DESIGN OF AUTOCLAVE FOR FRESH SHRIMP STERILIZATON PROCESS USING FINITE ELEMENT ANALYSIS

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ABSTRACT

Chloramphenicol is one of antibiotic compound which is an additional ingredient that is forbidden to be used in food products, especially in fresh shrimp product export. To avoid the used of preservative, then required sterilization process in a physical way which is vaporization using a high-pressure supercritical carbon dioxide (CO2). One of sterilization process for supercritical carbon dioxide is using autoclave media. Autoclave is a closed heating device used to sterilize or reducing a substance or object that is disserve by using high temperature and high pressure steam. In designing and constructing autoclave, the first step to be done is to define the function and the operation capacity. The function and capacity will determine the initial dimension of autoclave as well its working pressure and temperature. In this study, the autoclave was designed with quantitative methods and modeling using software Autodesk inventor 2016 based on finite element method. The given load is in the form of supercritical carbon dioxide pressure of 73.83bar and temperature of 31.3^{0}C. Based on the result of design, quantitative methods gives the safe result and optimized thickness needed autoclave usage.

Keywords: Chloramphenicol, carbon dioxide (CO2), fresh shrimp, autoclave, design.

1 INTRODUCTION

Chloramphenicol is one antibiotic compound which is an additional ingredient which is forbidden to be consumed in food products, especially fresh shrimp exports. Therefore we need a tool to reduce the chloramphenicol. Sterilization process that is able to reduce the preservative substances is by doing a high vapor pressure of supercritical carbon dioxide CO2 (Pratama, 2013). Closed heating device used to sterilize or reducing a substance or object that is harmful by using hot steam high pressure and temperature called the autoclave (Saputra, 2004). In designing the design and construction of the autoclave, the initial stage is done is to define the function and operation capacity. Due to the high pressure and temperature autoclave above the supercritical pressure, the stress concentration and discontinuities often occur at the confluence of the shell and head (Oyawale & Olaoye, 2007). So it is required special attention so that stress concentration and stress discontinuities occurring not cause the failure of the structure. Autoclave is a closed heating device to sterilize an object with high pressure and temperature.

The purpose of the design scale-up and analysis is to determine the critical areas, where the stress is still below the allowable stress of the material used. Simulation conducted to determine critical areas and stress that occur in this autoclave. Like Wise with autoclave construction done distortion theory calculations using Von Misses criterion, where the stress that occurs may not exceed the allowable stress of the material (Moss & Basic, 2013).

2. MATERIALS AND METHODS

The initial step is to determine the dimensions of the following autoclave with a capacity of 10 kg. Physical characteristic of shrimp is shown as Table 1.

Table 1. Shrimp Size

Parameter	Size
Shrimp length	200 mm
Shrimp width	35 mm
Shrimp weight	0,122 kg

From the physical data of shrimp on the Table 1 above, it can be calculated geometrically the cross sectional of shrimp for 10 kg capacity.
Cross-sectional area 1 shrimp= 200.35=700 mm2
Weight 1 shrimp assumed = 0,122 kg.
Value of 10 kg shrimp = 1000/0,122= 82 shrimps
Then cross-sectional area 10 kg = 82. 700= 57400 mm^2 or 6000 mm^2
Sectional area divided into three levels with 1 level = 400.500 = 20000 mm^2
For 3 levels is = 20000 mm^2. 3 = 60000 mm^2

2.1 Diameter of Autoclave

Then the steps taken are to determine the diameter of the autoclave, as shown in Figure 1 by following the design data in table 2 to create a 3D model of the tool to be observed and calculated the stress that occurs in the material.

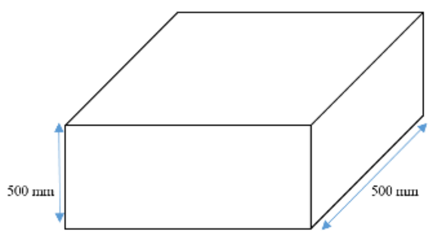

Figure 1. Cross-Sectional Area

2.2 Data Design

Based on the calculations and material, the design of the data obtained in the following Table 2 below:

Table 2. Data Design

Parameter	Size
Type pressure vessel	Autoclave
Production capacity	10 kg
Diameter	541,5 mm
Length	500 mm
Pressure design	7,383 MPa
Temperature design	31,1°C
CA	3,175
Joint Efficiency	0,85
Used material	ASME SA 516 Gr 70
Coefficient of expansion steel	0,000012/°C
Temperature ambient	28°C
The yield stress of material	262,000 N/mm^2
Safety factor	1,5
Material allowable stress	171,66717 N/mm^2

2.3 Stress and Strain Analysis

The next step is to analyze stress and tension using Autodesk inventor 2016 as shown in figure 2. it begins with creating a 3D model with predetermined dimensions.

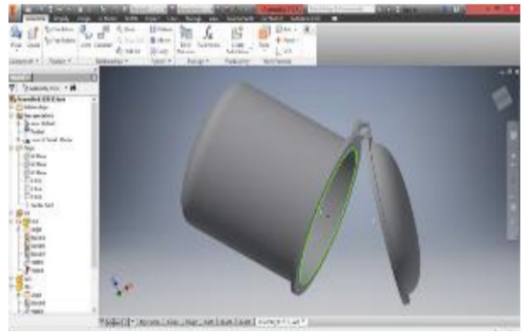

Figure 2. Autoclave 3D

Based on the way to analyze the data, voltage and strain using the formulas in Table 3 below:

Table 3. Analysis Formula

The Minimum Shell Thickness	$t_{s\,min} = \frac{PR}{SE + 0,4\,P} + CA$
Minimum Head Thickness	$t_{s\,min} = \frac{PR}{2SE + 0,2\,P} + CA$
Circumferential Stress	$\sigma_c = \frac{PD}{4t}$
Longitudinal Stress	$\sigma_l = \frac{PD}{2t}$
Radial Stress	$\sigma_r = \frac{F}{A}$
Thermal Load	$\Delta L = \alpha L_0 \Delta T$
Thermal Stress	$\sigma_{thermal} = E\alpha\Delta T$
Strain	$\varepsilon = \Delta L / L_0$
Von Mises Stress	$\boldsymbol{\sigma_{vm}} = \sqrt{\frac{(\boldsymbol{\sigma_x} - \boldsymbol{\sigma_y})^2 + (\boldsymbol{\sigma_y} - \boldsymbol{\sigma_x})^2 + (\boldsymbol{\sigma_z} - \boldsymbol{\sigma_x})^2}{2}}$

Formula Description
σ_r = Radial Stress, psi
σ_c = Circumferential Stress, psi
σ_l = Longitudinal Stress N/mm^2
σ_{vm}= Von Mises, N/mm^2
σ_t = Thermal Stress
P = Internal or external pressure, psi
D = Diameter of vessel, inches
t = Thickness of shell, inches
F = Force, N
A = Cross Section Area, mm^2
E = modulus of elasticity, N/m^2
α = Coefficient of expansion
ΔT = Mean Temperature, °C
ε = Strain, %
ΔL = Mean length, mm

L_0 = Initial length, mm

3. RESULTS AND DISCUSSION

3.1 Numerical Calculations

Numerical simulation process is a process for determining the strength of the material used. Autoclave in the design of geometric shapes are symmetrical, so only some parts that will be simulated. The first step taken before the simulation is envy 3D model to Autodesk Simulation Mechanical. In this window do is click "simulation" - launch active model – giving part name - type analysis – set current – linear – static stress with linear material models - mesh – generate 3D Mesh – element type – element brick. Next step is to edit material: material right click - edit - edit properties - data content material - ok, as well as fill material data in each part with the same data.

In Figure 3 show that the first boundary condition given is pressure on the inside part autoclave click - click on the inside - right click - add - surface pressure / traction - fill pressure with a magnitude 7,383 N/mm² – ok. Like Wise with the second boundary condition is the temperature, in the same way just a different choice.

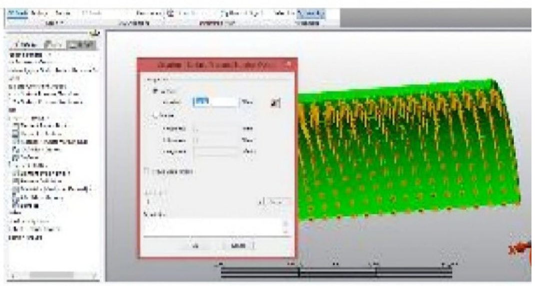

Figure 3. Pressure Boundary Condition

The next step is to do is to limit the sketch geometry and locking curve in the relative position to be the same it's seen on figure 4. Giving this fixed conditioned in silence and did not move. Steps to be done is to right click - add – surface general constraint object – fixed – ok.

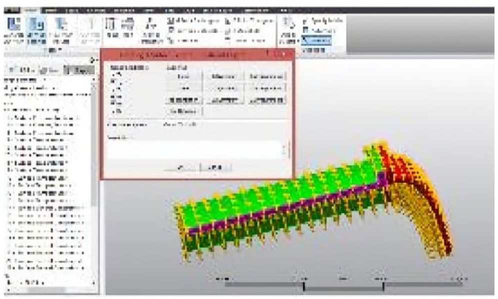

Figure 4. Fixed position

After making the provision of temperature and pressure boundary conditions and has given a fix on the autoclave, the next step is to perform a simulation, analysis click - Run with SimMech, it will exit the display as follows on Figure 5.

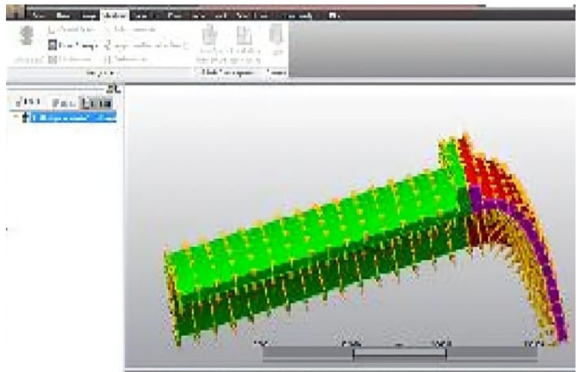

Figure 5. Running process

The results of the simulation output at this stage is the stage of completion using the software, describes the stages of software finite element, wherein the display is a value the power of the material used in the autoclave, the displacement, strain and stress Von Mises.

Displacement happens to the autoclave shown below with the pressure value 73.83 bar and temperature 31.1°C. The simulation results show displacement occurred in the center section head autoclave. The maximum displacement value of 0.1497589 mm occurring, and the minimum value is 0 or no change. This section will suffer most displacement due to pressure and temperature given in an autoclave.

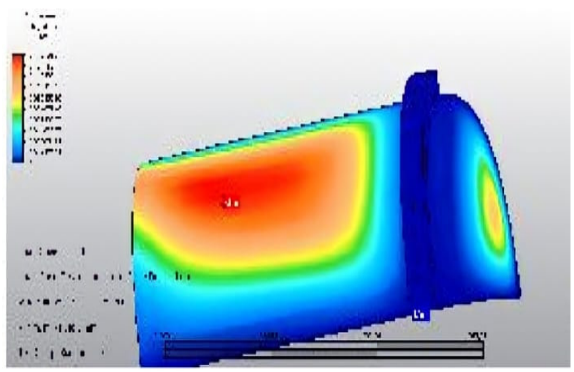

Figure 6. Displacement

On the Figure 6 viewing under visible strain that occurs in the autoclave there is an arch head. With a maximum strain value 0.000714255 mm / mm, and minimum strain value with the value 6,68319e-006. In the simulation results to see this strain, then the strain that makes them long in the arch head autoclave.

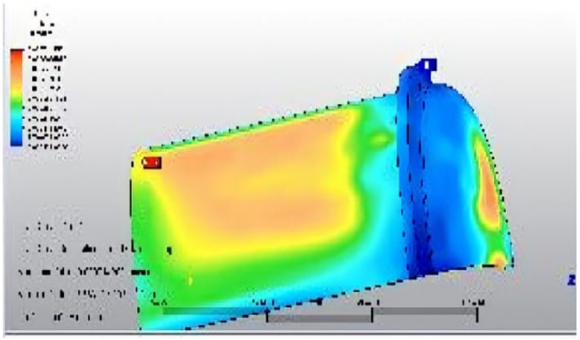

Figure 7. Strain Von Mises

On the Fig 7, shows that the distortion energy theory at a maximum stress value110,7372 N/mm², the minimum stress is at a value1,03615 N/mm². If the stress has exceeded the material yield stress, then failure will occur in the design of this autoclave.

3.2. Numerical Optimization of thick plates

The following discussion of the autoclave design is by numerical calculation, and the following calculation results on Table 4.

Table 4. Numerical Optimization of Thick Plates

Thick of plate (mm)	Displacement (mm)	Strain (%)	Stress Von Mises (N/mm2)
10	0,27850	0,00140	217,0989
12	0,22123	0,001 08	167,8449
14	0,18247	0,000 86	133,5333
16	0,14975	0,000 71	110,7372

After optimizing the design of the autoclave with numerical calculations, while the results of the optimization of the results of the simulation output is as follows:

1. Displacement happens to the slab thickness of 16 mm; 14 mm; 12 mm and 10 mm, there is the greatest displacement at a thickness of 10mm, which is equal to 0.438327 mm. The concentration of displacement in the closed autoclave design.
2. Strains that occur in slab thickness of 16 mm, 14 mm, 12 mm and 10 mm, are in the slab thickness 10 mm, which resulted in a stretch of 0.00262117 or 0.262117 %.
3. Von Mises stress that most occur between the slab thickness of 16 mm, 14 mm, 12 mm and 10 mm, is the slab thickness of 10 mm and 12 mm. At the plate thickness is declared unsafe because already passed the criteria limits the yield of material that is with stress that occur 406,383 and 316,082

3.3. Percentage Error

The percentage of error is to determine the value of the accuracy of the calculation of numerical analytic multiplied by 100%. In this calculation the authors determine the percentage error of the voltage Von Mises between analytic numerical that has been used to find the percentage error of the analytical and numerical with 4 variable slab thickness shown in the following Table 5.

Table 5. Percentage Error

Thick of plate (mm)	Von Mises analysis (N/mm2)	Von Mises numerical (N/mm2)	Error (%)
10	174,19896	406,383	19,76
12	145,35518	316,082	13,39
14	124,75507	253,801	6,57
16	109,30725	209,446	1,29

Percentage error of the results in Table 5, we then do a comparison between the value of the percentage of error to a thickness of 16 mm; 14 mm; 12 mm; 10 mm as shown in Figure 8.

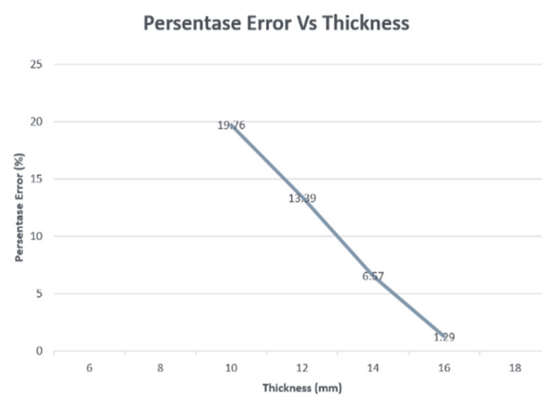

Fig 8. Curve the Percentage of Error and Slab Thickness

Based on the results that seen on Figure 8 for the calculation of the percentage of error that has been done, then the percentage error of 19.76% on a 10 mm thick plate is declared unsafe allowable stress yet still safe to the yield stress of the material. At 1.29% on a 16 mm thick plate is declared safe to operate. The graph above shows that percentage error that occurs is directly proportional to the value of analytical, numerical and optimization of the thick plate is used, so the thinner the slab thickness, the greater the percentage of error that occurred.

4. CONCLUSION

Based on the analysis that has been done, the conclusions obtained from this study is the results of stress calculations which have been done through analysis, numerical and optimization, shows that the use of plates with a thickness of 12 mm, 14 mm and 16 mm, smaller than the yield stress of material and can be declared safe. But, the plate 10 mm with numerical calculations have passed the limit allowable stress of material. Stress calculations on the slab thickness 14 mm and 16 mm, indicate where the stress happened has exceeded the yield of the material so stated criteria are still in safe circumstances.

The addition of a length of 0.0186 mm so do not affect the type of saddle used, but increasing the length cannot be ignored, but need to be considered. So as to avoid the concentration of stress or damage to the welding connection. Strain that occurs in the design of the autoclave through analytical calculations and numerical optimization is still far from the existing strain on the mechanical properties of materials. The value of the thermal stresses occurring is far from finished material allowable stress can be declared safe. The thinner the slab thickness is used, the greater the voltage generated, as well conversely the thicker plate is used, the less stress that occurs.

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