Anchovy Processing Machine – Head and Stomach Contents Removal Mechanism

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ABSTRACT

The market demand for the dried anchovies is relatively high for the consumers in the Asian pacific region, which comes with non-split and split form. The existing anchovies splitting machine does not completely remove the head and visceral matter of the anchovies. In this project, four different conceptual designs were proposed. The crank mechanism and conventional cleaning brush was selected as the best method for the removal of the head and stomach contents of anchovies. The analysis for the conventional cleaning brush mechanism indicates that a waste removal of about 80 to 90% of the anchovies' waste is possible using the Ansys finite element analysis based on the given data related to various materials used in the study.

Keywords: *Anchovy, Ansys finite element analysis, structural analysis, waste removal mechanism*

1.0 INTRODUCTION

Anchovies are tiny, green fish with blue reflections due to a silver-colored longitudinal stripe that runs from the base of the caudal (tail) fin. They range from 2 to 40 cm (0.79 to 15.75 in) for an adult fish, and their body forms are variable with more slender fish in northern populations. To be more specific, an anchovy is a tiny, silver salt-water forage fish or oily fish belonging to the *Engraulidae* and *Anchoa* breeds. There are approximately 145 species and can be grouped into 17 genera, which are located in the Indian, Atlantic, Pacific Ocean, and Mediterranean Sea. Nowadays, anchovies are served in many ways to flavor many dishes in small quantities. Currently, the anchovy industry may be one of the most dynamic food-producing industries in the world. The industry has experienced a continual transformation in virtually every decade, in-line with today's technology era of Industry 4.0. Delgado *et al.* and Dey *et al.* have covered extensively on the topics of fish and its consumptions [1, 2]. There is a need for continual improvement in the automated anchovy processing machine apart from extending or increasing the functionality of the machine. Consequently, modifications are needed to increase the productivity of the dried anchovies process. A good discussion on the fishing technology and preservation processes can be found in [3, 4].

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In South-East Asian countries, dried anchovy (*Setipinna taty*) or *ikan bilis* as it is popularly-known in Malaysia, or *ikan teri* in Indonesia, and *dilis* in the Philippines. In the ASEAN region covering Indonesia, Malaysia and Singapore, anchovies are often processed to make fish stocks, Javanese *sambal* or are deep-fried. Anchovies are generally used in a similar way to dried shrimps in the Malaysian food industry. Other uses of anchovies as food delicacies can be further seen in [5, 6].

2.0 DETAILED DESIGN ANALYSIS

2.1 Initial Conditions

Initial conditions are specific types of conditions that are active and enforced only at the starting of the analysis and simulation. They are primarily used for transient analyses, but sometimes are quite useful for steady state analyses. Table 1 shows the actual amounts of product and waste if we applied the traditional splitting method. All the weights are in grams (g). Table 2 indicates the quantities that will be assigned in this study as the initial conditions.

Table 1: Mass of the split anchovies

No	Total mass (g)	Viscera mass (g)
1	0.32	0.017
2	0.44	0.022
3	0.36	0.014
4	0.43	0.021
5	0.50	0.026
6	0.33	0.017
7	0.37	0.023
8	0.46	0.024
9	0.39	0.021
10	0.37	0.02

Table 2: Initial conditions

Initial Conditions	
Average anchovy’s velocity (m/s)	2.57
Average anchovy’s acceleration (m/s^2)	4.13
Motor rotational speed (rpm)	150
Mass of split anchovy (g)	0.5

2.2 Materials Data

The materials data was used to provide an overview of the engineering data management that was later utilized for the simulation and to determine the critical material properties data for each part of the mechanism. Generally, most parts of the mechanisms are made from the structural steel, the properties of which can be seen in Table 3 with the value of theoretical stress-concentration factor, K_t is taken as 2.52 [7]. However, the brush cleaner part that was typically used in the conventional cleaning brush mechanism is typically made from polyethlene material. Again, the properties of polyethylene can be referred to in Table 4.

With reference to the physical properties of the anchovy itself, Ustun and Turhan (2017) stated that the antioxidant property of the protein films as a by-product of anchovies could be improved by incorporating the thyme essential oil depending on its volume fraction [8].

Table 5 shows the non-linear material with the physicochemical, optical, mechanical and barrier properties of the anchovy by-product protein films with thyme essential oil [9]. Meanwhile, the gelatin films incorporated with the root essential oils have been shown to exhibit anti-oxidative property [10].

Table 3: Properties of structural steel

Parameters	Value
Density (kg/mm^3)	9.5e-07
Coefficient of thermal expansion (m/m°C)	0.00023
Specific heat (J/kg°C)	296
Thermal conductivity (W/mm °C)	0.0002.8
Tensile yield strength (MPa)	25
Tensile ultimate strength (MPa)	33
Reference temperature (°C)	22
Young's modulus (MPa)	1100
Poisson's ratio	0.42
Bulk modulus (GPa)	163
Shear modulus (GPa)	79.3
Theoretical stress - Concentration factor, K_t	2.52

Table 4: Properties of polyethylene

Parameters	Value
Density (g/cm^3)	0.88–0.96
Coefficient of thermal expansion (m/m K)	180-200
Specific heat (J/kg°C)	1550
Thermal conductivity (W/mm K)	0.3 – 0.5
Tensile yield strength (MPa)	3
Tensile ultimate strength (MPa)	15
Reference temperature (°C)	22
Young's modulus (GPa)	0.8
Poisson's ratio	0.44
Bulk modulus (Kbar)	30
Shear modulus (GPa)	0.117

Table 5: Properties of anchovy

Parameters	Value
Solubility (%)	6.34 ± 0.4
Transparency	1.28 ± 0.01
Tensile Strength (MPa)	1.46 ± 0.04
Elongation at break (%)	51.5 ± 2.2
Water vapour permeability (g·mm/m^{2}h·kPa)	1.5 ± 0.1
Oxygen permeability (mmol/kg)	14.0 ± 1.1

2.3 Geometry of Parts

The statistics list the number of entities that are contained in the body or part as well as the volume and surface area of the body. For parts, the sums of the volumes and surface areas of bodies contained within the part are displayed. The volumes and surface areas are measured automatically up to the limit specified by the measurement selection limit setting as depicted in Table 6.

Table 6: Geometry of parts

Materials				
Assignment	Non-linear material	Polyethylene	Structural steel	
Non-linear effects	Yes			
Thermal strain effects	Yes			
Bounding Box				
Length *X* (mm)	12.2	36	52	83
Length *Y* (mm)	3	1.3	64	30
Length *Z* (mm)	100	33.8	50	30
Properties				
Volume (mm³)	2044.8	1215.2	13023	32350
Mass (kg)	5.6642e-4	1.154e5e-3	0.10223	0.25395
Centroid *X* (mm)	2.5	1.1347e-15	-1.5959	0.2664
Centroid *Y*(mm)	2.1488	-6.7371e-17	1.0179	18
Centroid *Z* (mm)	-2.8058	-44.75	-39.828	-45.5
Moment of inertia *Ip1* (kg·mm²)	2.8898	0.10974	55.249	26.694
Moment of inertia *Ip2* (kg·mm²)	2.9261	0.23419	73.34	65.559
Moment of inertia *Ip3* (kg·mm²)	4.4786e-2	0.12487	87.412	65.557
Statistics				
Nodes	1788	2740	4972	471
Elements	878	378	2206	155
Mesh metric	None			

A number of patents were referred and studied prior to the final design selection decision for the head and stomach removal mechanism in this work [11-13].

2.5 Analysis Settings

Each analysis type includes a group of analysis settings that allow the operator to define various solution options that are customized according to the specific type. Table 7 depicts the step time that was used in the analysis which is the incremental change in time for which the governing equations are being solved and finding a solution for an unsteady problem.

Table 7: Step time

Step	**Step end time (s)**
1	1
2	2
3	3
4	4

3.0 RESULTS AND DISCUSSIONS

There are six parameters to be analyzed in which the results are shown in Table 8 for the selected values of solution parameters (Table 9). The data collected was then processed and later presented in the table of the summarized results as shown in Table 10. An analysis of this experimental data is crucial since it can be used to further develop the conceptual design of the proposed mechanism. A number of factors were then taken into account performed to verify this conceptual design.

The analysis for this research was done based on a number of problems which include the stress analysis, dynamic and non-linear problems. In order to clarify if there was a relationship between the parameters (initial conditions) and the acting surface (response variables), the average anchovy's velocity and maximum mass of split anchovy were selected compatible with the motor rotational speed values given by the machine's manufacturer.

The more detailed design, modeling and analysis of the conceptual design related to the stress analysis, dynamic and non-linear problems have been described at length by Mohd Nazri in his work on the anchovy head and stomach removal mechanism [14].

Table 8: Results related to physical tests performed on the anchovies

Time (s)	Total deformation (mm)	Equivalent stress (MPa)	Equivalent strain (mm/mm)	Pressure (MPa)	Frictional stress (MPa)	Force reaction (N)
0.2000	1.0310	4.25E-09	1.95E-02	1.1125	1.34E-02	2.26E-03
1.0000	5.2589	2.12E-08	0.18981	1.1127	3.55E-02	1.13E-02
1.4000	7.2456	2.11E-08	0.19421	1.1135	3.81E-02	1.13E-02
2.0000	10.227	2.09E-08	0.2106	1.115	4.03E-02	1.13E-02
2.5490	15.71	2.05E-08	0.24862	1.1177	4.21E-02	1.13E-02
3.0000	20.218	2.03E-08	0.27285	1.1195	4.02E-02	1.13E-02
3.1400	21.618	2.02E-08	0.28158	1.1199	3.92E-02	1.14E-02
3.4051	24.269	2.01E-08	0.32672	1.1209	3.84E-02	1.14E-02
3.791	28.127	2.01E-08	0.33375	1.1218	4.09E-02	1.14E-02
4.0000	30.217	2.01E-08	0.33711	1.1224	4.07E-02	1.14E-02

Table 9: Proposed solutions related to the waste removal of anchovy

Time (s)	Actual mass (g)	Mass (g)	Percentage of damage %	Environment temperature ℃
4	0.5	0.477	4.6	22

Table 10: Summary of results

Parameters	Value
Total mass of anchovy loss (g)	0.023
Mass of viscera matter (g)	0.026
Percentage of $waste_{0.5g_{after}}$ (%)	4.6
Percentage of clean anchovy (%)	95.4
Percentage of viscera removal (%)	86.67

4.0 CONCLUSION

The results for all the solutions have been generated and analyzed. The total mass of the anchovy loss is 0.023 g and the percentage of the visceral removal was determined with an output value of 86.67%. Thus, the conventional cleaning brush mechanism has achieved the objective of this study to remove about 80% to 90% of the anchovy's viscera matter. Theoretically, the analysis was done only for the perfect posture of the anchovy without taking into consideration the other external factors.

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