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ARTICLE

Investigation of Radial and Tangential Stresses Occurring in Epoxy (T300) Material Disc with Different Methods

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ABSTRACT

In this study, a composite disc with Epoxy (T300) material was considered. It is possible to come across different studies to examine the stress field on disks rotating or stationary under thermal loads. Discs play a vital role in the assembly of machine parts in industry. Knowing the behavior of machine parts against temperature allows very good data to be transferred to today's artificial intelligence world. Epoxy materials are very important today. Epoxies are made up of very strong fibers. They are used in unmanned aerial vehicles, spacecraft and the rocket industry. In addition, their maximum and minimum hardening properties, good adhesion properties and wear resistance are also quite high. In this study, an Epoxy disk (T300) subjected to linear increasing temperature was modeled. The stresses obtained on the discs were determined by different methods. As can be seen from the results, for a temperature of 150 °C, the average stress, strain and compression occurring sequentially in the inner and outer regions of the disk acts as 215.06 and –443.90 MPa. According to the results obtained, it was concluded that there are parallel increases in stresses as the temperature increases, and this can be proven by other different studies in the literature.

Keywords: Epoxy; Composite materials; Mathematical formulation

1. Introduction

The stresses related to the discs were determined by using different materials and methods. When the studies conducted in this field were examined, the stresses applied in different disc materials were compared with each other. There are many studies in the literature about discs. However, the studies obtained using the Chebyshev Pseudospectral method are quite few. A literature review was conducted for

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disks with thermal stress analysis using different materials. For example, in a study conducted, the thermal stress of a cubic quasicrystal circular disc was investigated. Within the scope of the study, thermoelastic stresses for a circular disk made of a cubic semi-crystal were determined using the semi-inversion method. The disk has been subjected to the temperature change of a quadratic function with radius or constant internal heat source. The findings obtained at the end of the study were compared with other studies. It has been seen that positive results have emerged in this regard [1]. In a different study, thermo-mechanical stress analysis of rotating fiber reinforced variable thickness disk was examined. The importance of stresses and displacements in discs with composite materials has been emphasized [2]. In a different study, the stresses occurring in an inhomogeneous disk rotating with varying thickness and density were investigated again. The results obtained are presented with graphs [3]. Again, in a different study, the thermoelastic behavior of a functionally graded rotating disk was studied [4]. In a different study, the Tresca yield limit was applied for stresses occurring in a circular disk of variable density. The results obtained have made a positive contribution to the literature [5]. In another study, thermo-mechanical analysis and optimization of functionally graded rotating disks were examined. Plane elasticity theory was applied with the finite element method in the study. The results obtained were shared with graphs [6]. Again, in a different study, stress analysis was investigated in functionally graded rotating disks with uneven thickness and variable angular velocity. At the end of the study, it was concluded that this had almost no effect on radial and peripheral stresses. Also in the study, the importance of the Von Mises criterion has been emphasized [7]. In another study, the elastic-plastic behavior of functionally graded rotating disks was investigated. As a result, it has been determined that the angular velocity of the flow decreases proportionally as the gradient index decreases [8]. Discs are often preferred in the engines of vehicles. They are vital for engines. For example, in the study, the strength analysis of the crankshaft of an increased diesel engine was examined [9]. In a study, the plasticity problem of a certain type of composite material, called functionally graded materials was investigated. Plasticity is a very important problem for materials. Knowing the temperature and material behavior is very important for improving the material design [10]. In another study, displacements occurring in disks with different materials were investigated [11,12]. It is available in different studies related to stresses occurring in materials. For example, in one study, the effect of transition thickness shear (TTS) stress on the prediction of forming boundary diagrams (FLDS) was studied [13]. In a different study, the stresses occurring in the hair were investigated by the finite element method [14].

2. Materials and methods

In this study, the dimensions of the disc were determined as a = 40 mm, b = 80 mm. The stresses obtained at temperatures of 50 °C, 75 °C, 100 °C, 125 °C, 150 °C were determined.

As shown in **Figure 1**, the inner radius of the disk is shown with a. The outer radius of the disk is shown by b. The disc material is Epoxy (T300).

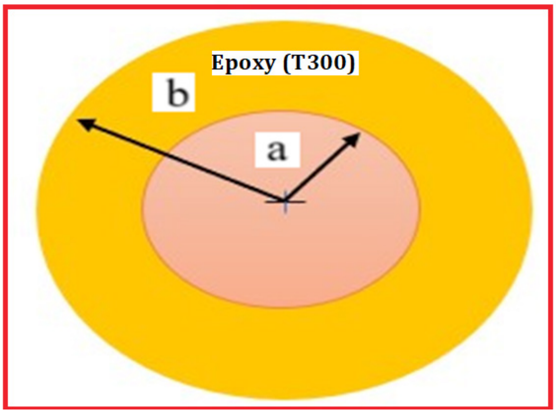

Figure 1. A disk model with Epoxy T300 material.

The mechanical properties of the Epoxy T300 material disc are given in **Table 1** below.

The modeling of the disk, the dimensions of which are defined in **Figure 2** below, is given in the ANSYS 2023 program.

Table 1.The mechanical properties of the Epoxy T300 material disc.

Material	**E_θ (GPa)**	**E_r (GPa)**	***k***	**α_r (1/°C)**	**α_θ (1/°C)**	**$\upsilon_{\theta r}$**
Disk	230	15	3.91	0.7×10^{-6}	12×10^{-6}	0.35

Source: [15].

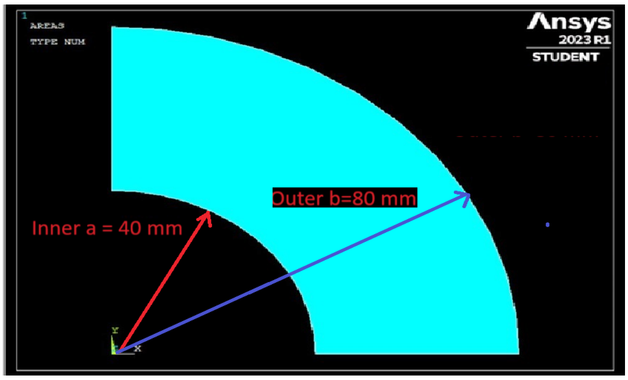

Figure 2a. Modeling of the disk in the ANSYS program.

Determining the node points of the disk in the ANSYS program is given in **Figure 2b** below.

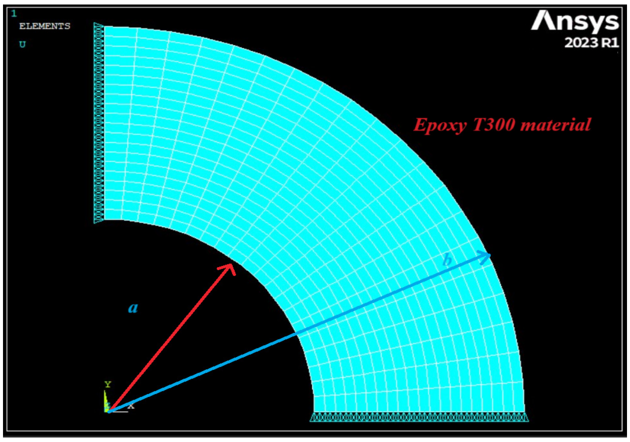

Figure 2b. Giving the node points of the disk with the ANSYS program.

As shown in **Figure 2** above, the disk is modeled with the ANSYS program. The inner radius is considered as 40 mm, and the outer radius is considered as 80 mm.

2.1 Formulation

The formulas developed for the disk modeled above are given in the following order:

The elasticity constants are seen below. The general equilibrium equation that can be used for a thin disk. $\sigma_z = 0$ is given below [16].

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

$$r^2F'' + rF' - k^2F = \frac{(\alpha_r - \alpha_\theta)(r^2 - ar)}{a_{\theta\theta}(b-a)}T_0 - \frac{a_{\theta\theta}T_0}{a_{\theta\theta}(b-a)}r^2 \tag{2}$$

When applying the Chebyshev method, with the differential matrix D equation [17]. Results requiring high precision can be achieved with a finite number of multiplications of the resulting vector and vector derivatives at sensitive points. In addition, the calculation of the derivative matrix can be applied from the Matlab m file.

$$r_j = \cos\{j\boldsymbol{\pi}|N\},\ j=0,\ 1,\ 2,\ 3\ \ldots N \tag{3}$$

$$F'(r_j) = (DF)_J \tag{4}$$

$$F=[F_0 \ldots F_n]^T,\ r_j \tag{5}$$

r_j is numbered from right to left and is recognized in the specified order [–1, 1].

$$[\frac{dF}{dr}(r_n)] \equiv D[F(r_n)] \tag{6}$$

$$[\frac{dF^2}{dr}(r_n)] \equiv D^2[F(r_n)] \tag{7}$$

The differential Equation (8) has been created. L_1 is the linear coefficient and RHSF expresses the equation on the right side.

$$L_1 F = RHSF \tag{8}$$

If the boundary conditions for $\sigma_r(a) = 0$ and $\sigma_r(b) = 0$ are applied to the above equations, the solution of RHSF is given below.

$$L_1 = r^2 D^2 + rD - k^2 r_j \tag{9}$$

$$\mathrm{RHSF} = \frac{(\alpha_r - \alpha_\theta)(r^2 - ar)}{a_{\theta\theta}(b-a)} T_0 - \frac{a_{\theta\theta} T_0}{a_{\theta\theta}(b-a)} r^2 \tag{10}$$

3. Conclusions and discussions

A computer program was used in this study. The stresses obtained on the Epoxy (T300) material were compared among themselves and with the literature. The radial stress occurring on the disk is given in **Table 2** below.

The tangential stresses occurring in the Epoxy (T300) material disk are given in **Table 3** below.

As can be seen in **Table 2**, it has been determined that the stresses obtained by two different methods are close to each other. For example, at a temperature of 25 °C, the stress obtained by the Psedudospectral Chebyshev Method is 71.029 MPa, while the stress value obtained by the analytical solution is 72.77 MPa. On the outer surface of the disc, it was determined that the stresses obtained by the Psedudospectral Chebyshev Method were –146.62 MPa, while the stress value obtained by analytical solution was –150.20 MPa. At higher temperatures, on the other hand, for 150 °C where there is an

Table 2. Calculation of radial stresses occurring in a disk with Epoxy (T300) material.

Temperature	**Disk**	**Psedudospectral Chebyshev method**	**Analytical solution**
°C		**σr (MPa)**	**σr (MPa)**
25	Inner	0	0
	Outer	0	0
50	Inner	0	0
	Outer	0	0
75	Inner	0	0
	Outer	0	0
100	Inner	0	0
	Outer	0	0
125	Inner	0	0
	Outer	0	0
150	Inner	0	0
	Outer	0	0

Table 3. Epoxy (T300) tangential stresses occurring on the material disk.

Temperature	**Disk**	**Psedudospectral Chebyshev method**	**Analytical solution**	**Average stress values**
°C		**σt (MPa)**	**σt (MPa)**	**σt (MPa)**
25	Inner	71.029	72.77	71.89
	Outer	–146.62	–150.20	–148.41
50	Inner	95.65	97.04	96.34
	Outer	–197.43	–200.29	–198.86
75	Inner	122.91	121.28	122.09
	Outer	–253.72	–250.35	–252.03
100	Inner	141.21	145.55	143.38
	Outer	–291.46	–300.41	–295.93
125	Inner	207.027	212.25	209.63
	Outer	–427.32	–438.10	–432.71
150	Inner	211.815	218.32	215.06
	Outer	–437.19	–450.61	–443.90

increase in these stresses. The stresses obtained on the inner and outer surface of the disk by the Psedudospectral Chebyshev Method were obtained as 207.027 MPa and –427.32 MPa respectively. As a result, the stresses obtained as an analytical solution were 218.32 Mpa and –450.61 MPa on the inner and outer surface of the disk respectively. The stresses obtained in **Figures 3–4** are given graphically below.

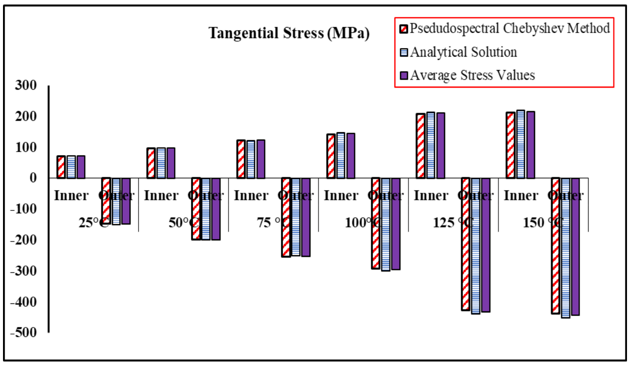

Figure 3a. Representation of tangential stresses occurring on a disk with Epoxy (T300) material with a linear graph.

In **Figure 3a**, the tangential stresses occurring in the disk are given as a linear graph so that they can be clearly understood. As shown in **Figure 3**, it was determined that there is a significant increase in stress intensity with temperature increase for the disk, while the stress intensity in the inner part of the disk is (+), and the stress intensity in the outer part of the disk is (–). It is observed that the stress value obtained for 25 °C is quite low compared to the stress value obtained for 150 °C. It is also noteworthy that the tangential stresses determined by both methods are close to each other.

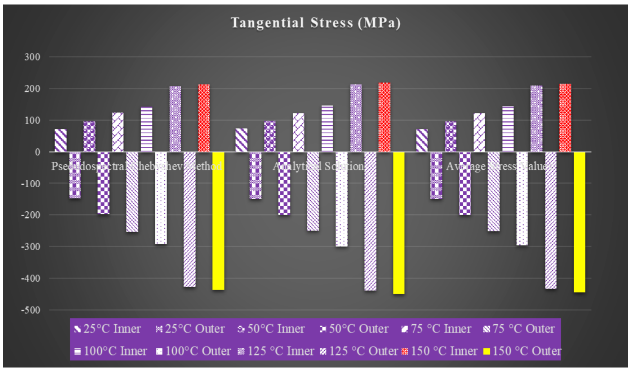

Figure 3b. The tangential stresses occurring on an Epoxy (T300) material disk with a different graph.

In **Figure 3b**, the stresses occurring on the inner and outer parts of the disk are clearly seen. It is seriously observed that the stresses occurring in the inner part of the disk are less than the stresses occurring in the outer part of the disk. This difference is also proportional to the temperature increase. The tangential stresses obtained by taking the averages of the stresses obtained at the end of both methods are given in **Figure 4** below.

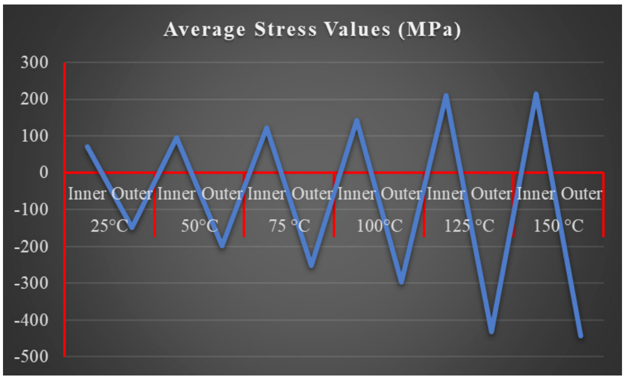

Figure 4. Determination of the average tangential stress.

In this study, the effect of axial tension was neglected. In this disc, only the stresses in the radial and tangential directions have been analyzed.

It is observed that the average stresses occurring in the disk also vary in proportion to the temperature change, and differ from each other in the inner and outer parts of the disk. It is clearly seen that the stress occurring on the outer part of the disk acts as (–), while the tangential stress occurring on the inner part of the disk acts as (+). As can be seen in **Figure 3**, the tangential stresses obtained at different temperatures are different. The results obtained show similarities with other studies conducted in the literature [18–20].

The accuracy of the results obtained reveals similar studies to the results of different studies in the literature review. For example, in a similar study, the stresses occurring in disks made of different materials were studied by different methods. Similar to this study, radial stresses are maximal in the central regions of the disk and close to the minimum in the inner and outermost regions [21,22]. In a different study, the calculated stresses on a disk with different mechanical properties were analyzed. Similarly, it has been found that the tangential stress is maximum in the innermost part of the disk and minimum in the outermost region [23]. In addition, it is believed that the results obtained by numerical analysis, a computer program, and the results obtained in **Tables 2 and 3** above are quite close to the results obtained by the Chebsey method, which generally indicates that the results are correct.

4. Results

The thermal stress behavior of a disk with Epoxy (T300) material was investigated using two different methods. At the end of the study, the following findings were reached. It was found that the numerical analysis obtained through a computer program and the results obtained using the Psedudospectral Chebyshev Method were similar to each other, the difference between stresses was about a maximum of 4%. It has been concluded that the Psedudospectral Chebyshev Method can be used to calculate the thermal stresses occurring in disks. When the tangential stresses obtained by both methods were examined, it was determined that the stresses occurring in the outer region of the Epoxy (T300) material disk were greater than the stresses occurring in the inner part. It has been observed that the effect of tangential stresses and radial stresses also increases proportionally as the temperature increases in the Epoxy (T300) material disk. It has been seen that the findings obtained at the end of this study are consistent with similar studies in the literature. In addition, it has been seen that the Epoxy December (T300) material disc can be used in the temperature ranges specified in this study.

Conflict of Interest

There is no conflict of interest.

Data Availability Statement

All data underlying the results are available as part of the article and no additional source data are required.

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