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Finite Element Analysis (FEA) Simulation of Semi-Automatic Otak-Otak Pin Insertion Mechanism

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Abstract: The demand for popular food in Johor, otak-otak, is increasing when it is served as an appetizer in almost all eateries and restaurants. The process of pinning bamboo skewers to attach nipah leaves is done manually by workers which is time-consuming and create a bottleneck in the production. The bottleneck exposed the unwrapped fish paste to the environment which can cause contamination. This research objectives are to determine the concept of otak-otak machine mechanism and to design and simulate the machine prototype with the holder and pin inserter to pin the wrapped otak-otak at both ends simultaneously. This study focused on otak-otak that use nipah leaves and bamboo skewers as its wrapper. Three prototype models were designed in SolidWorks software. The finite element analysis (FEA) method was used to analyse the model structures. Based on the result through static analysis, the prototype could withstand the input pressure of 0.2 MPa that was used to operate the machine. However, a displacement of 0.0128 mm (12.8 micron) on the structure indicates that the machine will be affected by vibration throughout its operation. Therefore, various changes and other related areas can be added to enhance the design and safety features of the otak-otak pin insertion machine.

Keywords: Otak-otak Machine, Pin Insertion, Finite Element Analysis (FEA)

1. Introduction

Otak-otak is a fish-based food product that is widely produced by Small Medium Industries (SME). The Ministry of Agriculture and Food Industry through the Department of Fisheries classifies fishery products as the product of agro-based industries [1]. Otak-otak is made of grounded fish mixed with spices and coconut milk, wrapped with leaf parcel, then grilled before being served. The demand for this popular food is increasing when it is served as an appetizer in almost all eateries and restaurants.

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The production of the otak-otak needs to be increased while maintaining its original taste by using nipah leaves as its wrapper.

There are a few significant reasons to automate the wrapping process of otak-otak such as hygiene and 3D (dirty, dangerous, and difficult). The process of pinning bamboo skewers to attach nipah leaves has been identified as the problem that caused the otak-otak production was not able to fulfill the high demand. The repetitive task will cause fatigue which will lead to inconsistencies in the wrapping process and increase production time for correction [2]. The risk of the worker's finger being punctured by the sharp bamboo skewer needs to be eliminated. The time-consuming of pinning the bamboo skewers into wrapped otak-otak has developed a bottleneck in the production line. Since the otak-otak will easily get contaminated with bacteria, hygiene and safety during the manufacturing process should be given attention [3]–[5]. Besides, seafood security, including food safety and hygiene, were factors influencing purchases of fish-based products [6].

A case study made by a previous researcher at Nur Fatin Ilham Enterprise shows that enterprises that are mostly in rural areas are still using traditional methods and the use of manpower as a whole [2]. Facing challenges in these new norms, Malaysia Government provided allocations for SMEs development in the 2021 budget. It comprises the Automation and Digitalization Facility (ADF), which will provide SMEs with an RM300 million incentive to implement automation and digitization to boost production and efficiency [7]. Therefore, the main goal of this research was attempted to design and simulate a semi-automatic otak-otak pin insertion system that could increase otak-otak production rate.

2. Materials and Methods

The machine structure and pneumatic circuit were designed based on previous research by Tonyson (2017) with improvements on safety requirements and production productivity. To develop a machine capable to produce the otak-otak, it is important to study the materials, standard parts, and pneumatic system components. S.C.A.M.P.E.R method was used in the brainstorming phase to find out all the possible options that could be the best solution for developing the design concept [8]. Then, a morphological chart was developed to produce a detailed design that shows the final selection of the equipment, the instrument to control the process, and the safety element on the otak-otak pin insertion machine.

2.1 Materials and components

The concept of the machine involved the cost of purchase, availability of the materials and components in the market, ease to handle and ease of machining. Aluminium and stainless steel are the most materials used in kitchen appliances and equipment [9], [10]. Table 1 lists the materials and components that are following the concept for designing the otak-otak pin insertion mechanism.

Table 1: Materials and components for otak-otak pin insertion machine

No.	Material / Component	Grade / Specification
1	Main structure	Aluminium 6061
2	Holder	Aluminium 3003
3	Lifter	Aluminium 3003
4	Bender	Aluminium 6061
5	Power supply	24V DC
6	Activation switch	Push button type
7	Pneumatic cylinder	1.0 MPa Double acting
8	Tubing	PU tube 4mm

2.2 Methodology of design concept development

Referring to the previous design, pin insertion cylinders are triggered by foot pedal actuation and the otak-otak was held with the operator's fingers during the pin insertion process [2]. This condition might cause injuries to the operator's fingers. Hence, the proposed mechanism for this project has been taken as shown in Figure 1 below.

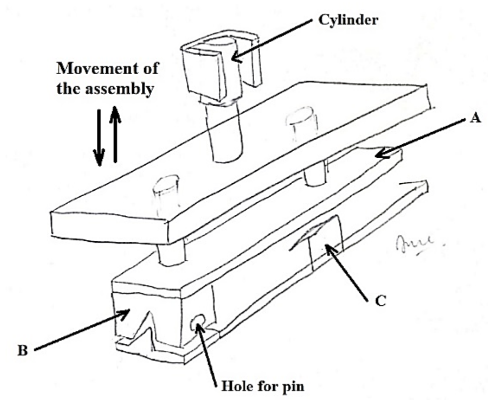


Figure 1: The idea for the whole system

Part A acted as a clamp to hold the otak-otak from being unwrapped when it is placed on the holder. Attached to it is Part B which is a bender that needed to push wrapped otak-otak into the holder (replacing operator's task). A lift-up mechanism to remove pinned otak-otak from the holder is labelled as C that is also acted as the ejector to push out pinned otak-otak directly to the basket. A change from the foot pedal to a hand push button was made to activate the system.

Based on the materials listed in Table 1, three 3D model designs were created using SolidWorks software to explain the complete description of the machine, consisting of its shape, dimensions, number of parts, and specifications. Figure 2 shows the model's design for this purpose.

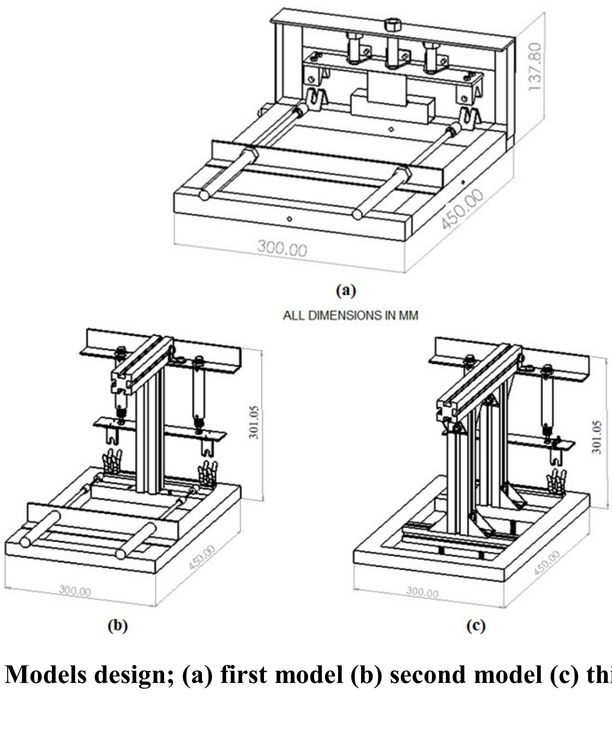


Figure 2: Models design; (a) first model (b) second model (c) third model

The first model is a frame-like structure that is attached to the most front of the machine table structure. One pneumatic cylinder involves two support pins to bend wrapped otak-otak. The bender and the otak-otak holder were designed as an A-shape. The second and third models were designed according to the existing otak-otak holder on the machine. Both designs involve two pneumatic cylinders with a T-shape bender attached to the plate at the end of the cylinder. Two aluminium bars act as a pillar and a beam to hold the bender unit in the second model. In the third model, three aluminium bars are involved where two bars act as a pillar and a longer beam is used to hold the bender unit.

2.3 Methodology for 3D model design analysis

Figure 3 shows the procedure for the static analysis using FEA method in SolidWorks Simulation. The analysis involves the main structure of the bender unit which is the frame for the first model, and the pillars and the beam for the second and third models. Bolts, nuts, and gusset that use to fasten the pillars and beam are neglected. The pre-processing started with designing a few models in SolidWorks CAD software. Each model design is using Aluminium 6061 as the study material with the load for the structures was set in an upward direction at a minimum pressure for clamping, which is 0.2 MPa [11]. Figure 4 shows the location of fixed surfaces and load for the analysis.

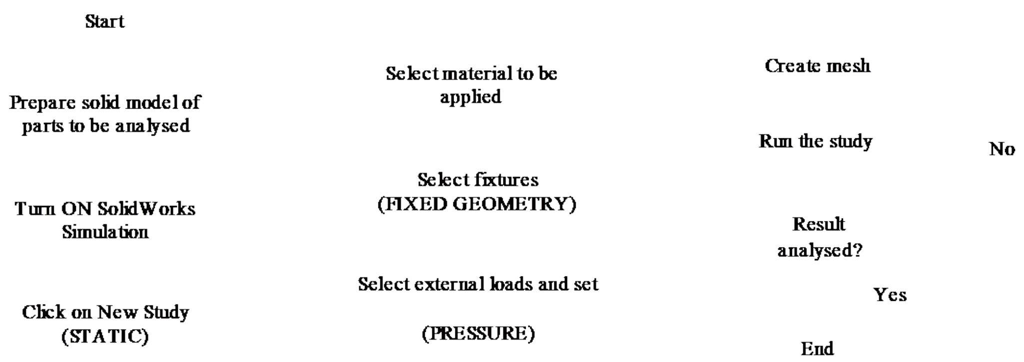


Figure 3: Procedure for static analysis in SolidWorks Simulation

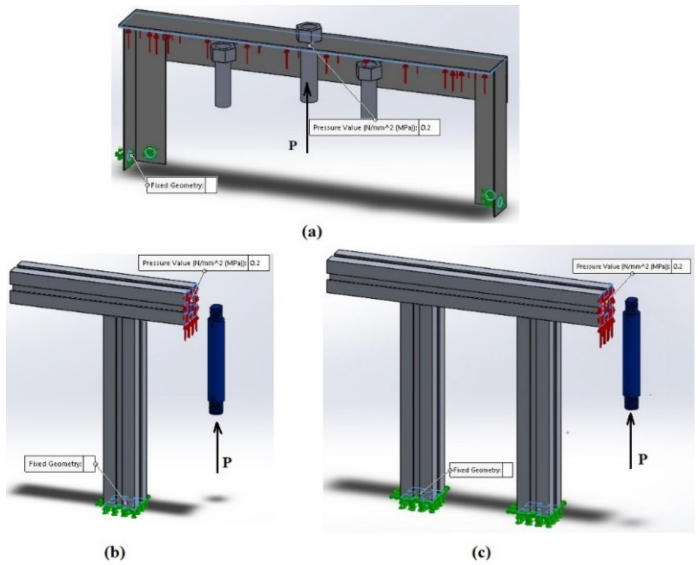


Figure 4: The location of fixed surfaces and load for static analysis for (a) first model, (b) second model, and (c) third model

In this research, solid mesh had been used with standard mesh method. As the application does not need micron precision motion, an element size of 5.00 mm with 0.25 mm tolerance is necessary to be utilized in this simulation. The maximum stress value will increase which is related to a more detailed mesh generated that gives a more accurate stress value [12]. The details of mesh used for all designs are shown in Table 2. There were three parameters were observed in the post processing stage of this static analysis which are the Von Mises stress, displacement, and strain.

Table 2: Details of mesh

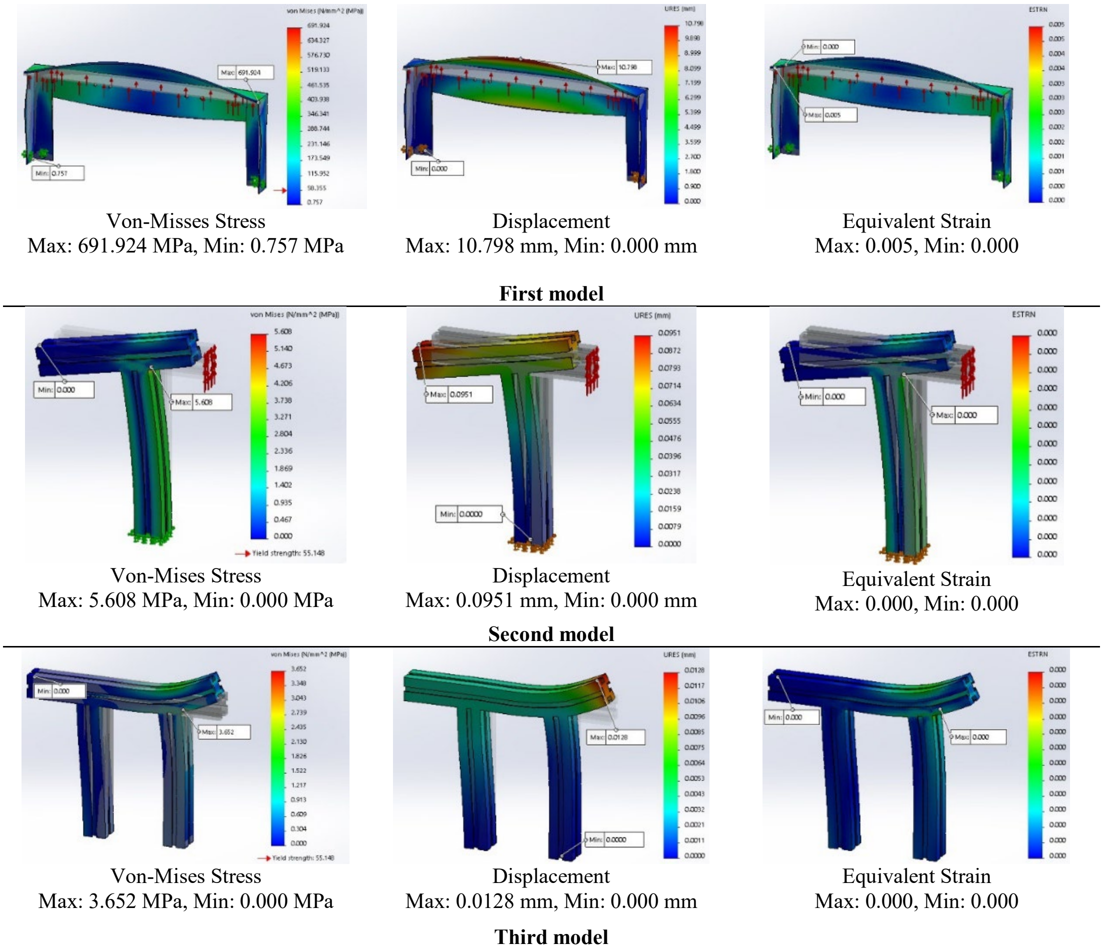
Mesh type	Solid mesh
Mesh method	Standard
Jacobian points	4 points
Element size	5.0 mm
Tolerance	0.25 mm
Mesh quality	High

3. Results and Discussion

The static analysis is important in resulting the decision on producing the final design of the otak-otak pin insertion machine. This is to ensure that the machine structure could withstand the pressure and forces involved during their operations.

3.1 The FEA results on 3D model design

Figure 5 below shows the FEA results that occurred on each model design.



Von-Misses Stress Max: 691.924 MPa, Min: 0.757 MPa | Displacement Max: 10.798 mm, Min: 0.000 mm | Equivalent Strain Max: 0.005, Min: 0.000

First model

Von-Mises Stress Max: 5.608 MPa, Min: 0.000 MPa | Displacement Max: 0.0951 mm, Min: 0.000 mm | Equivalent Strain Max: 0.000, Min: 0.000

Second model

Von-Mises Stress Max: 3.652 MPa, Min: 0.000 MPa | Displacement Max: 0.0128 mm, Min: 0.000 mm | Equivalent Strain Max: 0.000, Min: 0.000

Third model

Figure 5: The result for static analysis

3.2 Final design

Based on the results in Figure 5, the third model was selected which has the most stable structure and have been chosen as the final design. Figure 6 shows the third model when attached to the top frame of the main machine structure.

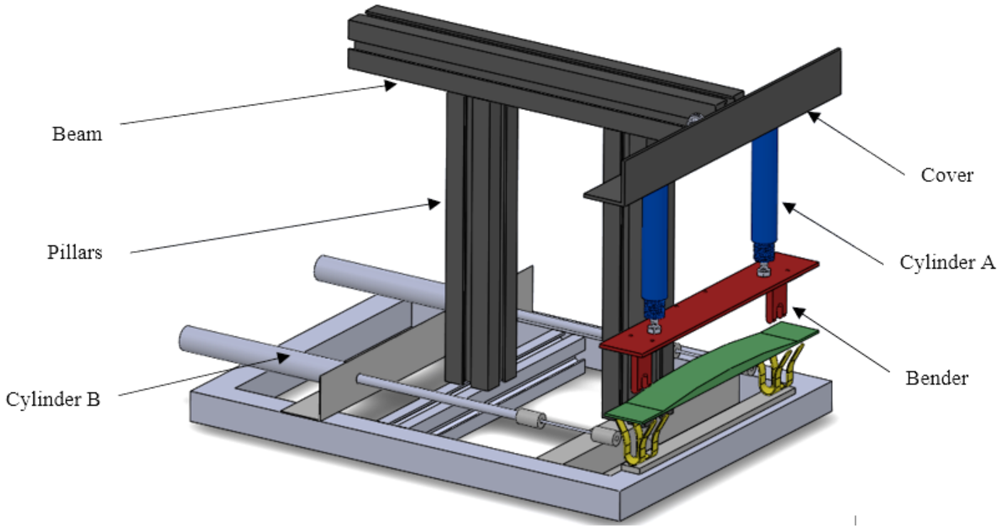


Figure 6: New components attached to the top frame of the existing machine structure

Referring to Figure 6 above, the first model shows the maximum value of stress, displacement and strain which are 691.924 MPa, 10.798 mm and 0.005 respectively. The safety factor for this model is lower than 1 which shows that the design will fail. When the design changed to the second model, more displacement occurred at the back of the beam with a maximum value of 0.0951 mm and the maximum stress is 5.608 MPa. There is also a moment on the pillar that causes it to rotate in the direction of displacement. Using two pillars as in the third model, the smaller displacement occurred at most front of the beam which shows a maximum value of 0.0128 mm, and a maximum value of stress is 3.652 MPa. The safety factor for these models is more than 1, means it will not fatigue.

Based on the results, the third model design has been selected as the final design for the otak-otak pin insertion machine as the FEA analysis shows it has a lower value of stress and displacement compared to the first and the second design. This displacement can be reduced or eliminated when gussets are installed as fasteners between the beam and pillars.

4. Conclusion

This research study has been successful and achieved the objectives as previously set. The design concept of a semi-automatic otak-otak pin insertion machine was determined. Based on the design concept, the mechanism for otak-otak making machine provided the elements that help to make the pinning process easier and safer. The analysis method using FEA in SolidWorks Simulation helps to validate the best design for the mechanism. Although there is a small displacement occurred during operation, it is expected that the machine structure will experience vibration during its operation. Therefore, various changes and other related areas can be added to enhance the design and safety features of the otak-otak pin insertion machine.

Acknowledgement

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