DOI: 10.38061/idunas.1039891

IDUNAS	NATURAL & APPLIED SCIENCES JOURNAL	2023 Vol. 6 No. 1 (21-28)

Investigation of the Strength Behavior of a Fuselage Structure Placed In a Linearly Expanding Wing With Circular Ends In Cross-Section

Research Article

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DOI: 10.38061/idunas.1039891

Received: 22.12.2022; Accepted: 27.06.2023

Abstract

In this study, a structurally different drop wing geometry was modelled and its mechanical behavior was investigated with computer aided analysis software within the finite element method. The tip of the drop wing geometry consists of one large and the other small circles. There were linear line profiles between them. In order to prevent collapse in the wing geometry modelled with the plate structure, a profile in the rigid body structure was created and its effect was investigated. The effect of the wing length and the plate thickness covering the wing was examined and shown in the results. It was defined as the profile material for the wing made of steel and for the standard features. In the static examinations carried out under the pressure loading applied on the wing, it was determined that the vertical deformation caused by the wing length was not linear, and the stresses that occur with the increasing wing plate thickness form a decreasing function. The stresses that occur in the inside of the wing support were intense in the support area, but also in the bending areas.
Keywords: Wing, Plate, Surface pressure, Stress.

1. INTRODUCTION

The wing is the fundamental component that humans have studied and refined since the dawn of time in order to give them the ability to fly. Wings are generally utilized in glider-style constructions, which resemble rudimentary airplane structures that allow gliding and are inspired by birds. As a result of the development phase, it was merged with the engine part and acquired its current aircraft form once it was realized that flying with human power was challenging. The aerodynamic performance that improves the flight condition is the most crucial wing design parameter. Under operational circumstances, it must also offer a few mechanical qualities. Numerous studies have generally been built around figuring out the ideal weight and strength ratios.

The effect of wing thickness and geometry to reduce weight on the wing [1] was investigated by considering aerodynamic/structural features in combination. In the hybrid structure [2], wing design methods capable of multiple optimization were investigated and a multi-purpose genetic algorithm was developed. Different structures suitable for the 2D and 3D wing profile [3] structure have been designed with the appropriate optimization method and a great deal of savings has been achieved. An airplane [4] in the wing body structure for transonic airplanes is designed with computer aided flow analysis and constrained inverse design method. Wing body design [5] for subsonic transport has also been examined and a reduction in weight has been achieved with an increase in performance. The aerodynamic shape structure of a wing was investigated, and its control was studied for two cases with and without load reduction [6].

In the research that demonstrated improvement, ideal outcomes were established. Using a parametric examination method, Jiapeng et al. [7] created a quick modeling process for the structural design of a wing. The varied fiber orientations and layer thicknesses of an aircraft composite sheet in bending state were studied by Rajappan and Pugazhenthi in 2013 [8]. A wing with a variable camber structure has been created [9], and attributes that can reduce noise and save fuel have been attained. A method that can adhere to the design requirements on the model has been established for the optimization method [10], and an improvement in performance has been made in the design.

A new wing design was created by evaluating the literature information and the interaction between the plate and the wing profile was investigated.

2. MATERIAL AND METHOD

In order to carry out the study, a general wing profile was created with a computer aided drawing program. This aerofoil is modelled symmetrically in a linear section structure, not used in standard airplanes and not in a way to form a higher protrusion on one surface. A solid body profile is placed inside the wing model. With this model, which is not in the standards, it is investigated how the plate-solid body interaction affects the wing. In Figure 1, basic geometric information for the wing is shown. Its wingspan is 100 mm and its length is basically 200 mm. The front and rear ends are modelled as circular with radiuses of 20 mm and 10 mm, respectively. The wing is modelled as a plate and its thickness is 1 mm. The thickness of the structure used for support in the inner section is 1 mm. For the wing in the figure, a pressure of 1000 Pa was applied only from its upper surface. One end of the wing and profile structure is fixed to form a support. The interaction between the plate forming the wing and the inner section structure is in the frictional surface structure. There is a relative interaction between the two structures, depending on Columb's law of friction. The friction coefficient was used as 0.3.

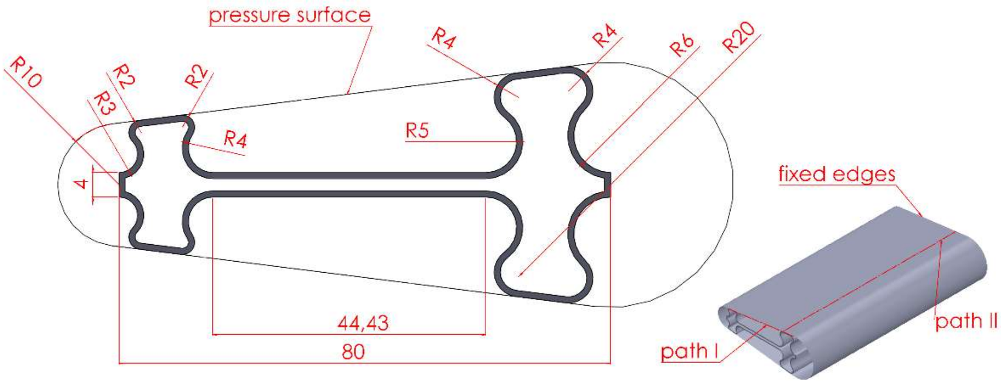

Figure 1. Wing geometry and dimensions

For the results, a path was created on the free section edge of the wing and the deformation and stresses related to the wing were taken over this path and graphed. For the profile structure in the inner section, a line called "path II" was created and the profile deformation was shown. Stress results are given in Von-Mises stress type.

$$\sigma_{VM} = \sqrt{\frac{(\sigma_1-\sigma_2)^2+(\sigma_2-\sigma_3)^2+(\sigma_3-\sigma_1)^2}{2}} \quad (1)$$

3. RESULTS AND DISCUSSIONS

The analysis's findings have no dimensions in order to highlight the impact of unit length. Path I in Fig. 2 illustrates the vertical deformation. Cross-section lines are used to indicate the areas where the plate makes contact with the support platform. Below the vertical axis, a negative deformation distribution is shown as a result of the downward pressure imparted across the wing. It has been found that the distortion increases as wing length increases. Deformation in the contact region behind the section began to slow down, but it suddenly accelerated in the front of the section.

The incoming deformation distribution is similar in all results. However, the place where the highest deformation occurs moves towards the back corner of the section as a result of the increasing l/b ratio. Increasing the l/b ratio from 2 to 3 nearly doubled the maximum deformation value. However, increasing the 1/b ratio from 2 to 4 caused a deformation increase more than 3 times compared to the first case. Therefore, although the distribution was similar, the rate of increase did not occur linearly.

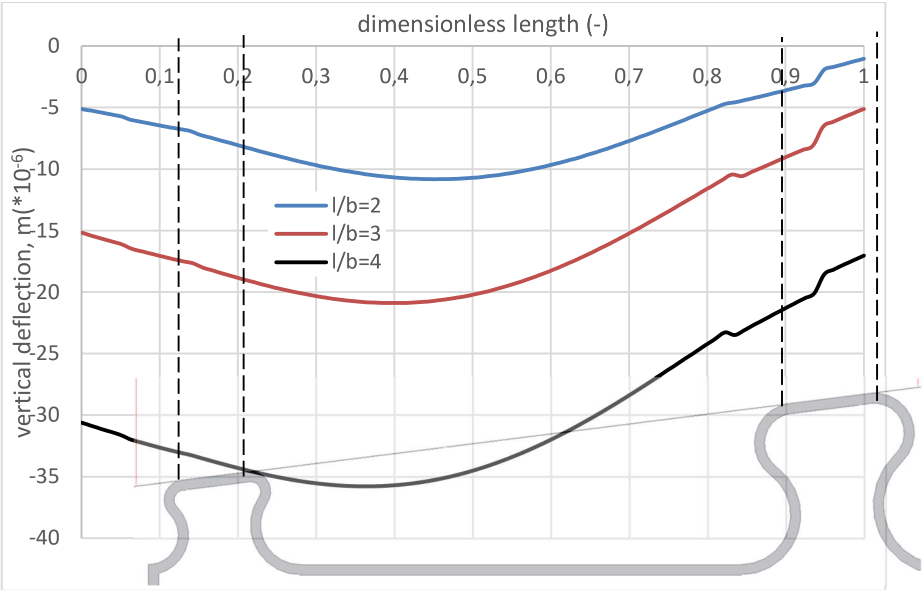

Figure 2. "Deformations in the vertical direction according to the wing length/width ratio on the path I line

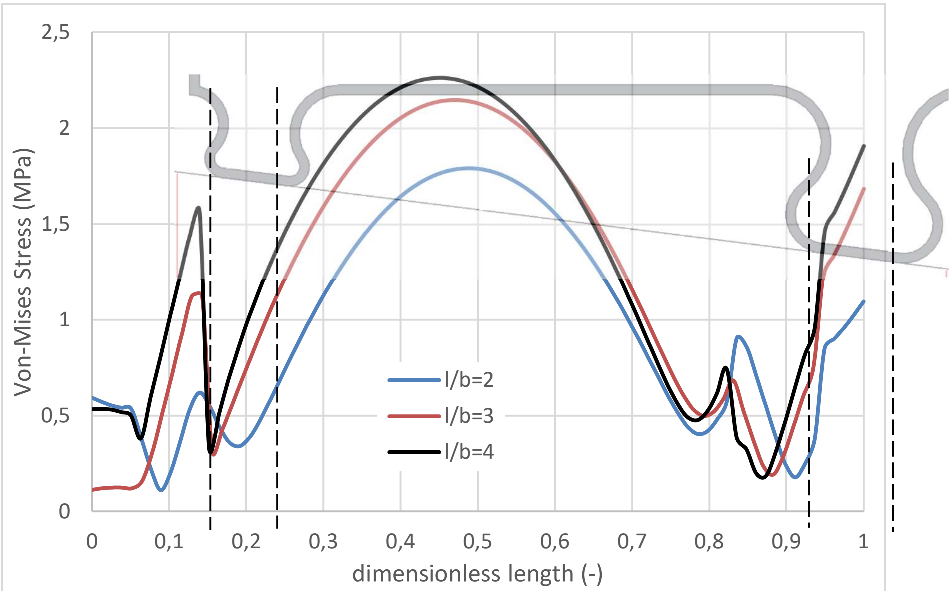

Figure 3. Stresses on the path I line according to the wing length/width ratio

Figure 3 shows the stress distribution on path I. The stress distribution was formed as 3 high value regions in all results, with the largest value in the middle part. These regions where the stresses intensified and increased/decreased abruptly occurred in the areas where the in-wing platform was in contact. The difference ratio between the highest values was less than the deformation difference ratio in the vertical direction. The region with the highest value moved towards the back of the wing as a result of the increasing l/b ratio.

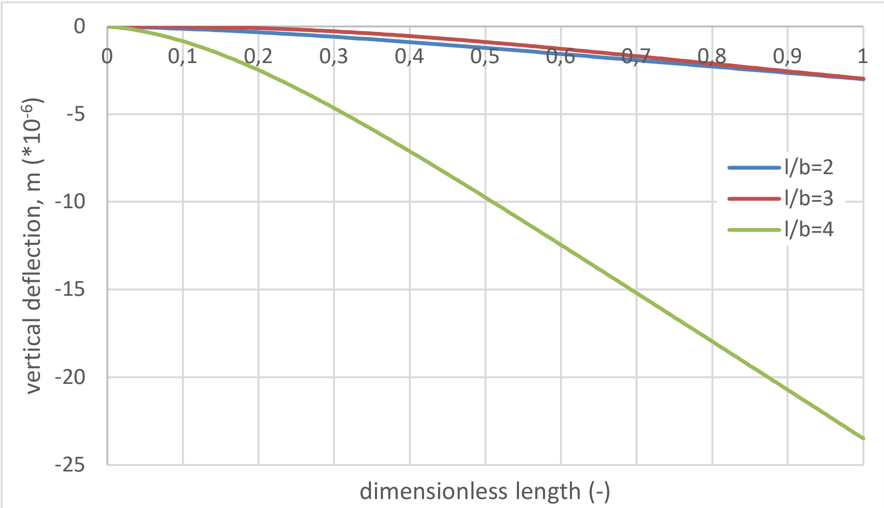

Figure 4. Deformation in the vertical direction according to the wing length/width ratio on the path II line

In Fig. 4, the deformation results in the vertical direction over the platform from the path II line are taken. In the results showing the dimensionless length fixed support behavior, the difference between the results for the l/b ratio 2 and 3 was small. However, the deformation is very high for the l/b ratio of 4. The reason for this is the fact that more shear-related deformation occurs at the free end of the blade as a result of the increased length.

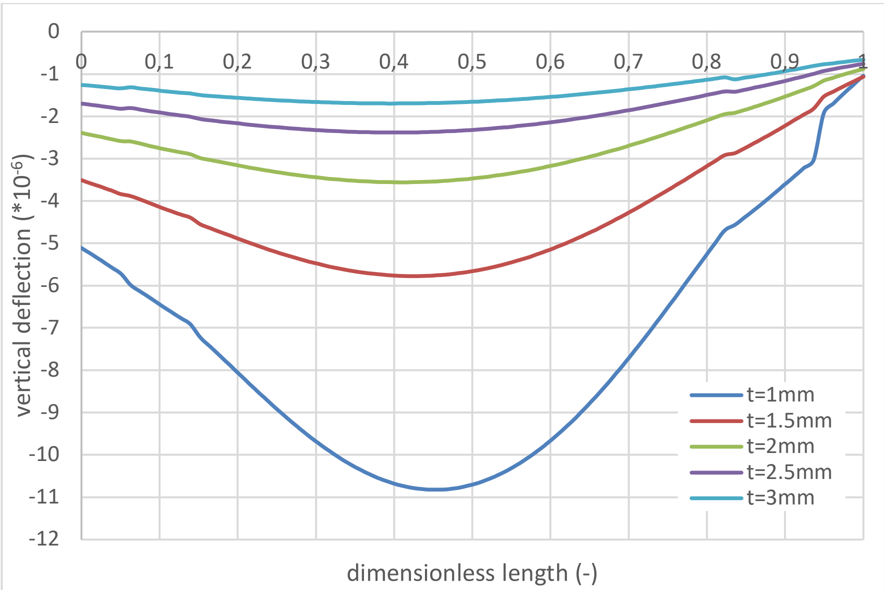

Figure 5. Deformation in the vertical direction according to the wing length/width ratio on the path I line

For l/b=2 ratio, deformation values are shown in Fig. 5 for plate results with different thickness than path I position. Each part of the homogeneously formed plate is of equal thickness. Although the deformation distribution did not change as a result of increasing thickness, the values were formed as a decreasing equation.

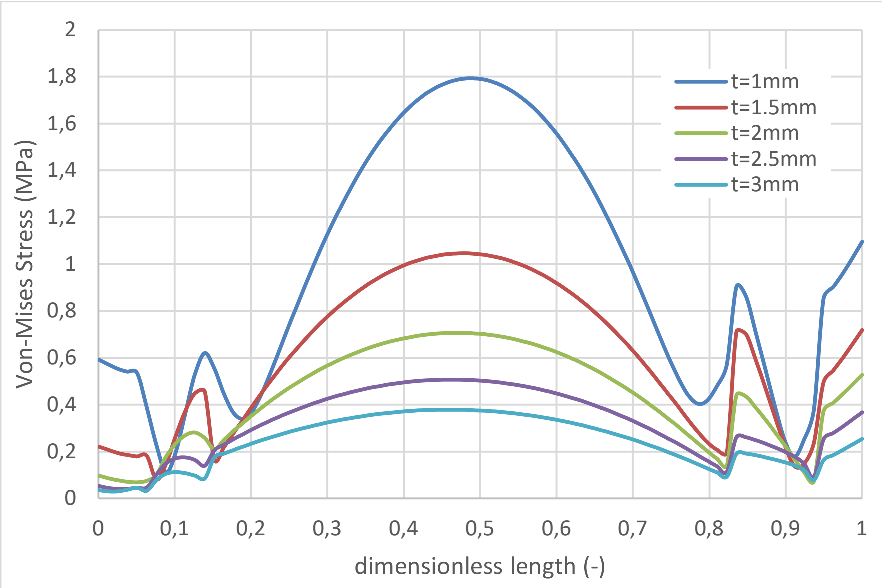

Figure 6. Stresses on the path I line according to the wing length/width ratio

Fig. 6 shows the stresses occurring at the path I location. The tensile value decreased from 1.8 MPa to 0.4 MPa as a result of increasing thickness. The general distribution is similar. The values on the right side of the stress intensities are greater than the values on the left side, except for the center region where the highest stress occurs. The reason for this can be shown as the larger circular tip and in-wing profile area at the front end of the wing.

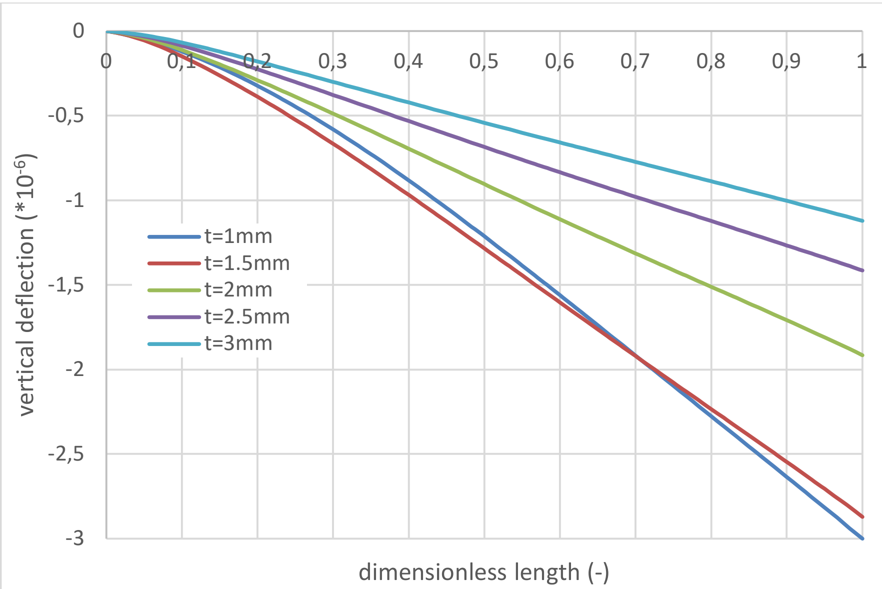

Figure 7. Deformation in the vertical direction according to the wing length/width ratio on the path II line

In Fig. 7, the deformation structure formed on path II is shown for different plate thicknesses. The geometric toughness resulting from the increased thickness reduced the deformation. A non-linear ratio occurred between the reduction rate and the thickness.

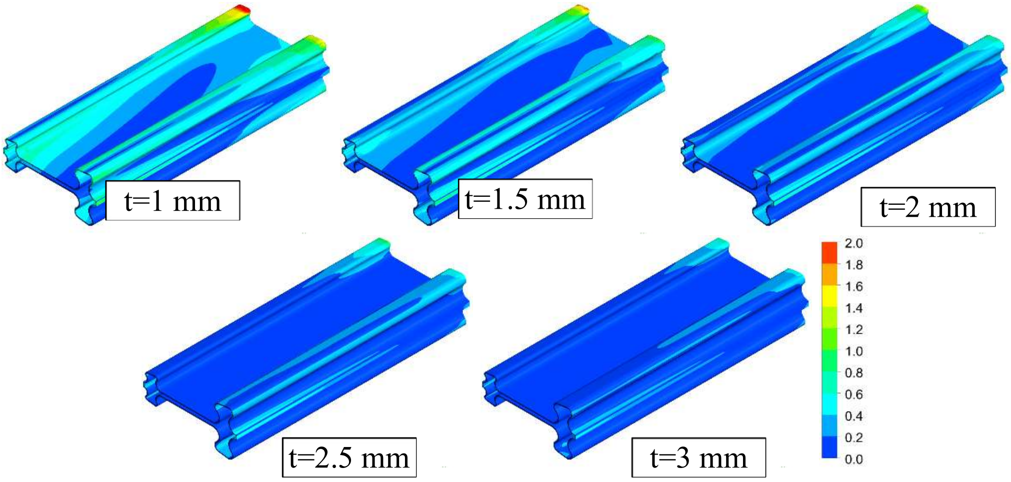

Figure 8. Stresses in the wing support profile

Von-Mises stress distributions caused by different thicknesses are shown in figure 8 for the aerofoil. With increasing thickness, the stress values decreased, and the stress regions formed at high values became smaller. The places where the highest stresses occur are in the support region. In addition, the places where the geometry direction changes in the bending places of the profile seem to be regions where high stresses occur.

5. CONCLUSIONS

In this project, a 3D model of a wing section was created. An in-wing platform was made for support because the shape of the model is a plate in a thin shell structure. These constructions represent the wing part in the overall structure, despite the lack of a specific standard. To sum up some data regarding the wing design that is being studied in terms of static bending state;

- It was observed that the wing deformation increased as a result of increasing wing length and it was determined that this increase was not linear.
- High stress values were observed at the edges of the contact area of the support platform and in the middle of the wing.
- While increasing wing length causes a dominant increase in the deformation value, this increase in the stress value is at a lesser level.
- While similar results were obtained for the wing length-width ratios 2 and 3 in the deformation of the wing support profile, a 4-fold ratio causes high deformation.
- Increasing thickness value changed the deformation and stress values as a decreasing function.
- The stresses have generally occurred in the support area and bending places of the profile.

6. REFERENCES

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