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Design, Analysis and Optimization of Bun Machine Frame

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Abstract

Bun Machine is proposed to produce compact round shape dough and it capable to increase the production of dough according to daily order. It is involved several components to complete the fully process such as screw conveyer, table, base and transmission parts onto it with compact shape. This make the frame among of the important part in order to ensure smooth production and give maximum safety along with due consideration to the weight aspect. To fulfill these criteria it is important to consider various parameters involved in the design of frame, right from the material to be used, size and up to the forces and impacts that it might encounter. Aluminum profile was selected as structural members because serves a dual function of giving structural safety and at the same time incorporates mounting of the components. This paper will discuss the design, analysis and optimization size of aluminum profile by develop and evaluate a full scale computational model of frame by using static load simulation with Autodesk Inventor and software and further define the computational results. The initial results help researcher in determining the best frame of the machine.

Keywords: *Bun machine, frame, Autodesk Inventor and static load*

1. Introduction

Food processing is considered as a sunrise industry because of its large potential for growth and socio-economic impact. It not only leads to income generation but also helps in reduction of wastage, value addition, and foreign exchange earnings and enhancing manufacturing competitiveness. Nowadays, quality and food safety have become competitive edge for the enterprises producing foods and providing services [1]. In Malaysia, food processing sector is growing about 5 percent per year with dairy, bakery and processed fish product among the leading sectors [2]. The Government of Malaysia has identified the food processing sector as one of the critical industries for the overall economy and as a potential contributor to exports. Proper investment in food processing, technical innovation and infrastructure facilities could meet domestic need. A strong and dynamic food-processing sector plays a significant role in diversification of agricultural activities, improving value addition opportunities and creating surplus for export of agro-food products [3].

As been mentioning earlier, bakery is among of the leading factors in food processing industries. Towards changes in consumer lifestyles, rising per capita income, increasing urban population raises it demand for processed convenience foods [4]. One the well-known product from bakery is bun. Bun refers as small rounded bread [5]. Base on site visit in Tok Ayah Food Industries Sdn Bhd in Skudai, Johor, bun is produced by using manual handling. As a result, sometimes it is difficult to fulfill high demand from customer. Base on that reason, several bun machines was develop in the market as shown in Figure 1 as a solution for small and medium sized business in food manufacturing.

Fig.1 Bun Machine [6]

As we know that innovation is a fundamental catalyst to the growth and development of a country economy. The ever changing and uncertainty of world recent economy demand Malaysia to put innovation and creativity as a key factor to achieve a knowledge-based economy [7]. Thus, base on that reason researcher try to develop their innovation to solve problem regarding of bun production rather than buy the products.

2.0 Background

Bun Machine is proposed to produce compact round shape dough and it capable to increase the production of dough according to daily order. This bun machine feeding mode based on the principle of crushing which dough is through extrusion process. It is involved several components to complete the fully process such as screw conveyer, table, base and transmission parts onto it with compact shape as shown in Figure 2. This make the frame among of the important part in order to ensure smooth production and give maximum safety along with due consideration to the weight aspect. To fulfill these criteria it is important to consider various parameters involved in the design of frame, right from the material to be used, size and up to the forces and impacts that it might encounter [8]. Aluminum profile was selected as structural members because serves a dual function of giving structural safety and at the same time incorporates mounting of the components as shown in Figure 3.

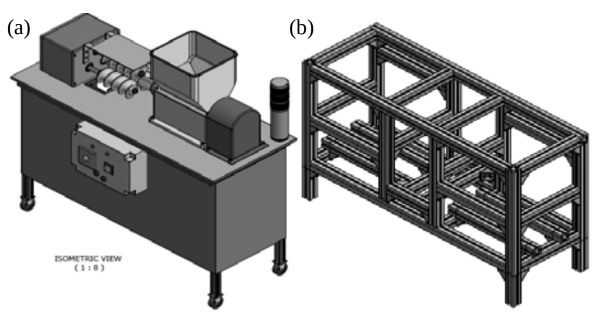

Fig. 2 Innovation of existing Bun Machine; (a) Complete assembly (b) Main Frame

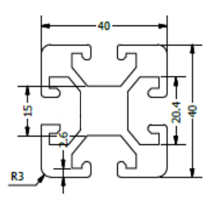

Fig. 3 Cross section of aluminum profile in mm

The finite element analysis (FEA) is one of the analysis tool, which can be applied to a range of engineering problem. The finite element modeling process allowed for discrediting geometries into small fundamental volumes called finite element. It is then possible to write the governing equations and material properties for these elements. These equations are then assembled by taking proper care of results that describe the behavior of the original complex body being analyzed. Through FEA software it is possible have number of alternative designs before fabrication. The use of FEA tools can convert the geometry into element and calculating various properties for each element such as geometry, material properties, constraint and loading. This forms the input for the analysis. It also can generate the finite element mesh by making a suitable approximation to the geometry. Then it can calculate the nodes and element properties and allowed the material properties to be specified[9,10]. This paper will discuss the design, analysis and optimization size of aluminum profile by develop and evaluate a full scale computational model of frame.

3.0 Research Methodology

3.1 The Design Process

This section provides an outline of the design process activities as shown in Figure 4.

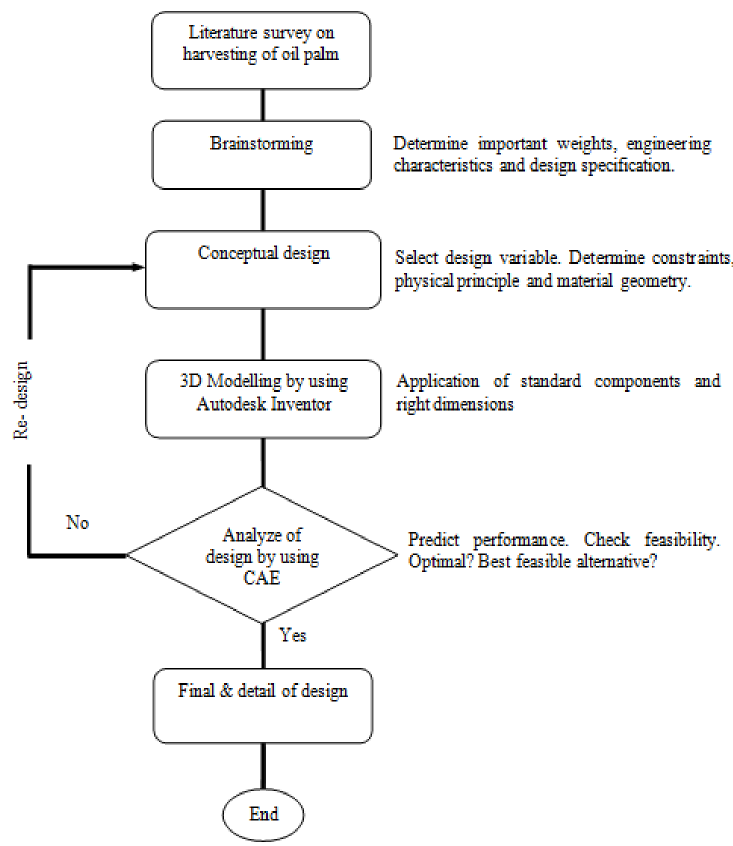

Fig. 4 Flow chart of research activities

3.2 Design Concept

The design concept of this bun machine is refer to feeding mode based on the principle of purging soft dough through extrusion process by using screw conveyer type. All the arrangement of elements is in compact shape to reduce size. However, it still uses food grade materials such as stainless steel 304, stainless steel 316, PTFE, and polypropylene as shown in Figure 2. Thus, the main frame need to support total weight of those elements.

3.3 Frame Analysis

3.3.1 Finite Element Analysis

The purpose of this analysis is to predict theoretically the ability frame of bun machine can support on subjected load. After complete 3D modelling of the design by using Autodesk Inventor, the structure analysis is conducted by using finite element analysis (FEA) provided by Autodesk Inventor. Finite element models depicted in Figure 5, are meshed with 3D tetrahedral meshing. The total number of nodes and elements are 356932 and 1976444 for the complete model.

Fig. 5 Mesh analysis of frame

Average Element size is 0.100, minimum element size is 0.200, grading factor is 1.500 and maximum turn angle of 60 degree as the mesh setting, while 0.750 was used as the h refinement threshold with a stop criteria of 10.00% for the convergence setting, the following were achieved as shown in Figure 5.

3.3.2 Materials

Summarizes characteristics of the materials used in the models are shown in Table 1 and Table 2.

Table 1: characteristics of the materials used in the bun machine frame

Name	Stainless Steel (S304)	
General	Mass Density	8 g/cm^3
	Yield Strength	250 MPa
	Ultimate Tensile Strength	540 MPa
Stress	Young's Modulus	193 GPa
	Poisson's Ratio	0.3
	Shear Modulus	74.231GPa

Name	Aluminum 6061	
General	Mass Density	2.7 g/cm^3
	Yield Strength	275 MPa
	Ultimate Tensile Strength	310 MPa
Stress	Young's Modulus	68.9 GPa
	Poisson's Ratio	0.33
	Shear Modulus	25.902 GPa

Table 2: Structural Parts and materials specification

Parts		
No	Item	Material
1.	Frame	Aluminum 6061
2.	Supporter	Aluminum 6061
3.	Cap Screw and nut	Stainless Steel 304

3.3.3 Load, Constraints and Simulation

Loads are generally estimated using the classification rules [11]. Prediction of loads that the bun machine experiences is static loads. This consists of loads, which do not vary with time, or even if they vary, the effect of time could be neglected. Force that have been imposed downward to the structural model. The load is distributed uniformly on their compartment. Estimation load is based on prediction given by Autodesk Inventor software as for an example shown in Figure 6 and Figure 7. Through structural analysis loads have been applied increasingly until the structure failure to determine the maximum load could be supported.

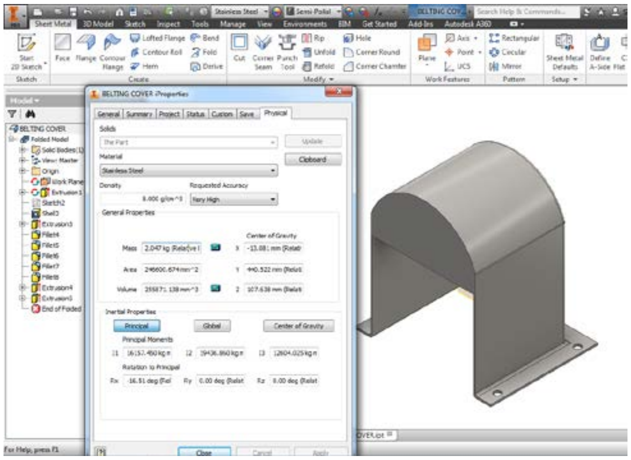

Fig. 6 Estimation load is base on prediction given by Autodesk Inventor software.

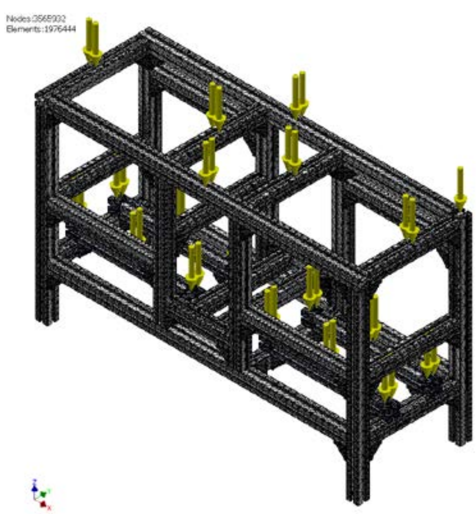

Fig. 7 Load that apply on frame

The load that applied on the frame briefly divided into 3 compartments. Load distributions on frame subjected in the following Table 3.

Table 3: Load distribution

No	Part	Location	Total Load
1	Dough rounder system	On top of frame	643.585 N
2	Mechanism system	Bottom of frame	147.15 N
3	Mechanism system	Bottom of frame	93.195 N

Simulation method for parametric geometry is based on exhaustive set of configurations that solves all combinations of the parameters.

4. RESULT AND DISCUSSION

4.1 Result on analysis

Static analysis successfully to simulate load that applied on the frame. The results of the numerical analysis in Table 3 revealed that the maximum deflection is 0.0361337 mm and maximum Von Mises Stress value is 23.1151 MPa. It is also shown in Figure 8 and 9.

Table 3: Result summary of stress analysis

Parts		
Name	Minimum	Maximum
Von Mises Stress	0.000051576 MPa	23.1151 MPa
1st Principal Stress	-13.7153 MPa	30.5584 MPa
3rd Principal Stress	-37.6142 MPa	7.93792 MPa
Displacement	0 mm	0.0361337 mm
Safety Factor	10.8154 ul	15 ul
Stress XX	-36.8302 MPa	14.4604 MPa
Stress XY	-5.7037 MPa	5.27864 MPa
Stress XZ	-8.59121 MPa	9.99954 MPa
Stress YY	-15.5758 MPa	10.7618 MPa
Stress YZ	-6.40393 MPa	5.09092 MPa
Stress ZZ	-18.1953 MPa	24.3169 MPa
X Displacement	-0.00650282 mm	0.00683332 mm
Y Displacement	-0.00166101 mm	0.00416151 mm
Z Displacement	-0.0359331 mm	0.00077286 mm
Equivalent Strain	0.0000000007 ul	0.00012256 ul
1st Principal Strain	-0.0000002550 ul	0.00012883 ul
3rd Principal Strain	-0.000149679 ul	0.0000006772 ul
Strain XX	-0.000144398 ul	0.0000485663 ul
Strain XY	-0.0000384187 ul	0.0000355556 ul
Strain XZ	-0.0000626796 ul	0.0000673544 ul
Strain YY	-0.0000396697 ul	0.0000373451 ul
Strain YZ	-0.0000431353 ul	0.0000409206 ul
Strain ZZ	-0.0000708889 ul	0.0000894545 ul

Although figure 8 and figure 9 show that structure have major change especially on their column after load applied but the number of the deflection is small and stress that exist is below than yield strength value of that material. So, it still in good condition. However further improvement should be enhanced to prevent failure on that frame later. Design of frame should be modified especially at centre of frame compartment.

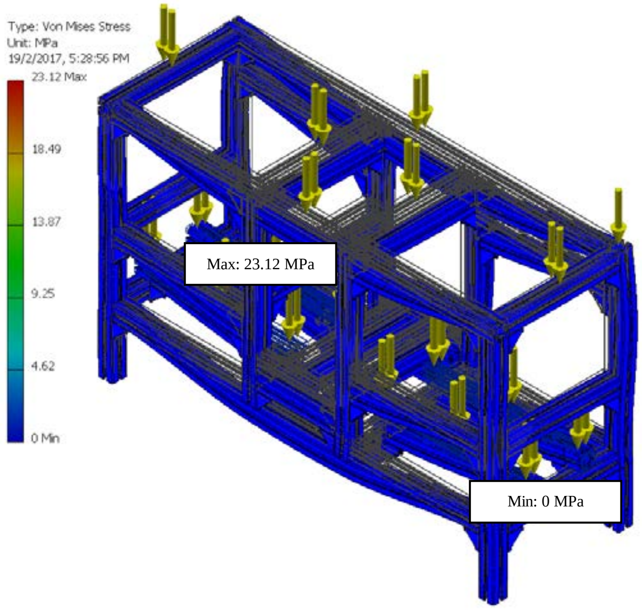

Fig. 8 Von Mises Stress of bun machine frame

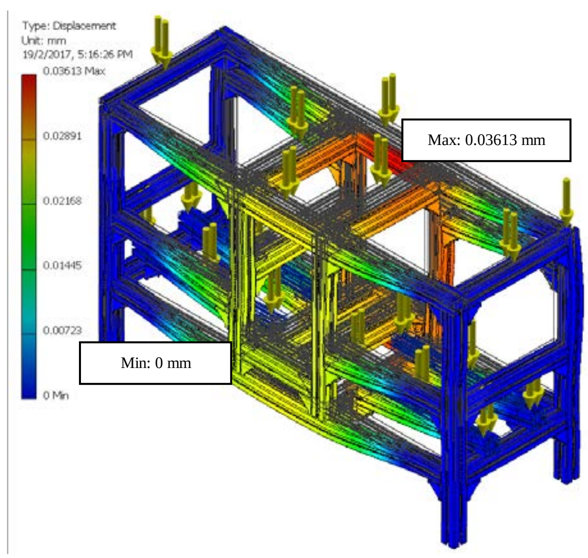

Fig. 9 Displacement on vertical axis of bun machine frame

In Figure 10, the ratio of the maximum stress that a structural part of material can withstand to the maximum stress estimated for it in the use for which it is designed.

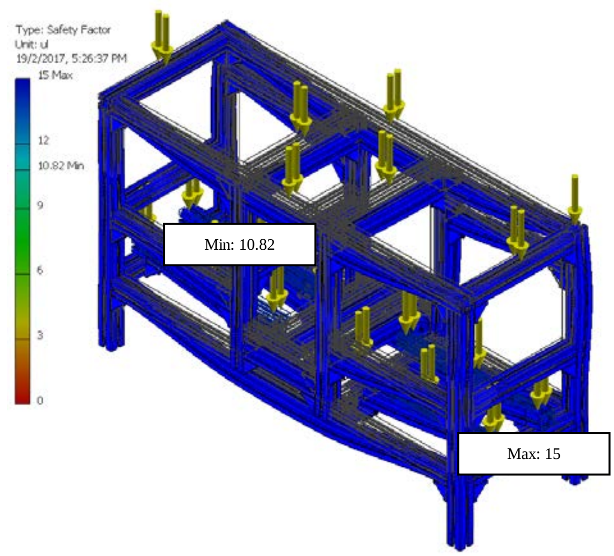

Fig. 10 Safety factor consideration based on bun machine subjected loading

On the other hand, based on Figure 11, it can be conclude that the 1st principal stress that show the maximum tensile stress induced in the part due to the loading conditions, 30.56 MPa is still below than material properties specification.

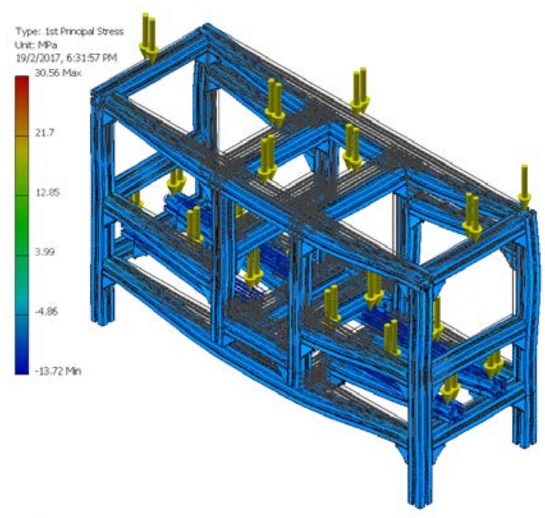

Fig. 11 1st principle stress on bun machine frame

5. Conclusions

Static analysis using finite element analysis software was successfully carried out to determine ability maximum deflection and its location on the frame of bun machine. Besides that, in this study Von Mises Stress also determined to compare with the yield strength of the material that uses for aluminum profile. Aluminum profile 40mm x 40mm still can support load that applied on that frame. Furthermore, aluminum profile was selected as structural members because serves a dual function of giving structural safety and at the same time incorporates mounting of the components. Through this result, its contribution allows faster and efficient model generation especially during modification.

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