# WEIGHT OPTIMIZATION OF CHAMBER FOR VACUUM CASTING TECHNOLOGY

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***Abstract***
*The purpose of this paper is optimization of real vacuum chamber. The goal is lowering the weight while geometry is kept. Methods of parametrical modelling and automated optimization in chosen FEM software will be used for executing the analysis. Results obtained during optimization can be used in the future realization of vacuum chamber for Rapid prototyping technology.*
***Key words:*** *vacuum chamber, stress analysis, welds shape.*

## INTRODUCTION

Nowadays, there are high requirements on a manufacture. There is effort to make engineering process faster on one side, and to lower the cost on the other side. This is a reason why are more widely used technologies Rapid prototyping and also Vacuum casting. This method is highly effective for producing prototypes in limited amount. Increasing the number of pieces also increases the cost and complexity of whole process. It is useful to think about automation of manufacturing process in case of need producing tens or hundreds of pieces. This resulted to design an automated line for filling silicone moulds in vacuum.

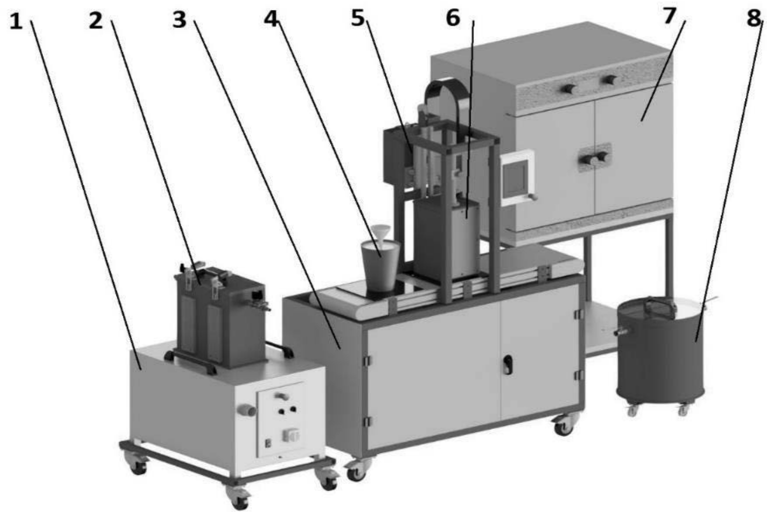


**Fig. 1** Automatic vacuum casting technology device

**Fig. 1** shows whole assembly for automated vacuum filling of silicone moulds. The mould (4) is placed on conveyor belt (3) and moved to a place of filling. Vacuum chamber (6) is moved down on a linear guide (5). The mould itself is filled there. Injected material is located in the buffer (2) and it is also connected to the source of vacuum. The material flows through gear pump – Dekumed (1). The chamber is lifted after the filling process is finished and it is able to place mould from belt to oven (7).
At this time the line is not fully completed, therefore the chamber has to be lifted manually. This chamber is relatively heavy according to dimensions and used materials. That's why hand lifting is difficult. The dimensions of chamber are 200x200x400 mm (WxDxH) and it's made of 5 mm thick steel plates welded

together. The front window is made of 20 mm thick polycarbonate. The original design counted with walls thickness 8 mm, but for verification process it was produced from 5 mm thick material.

## MATERIALS AND METHODS

A static analysis was done to realize points of optimization. The model was cleared of unnecessary components (threads, etc.) and loaded by atmospheric pressure on outer surfaces. (Martikan, Brumercik, & Bastovansky, 2015)

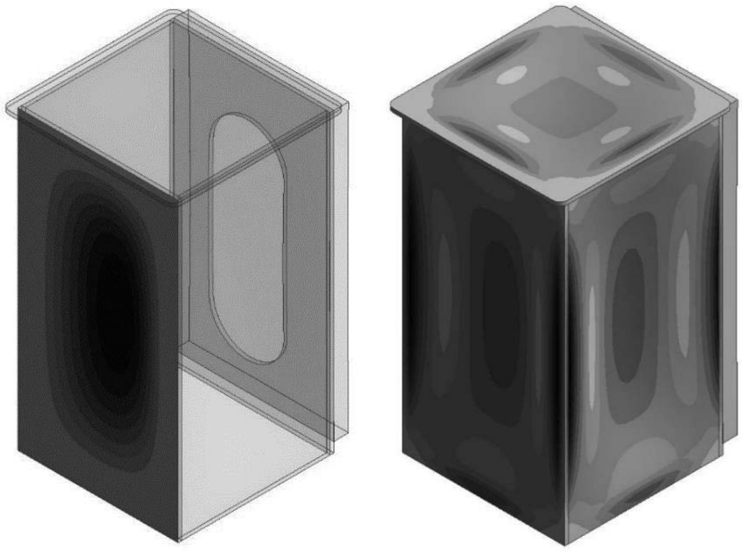

**Fig. 2** Results of stress analysis, left - max. deformation, right - max. stress

Results showed that the construction is critical in two reasons. The first is deformation of walls and the second is stress in corners of the chamber. At this moment the optimization was divided into two steps:

- Find out the best shape of the weld according to maximal stress.
- Lower the thickness of walls with maximal deformation up to 0,5 mm.

All of the welds are corner type. We recognize three types of corner welds – flat, convex and concave. The goal of this chapter is to get know maximal stress in weld using the same welds height parameter. It's important to know also maximal allowed weld stress:

$$\sigma_{Dzv} = \beta.\alpha_{\perp}.\frac{R_e}{k}.c_{II}[MPa]$$

Where:

- Corner welds height parameter; $\beta$=1,3-0,03.t=1,15 (pre t<10mm)
- Welded connection conversion parameter; $\alpha_{\perp}$=0,75÷1, chosen 1
- Yeld point of steel 11 423; $R_e$=260 MPa
- Safety factor for non-hardened steels; k=1,7-2, chosen 1,7
- Pulsating load lowering parameter; $c_{II}$=0,85

After calculation:

$$\sigma_{Dzv} = 127\ MPa$$

Maximal stress can’t exceed calculated value 127 MPa. (Málik, a iní, 2013)


**Fig. 3** Differrent corner welds, left - convex, middle - flat, right – concave

The height of a weld is dependent on a thickness of welded material, according to standard STN 05 0025 (Čilík & Žarnay, 2001). The following condition must be satisfied:

$$a \leq 0,7\ .\ t$$

For thickness t=5 mm was height calculated to $a_{max}$=3,5 mm and this dimension was used for modelling. The analysis resulted, that the shape of weld does not affect magnitude of stress, but the distribution of it. The calculated stress didn’t exceed 78 MPa for all 3 types of weld (concave – 68 MPa; flat – 78 MPa; convex – 73 MPa). The best stress distribution of stress provided convex shape, therefore was chosen for next computation and suggested for manufacture.

Parametric modelling in software Autodesk Inventor 2017 was connected with optimization algorithms of Ansys Workbench v17.5 for optimizing vacuum chambers walls. (Lawrence, 2013) Thickness of wall was used as an input parameter and the range was set from 3 mm to 8 mm. Output parameter was deformation and it couldn’t exceed more than 0,5 mm. Dependence between walls thickness and deformation shows **Fig. 4**.

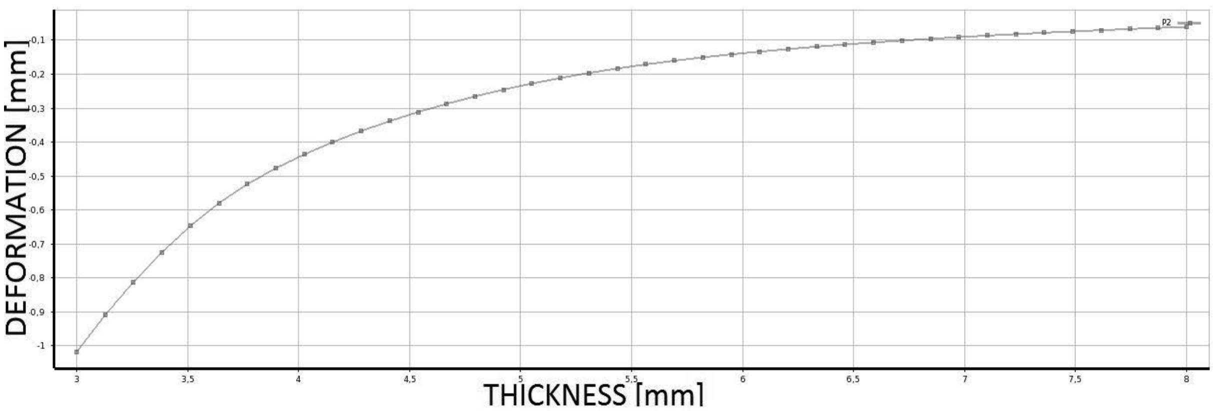


**Fig. 4** Dependence of deformation on thicknes

The simulation resulted that minimal thickness with deformation to 0,5 mm is 3,84 mm. (Faturik, Trsko, Hrcek, & Bokuvka, 2014) According this results was model modified, calculated its weight and statically loaded once again.

## RESULTS AND DISCUSSION

Using optimization process was calculated minimal thickness of sheet metal to 3,84 mm. The height of weld a=2,7 mm matches to this thickness. The chamber was modelled using these parameters to be used for control calculation. Chamber manufactured by this method doesn't exceed maximal allowed stress or deformation. Maximal stress was calculated to 111 MPa and the deformation to 0,499 mm. Comparison of weight-loss of the chamber shows **Tab. 1**

**Tab. 1** Comparison of weight-loss

| Variant | Weight [kg] | Saving [%] | Saving [kg] |
|---|---|---|---|
| Design – 8 mm | 24,84 | 0 | 0 |
| Reality – 5 mm | 16,36 | 34,1 | 8,48 |
| Calculated minimum – 3,84 mm | 13,09 | 47,3 | 11,75 |

## CONCLUSIONS

It's able to lower the weight significantly by using optimization processes. The weight of chamber was lowered by 3,27 kg (20%) against real piece and by 11,75 kg (47,3%) against the first design. It's needed to remember that sheet metals are produced in standardised thicknesses with tolerances (±0,3 mm in this case). The calculated thickness was rounded up to 4,5 mm which resulted into weight-loss only 1,4 kg (8,6%) against real weldment.

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