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RESEARCH ARTICLE

Stresses Occurring on a Cylinder with Annular Silicon Carbide (SiC), Ti6Al4V and Copper (Cu) materials

Hüseyin Fırat Kayıran*

Mersin Provincial Coordinator, Department of Agriculture and Rural Development Support (ARDSI), Mersin, Turkey

ABSTRACT

In this study, the stresses occurring in the annular cylinder modeled as a circular layer were analyzed numerically. Of the materials selected in accordance with the cylinder; Silicon Carbide (SiC) is known to be frequently used in the aviation industry due to the high abrasion and erosion resistance of the material. In this study, Silicon Carbide (SiC) is located in the upper layer of the annular cylinder due to its high strength. Titanium alloy and Ti6Al4V materials are also used in the aircraft and defense industry, where high strength, low weight and resistance to high temperatures are of great importance. Copper (Fr) material also shows high corrosion resistance. At the end of the study, it was seen that Silicon Carbide (SiC) with high elastic modulus has higher resistance to heat than Ti6Al4V (Titanium alloy) material. It has been observed that the stresses occurring in the Ti6Al4V (Titanium alloy) material part are higher than in the Copper (Cu) material Fractions. The results obtained at the end of the study were shared with graphs. In addition to the results obtained, the stresses obtained in a regional part of the disk with the ANSYS 2024 program were shown with graphs.

Keywords: cylinder, mathematical formulation; stress analysis

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1. INTRODUCTION

Disks are called critical parts in many basic machines today. When the different studies in the literature are examined, there are satisfactory studies about the stresses occurring in the discs. There are two main types of stress in rotating disks. These types of stresses are radial and circumferential (tangential) stresses. These stresses vary depending on the rotation speed, material properties and geometric structure. In a study conducted on this subject, the effects of rotation speed and temperature on stress distribution in rotating disks were investigated. At the end of the study, one of the most important results is that there is an increase in stress intensity at high speeds and high temperatures. The accuracy of the results obtained shows similarities with other scientific studies in literature. (1). Similarly, in another study, the thermal and elastic stresses in a rotating annular disk were determined mathematically. It has been observed that there are increases in stress as the temperature increases (2). The effect of the anisotropic properties of composite materials on the stress density and the stress distribution of rotating disks made of composite materials have been determined (3). In a different study, the finite element method was used to analyze stresses in rotating disks made of functionally graded materials. The effects of various material gradients on stress density have been considered (4). In another source, the analysis of

* Corresponding author: huseyinfirat.kay@tkdk.gov.tr

stresses in anisotropic materials, especially annular disks, was performed (5). Partial differential equations and their applications, mathematical methods that can be used to solve stress problems in annular disks are discussed. It is thought that choosing the appropriate material can reduce deformations in materials (6). In this study, the stresses occurring in the cylinder were determined by considering the annular combination of different materials.

The most important feature that distinguishes this study from others is the selection of suitable materials. Performing a stress analysis of a composite cylindrical structure consisting of Silicon Carbide (SiC), Ti6Al4V (Titanium alloy) and Copper (Cu) materials requires understanding the mechanical properties of each material and how they interact under various loading conditions. The purpose of this study is to analyze the stress of a composite cylindrical structure consisting of Silicon Carbide (SiC), Ti6Al4V (Titanium alloy) and Copper (Fr). With this analysis, thermal stresses were calculated by taking into account the thermal expansion coefficient and temperature change of each material.

2. MATERIALS AND METHODS

In this study, there is Ti6Al4V in the innermost part of an annular cylinder, Copper (Fr) in the middle part and Silicon Carbide (SiC) in the outermost part. The stresses occurring in the system were determined by developing a mathematical computer program. The formulas used for the multi-layered annular circular cylinder are given below (Figure 1).

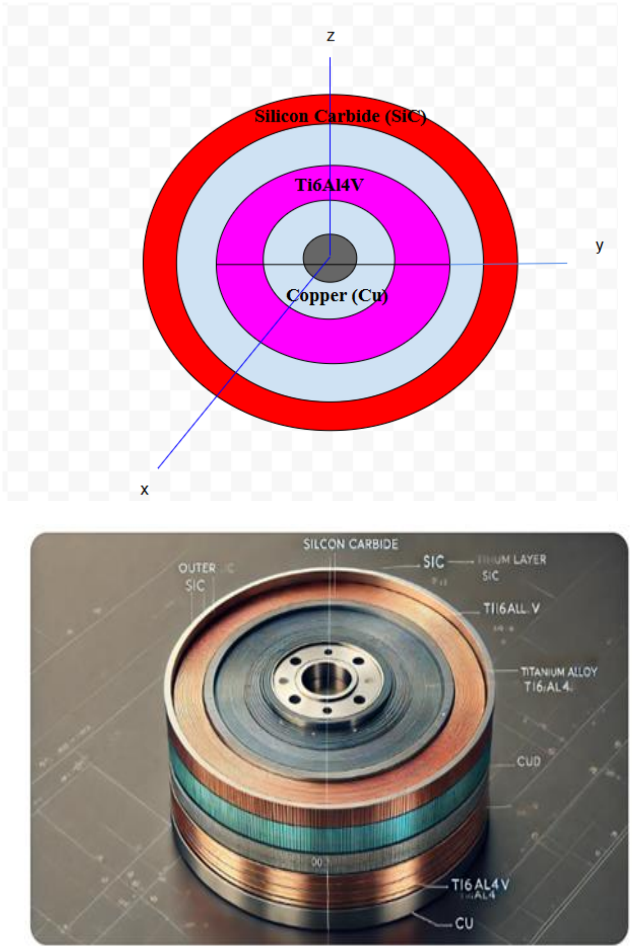

Figure 1. An annular disc and an example of its modeling

In Figure 1, the Copper (CU), the middle layer is Ti6Al4V and the outer layer is Silicon Carbide (SiC). The materials are as follows: Fructose, fructose, fructose, fructose, fructose and fructose. Silicon Carbide (SiC) was selected as the high modulus of elasticity for the outer material.

2.1. Heat conduction equation and solution

Consider a multilayered thin annular disk occupying the space $r_{i-1} < r < r_i$, $0 < \theta < 2\pi$, $0 < z < h$. The following Fig. 1. gives the geometrical representation of the multilayered annular disk.

Figure 2 illustrates the geometric representation of the layered circular disc.

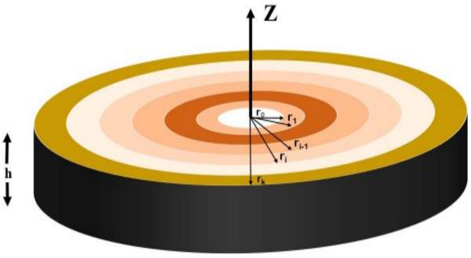

Figure 2. Multilayered disc (7)

The heat conduction equations occurring in a multilayer circular disk (disk) depending on the temperature are derived as follows: (8-9-10)

$$\frac{1d}{rd_r}((r\lambda_1 T_1)\frac{d(T_i)}{dr}) + \frac{1d}{r^2 d_\theta}(\lambda_1(T_i)\frac{d(T_i)}{d\theta}) + \frac{d}{dz}(\lambda_1(T_i)\frac{d(T_i)}{dz}) = \rho_i C_i T_i \frac{d(T_i)}{dT} \quad \text{(Eq. 1)}$$

$T_i = 0$, t=0, Boundary conditions; Inner surface of the first layer (i=1),

$$\lambda_1(T_1)\frac{d(dT_1)}{dr} + h_0 T_1 = 0 \quad \text{(Eq.2)}$$

On the outer surface of the k-th layer (i=k), and at the interface of the i-th layer (i=2, 3,…,k). The boundary conditions are determined by the basic equations in the cylindrical coordinate system. The equations are derived from each other.

In the cylindrical coordinate system, the boundary conditions for thin disc with support at both ends are (11):

$$\Lambda^2 \Lambda^2 \Lambda w^i = \frac{-1}{(1-v_i)D_i}\Lambda^2 D M_T \quad \text{(Eq. 3)}$$

$$D_i = \frac{E_i \Lambda h^3}{12(1-v^2)} \quad \text{(Eq. 4)}$$

Boundary conditions: $r=r_0$, $r\_r=r_k$ Moments and stresses are given below using Hooke's Law.

Stress components are;

$$\sigma_{rr} = \frac{1}{h}N_{rr+} + \frac{12z}{h^3}M_{rr} + \frac{1}{(1-v_i)}L \quad \text{(Eq. 5)}$$

L is a mathematical coefficient.

$$L = (\frac{1}{h}N_{T+}\frac{12z}{h^3}M_T - \alpha_i(T_i)k^2 E_i T_i \quad \text{(Eq. 6)}$$

$$\sigma_{\theta\theta} = \frac{1}{h}N_{\theta\theta+} + \frac{12z}{h^3}M_{\theta\theta} + \frac{1}{(1-v_i)}(\frac{1}{h}N_{T+}\frac{12z}{h^3}M_T - \alpha_i(T_i)k^2 E_i T_i \quad \text{(Eq. 7)}$$

$$M_T = E_i\int_0^h \alpha_i(T_i)T_i z dz \quad ; \quad N_T = E_i\int_0^h \alpha_i(T_i)T_i z dz \quad ; \quad \alpha_i(T_i) = \alpha_{i0}\exp(w_2 T_i) \quad \text{(Eq.8)}$$

Here $\alpha_i(T_i)$is the temperature dependent coefficient of linear thermal expansion assumed as:

The disk modeled in the ANSYS 2024 program within the scope of the study is shown below in Figure 3

Figure 3. A ring of the disk modeled in ANSYS 2024

Constant temperatures with respect to the radius were applied to the cylinder model created for the analysis. tangential stresses were determined for 5 different temperature values. As can be seen in Figures 4 and Figure 5, these temperature values are entered from the "Thermal Loads" (Define Lo-ads>Apply>Temperature) section of the program for numerical analysis in such a way that they are constant throughout the cross-section. Thermal loads determined as 20C, 40C, 60C, 80C, 100C and 120C were applied respectively. The ambient temperature was ignored during Deceleration. Considering temperatures ranging from 0°C to 120°C, the analysis obtained for the disk subjected to stress is shown below in Figure 4.

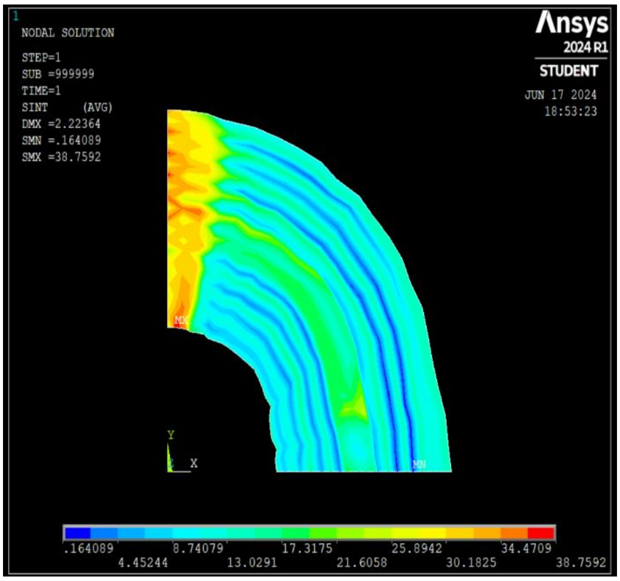

Figure 4. Regional stress analysis of the disk using the ANSYS 2024 program

As can be seen in Figure 4, the stresses on the outer part are excessive. The difference of colors refers to the change in stresses.

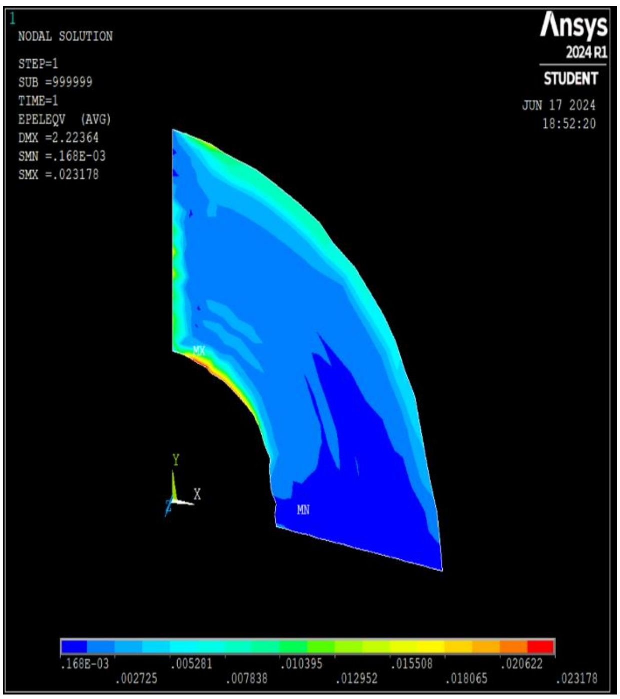

Figure 5. Elastic stress analysis of the disk region using the ANSYS 2024 program

In Figure 5, it is observed that the stresses change against temperatures that are not considered homogeneous. When examining the stresses obtained using the ANSYS program, it is observed that the stresses vary according to the differences in the disk materials.

3. RESULTS AND DISCUSSION

At the end of this study, it is observed that the heat resistance of the material with a high modulus of elasticity depending on the tangential stress is excessive. The results obtained by numerical analysis of tangential stresses occurring in different directions are given below between Figures 5-8 with graphs. The mechanical properties of the materials constituting the disk are provided below in Table 1.

Table 1. Mechanical properties of annular disk (12-14)

Disc	E (GPa)	*Thermal conductivity* W/mk	Thermal diffusivity mm2/s	$\alpha r\ (1/\ oC)$	$\upsilon_{\theta r}$
SiC	410	490	10.67	$4x10^{-6}$	0.17
CU	110	398	111	$16.5x10^{-6}$	0.34
Ti6Al4V	114	6.7	2.72	$8.6x10^{-6}$	0.33

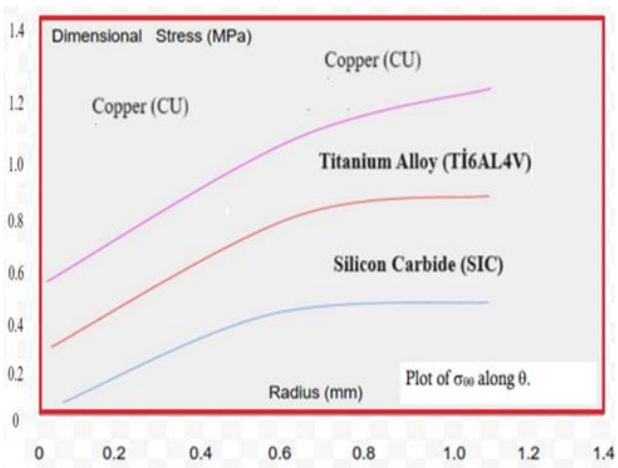

Figure 6. Tangential stresses occurring in the environmental direction

As can be seen in Figure 6, the stress value occurring along the radius differs according to the mechanical properties of the materials.

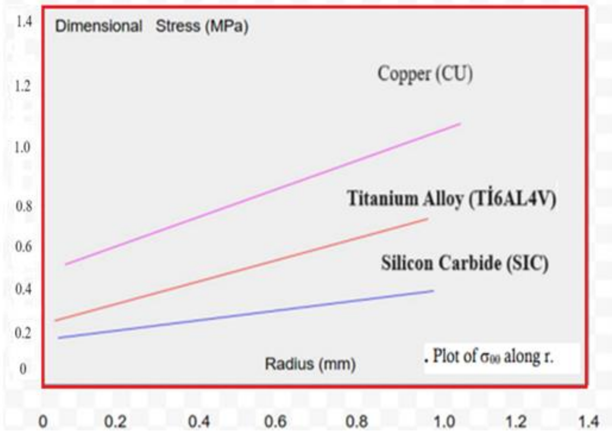

Figure 7. Tangential stresses occurring in the radial direction

As can be seen in Figure 7, the Fractions occurring in the radial direction was most in the Copper (CU) material part. The lowest stress occurred in the Silicon Car-bidet (SIC) material part.

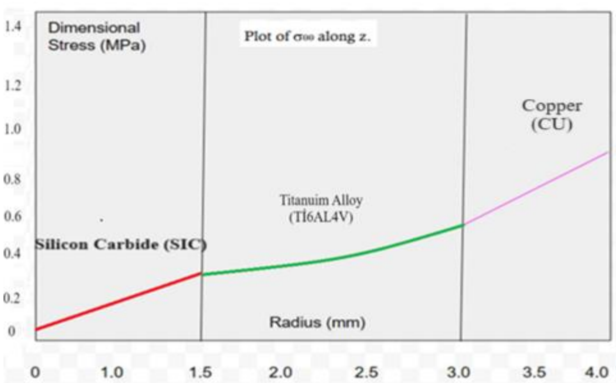

Figure 7. Tangential stresses occurring in the axial direction

As can be seen in Figure 7, the rate of change of stress is also quite different from each other. While there is a slight increase in Copper (CU), this increase is interpreted as slower in Titanium Alloy (TI6AL4V). Silicon Carbide (SIC) is a linear increase.

The results obtained at the end of this study are in line with other similar studies in literature (15-16). The stresses occurring in the tangential direction are greater than the stresses occurring in the radial direction. The stresses occurring in the radial direction are greater than the stresses occurring in the axial direction. It was found that the tangential stresses obtained in the part where the copper (CU) material was used were higher than in the Fractions with TI 6AL 4v material. It is observed that the tangential stress occurring in the section where TI 6AL 4v material is located is higher than in the section with silicon carbide (SiC) material.

4. CONCLUSION

In this study, the stresses that occur at the end of heat delivery to an inhomogeneous multilayer annular disk were investigated. In this study, mathematical programming was developed. It has been revealed that the material-based part of silicon carbide (SiC) with a high elasticity modulus has a higher tensile strength compared to the region where the TI 6AL 4v material is located. It has been observed that the mechanical strength of the TI 6AL 4v material in this part is higher than that of copper (Cu). The mechanical strength of the TI 6AL 4v material is higher than that of copper (Cu). The mechanical strength of the TI 6AL 4v material is Frequently higher. With this study, it is thought that the determined materials may be usable. It is estimated that the results obtained may be compatible with similar studies conducted earlier.

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