# Investigation of stresses occurring in rotating cylinders made of Boron carbide (B4C) and Silicon carbide (SIC) materials by using finite element method

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**Abstract:** This paper focuses on some mathematical and numerical aspects of elastic stress. The distribution of elastic stress in rotating cylinders made of Boron carbide (B4C) and Silicon carbide (SIC) materials is analyzed analytically. Boron carbide, which will be Decelerated for projects in the defense industry and automotive fields, is among the precious metals in the world. Silicon carbide is one of the most widely used structural ceramics. silicon carbide is one of the most durable ceramic materials. Boron carbide (B4C) and Silicon carbide (SIC) are used in aircraft industry, unmanned aerial vehicles, electric vehicles. The stress value obtained at the end of the analysis was compared with the ANSYS 2023 R1 program. The results obtained are close to each other. For example, if the results obtained are compared with each other, the tangential stress obtained in the boron rib material is about 35% higher than that of silicon carbide. The novelty and importance of the research are quite high. Rotating cylinders determined materials are used in aircraft, unmanned aerial vehicles. It is intended to share the results obtained when using two materials with high strength with the literature. The radial stresses are continuously zero at the innermost and outermost parts. Tangential stresses are more than radial stresses. It has been observed that the tangential stresses obtained in the ANSYS 2023 R1 program are higher than the radial stress. Within the scope of the study; the Von Mises yield criterion is taken into account in the plane shape change reference. The findings obtained at the end of the study are shared in graphs. At the end of the study, it is determined that the stresses occurring in the cylinder with silicon carbide (SIC) material were more than Boron carbide (B4C). Moreover, the results are compared among themselves.

**Key words:** finite element method, Mathematical modeling, Elastic stress distribution, Boron carbide (B4C), Silicon carbide (SIC).

## 1. Introduction

The innovation of this study is very important from an engineering point of view. Rotating wipers are often used in machine parts in the air industry. The stress behavior of two different materials has been investigated. In addition, studies carried out to understand this issue have been investigated in detail. In this context, the effect of poisson's ratio on functionally graded pressure vessels was investigated in a study [1].In another study; the stresses occurring in hollow cylinders with FGM material were investigated. The radial and tangential stresses obtained at the end of the study were revealed separately. They have revealed the importance of the design of hollow cylinders [2, 3]. The stresses occurring in isotropic cylinders are shared as a table [4].

In a different study, the stresses and displacements in spherical shells made of functionally graded material

subjected to internal and external pressure were calculated and the results obtained were shared with the literature [5]. Elastic stresses in hollow cylinders and spheres were investigated by thermal stress analyses of a disk subjected to mechanical load and linearly increasing temperatures in [6, 7]. In other study, the stresses occurring in the FGM hollow disk and cylinder subjected to homogeneous internal pressure were examined [8].

Finite element method is the use of calculations, models and simulations to understand how an object may behave under various physical conditions. This method have been used recently to many problems several applied fields, such as engineering mechanics [9, 10], mathematics [11] and others [12, 13].

Different studies contributing to materials science were given respectively; Carbon laminated composite and e-glass epoxy rotary brake discs, Glass fiber reinforced polymer composites: short characterization of mechanical and thermal properties of natural fiber reinforced thermoplastic composites and improvement of wear behavior of epoxy resin with boron carbide reinforcement were investigated. The results obtained are shared with the graphs [16, 17]. In one of the studies, thermal stresses were investigated in composites with thermoplastic materials. In addition, in a different study, the mechanical functions of boron carbide material were investigated [18, 19].

It is very important to examine the elastic stresses that occur in machine parts using with this known method. Cylinders are also preferred in the field of engineering and heavy industry. Rotating cylinders are also frequently used in unmanned aerial vehicles, airplanes and the aerospace industry. In this study, two different material cylinders were determined in this context. The differences between the obtained elastic stresses were deciphered.

### 1.1. Experimental

In this section, each method is discussed in detail and step by step. It is given how these methods calculate the temperature distribution of cylinders with rotating Boron carbide (B4C) and Silicon carbide (SIC) materials. The angular velocity of the cylinder is determined as 50 rad / s. According to the analytical and FEM test results, the results of elastic stress were obtained. Three different methods are given: (i) finite element program (Ansys 2023 R1), (ii) analytical solution (mathematical modeling) and (iii) our results are compared with other studies in the literature.

### 1.2. ANALYTICAL SOLUTION

The inner radius and outer radius of the cylinder are respectively determined as 50 mm and 100 mm. The mechanical properties of boron carbide and silicon carbide cylinders to be analyzed are given in Table 1 below

**Table 1**. Displacements in the radial direction occurring inside the discs.

| No | E (Gpa) | Density ($kg/m^3$) | Inner half diameter(mm) | Outer semi-diameter(mm) |
|----|---------|---------------------|--------------------------|--------------------------|
| 1  | 460     | 2520                | 50                       | 100                      |
| 2  | 480     | 3210                | 50                       | 100                      |

### 1.3. Stress analysis in cylinders

The boundary layer on a rotating cylinder with axial flow is shown in Figure 1.

The two-dimensional equilibrium equation in cylindrical coordinates is derived from the reference [15] and the following equations are derived. Stresses were determined in radial and tangential directions. A is a coefficient, where C1 and C2 are integral constants.
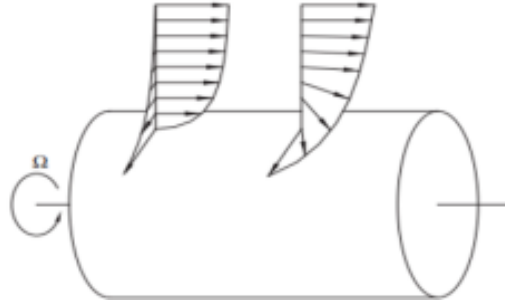
**Figure 1**. Boundary layer on a rotating cylinder with axial flow [14]

$$F = C_1 r^{(n+k)/2} + C_2 r^{(n-k)/2} + A_r^{(3+gama)} \tag{1}$$

It is obtained. Radial and tangential stresses,

$$\sigma_r = C_1 r^{(n+k-2)/2} + C_2 r^{(n-k-2)/2} + A_r^{(2+gama)} \tag{2}$$

$$\sigma_\theta = (n+k)/2 C_1 r^{(}n+k-2)/2) + (n-k)/2 C_2 r^{(}(n-k-2)/2) + (3+gama)Ar^{(}2+gama) + (P(r)w^2 r^2) \tag{3}$$

## 1.4. Results and discussion

**Table 2**. Stresses occurring in the cylinder

| Surface | n | Tangential Stress (Mpa) | ANSYS 2023 | Axial stress (Mpa) | Radial Stress (Mpa) |
|---|---|---|---|---|---|
| In (B4C) | n=-1 | 770,067 | 769,052 | 260,00 | 0 |
| Outside (B4C) | n=-1 | 119,155 | 117,275 | 40,235 | 0 |
| In (SIC) | n=-1 | 575,54 | 574,00 | 189,42 | 0 |
| Outside (SIC) | n=-1 | 89,059 | 88,77 | 29,309 | 0 |
| In (B4C) | n=-0,5 | 555.618 | 556,013 | 180,00 | 0 |
| Outside (B4C) | n=-0,5 | 85,972 | 83,714 | 29,026 | 0 |
| In (SIC) | n=-0,5 | 415,266 | 418,993 | 131,136 | 0 |
| Outside (SIC) | n=-0,5 | 64,258 | 62,007 | 21,148 | 0 |
| In (B4C) | n=0 | 380.16 | 376,146 | 135,00 | 0 |
| Outside (B4C) | n=0 | 60,335 | 19,860 | 43,966 | 0 |
| In (SIC) | n=0 | 284,130 | 285,118 | 127,62 | 0 |
| Outside (SIC) | n=0 | 43,966 | 44,747 | 14,469 | 0 |
| In (B4C) | n=0,5 | 272.17 | 85,00 | 203,818 | 0 |
| Outside (B4C) | n=0,5 | 42,195 | 41,247 | 14,246 | 0 |
| In (SIC) | n=0,5 | 203,818 | 201,885 | 98,352 | 0 |
| Outside (SIC) | n=0,5 | 31,538 | 30,975 | 11,379 | 0 |
| In (B4C) | n=1 | 190,08 | 188,44 | 69,00 | 0 |
| Outside (B4C) | n=1 | 29,411 | 26,040 | 9,931 | 0 |
| In (SIC) | n=1 | 142,065 | 140,112 | 50,424 | 0 |
| Outside (SIC) | n=1 | 21,983 | 20,552 | 7,235 | 0 |

The inner half diameter of the modeled cylinder is 50 mm and the outer half diameter is 100 mm.One of the cylinders was selected as Boron carbide (B4C) material. The material of another cylinder was determined to be Silicon carbide (SIC). At the end of the literature review, it was understood that Boron carbide (B4C) and Silicon carbide (SIC) material cylinders can be used today. Radial, tangential, axial and equivalent stress distributions were formed in cylinders consisting of hollow cylinders of two different materials subjected to angular velocity during rotation.It has been determined that the radial stress distributions in the inner and outer parts of the cylinders are zero. The tangential stresses show a decreasing distribution from the inner to the outer part of the cylinder. It occurs at the largest value of the rating parameter of the most regular distribution. the stresses formed in hollow cylinders subjected to an angular velocity of 50 rad/s are given in Figure 1-6 below. In Table 2, stress values of bronze and titanium material cylinders exposed to different angular velocities are given.

In Figure 2 below, radial stresses occurring in a titanium material cylinder rotating at an angular velocity of 50 rad/sec are given.
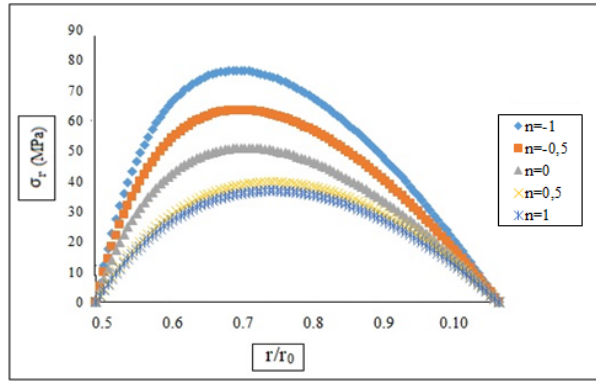


**Figure 2**. Radial stresses occurring in an angular (50 rad/sec) rapidly rotating Bor karbür (B4C) material cylinder.

In Figure 3 below, radial stresses occurring in Silicon karbür (SİC) material cylinder rotating at an angular velocity of 50 rad/sec are given.
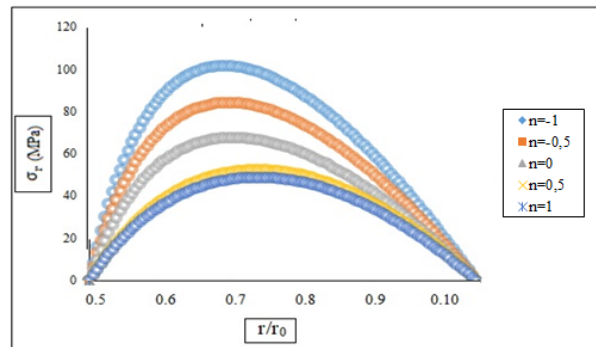


**Figure 3**. Radial stresses occurring in an angular (50 rad/sec) rapidly rotating Silicon karbür (SİC) material cylinder.

In Figure 5 below, the tangential stresses occurring in a Silicon karbür (SİC) material cylinder rotating at an angular velocity of 50 rad/sec are given.
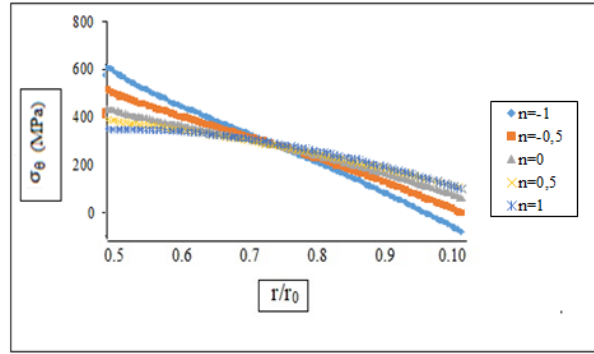
**Figure 4**. Tangential stresses occurring in an angular (50 rad/sec) rapidly rotating Bor karbür (B4C) material cylinder.
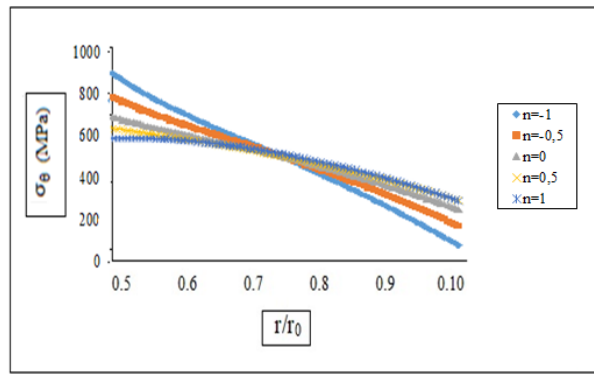


**Figure 5**. Tangential stresses occurring in an angular (50 rad/sec) rapidly rotating Silicon karbür (SİC) material cylinder.

In Figure 6 below, axial stresses occurring in a titanium material cylinder rotating at an angular velocity of 50 rad/sec are given.
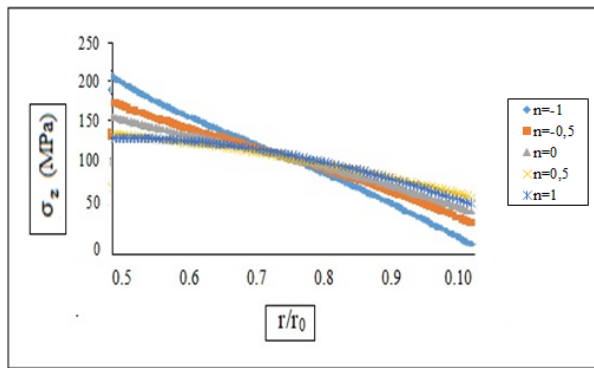


**Figure 6**. Angular (50 rad/sec) rapidly rotating titanium Bor karbür (B4C)material in the cylinder that occurs axial stresses.

In Figure 7 below, axial stresses occurring in a Bor karbür (B4C) material cylinder rotating at an angular velocity of 50 rad/sec are given.

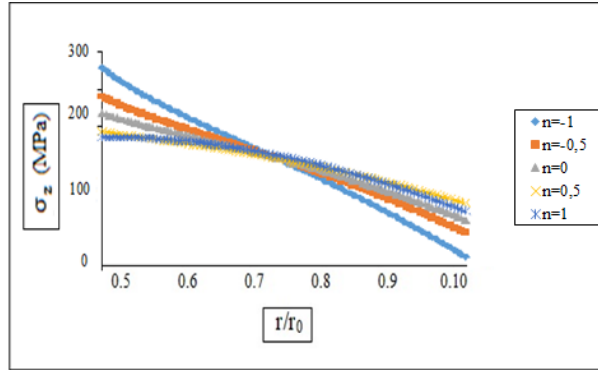In Figure 8-10 given below, the nodal points of the cylinder were modeled in the ANSYS 2023 R1 program

**Figure 7**. Angular (50 rad/sec) rapidly rotating Silicon karbür (SİC) material in the cylinder that occurs axial stresses.

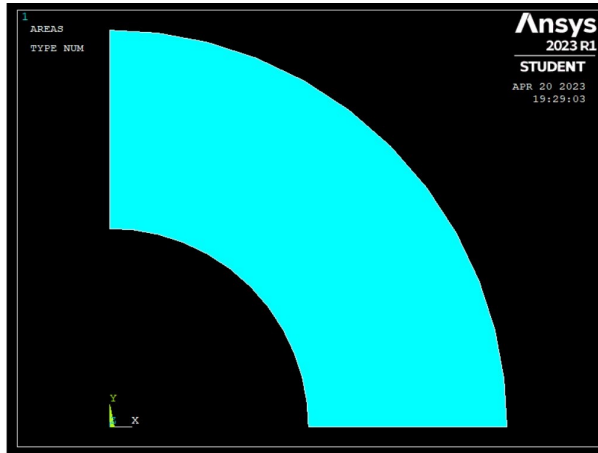and determined. In addition, the force applied to the cylinder is revealed.



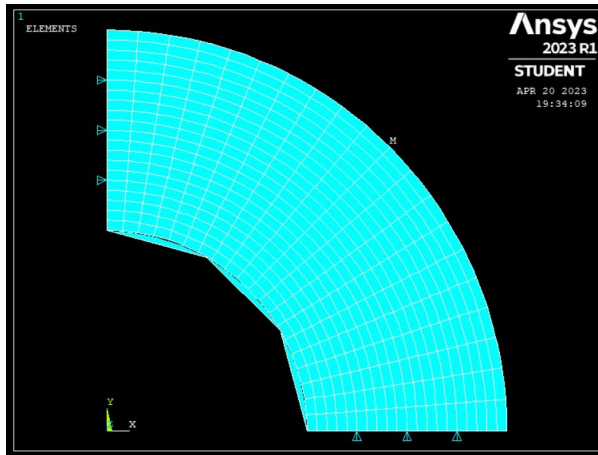**Figure 8**. Entry of the cylinder dimensions into the ANSYS 2023 R1 program.



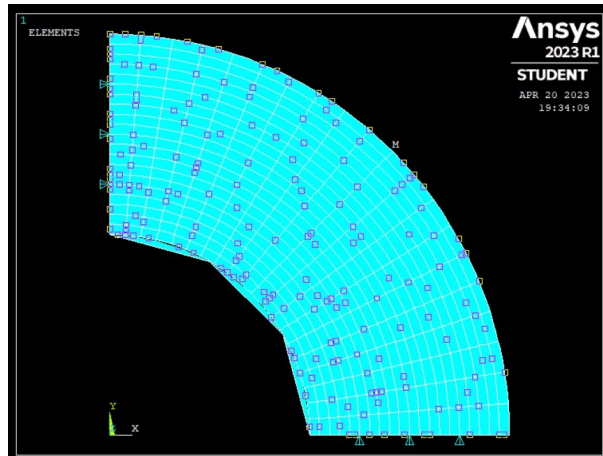**Figure 9**. Modeling of the cylinder with ANSYS 2023 R1 program.

**Figure 10**. Detection of nodal points in the cylinder.

## 2. Conclusion

In this study, the stresses occurring in hollow cylinders rotating with Boron carbide (B4C) and Silicon carbide (SIC) materials were investigated. The results obtained were compared among themselves. Dec. As a result of the researches, the radial stresses in the innermost and outermost parts of the cylinders are zero.

It is inversely proportional to the increase of the rating parameter of the stresses in the cylinders.

The tangential stresses occurring in the inner part of the silicon carbide (SIC) cylinder are approximately 33.79% greater than the stresses occurring in the Boron carbide (B4C) cylinder when n = -1 and w = 50 rad/s;

The axial stresses occurring outside the silicon carbide (SIC) cylinder are approximately 37.26% greater than the stresses occurring in the Boron carbide (B4C) cylinder when n = -1 and w = 50 rad/s; It was determined that the radial stresses were higher in the Silicon carbide (SIC) cylinder than in the cylinder with Boron carbide (B4C) material.

It has been observed that the numerical results obtained and the analytical results obtained with the ANSYS 2023 R1 program show similarities with each other. It is thought that the difference between numerical and analytical results is around 3% maximum, which can be considered as an excellent result.

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