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INFLUENCE OF LONGITUDINAL STIFFENING RIB HEIGHT ON THE STRESS-DISPLACEMENT BEHAVIOUR OF A THIN-WALLED CONSTRUCTION OF HOUSING

Research paper

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Abstract: This paper presents an analysis of the influence of longitudinal stiffening rib height on the stress-displacement behaviour of a thin-walled machine housing. The analysis was carried out in SolidWorks Simulation using the finite element method within a linear static analysis. A simplified thin-walled housing model, 500 × 300 × 150 mm in size and with a wall thickness of 3 mm, was used as the reference geometry. The real functional purpose of the housing and its structural complexity were neglected, so the study focuses on the effect of rib height under a centrally applied static load on the upper plate. The housing was loaded by a force of 2000 N acting over an area of 100 × 100 mm. Five variants were compared: M0 without ribs and M1–M4 with two longitudinal ribs 20, 40, 60 and 80 mm high. For each model, von Mises stress, maximum resultant displacement and equivalent static stiffness were analysed. The results show that increasing rib height reduces displacement and increases stiffness. The most pronounced difference was obtained between M0 and M3, where displacement was reduced by 77.9%, while stiffness increased from 726.5 to 3280.8 N/mm. Further rib height increase produced a smaller stiffness gain with higher local stresses..
Key words: thin-walled housing, stiffening ribs, static stiffness, finite element method, von Mises stress

INTRODUCTION

Thin-walled structures and housings are often used in mechanical engineering practice due to their simple manufacturing process, low mass and easy adaptation to different operating and environmental requirements (Budynas & Sadegh, 2020). The drawback of thin-walled structures is reflected in increased stresses, deformations and reduced stiffness. For this reason, stiffening ribs are often applied in practice, since they contribute to the resistance of the structure without a considerable change in the overall thickness of the base wall (Jiang et al., 1997; Rezaiefar & Galal, 2022; Zou et al., 2019). The application of modern software tools represents an important part of contemporary engineering design, especially in the design and comparison of different structural and technological solutions (Desnica et al., 2025). The functionality and influence of ribs on the structure depend on their geometrical parameters, such as height, thickness, position and number of ribs. Despite their positive effects, ribs can lead to local stress concentrations, especially in the zones where the ribs are joined to the base plate and at the rib ends (Pilkey et al., 2020). In addition to deformations, it is also necessary to analyse the stress distribution in the structure. In this paper, a linear static analysis was carried out using the finite element method in SolidWorks Simulation (Bathe, 2008; Dassault Systèmes, 2026; Desnica et al., 2022; Zienkiewicz et al., 2013). Five variants of the thin-walled housing were analysed, ranging from the housing without ribs to the housing with ribs up to 80 mm high. The aim of the paper is to determine the influence of rib height on the maximum von Mises stress, maximum resultant displacement and equivalent static stiffness of the structure. For an isolated assessment of the influence of longitudinal stiffening rib height, the housing was considered as a fully idealized thin-walled structure, excluding its real functional purpose and structural details. The load position was selected at the centre of the upper plate of the structure, since this is the location where the largest bending moment and the greatest deflection of the upper plate are expected.

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MATERIAL AND METHODS

The numerical analysis was carried out on a simplified model of a closed thin-walled housing supported by four feet. The foot wall thickness was the same as the wall thickness of the housing. In a real structure, the feet are represented as hollow profiles welded to the structure, while for this study an idealized case was adopted, where the feet are fully bonded to the housing. The analysis was performed through five structural variants. The reference model was M0, without ribs, while the remaining models, M1–M4, were designed with two longitudinal ribs on the outer side of the upper plate. For all variants, the ribs had the same length of 420 mm and thickness of 3 mm, while the rib height varied from 20 mm to 80 mm. The rib position, load, material, support conditions and mesh parameters were kept the same for all models, while only the rib height was changed depending on the model. Fig. 1 shows the construction of the reference model M0 without ribs and model M3 with ribs 60 mm high.

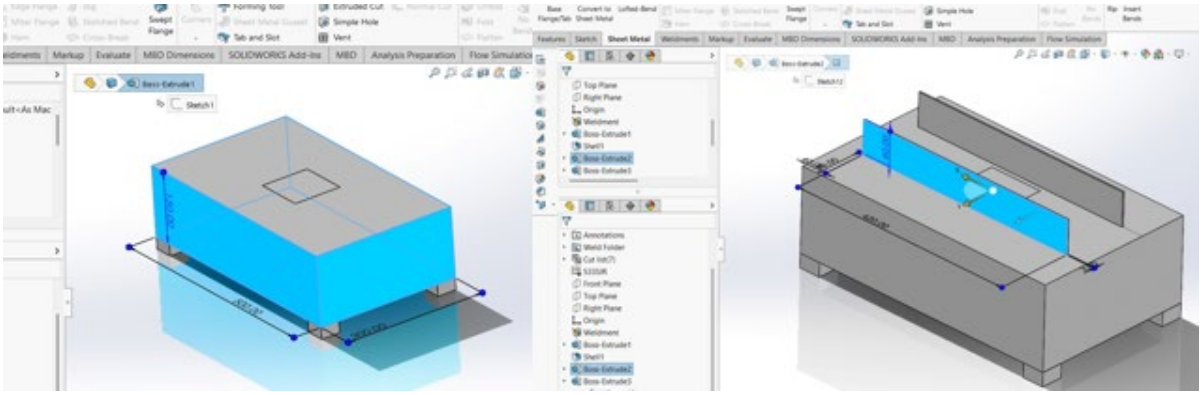


***Fig. 1**. Construction of thin walled-machine with and without rib*

The adopted housing material was S355JR steel (Institut za standardizaciju Srbije, 2020). The material specifications used in the numerical analysis were the modulus of elasticity, density, Poisson's ratio and yield strength. The simulation was performed in SolidWorks Simulation as a linear static analysis. Regarding the loading conditions, the housing was loaded on the outer side of the upper plate, where the force was applied over the defined surface. Fig. 2 shows the support conditions of the structure, defined using Fixed Geometry on the lower surface of each foot, while Fig. 3 shows the mesh generation and the action of the applied force on the thin-walled housing.

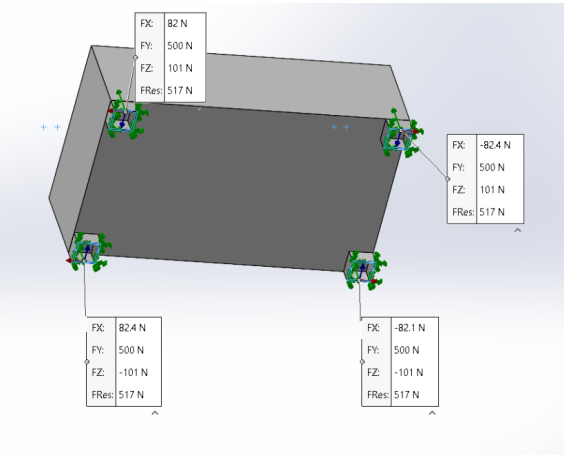


***Fig. 2**. Fixed Geometry, uniform positioning of the support*

The stress-displacement state was assessed using the maximum von Mises stress and the maximum resultant displacement. In addition, the equivalent static stiffness was calculated using the following equation:

$$k = \frac{F}{u_{max}} \tag{1}$$

In Eq. (1), *F* represents the total applied force, while u_{max} represents the maximum displacement of the model. For comparison of the models, the increase in stiffness and the reduction in displacement were evaluated relative to the reference model without ribs. Before comparing all models, mesh independence was checked on model M3, and three global element sizes were analysed: 6 mm, 4 mm and 3 mm. For the final analysis and comparison of all models, a 3 mm mesh was adopted, since the change in maximum displacement between the 4 mm and 3 mm meshes was 0,84%, while the stress changed by 4,7%. The mesh setup is shown in Fig. 3.

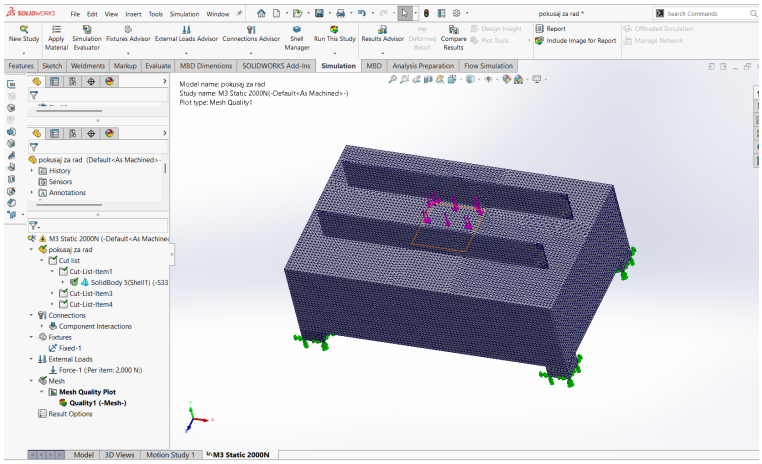


Fig. 3. *Creating mesh for construction*

Table 1. *Geometrical parameters of analysed models*

Model	Number of ribs	Rib length (mm)	Rib height (mm)	Rib thickness (mm)
M0	0	/	/	/
M1	2	420	20	3
M2	2	420	40	3
M3	2	420	60	3
M4	2	420	80	3

RESULTS AND DISCUSSION

The obtained numerical results showed that the addition of longitudinal stiffening ribs considerably reduces the displacement of the upper housing plate and increases the equivalent static stiffness of the structure (Jiang et al., 1997; Rezaiefar & Galal, 2022). Each model was analysed under the same loading conditions, support conditions, material type and mesh parameters, allowing the results to be directly compared. Table 2 presents the simulation results.

Table 2. *Numerical results from simulation*

Model	Rib height (mm)	u_{max} (mm)	K (N/mm)	$\sigma_{vM,max}$ (MPa)
M0	/	2,7530	726,5	181,8
M1	20	1,3120	1524,4	183,8
M2	40	0,7274	2749,5	317,7
M3	60	0,6096	3280,8	316,1
M4	80	0,5736	3486,8	346,6

The largest maximum displacement, shown in Fig. 4, was obtained for the housing without ribs, i.e. model M0, where the displacement was 2.7530 mm and the equivalent static stiffness was 726,5 N/mm. When the same simulation was performed on model M1, which has two longitudinal ribs 20 mm high, the maximum displacement was reduced to 1,3120 mm, while the stiffness increased to 1524,4 N/mm, as shown in Fig. 5. After comparing the first two models, it can already be concluded that even a small rib height considerably increases the resistance of the housing.

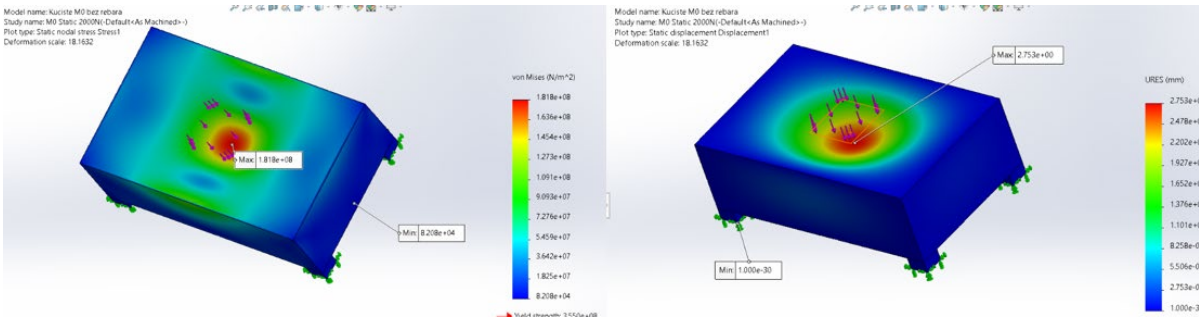


Fig. 4. *FEM results for M0: von Mises stress distribution left and resultant displacement distribution right*

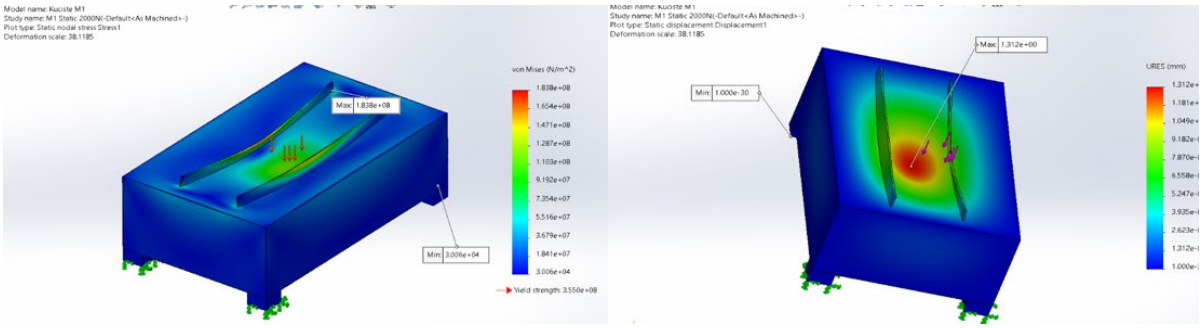


Fig. 5. *FEM results for M1: von Mises stress distribution left and resultant displacement distribution right*

For model M2, the rib height was increased to 40 mm, where the displacement decreased to 0,7274 mm, while the stiffness increased to 2749,5 N/mm, as shown in Fig. 6.

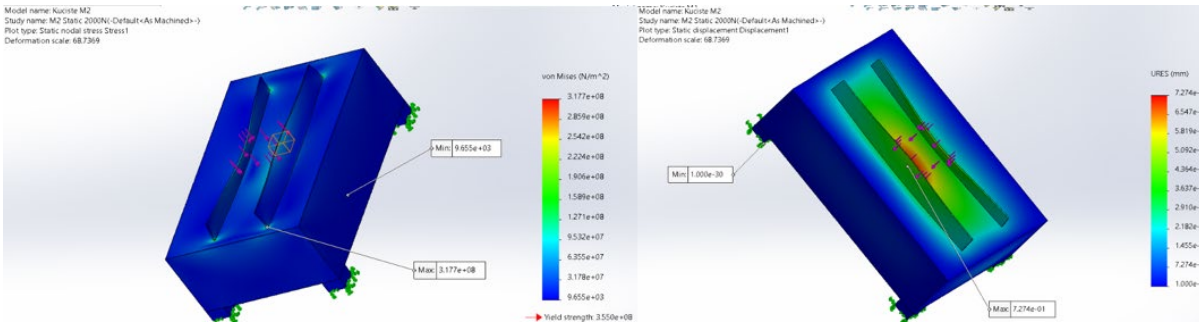


Fig. 6. *FEM results for M2: von Mises stress distribution left and resultant displacement distribution right*

With the further increase in rib height to 60 mm for model M3, the maximum displacement was 0,6096 mm, while the stiffness reached 3280,8 N/mm, as shown in Fig. 7.

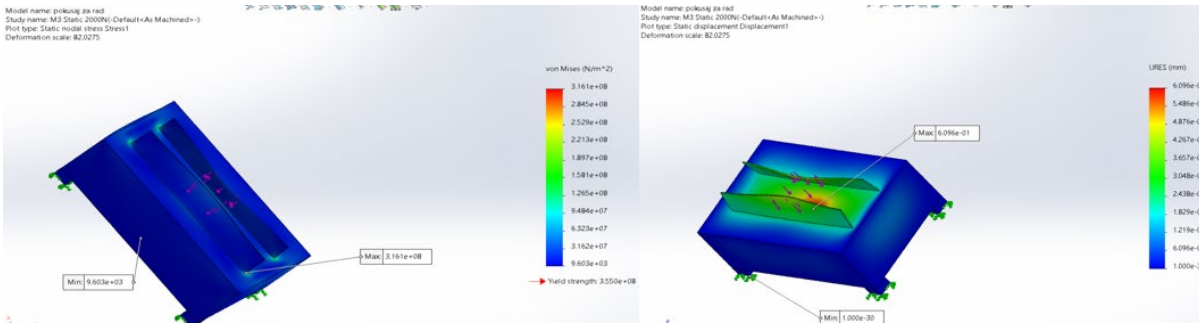


Fig. 7. *FEM results for M3: von Mises stress distribution left and resultant displacement distribution right*

The comparison of the reference model and model M3 showed a 77,9% reduction in maximum displacement, along with a 351,6% increase in stiffness. Based on the obtained results, it can be concluded that ribs with a height of 60 mm provide a pronounced stiffening effect for the thin-walled housing. The lowest maximum displacement was obtained for model M4, where the rib height was 80 mm and the displacement was 0,5736 mm. However, the stiffness increased by only slightly more than 6% compared with model M3, as shown in Fig. 8.

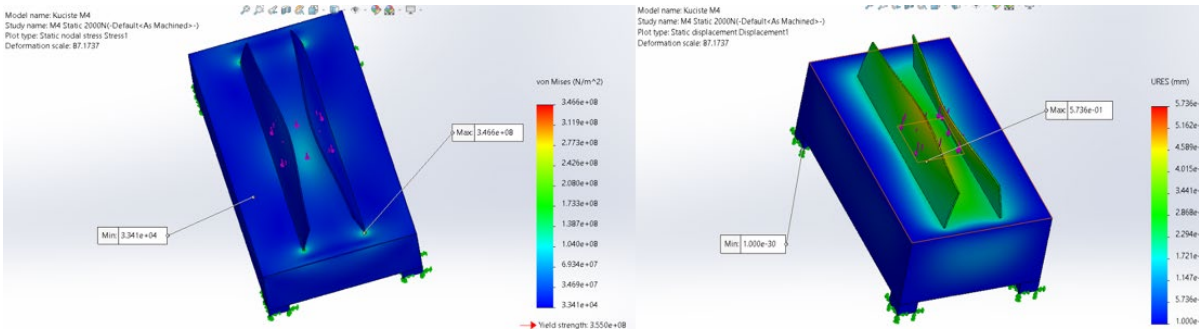


Fig. 8. *FEM results for M4: von Mises stress distribution left and resultant displacement distribution right*

The issue that appears is related to the von Mises stress, which in model M4 reaches 346,6 MPa, a value very close to the yield strength of S355JR steel, which is 355 MPa. For this reason, it can be concluded that further increasing the rib height after a certain value gives a smaller contribution to stiffness while increasing local stress concentrations (Pilkey et al., 2020). In models that contain ribs, the maximum von Mises stresses occur in the zones of rib ends and at the transitions between the ribs and the contact surface to which they are

connected, as can also be observed in the figures. This stress distribution is expected because the ribs in the numerical model were idealized with sharp transitions, without modelling fillets at the joint transition. In addition, the geometry of the welded joint that would connect the ribs to the rest of the structure was also neglected. Therefore, maximum local stresses should be interpreted together with the location where they occur, while the maximum displacement is a more suitable indicator of the structural stiffness. The graph with the obtained results is shown in Fig. 9.

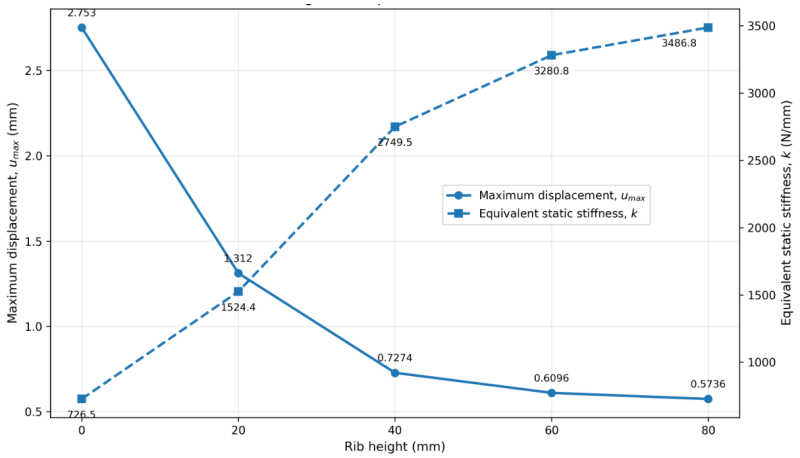


Fig. 9. *Effect of ribs height on maximum displacement and equivalent static stiffness.*

CONCLUSION

After the performed linear static FEM analysis, it can be concluded that the height of longitudinal stiffening ribs has a considerable influence on the stress-displacement behaviour of the thin-walled housing. The comparison of all models clearly shows that all models with ribs have higher equivalent static stiffness and lower maximum displacements compared with the reference model without ribs. The obtained results justify the application of ribs in thin-walled structures. The most pronounced change compared with the reference model M0 was observed for model M3 with ribs 60 mm high. This model proved to be a suitable solution, compared with the reference model, for reducing the maximum displacement and achieving a multiple increase in structural stiffness, while still remaining within the prescribed yield strength limits for S355JR steel. After model M3, one additional increase in rib height to 80 mm was analysed on model M4. However, this final increase had a very small effect on stiffness, while the structure approached the upper yield strength limit of the material. This leads to the conclusion that increasing the rib height after a certain value does not result in a proportional improvement of the entire structure. In particular, models with greater rib height showed an increase in local von Mises stresses, especially in the zones of rib ends and at the transitions to the upper surface of the structure, where the ribs are connected. An important aspect in selecting the rib geometry is to consider local stress concentrations in addition to displacement reduction. Possible directions for further research and development of this topic include the analysis of transition radii at the rib ends, more detailed modelling of the structure in terms of creating a realistic welded joint, both at the supports and on the ribs, and evaluating the achieved stiffness in relation to the increase in the mass of the structure.

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