junaidi, N.: Development of Keropok Keping drying machine for small & medium enterprises (SMEs). In: IOP Conference Series: Materials Science and Engineering, vol. 114, no. 1, p. 12037 (2016)
3. Huda, N., Li Leng, A., Xian Yee, C.: Chemical composition, colour and linear expansion properties of Malaysian commercial fish cracker (keropok). Asian J. Food Agro-Ind. **3**(305), 473–482 (2010)
4. Taewee, T.K.: Cracker 'Keropok': a review on factors influencing expansion. Int. Food Res. J. **18**(3), 855–866 (2011)
5. Fellows, P.: Food Processing Technology: Principles and Practice. Elsevier, Amsterdam (2009)

Springer

http://www.springer.com/978-981-10-6501-9

Modeling, Design and Simulation of Systems
17th Asia Simulation Conference, AsiaSim 2017,
Melaka, Malaysia, August 27 – 29, 2017, Proceedings,
Part II
Mohamed Ali, M.S.; Wahid, H.; Mohd Subha, N.A.;
Sahlan, S.; Yunus, M.A.; Wahap, A.R. (Eds.)
2017, XXVI, 779 p. 419 illus., Softcover
ISBN: 978-981-10-6501-9