DESIGN OPTIMISATION OF METALLIC BOSSES FOR TYPE IV HYDROGEN TANKS PRODUCED BY FILAMENT WINDING

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In the generation, delivery, and end use of hydrogen there is a need for storage vessels. In all cases, these vessels require an interface to connect the tank to a system to fill and dispense the tank contents, whether in gaseous or liquid form. A key component of the tank is the boss which is fundamental to the safety of the tank, as failure to seal the metallic part to the plastic liner will form a gas leak path, creating an explosive atmosphere around the tank. Using the FEA software package ANSYS, it is possible to virtually prototype hydrogen tank designs, using the results to understand the performance of the component parts at burst pressure. The procedure developed allows the designer to define the basic geometry constraints within the CAD software. Following this, the CAD geometry is imported into Ansys, and the operational parameters necessary to define the nominal working pressure conditions are applied. ANSYS is used to optimize the geometric parameters. This approach provides for an autonomous design optimization process, allowing the input of customer design changes, such as a request to make a larger diameter tank, while the computer optimizes the components for those conditions, finding the boss design that provides the best tank performance. The preliminary results indicate that the rib structure provided the highest weight reduction whilst minimising stress.

01 Introduction

Rotational moulding has been recognised as a process for the effective manufacture of one of the components of Type IV gaseous hydrogen tanks, known as the liner (see Fig. 1). The liner requires a polymer with high gas barrier properties. Hydrogen tanks also feature bosses to facilitate the connection of the tank to the gas filling and distribution system, as shown in Fig. 1.

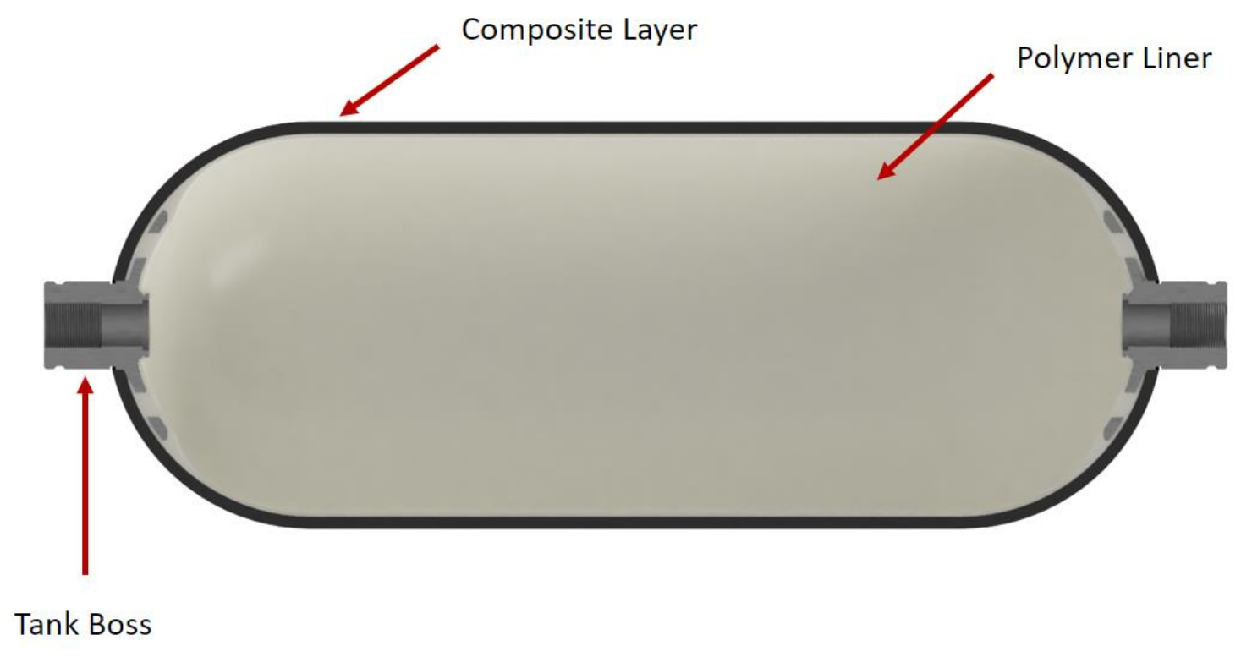

Fig. 1 Typical Components of a Type IV Tank


Anchor Inserts. (2022). Available at: https://www.anchorinserts.co.uk

Roto Experts. (2022). Available at: http://www.rotoexperts.co.za/rotomoulding/

Fig. 2 Examples of Mould-in Inserts Used in the Rotational Moulding Industry

There are three major challenges faced when combining metal parts within rotomoulded plastic parts: providing adequate heat transfer to the metal part resulting in poor encapsulation of the boss (Fig.3) and minimizing the difference in shrinkage between the plastic and metal. Incorrect design can lead to localised overloading of the fibres and tank failure as shown in Fig 4.

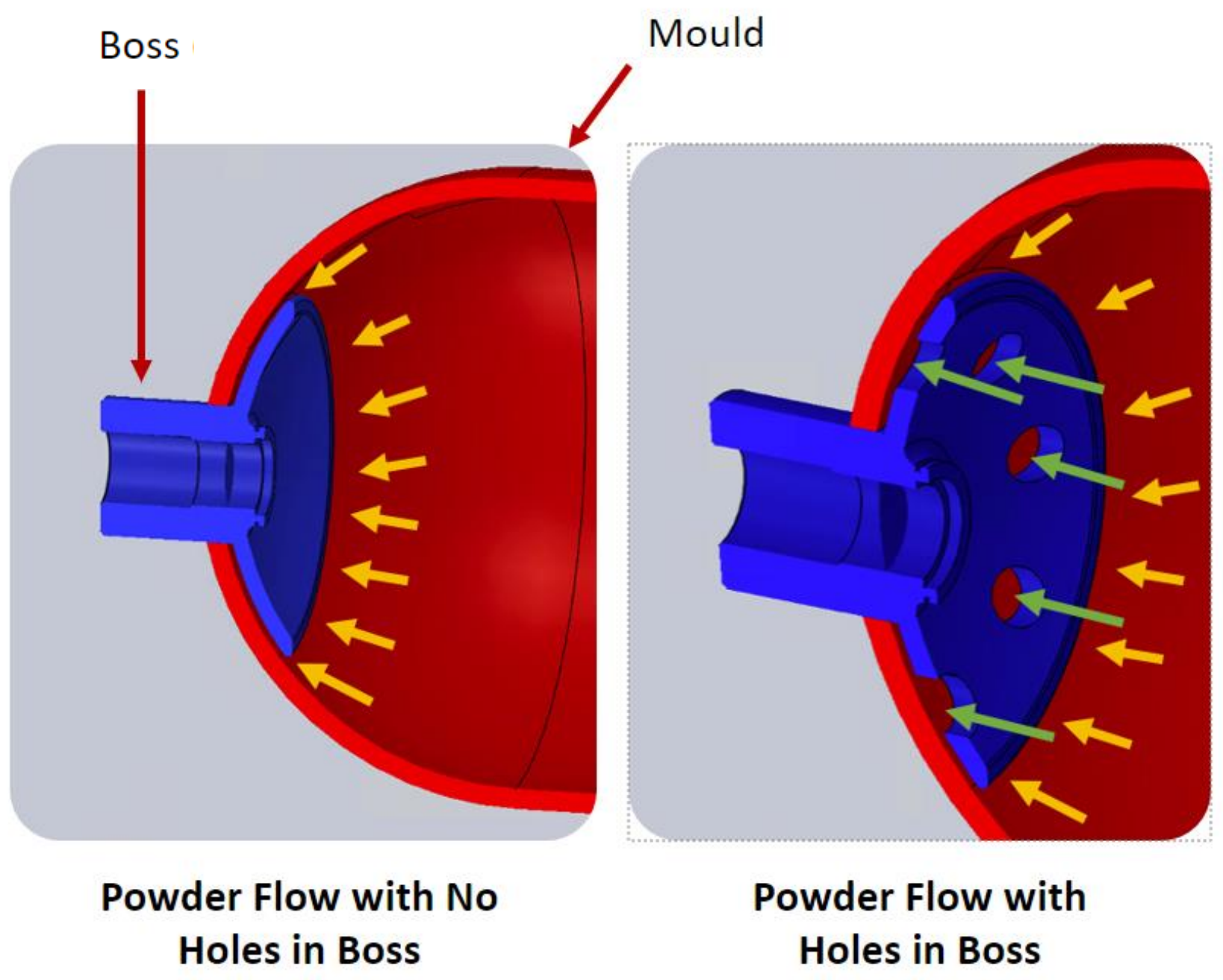

Fig. 3 Powder Flow Around Boss (Orange), Powder Flow through Boss to Encourage Encapsulation (Green)


Adapted from:10.1016/j.matpr.2020.02.872

Fig. 4 Catastrophic Failure of Boss

The area around this part is a potential hydrogen leak path and should be well encapsulated within the polymer. Torque applied during assembly to fit the temperature, pressure, regulator device (TPRD) can break the bonding between the metal boss and polymer. The aim of the work was to produce high-quality hydrogen tank liners by improving the encapsulation of the bosses within the polymer liner.

02 Method

Solidworks was used to produce the CAD geometry of the boss and liner parts in the study. The design was simplified to reflect the geometry for a typical boss. The models created for the work were setup with certain dimensions set to allow ANSYS to read and write to the CAD file, this allowed the simulation to drive the CAD model dimensions.

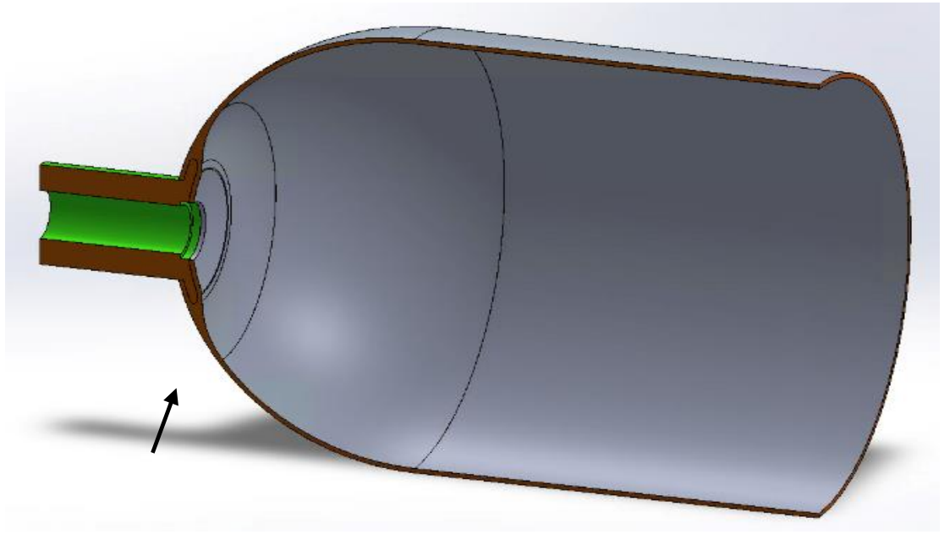
Fig. 5 (a) Brown Face Showing Symmetry Face 1

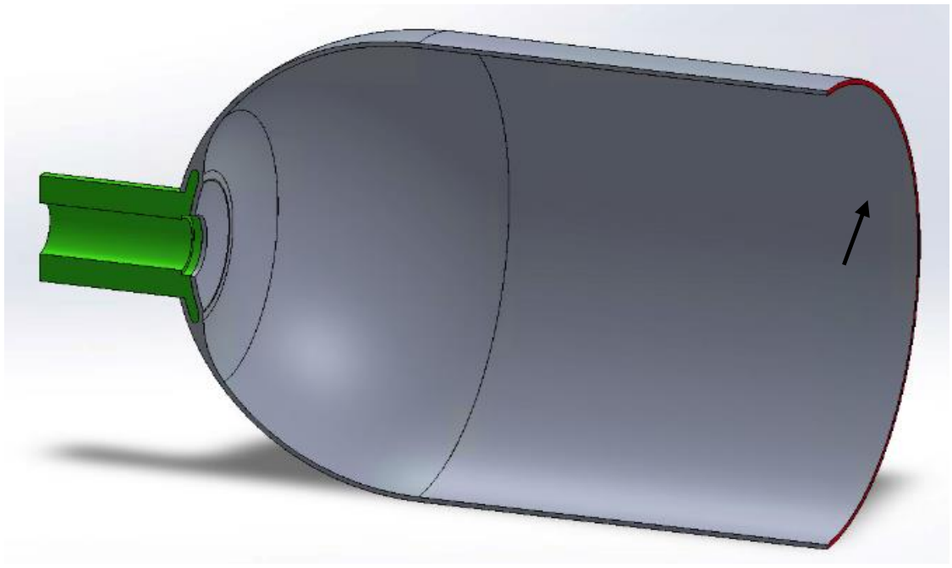
Fig. 5 (b) Red Face Showing Symmetry Face 2

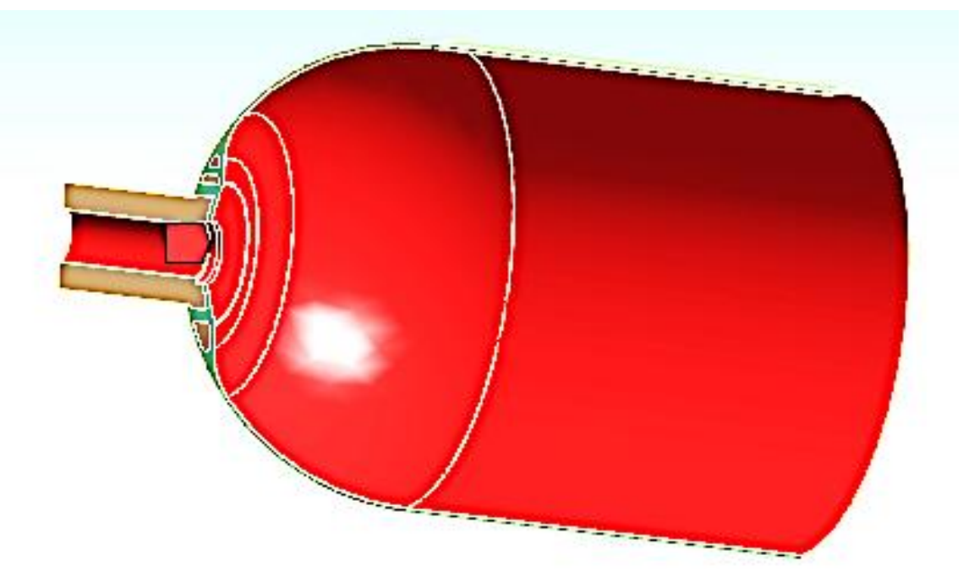
Fig. 5 (c) Loading Scenario

The CAD models were studied using ANSYS. An axisymmetric setup was used to reduce the computation time, studying ¼ of the total tank liner and boss assembly. A fixed constraint was used at the mid-section face. Two planes of symmetry were applied as shown in Fig. 5 (a) and (b). Standard materials used were Nylon 6 (PA6) and a 316 grade of stainless steel along with a default mesh setting. The study outputs were the mass of the boss and the maximum stress in the boss component. Surfaces where the boss and liner were in contact were assumed to be bonded together and a pressure of 5 MPa was applied in all studies, as shown in Fig. 5 (c). Design optimisation was then carried out in two parts. Initially the model was simplified as far as possible, as shown in Fig. 6, and a surface response obtained. This setup was used to identify the effects of the plate diameter and plate thickness on the maximum stress in the boss part. This was followed by a more detailed study looking at the effects of weight-saving design details including holes, castellations, and finally ribs.

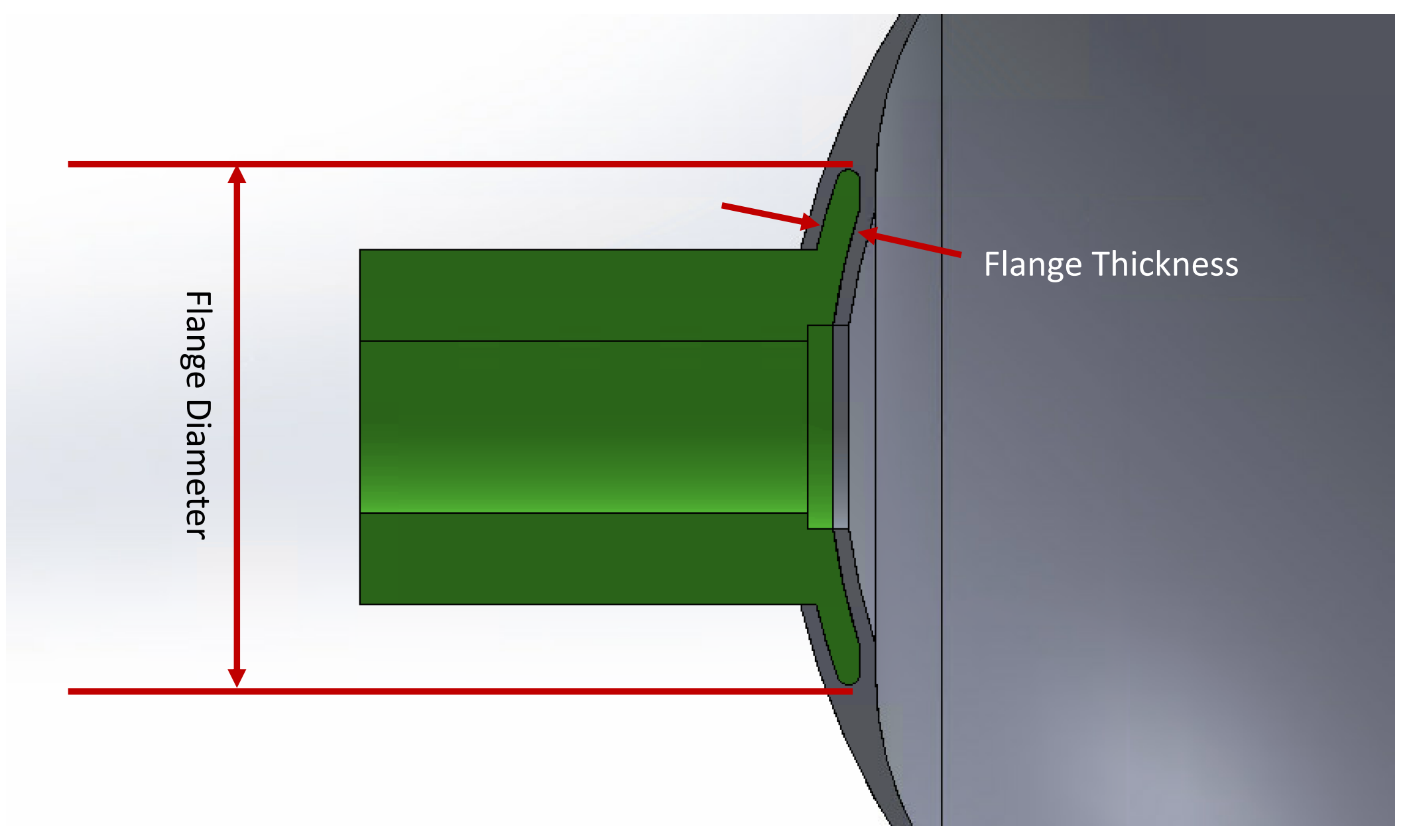

Figure. 6 Schematic Diagram of Metal Boss Designed in Solidworks

03 Results

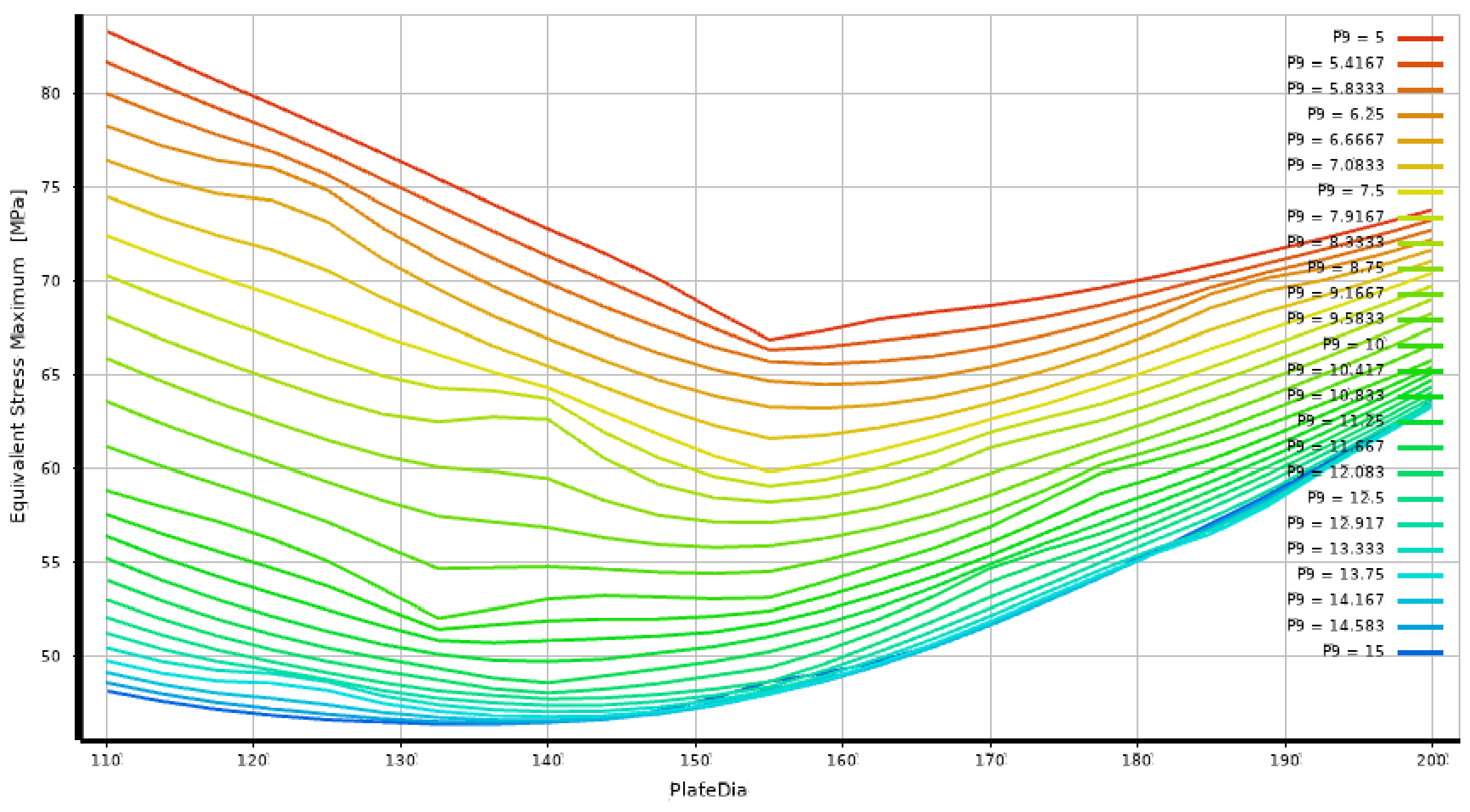

Fig. 7 Effect of Plate Diameter (in mm) and Plate Thickness (P9 in mm) on the Maximum Stress in the Boss Component

Fig. 7 illustrates the relationship between plate thickness (P9), diameter, and the maximum stress in the boss. It can be observed that increasing the plate thickness decreases the maximum stress observed in the part in all cases. Similarly, increasing the diameter of the plate decreases the stress in the part initially, before reaching a limit at approximately 155 mm. Increasing the plate diameter above this limit increases the stress observed in the part. The optimal geometry for minimum mass and stress is found to be 155 mm plate diameter with a 10 mm plate thickness.

The direct optimisation tool within ANSYS was used to find identify the effect of various design elements and their respective sizing. The objective was to minimise the maximum stress value in the boss component while also minimising weight. Fig. 8 shows the optimal designs which minimise maximum stress in the boss using ribs, castellations and holes.

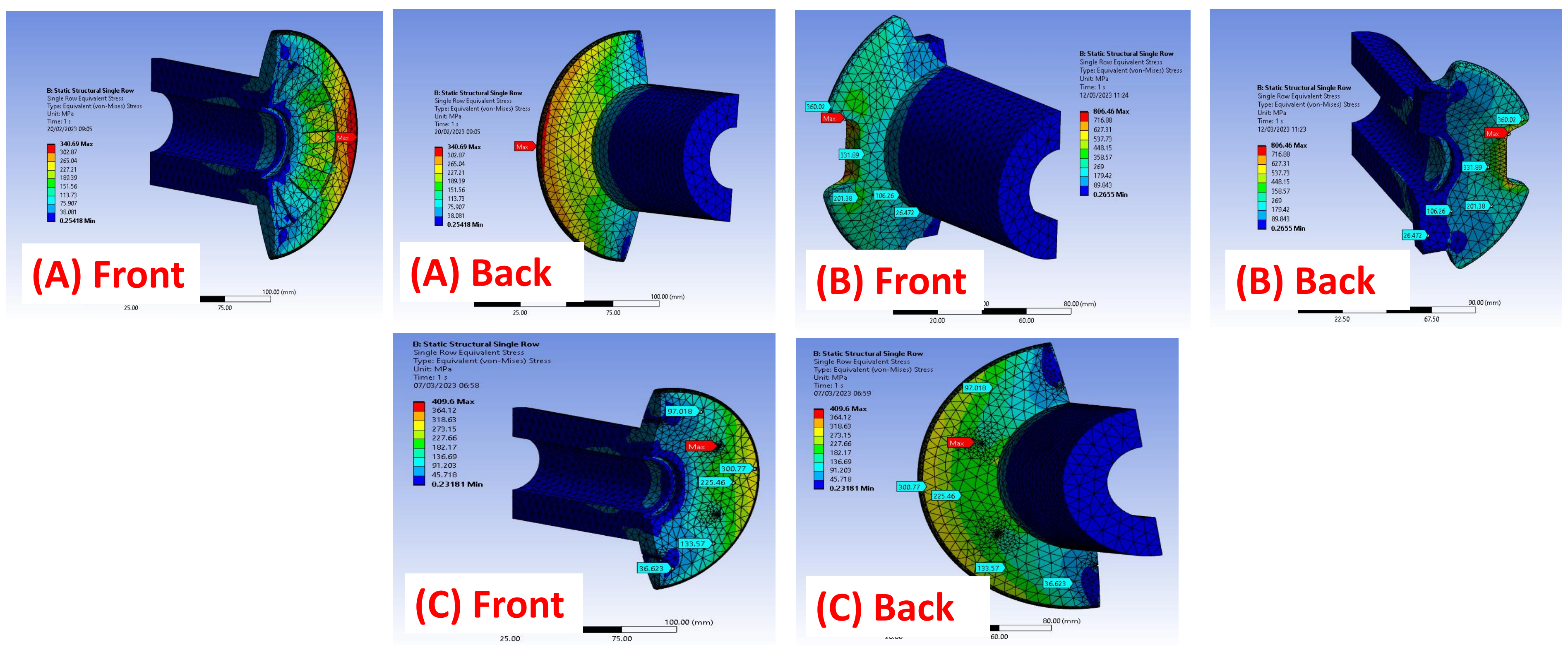

Fig. 8 Stress Distribution on Metal boss using ribs (A), Castellations (B), and Holes (C)

04 Conclusions

Boss component design is fundamental to the safety of the tank, as failure to seal the metallic part to the plastic liner will form a gas leak path, creating an explosive atmosphere around the tank. The procedure developed in this work allows the tank designer to define the basic geometry constraints within the CAD software. ANSYS is used to optimize the geometric parameters and optimal designs which minimises maximum stress in the boss using ribs, castellations and holes. The preliminary results indicate that the rib structure provided the highest weight reduction whilst minimising stress.