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Design and Validation of Horizontal Steam Retort with Capacity of 100 kg Presto milkfish Using Finite Element Method (FEM)

Nofrizal Fajar Satria Pratama[1*], Danang Dwi Saputro[1]

1 Department of Mechanical Engineering, Faculty of Engineering, Universitas Negeri Semarang, Indonesia

* satrianfsp14@students.unnes.ac.id

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Abstract

Retorts are used in the food processing industry to sterilize packaged food products. Sterilization of presto milkfish using retort is done at 120°C and 2 bar pressure. The retort is designed to work safely under these load conditions. This study aims to determine the safety quality of the horizontal steam retort design. Design validation is done by static analysis using finite element method (FEM) with Solidworks software. The retort design uses 18Cr-8Ni type 304 stainless steel material, with a sterilization load of 120°C temperature, 2 bar pressure, and 100 kg of milkfish load. The analysis showed that the most considerable Von-Mises stress occurred on the torispherical head with a value of $70.52 \times 10^6\ N/m^2$. The largest displacement occurs at the torispherical head of the retort door with a value of 1.078 mm. The retort design is concluded to be safe to use under sterilization load conditions with a safety factor value of 2.9.

1 Introduction

Retort is a device used in the food processing industry for the sterilization process of packaged food products using high temperature and pressure [1]. Based on the heating medium used, retorts are generally divided into three types: hot water, steam, or a combination of both. Steam retorts are the most common in small industries due to their low cost, flexibility, and suitability for small-scale production [2]. for the retort scheme can be seen in Figure 1.

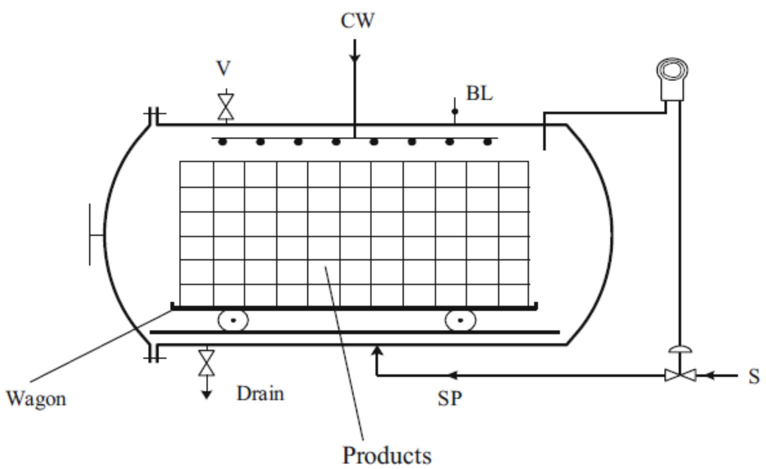

Figure 1. Horizontal steam retort [3]

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Retorts play an important role in the thermal processing of food. The retort is used as a steam vessel for sterilization at high temperature and pressure, so the retort design must have good safety qualities. The sterilization process of presto milkfish using a retort is carried out at a temperature of 120°C and a pressure of 2 bar. It is known that the design capacity of the retort is for 100 kg of milkfish. The retort design uses 18Cr-8Ni type 304 stainless steel material, with a sterilization load of 120°C temperature, 2 bar pressure, and 100 kg of milkfish weight.

Validation of the retort design with the FEA method has been done by [4] with vertical retort design is used for the sterilization process of shrimp, with a capacity of 10 kg. The retort design uses the American Society of Mechanical Engineers (ASME) [5] section IV standard with ASME SA 516 Gr 70 material. The results obtained by the thickness of the retort material greatly affect the safety quality. The thinner the material, the greater the von Mises stress. Otherwise, the thicker the material, the smaller the stress.

Validation of the design of a horizontal retort with a capacity of 180 liters has been done by [6] using AISI 1015 material. Tests were carried out with operating loads at pressures of 2 bar, 10 bar, 20 bar, and 30 bar. The results show that the voltage at a pressure of 2 bar is 21 MPa, a pressure of 10 bar is 103 MPa, a pressure of 20 bar is 206 MPa, and at a pressure of 30 bar is 309 MPa.

This study aims to determine the safety quality of horizontal steam retort design using 18Cr-8Ni type 304 stainless steel material, with a sterilization load of 120 °C temperature, 2 bar pressure, and a milkfish weight of 100 kg. The retort construction refers to ASME section IV (2019) [7]. Design validation in the form of static analysis of finite element method (FEM) using Solidworks software.

2 Research Methods

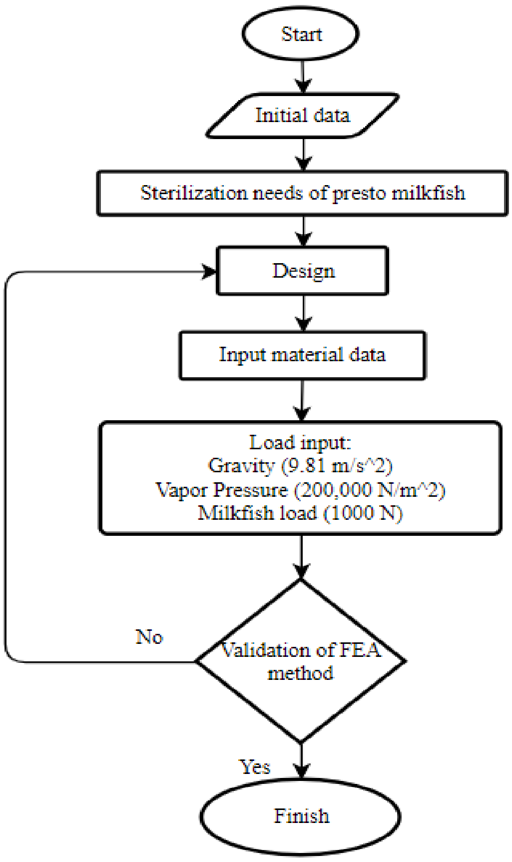

Figure 2. Flowchart of the research

Design validation using static analysis of finite element method (FEM) with Solidworks software. FEM is a numerical analysis method used to analyze the distribution of stress, strain, displacement, deformation, and safety factors in various design structures [8–10]. The research flow chart can be seen in Figure 2.

3 Results and Discussion

3.1 Horizontal steam retort material

The retort is designed using 18Cr-8Ni type 304 stainless steel material with yield strength and tensile strength, respectively, 205 MPa and 515 MPa. The material specifications used in each part of the retort are based on ASME (2019) [5] standards can be seen in Table 1.

Table 1. Retort material specifications

No.	Part	Specification Number	Grade	Nominal Composition	Form
1.	Cylinder	SA-240	304	18Cr-8Ni	Plate
2.	Torispherical head	SA-240	304	18Cr-8Ni	Plate
3.	Door assembly	SA-240	304	18Cr-8Ni	Plate
4.	Door shaft	SA-479	304	18Cr-8Ni	Bar
5.	Door flange	SA-182	F304	18Cr-8Ni	Forgings
6.	Nozzle pipe	SA-312	TP304	18Cr-8Ni	Smls. Pipe
7.	Security pipe	SA-312	TP304	18Cr-8Ni	Smls. Pipe
8.	Nuts and bolts	SA-182	F304	18Cr-8Ni	Forgings
9.	Rail	SA-182	F304	18Cr-8Ni	Forgings
10.	Support saddle	-	S45C	-	Plate
11.	Hinge shaft	-	S45C	-	Round bar
12.	Hinge	-	S45C	-	Hollow bar
13.	Arm and ear	-	S45C	-	Plate

3.2 Retort design and dimensions

The retort design used for the presto milkfish sterilization process can be seen in Figure 3. The dimensions of the retort using the ASME 2019 standard can be seen in Table 2.

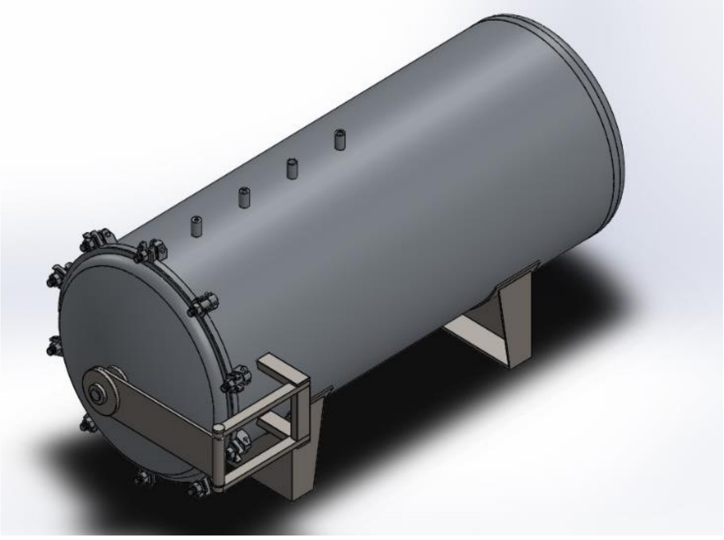

Figure 3. Horizontal steam retort design

Table 2. Retort dimensions

No.	Part	Dimension	Thickness or Diameter	Quantity
1.	Cylinder	OD = 776 mm ID = 768 mm Length = 1800 mm	4 mm	1
2.	Torispherical head	OD = 776 mm ID = 764 mm Chrown R = 776 mm	6 mm	1
3.	Door head	OD = 776 mm ID = 764 mm Chrown R = 776 mm	6 mm	1
4.	Hinge arm	Length = 520 mm Width = 160 mm	12 mm	1
5.	Hinge axis pin	Length = 190 mm Width = 25 mm	∅20 mm	1
6.	Hinge axis	OD = 40 mm ID = 30 mm Length = 180 mm	5 mm	1
7.	Hinge ear	Length = 350 mm Width = 40 mm	20 mm	2
8.	Bolt	MSQ24 x 3 mm	∅20 mm	10
9.	Main steam nozzle pipe	OD = 33.4 mm ID = 27.4 mm	3 mm	1
10.	Manometer pipe	OD = 33.4 mm ID = 27.4 mm	3 mm	1
11.	Manometer pipe	OD = 33.4 mm ID = 27.4 mm	3 mm	1
12.	Safety valve pipe	OD = 33.4 mm ID = 27.4 mm	3 mm	1
13.	Support saddle	Base plate Web plate Wear plate	12 mm 6 mm 6 mm	2

3.3 Design validation

The static analysis load is the sterilization condition, as well as the capacity load of 100 kg of milkfish, which can be seen in Table 3.

Table 3. Retort load for static analysis

No.	*Part*	Beban	Nilai Beban
1.	All parts of the retort	Gravity	9.81 m/s^2
2.	All parts of the retort	Vapor pressure	$200{,}000 N/m^2$
3.	Cylinder and saddle	Milkfish load	1,000 N

The retort design fixture for static analysis is located on the bottom surface of the saddle to serve as a support for the test and is aligned with the direction of gravity of the object, as shown in Figure 4.

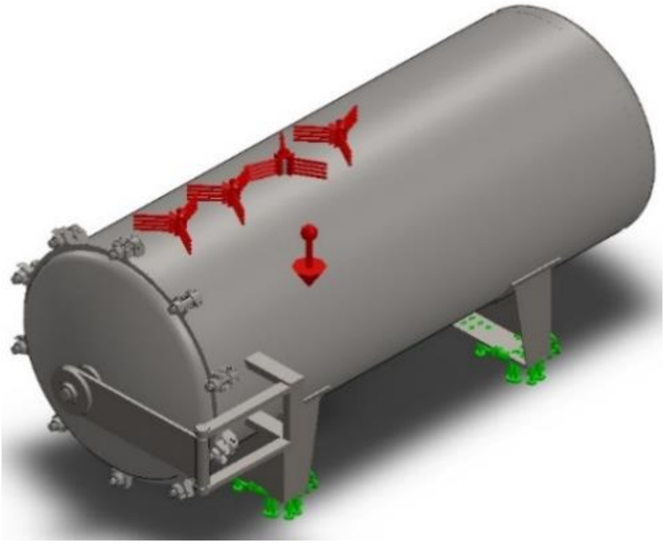

Figure 4. Retort design fixture

Figure 5 shows the results of the static analysis using the FEM method show the maximum displacement and von-mises stress values of the design. The largest displacement of 1.078 mm occurs at the torispherical head of the retort door, while the smallest displacement of 0 mm occurs at the pipe flange under the shell because it is not directly exposed to loading. The deformation shown is the actual deformation (scale: 1).

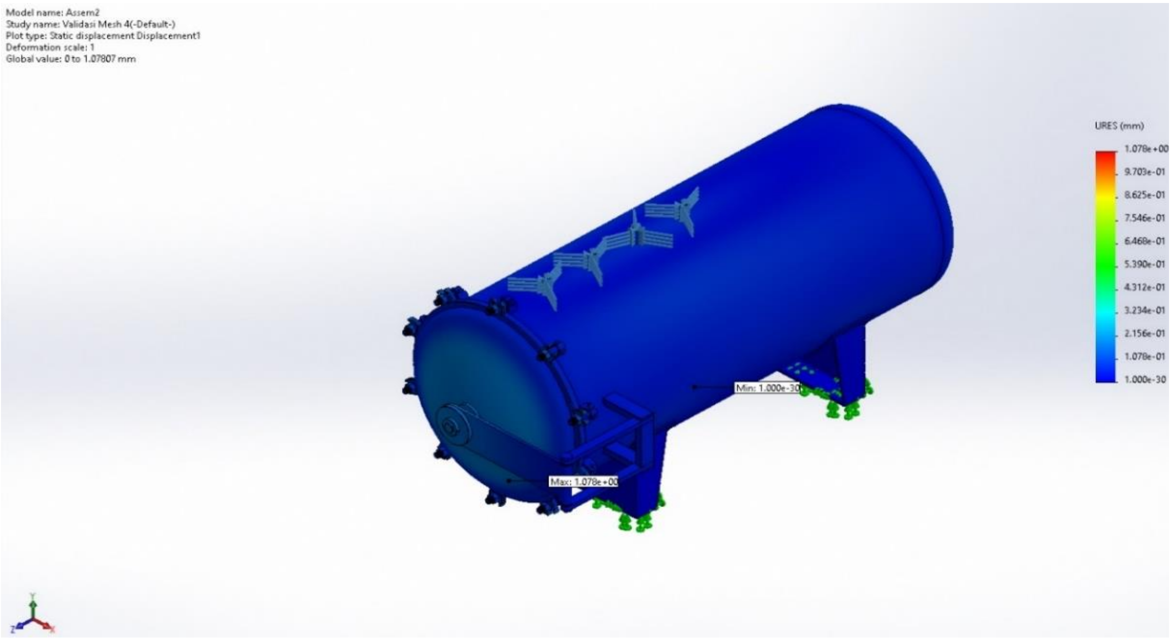

Figure 5. Displacement of the retort

The largest von Mises stress, 70.52×106 N/m2, occurs at the torispherical head shown in red as shown in Figure 6. The smallest von Mises stress of 0 mm occurs on the pipe flange under the shell because it is not exposed to loading. The deformation shown is the actual deformation (scale 1:1).

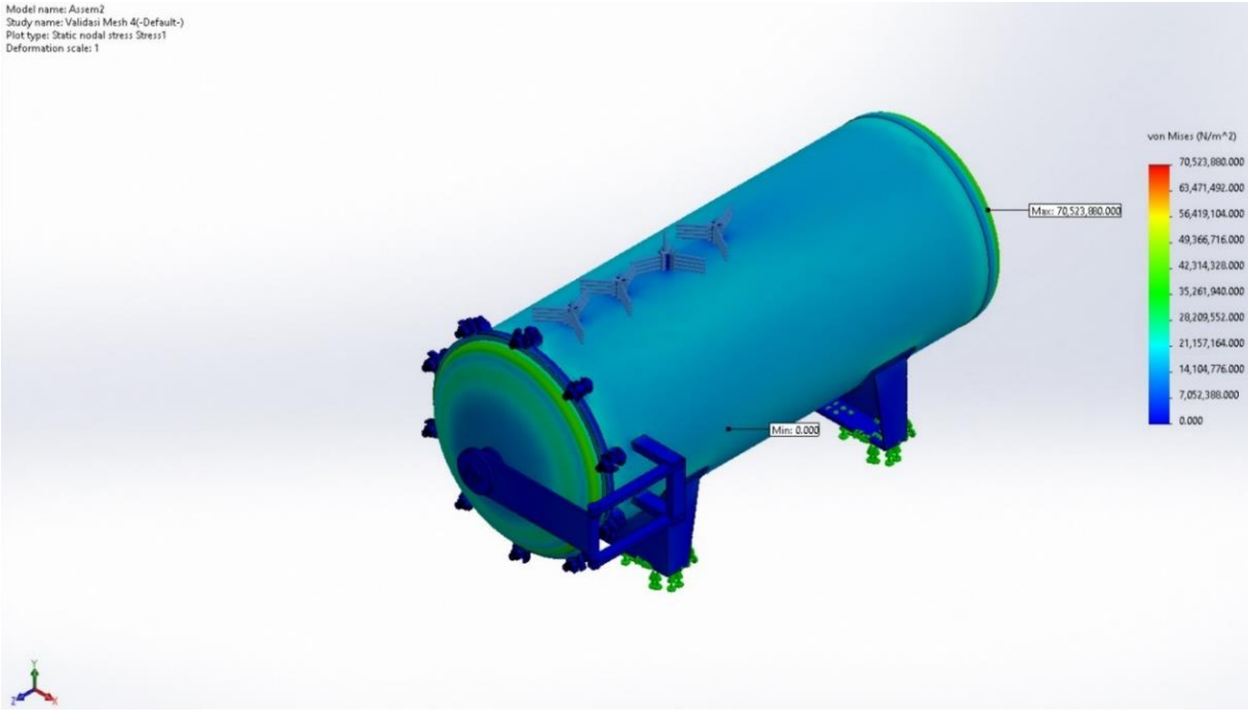

Figure 6. Von Mises stress of the retort

Validation is used to ensure that the retort design is safe to use in the sterilization process. The parameter to determine the safety level of the retort design is the von Mises stress. The retort design has good safety quality if the maximum von Mises stress is lower than the yield strength of the material. The largest von-Mises stress on the retort is 70.52×10^6 N/m^{2,} and the yield strength of the 18Cr-8Ni type 304 stainless steel material is 205×10^6 N/m^2, so it can be concluded that the retort design is safe and does not experience plastic deformation with a safety factor of 2.90 as in the following calculations and the results in table 4.

$$SF = \frac{205 \times 10^6\ N/m^2}{70{,}52 \times 10^6\ N/m^2}$$

$$= 2{,}90$$

Table 4. Static analysis results of horizontal vapor retort

No.	Static analysis data	Static analysis results	
		Part	Value
1.	Von-mises stress max.	Torispherical head	$70{,}52 \times 10^6$ N/m^2
2.	Displacement max.	Torispherical head	1,078 mm
3.	Safety factor min.	Torispherical head	2,90

4 Conclusion

Based on the static analysis results provided in the table, the following conclusions can be drawn regarding the performance of the torispherical head demonstrates acceptable mechanical performance under the given loading conditions, with stresses and displacements within reasonable limits. The safety factor of 2.90 indicates a safe and reliable design, suggesting that the component is structurally sound for its intended application.

5 Acknowledgement

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