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Article

Calculation of elastic tensile behavior of CF/PA6 composite material disc

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Abstract: In this paper, the characteristic behavior of the disc consisting of thermoplastic composite CF/PA6 material was considered. Analysis was made by taking into account the usage areas of the materials and referring to certain temperatures between 30 ℃ and 150 ℃ temperatures. Composite materials are lightweight, they show high strength. For these reasons, they are preferred in technology, especially in the aircraft and aerospace industry. With this study, the radial and tangential stresses determined within a certain temperature The temperatures were determined and compared with previous studies in the literature. According to the results obtained, it is believed that the thermoplastic composites CF/PA6 disc design can be used in engineering.

Keywords: elastic stress; thermoplastic composite; elastisite modulus; temperature; disc

1. Introduction

The behavior of stresses in the disc based on the CF/PA6 material has been studied numerically. In the study, Disk materials were determined by taking into account the optimum temperatures after literature review. As it is known, composite materials are lightweight, they show high strength. For these reasons, they are preferred in technology, especially in the aircraft and aerospace industry. With this study, the radial and tangential stresses determined within a certain temperature The results obtained were compared with the studies conducted by different authors previously. According to the results obtained, thermoplastic composites CF/PA6 disc design is considered to be usable in engineering. Composite materials consist of two different material compositions and have new properties. Decomposed property. We can see thermoplastics, especially composite materials, everywhere with today's technology. These materials are advantageous in terms of their mechanical properties when combined with the designed parts, the stress sensitivity needs to be known, and it is also bendable and ductile. The numerically obtained results are in accordance with the literature. Materials science is very important in today's technologies. Materials are almost the constitution of machine parts. Knowing the stresses of materials and material parts against temperature is of great importance in the advancement of material technology. In the literature review, it has been seen that stress analyses of different disk materials have been performed, but the adaptation of these studies to the newly used materials today is considered incomplete. The thermal stress behavior of a circular disc used in brakes has been studied by two different methods. The results are shared with the graphs, it has been seen that the margin of error obtained in analytical and numerical results is very small [1]. In another study; the behavior of the preferred discs in automobile braking systems in the friction environment has been studied [2]. In another study; The interpretation and stress behavior of the disks used in railway systems have been investigated by means of a computer program [3]. In another study, the behavior of a circular disk subjected to friction against temperature has been studied [4]. In the other two studies, the stresses occurring on disks with different materials were examined and compared with other results obtained in the literature. It has been clearly observed that the results obtained at the end of the disc materials show different mechanical properties are completely different from each other, the stresses change with temperature [5,6] again in different studies; The mechanical behaviors and thermal conduction occurring in a layered disk modeled in the form of rings have been investigated. In addition, the stresses occurring on disks consisting of different layers have been analyzed [7,8].

2. Materials and methods

The materials of the discs have been specially researched. The plane stress has been treated as zero. The modeled disk is shown in **Figure 1** below [9].

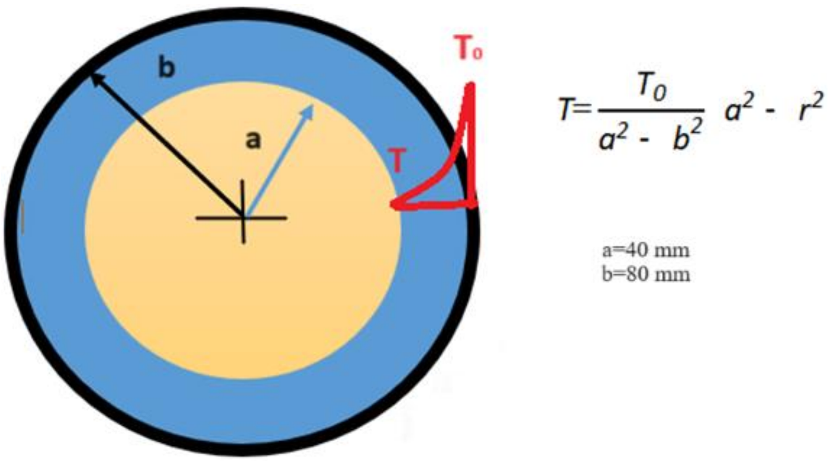

Figure 1. CF/PA6 composite composite disc.

$$\frac{r(d\sigma_r)_i}{dr} + (\sigma_r)_i - (\sigma_\theta)_i = 0 \qquad (i = 1) \tag{1}$$

As can be seen in the formulas; r can be called the disk radius. The different stresses that occur are given below.

$$\varepsilon_r = \frac{du}{dr} = a_{rr}\sigma_r + a_{r\theta}\sigma_\theta \tag{2}$$

$$\varepsilon_{\theta i} = \frac{u}{r} = a_{r\theta}\sigma_r + a_{\theta\theta}\sigma_\theta \tag{3}$$

By establishing a relationship between the general equation and the function F, Equation (4) is derived below.

$$a_{\theta\theta}r^2\frac{d^2F}{dr^2} + a_{\theta\theta}r\frac{dF}{dr} - a_{rr}F = -\alpha_\theta r^2\frac{dT}{dr} + \alpha_r Tr - \alpha_\theta Tr \tag{4}$$

In an environment where the temperature increases parabolically from the inside out; T_0 is the symbol of the first temperature on the disk. Tr symbolizes the temperature that occurs at any regional point on the disk.

$$T = \frac{T_0}{a^2 - b^2}(a^2 - r^2) \tag{5}$$

For the solution of equations in general:

$$\sigma_r = \frac{F}{r} = C_1 r^{k-1} + C_2 r^{-k-1} + Ar^2 + C \tag{6}$$

$$\sigma_{\theta i} = \frac{dF}{dr} = kC_1 r^{k-1} + kC_2 r^{-k-1} + 3Ar^2 + C \tag{7}$$

By reference to the constants *A* and *C* "λ" and *k*, the general stress equations arise.

$$A = \lambda \frac{3(\alpha_\theta - \alpha_r)}{a_{\theta\theta}(9 - k^2)} \tag{8}$$

$$C = \lambda \frac{(\alpha_r - \alpha_\theta)b^2}{a_{\theta\theta}(1 - k^2)} \tag{9}$$

$$\lambda = \frac{T_0}{(b^2 - a^{2)}} \tag{10}$$

$$k^2 = \frac{a_{rr}}{a_{\theta\theta}} \tag{11}$$

$$C_1 = \frac{Aa^{k+3} + Ca^{k+1} - Ab^{k+3} - Cb^{k+1}}{(b^{2k} - a^{2k)}} \tag{12}$$

$$C_2 = -C_1 a^{2k} - Aa^{k+3} - Ca^{k+1} \tag{13}$$

Thermal stresses analysis

The disc with CF/PA6 material is fixed. The inner radius and outer radius of the disk have been determined. The temperature shows a parabolic increase from the inner to the outer part. The disk modeled by ANSYS finite element program is given in **Figure 2** below.

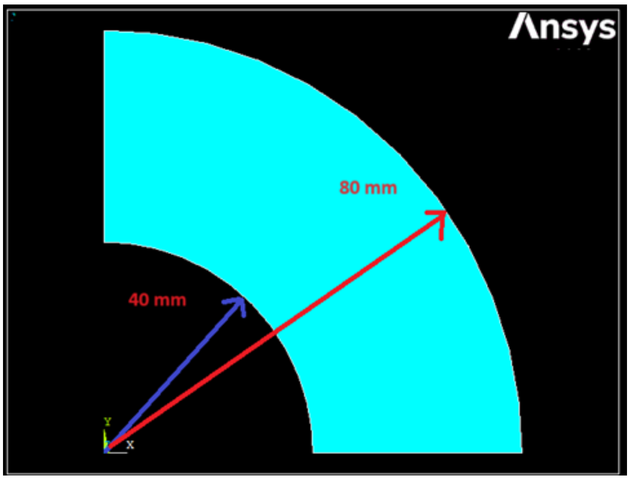

Figure 2. Disk modeling with ANSYS program.

The modulus of elasticity and other properties of CF/PA6 composite material are given in **Table 1**.

Table 1. Mechanical properties of CF/PA6 composite material [10–12].

E_θ	E_r	k	α_r	α_θ	$\upsilon_{\theta r}$
230	15	3.91	8×10^{-6}	2.8×10^{-6}	0.37

The stress values obtained at the end of the numerical analysis of the circular disc with CF/PA6 material are shown in **Table 2** below. Tangential stresses have compression intensity in the inner region, tensile intensity in the outer region.

Table 2. Numerical analysis of circular discs with CF/PA6 material.

Temperature ΔT (°C)	Surface	Tangential Stress (MPa)	Radial Stress (MPa)
30	Inner	4.47	0
	Outer	−7.34	0
60	Inner	8.94	0
	Outer	−14.69	0
90	Inner	13.40	0
	Outer	−22.03	0
120	Inner	17.88	0
	Outer	−29.37	0
150	Inner	22.34	0
	Outer	−36.72	0

Figure 3 below is the stress graph that occurs at the end of the analysis.

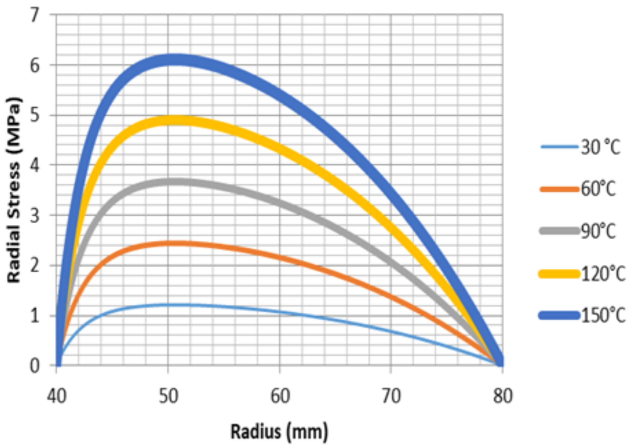

Figure 3. Stress graph of CF/PA6 composite material disc (in the radial direction).

In **Figure 3**, the stresses that occur in the radial direction increase from the inner part of the disk to the outside. It decreases from the middle part towards the end zone.

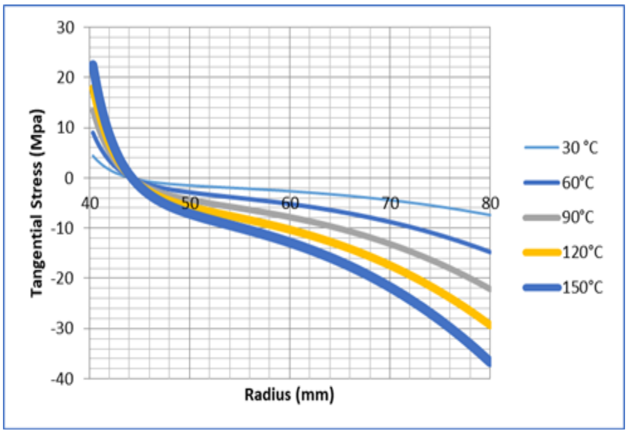

Figure 4. Stress graph of CF/PA6 composite material disc (in the tangential direction).

The radial stresses calculated for the disc modeled with CF/PA6 were determined as zero. The tangential stresses determined for the composite disc with thermoplastic CF/PA6 material are given in **Figure 4**.

Figure 4 is a graph of tangent stresses occurring on a CF/PA6 composite material disk.

As can be seen in **Figure 4**, the tangential stresses are tensile stress in the inner regions of the CF/PA6 material disk, and compressive stress towards the outer regions. It differs in stresses depending on the temperature.

In **Figure 5**, the tangential stresses obtained in the inner part of the disk for temperatures of 30 ℃ and 150 ℃ occurring in the CF/PA6 material disk are graphically given.

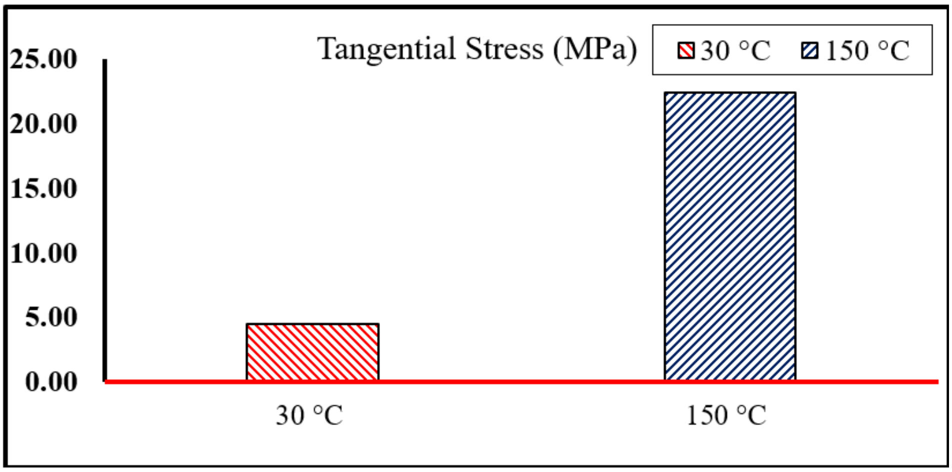

Figure 5. Stresses caused by CF/PA6 material in the inner region of the disk (in the tangential direction).

In **Figure 5**, it was determined that the increase in stress values, which are mathematically calculated in the inner region of the disk, depends on the temperature. 30 ℃ to 150 ℃, the tangential stress value increases by about 5 times.

In **Figure 6**, the stresses obtained on the CF/PA6 material disk in its outer part for temperatures of 30 ℃ and 150 ℃ are graphically presented.

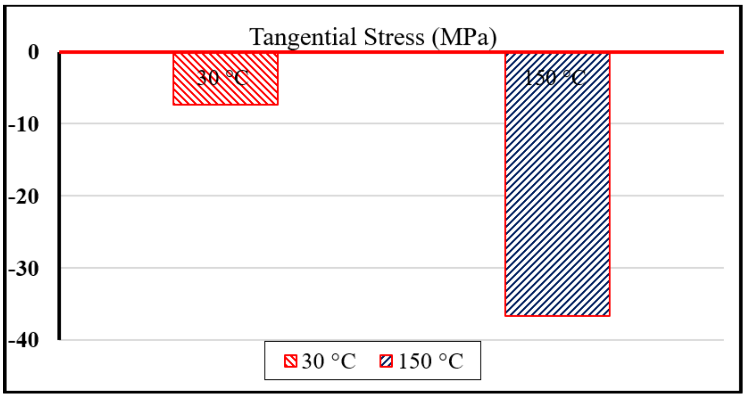

Figure 6. Stresses caused by CF/PA6 material in the outer region of the disk (in the tangential direction).

As the temperature increases from 30 ℃ to 150 ℃, it is observed that the tangential stress value increases by about 5 times in the outer parts.

It is understood that the findings obtained in this study give similar results to some studies. For example, the stresses occurring on an Aluminum alloy disk are zero in the innermost and outermost regions of the disk [12]. Its compatibility with other studies is that the analysis results obtained using mathematical programming are considered applicable [13,14].

3. Results and discussion

Mathematical modeling was performed at optimum temperatures for thermoplastic CF/PA6 material disc.

The effect of temperature is in the form that it increases parabolically from the inner surface of the CF/PA6 material disk to the outer surface.

At the end of the model, tangential and radial stresses formed in the disk were determined by means of a mathematical program. The table was created by drawing graphs.

The radial stress component is zero and close to zero on the innermost and outermost surfaces of the disc with CF/PA6 material.

As the temperature increases from 30 ℃ to 150 ℃, there are increases in tangential and radial stresses.

Radial stresses have appeared in the form of pull stress. Radial stresses can reach their highest value in approximately r = 50 mm regions of the CF/PA6 material disc.

Stresses in the tangential direction are calculated first as compressive stress and then as tensile stress.

As the most important result of this study conducted by deriving a mathematical program, it is believed that the CF/PA6 material disk can be selected appropriately at certain temperatures in disk designs.

Conflict of interest: The author declares no conflict of interest.

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