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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

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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.

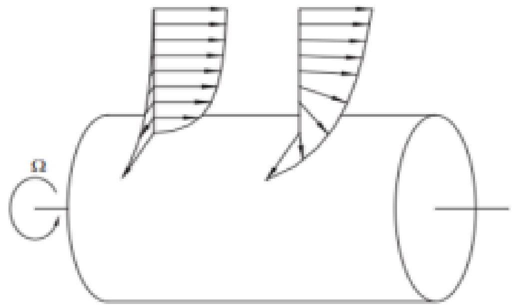

Figure 1. Boundary layer on a rotating cylinder with axial flow [14]

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

It is obtained. Radial and tangential stresses,

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

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

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.

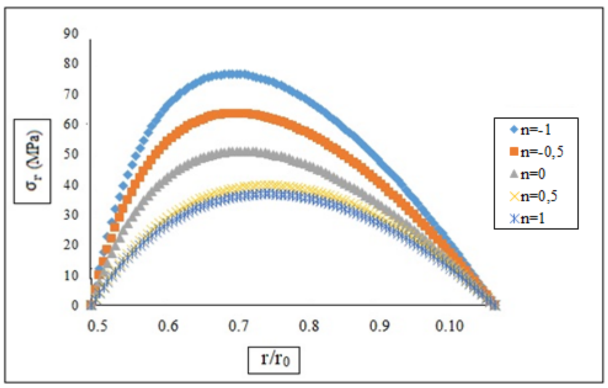

Figure 2. Radial stresses occurring in an angular (50 rad/sec) rapidly rotating Bor karbür (B4C) material cylinder.

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

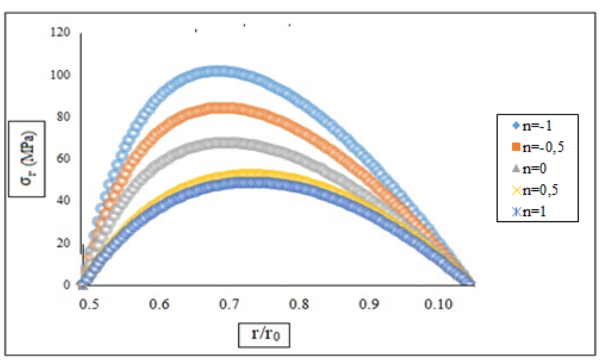

Figure 3. Radial stresses occurring in an angular (50 rad/sec) rapidly rotating Silicon karbür (SİC) material cylinder.

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.

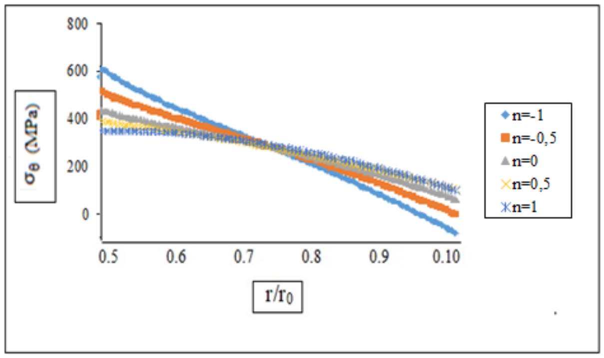

Figure 4. Tangential stresses occurring in an angular (50 rad/sec) rapidly rotating Bor karbür (B4C) material cylinder.

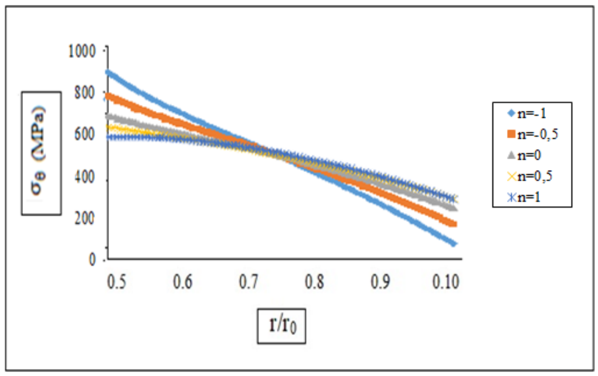

Figure 5. Tangential stresses occurring in an angular (50 rad/sec) rapidly rotating Silicon karbür (SİC) material cylinder.

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

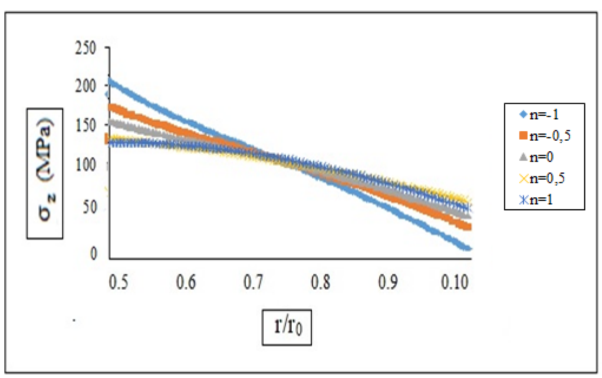

Figure 6. Angular (50 rad/sec) rapidly rotating titanium Bor karbür (B4C)material in the cylinder that occurs axial stresses.

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

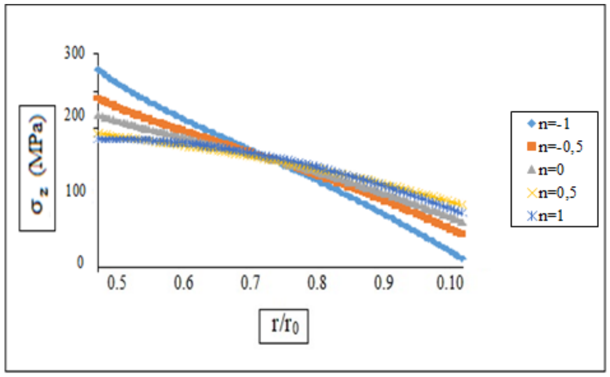

Figure 7. Angular (50 rad/sec) rapidly rotating Silicon karbür (SİC) material in the cylinder that occurs axial stresses.

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

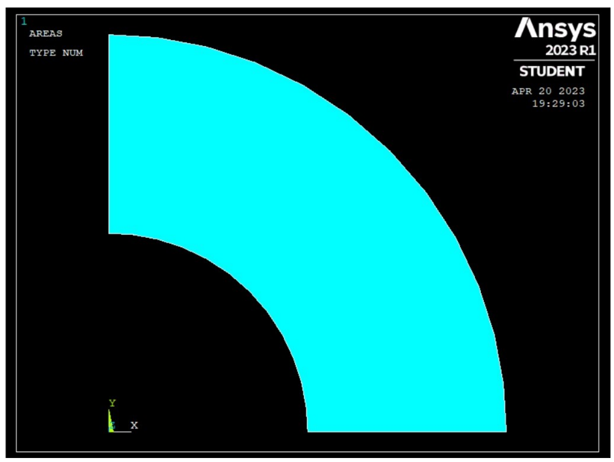

Figure 8. Entry of the cylinder dimensions into the ANSYS 2023 R1 program.

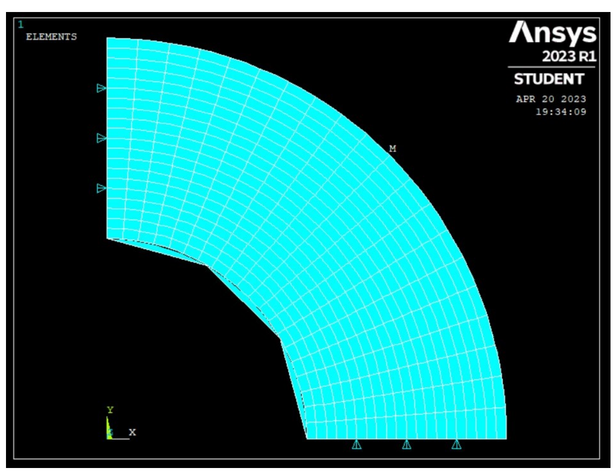

Figure 9. Modeling of the cylinder with ANSYS 2023 R1 program.

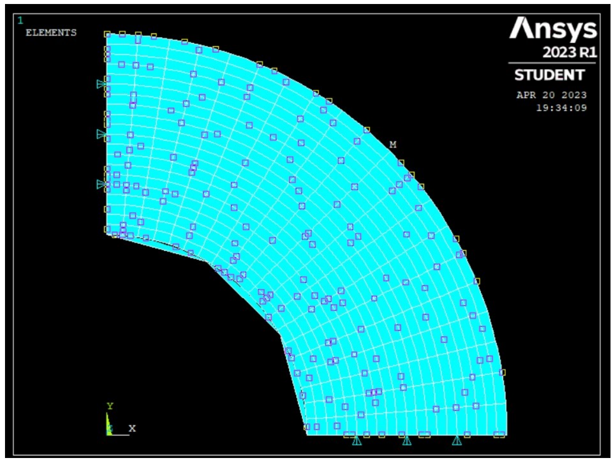

Figure 10. Detection of nodal points in the cylinder.

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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References

[1] Eker M, Semipabuc D. Generalized Thermoelastic Behavior of an Isotropic Hollow Cylinder, Turkish Journal of Nature and Science, 2022; 1:123-128.

[2] Holder N, Öztürk M. Precise solutions for stresses in functional grade pressure vessels. Composites Part B: Engineering, 2001; 32:683-686.

[3] Bosphorus C. Elastic Analysis of a Hollow Cylinder Made of Functional Grade Material Subjected to Internal Pressure, International Scientific and Professional Studies Journal, 2018; 2:56-66.

[4] Horgan CO, Chan AM. The Pressurized Hollow Cylinder or Disk Problem for Functionally Graded isotropic Linear Elastic Material, Journal of Elasticity,1999; 55:43-59.

[5] Nejad MZ, Abedi M, Lotfian MH, Ghannad M. A Definitive Solution for Stresses and Displacements of Pressurized FGM Thick-Walled Spherical Shells with Exponentially Varying Properties", Journal of Mechanical Science and Technology, 2012; 12: 4081-4087.

[6] Obata N, Noda N. Constant thermal stresses in a hollow circular cylinder and a hollow sphere of a functionally gradiated material. Journal of thermal stresses, 1994; 17:471-487.

[7] Nie GJ, Batra RC. Stress analysis and material adaptation in isotropic linear thermoelastic incompressible functionally graded rotating disks of variable thickness. Composite Structures, 2010; 92:720-729.

[8] Peng Xu-Long, Li Xian-Female. The effects of gradient on stress distribution in rotating functionally graded solid disks. J of Mechanical Science and Technology, 2012; 26:1483–1492.

[9] Kayiran HF.Numerical analysis of composite disks based on carbon/aramid epoxy materials. Emerging Materials Research, 2022; 11: 155-159 .

[10] Uçar M, Kayiran HF, Korkmaz AV. Gamma Ray Shielding Parameters of Carbon-Aramid/Epoxy Composite. Emerging Materials Research, 2022; 11: 338-344.

[11] Bulut H, Aktürk T, Uçar Y. The Solution of Advection Diffusion Equation by the .Finite Elements Method, International Journal of Basic Applied Sciences, 2013; 13:88-97.

[12] Biswal K, Bhattacharyya S. Dynamic response ofstructure coupled with liquid sloshing in a laminated com-posite cylindrical tank with baffle.Finite Elements in Analysisand Design, 2010; 11:966–981.

[13] Biswal K, Bhattacharyya S, Sinha P. Dynamic response analysis of a liquid-filled cylindrical tank with annular baffle. J of Sound and Vibration, 2004; 1:13–37.

[14] Melikhov IF, Chivilikhin SA, Popov IY. Flow on the surface of sloped rotating cylinder. Zeitschrift für angewandte Mathematik und Physik,2020; 4:1-1.

[15] Timoshenko SP, Goodier, J.N. Theory of Elasticity, 3rd Edition, McGraw Hill, New York, 1970.

[16] Kayıran HF. Rotating brake discs with carbon laminated composite and e-glass epoxy material: a mathematical modeling. I Polymer Journal, 2023; 4:457-468.

[17] Sathishkumar TP, Satheeshkumar S, Naveen J. Glass fiber-reinforced polymer composites: A review. J. Reinf Plast Composites, 2014; 33:1258-1275.

[18] Kısmet Y, Dogan A.Characterization of the mechanical and thermal properties of rape short natural-fiber reinforced thermoplastic composites. I Polym Journal, 2022; 31:14-.

[19] Tasyurek M, Duzcukoglu H. Improving the wear behavior of epoxy resin with boron carbide reinforcement. I Polym Journal, 2022; 31:169-184.