NUMERICAL ANALYSIS FOR OPTIMIZATION OF PRESSURE VESSEL

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Abstract
This study deals with creating s finite element model (FEM) of filter for future optimization. The filter is composed of two parts. These parts are pressure vessel and filter partition. Finite element analysis (FEA) is a good tool for predicting the state after load in a pressure vessel. FEA can find out hidden danger unachievable by analytical solution. On one hand, numerical solution can show critical part of the product, on the other hand can show over-size areas. First point of interest is thickness of pressure vessel. Thickness reduction will result in weight loss. The aim of this study is a verification numerical solution by analytical solution and to select over-size areas for future optimization.

Key words: *finite element analysis, thin-walled pressure vessel, filter, MSC Marc*.

INTRODUCTION

Pressure vessels are used in many different kind of industry. Thin-walled pressure vessel can perform the function as diving bottle, overpressure chamber, distillation tower or filter. They are metal containers. They are fulfilled by liquid or gas under pressure. Construction of the pressure vessel is welded from sheet plate usually. Material of sheet is galvanized metal, stainless steel or steel. They have two configurations and that horizontal position and vertical position. Problematic of pressure vessel is describing in (*Megyesy, Buthod 2008*; *Moss, Basic 2013*). The key of the pressure vessel is durability before damage by high pressure. This study is a pressure vessel like a part of the filter. They requirements are placed on the speed of filtration and weight of the device. The effort of many companies is to reduce weight and make filtration more efficient.

Filtration is process of separate between fluid and solid phase. This topic is describing in book (*Perlmutter 2015*). Suspension is conducted through the filter which stopped solid pollution and the liquid continues. Base part of the filter is filtering layer. It was created from textile, sieve or porous plate. The result must have the quality required by the customer. The subject of this problem is in (*Cheremisinoff 1989*). Liquid is generally used in process of filtration like a final product or can be used as supporting product for the next production. Filtrate liquid are used in wide spectrum of industry application as chemical industry, automotive, oil industry, glass production or food production. The incentive to crate this work has given (*Mutava* 2016)

MATERIALS AND METHODS

Design of the filter is shown on Figure 1. FEA will be restricted only on pressure vessel. Filter partition will be included in future study. The vessel was rolling from the sheet with 3 mm thickness. Full length of the vessel is 1072 mm. It is assumed from two parts. The first part is a cylinder with diameter 219 mm and the second part is hemispheric. The next part is the lid. Head part of the lid has diameter 262 mm. The filter has vertical configuration. Filling hole was on the side and the emptying hole was on the bottom of hemisphere. Due to the dimension, the vessel was considered like a thin-walled in FEA. Material of the vessel and lid was chosen as stainless steel 1.4301. This steel can easily be cold rolled, drawn and stamped. This steel can easily be welded by any conventional joining technique, except the oxyacetylene torch. The material has a Young´s modulus of 200×10^3 MPa, tensile strength of 1275 MPa, Yield strength 965 MPa and Poisson ratio of 0.3. The alloy steel was assumed to be isotropic linear-elastic in FEA. Construction pressure on the vessel was set on 1.3 MPa and operational pressure was set on 1 MPa.

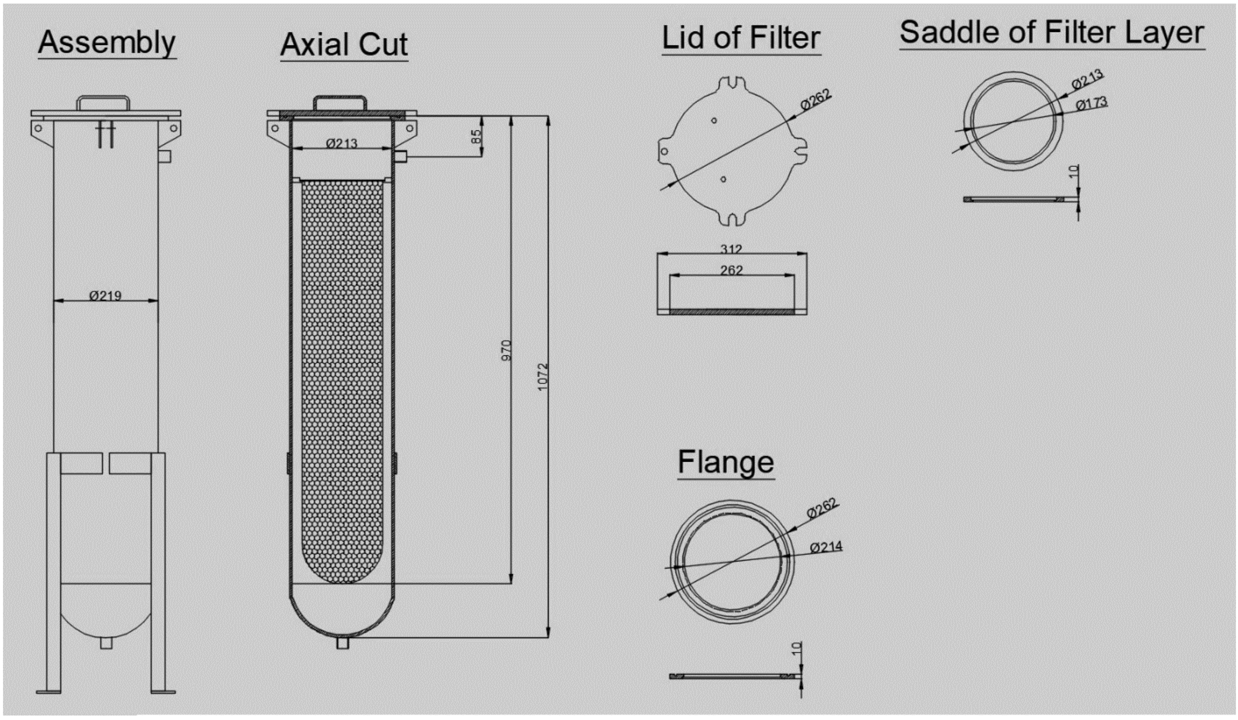

Fig. 1 Design of filter

Analytical solution was made only for cylinder part of a vessel at a sufficient distance from the stress change points.
Maximal axial stress can be calculated by equation (1)

$$\sigma_a = \frac{p \cdot r}{2 \cdot h} \tag{1}$$

where p is operation pressure (Pa), r is the mean radius of the vessel (mm) and h is wall thickness of the vessel (mm).
Maximal tangential stress can be calculated by equation (2)

$$\sigma_t = \frac{p \cdot r}{h} \tag{2}$$

where describe of member is the same for the equation (1).
Equation (3) is the Von Mises criterion for plane stress

$$\sigma = \sqrt{\sigma_1^2 - \sigma_1 \sigma_2 - \sigma_1^2} \tag{3}$$

where subscript σ_1 replace with σ_a and σ_2 replace with σ_t.
History of creating a computing model was captured on figure 2. Simplification was made in drawing the model. Some parts were neglected. The model was drawled in software Autodesk Inventor 2018 (Figure 2a). This created model was imported in FEMAP for to create meshes. Solid model was reduced to mid-surface (Figure 2b). The lid was meshed separately. The vessel was contained in square shell an element with constant thickness 3 mm. The lid was meshed as solid with hex linear elements. Both meshed models are imported in MSC Marc software (Figure 2c). There was set boundary condition. The vessel was fixed on the ring which represents rack. Vessels lid was assembled to the vessel by glued contact. Inner pressure was made by face load and set on 1 MPa.

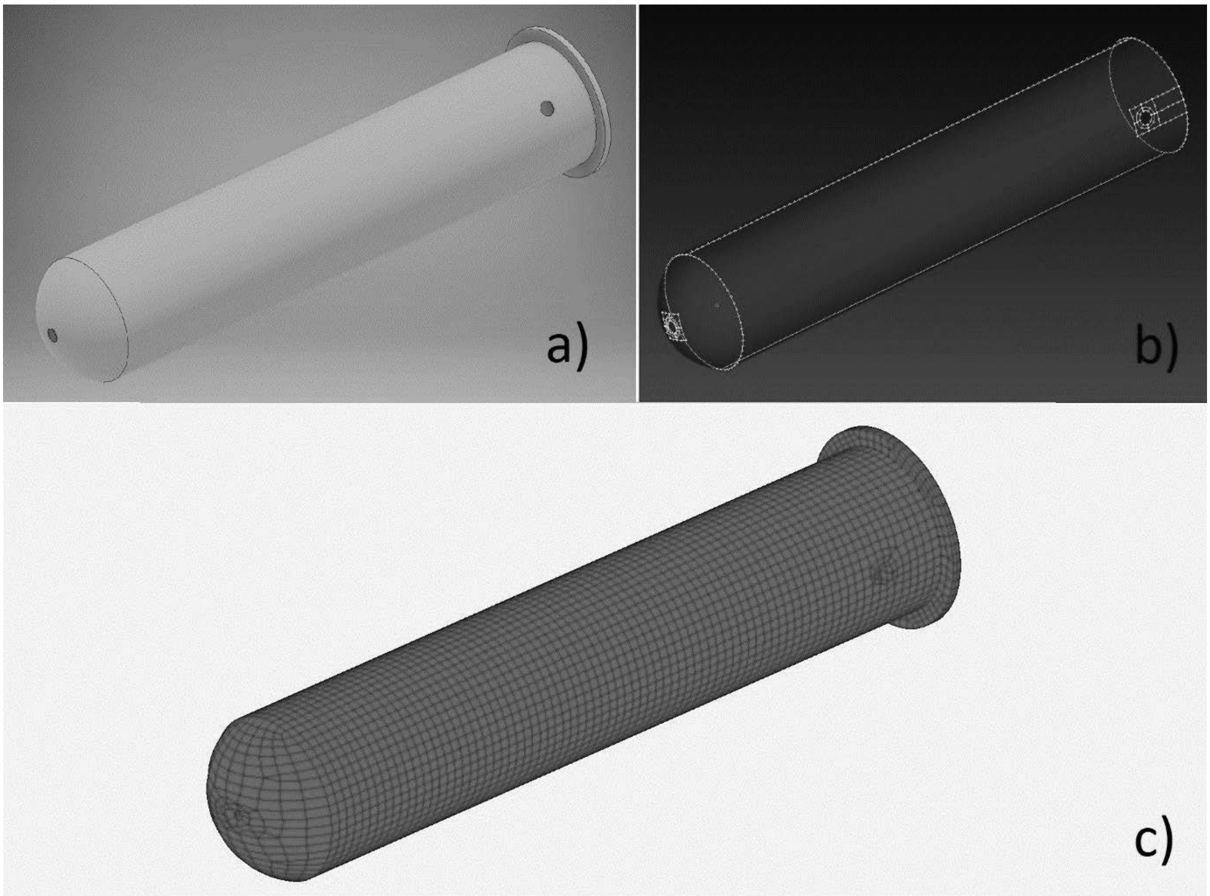

Fig. 2 FEM model creating sequence

RESULTS AND DISCUSSION

The results of analytical solution are shown in table 1. Difference was 0.83 % between analytical solution and numerical solution.

Tab. 1 Comparison analytical and numerical solution

Method	Von Mises Stress MPa
Analytical	31.61
Numerical	31.35

The FEA results were illustrated in Picture 3. Lowest Von Misses stress was determined on the hemisphere. The value of stress was 26 MPa. Maximum Von Misses stress was 83.01 MPa. This critical area was around filling hole. The lid was another area with stress concentrates. Stress concentrated in center of lid with maximal value 50.72 MPa. This solution was designed as worst situation of the pressure vessel. There is the space for considers to make a more detailed model. Welded flange is added in design of filters. Join was replaced as glued contact. It can lead up to growing stress in analyzing area. Flange can result in an increase a durability against pressure. The vessel is more durable with every other part.

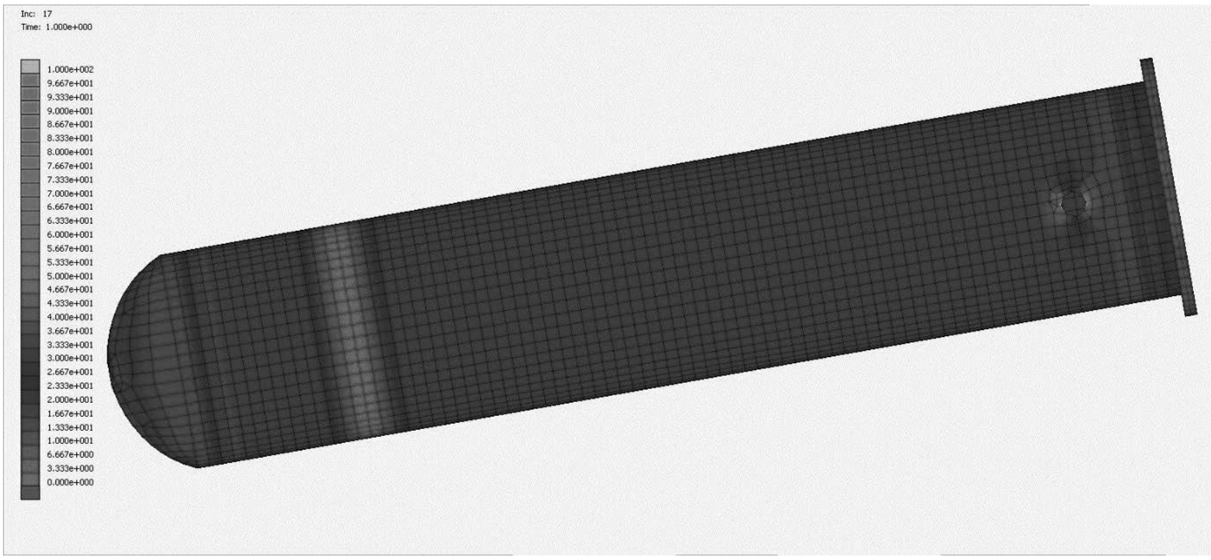

Fig. 3 Von Mises stress on pressure vessel

CONCLUSIONS

The aim of this analysis was to make the first study on concrete filter. The first part of the article was showed a comparison between analytical and numerical solution. The difference was 0,83 % between this solution. This result was only for cylinder part of the vessel. Analytical solution was hard used around hole or surface curvature. This results were captured easier by numerical solution. Finding of over-size or under-size areas lead up to better construction of the technical part. Pressure vessel can have had lower weight with same safety in this particular case. Analyses showed two critical areas. The first critical area was around filling hole. Less significant critical area was in the centre of the lid. On the other side, bottom hemisphere is over-size of the vessel. Significant thickness reduce can be done at the hemisphere end of the vessel. Next reduce of thickness can be done on cylindrical part of vessel. It is necessary to focus on the location around the filling hole. There is need to add more wall thickness or some reinforcement part. Critical location on the lid can be solved by the growing size of thickness or change shape of the lid. If hemisphere lid is used, the stress will dramatically reduce. Future studies will deal with find out the optimal shape of a vessel of the filter.

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