



## Numerical Analysis of Displacement of Circular Discs Based On Boron Carbide ( $B_4C$ )-Silicon Carbide (SiC) and Silicon Nitride ( $Si_3N_4$ ) Materials

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**Abstract:** In this study, the radial behavior of disks are made of different materials and increasing from the inner surface to the outer surface under temperature distribution was analyzed analytically, assuming that the modulus of elasticity does not change with temperature. The resulting calculations were supported by the ANSYS program. Boron carbide ( $B_4C$ ) is often used in the space industry in our country. The model of the first disc is the material of boron carbide ( $B_4C$ ), and the model of the materials of the second and third discs are silicon carbide (SiC) and silicon nitride ( $Si_3N_4$ ), respectively. Discs mounted on any machine part may be subject to displacement at different temperatures. Discs can show different properties according to material and different temperature. At the end of the literature research, it was observed that experimental and numerical thermal stress analyses were performed and radial and tangential stresses were calculated at different temperatures in the disks. There have been insufficient studies to examine the radial displacement behavior of the discs under different temperature effects. In different studies, metal materials such as stainless steel and aluminum were mainly investigated. The difference of this study compared to previous studies are that the size of the modelled disk diameter and the specified temperature range are close to each other. Because small diameter disks are generally preferred in the defense industry and other unmanned aerial vehicles, as well as in the space technology, where temperature change is the main factor. Therefore, boron carbide ( $B_4C$ ) and silicon carbide (SiC), which are important materials in the aerospace industry today, were calculated the displacement values of silicon nitride ( $Si_3N_4$ ) at temperatures of  $40^\circ C$   $-50^\circ C$   $-60^\circ C$   $-70^\circ C$   $-80^\circ C$   $-90^\circ C$  and shared with the literature. At the end of this numerical analysis, it was determined that the displacement value at  $40^\circ C$  on the inner surface of the boron carbide ( $B_4C$ ) material was 100.00 % higher than silicon carbide (SiC) and 157.14% higher than silicon nitride ( $Si_3N_4$ ). At the end of this study, it was concluded that it is possible to use these disc materials with high hardness and good strength.

**Keywords:** Modulus of elasticity, poisson's ratio, thermal expansion coefficient, disc, displacements.

### Bor Karbür ( $B_4C$ )-Silikon Karbür (SiC) ve Silisyum Nitrür ( $Si_3N_4$ ) Malzemeli Dairesel Disklerin Deplasmanlarının Nümerik Analizleri

**Öz:** Bu çalışmada, farklı malzemelerden yapılmış ve sıcaklık dağılımı altında iç yüzeyden dış yüzeye doğru artan disklerin radyal davranışı, elastisite modülünün sıcaklık ile değişmediği varsayılarak analitik olarak analiz edilmiştir. Elde edilen hesaplamalar ANSYS programı tarafından desteklenmiştir. Bor karbür ( $B_4C$ ) ülkemizde uzay endüstrisinde sıklıkla kullanılmaktadır. İlk diskin modeli Bor karbür ( $B_4C$ ) malzemesidir ve ikinci ve üçüncü disklerin malzemelerinin modeli sırasıyla Silisyum karbür (SiC) ve Silisyum nitrürdür ( $Si_3N_4$ ). Herhangi bir makine parçasına monte edilen diskler, farklı sıcaklıklarda yer değiştirmeye maruz kalabilir. Diskler malzemeye ve farklı sıcaklıklara göre farklı özellikler gösterebilir. Literatür araştırması sonunda; deneysel ve sayısal termal gerilme analizlerinin yapıldığı ve disklerde farklı sıcaklıklarda radyal ve teğetsel gerilmelerin hesaplandığı görülmüştür. Disklerin farklı sıcaklık etkileri altında radyal yer değiştirme davranışlarını incelemek için yeterli çalışmaların olmadığı görülmüştür. Farklı çalışmalarda, paslanmaz çelik ve alüminyum gibi metal malzemelerin ağırlıklı olarak araştırıldığı görülmüştür. Bu çalışmanın önceki çalışmalara göre farkı; modellenen disk çapının büyüklüğü ve belirtilen sıcaklık aralığı birbirine yakın olmasıdır. Çünkü küçük çaplı diskler

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genellikle savunma sanayinde ve diğer insansız hava sahası araçlarında ve sıcaklık değişiminin ana faktör olduğu uzay teknolojisinde tercih edilmektedir. Bu nedenle, günümüzde havacılık endüstrisinde önemli malzemeler olan Bor karbür ( $B_4C$ ) ve Silisyum karbür ( $SiC$ ), Silisyum nitür ( $Si_3N_4$ ) 'ün  $40^\circ C$  - $50^\circ C$  - $60^\circ C$  - $70^\circ C$  - $80^\circ C$  - $90^\circ C$  sıcaklıklarında elde edilen yer değiştirme değerleri hesaplanmış ve literatürle paylaşılmıştır. Bu nümerik analizin sonunda, Bor karbür ( $B_4C$ ) malzemeli diskin iç yüzeyinde  $40^\circ C$ 'de yer değiştirme değerinin Silisyum karbürden ( $SiC$ ) %100.00 ve Silisyum nitürden ( $Si_3N_4$ ) % 157.14 daha yüksek olduğu belirlenmiştir. Bu çalışmanın sonunda, bu disk malzemelerinin yüksek sertlik ve iyi mukavemet ile kullanılmasının mümkün olduğu sonucuna varılmıştır.

**Anahtar Kelimeler:** Elastisite modülü, poisson oranı, termal genleşme katsayısı, disk, deplasman.

## 1. Introduction

Temperature is a parameter that seriously affects the material behavior. Changes in temperature can cause undesirable deformations in materials. It is very important to know the behavior of each material against temperature for today's studies. When the thermal stresses on the discs are investigated; The stresses occurring at different temperatures on the functional graded metal material is investigated in a study [1]. They studied the radial deformations that occur in the discs [2]. Radial, tangential (circle) stresses and radial displacements in the hollow cylinder exposed to internal pressure were analyzed analytically and numerically [3]. In another study conducted; They investigated thermal stress using a genetic algorithm [4]. In a different study; the thermoelastic behavior of hollow cylinders were analyzed [5]. In different studies, thermal stress analysis was performed for two different discs subjected to parabolic increasing temperature distribution in the region from the inner surface to the outer surface of the discs. Disk-I is cast iron, Disk-II is made of ceramic material. Solution was prepared for two different discs. Considering that the modulus of elasticity does not change with temperature, the thermal stresses occurring in the radial direction of the disc were calculated [6]. In other studies; By determining the radial and tangential stresses occurring in the double material discs consisting of a boron carbide disc and Aluminum-boron carbide, Aluminum-zirconium at different temperature ranges were determined, The obtained results were shared with the literature [7-8].

In a different study, the effect of welding wire thermal expansion coefficient on residual stresses resulting from the welding process was investigated theoretically. The residual stresses resulting from the welding process of the thermal expansion coefficient of the welding wire have been investigated by taking the different welding wire as reference. At the end of the study, it is thought that the problems that may arise by improving the mechanical properties of the welding wire can be prevented [9]. In another study; The effect of non-design geometric change on the stress distribution in the connection holes of the base plates were investigated by developing a finite element model. The obtained results were shared with the literature-[10].

Numerical calculation of thermal stress analysis in machine parts makes academic studies quite easy. It is seen that there are more than one study on this subject in the literature. For example, when the studies are examined; It has been observed that the shear forces occurring in aluminum alloy are determined by numerical analysis and finite element method and the results was obtained is applicable the results which were obtained is applicable [11]. Linear-elastic stress analysis in adhesive-bonded shaft-hub connections were performed by ANSYS program. The obtained results were interpreted with graphics [12]. It is very important to analyze the radial and tangential stresses occurring in the discs. There are more than one examples of disc rotating at high speeds (gear wheel, flywheel, marine, aviation, gas turbines, gears) in engineering applications. For this reason, knowing the stress and radial displacement of rotating parts has been of major interest to researchers [13].

In the studies carried out; Elastic deformation of concave-thick solid rotating discs and parabolic-thick rotating discs were investigated. It was determined that the displacement value occurring on disks of variable thickness was greater than the amount of displacement calculated on disks of fixed thickness [14-15]. The stresses and displacements occurring in rotating circular discs of variable thickness were determined, and the stresses and displacements occurring in the double-dimensional rotating thickness discs were investigated and the results were presented in graphics [16-17]. In other studies; Time-varying stress analysis of hollow discs with different materials and functionally graded infinite-length cylinders were performed. The displacements and deformations that occurred were shared in graphics [18-19].

In a different study; considering both Dirichlet and Neumann boundary conditions; Stress analysis of a circular disc made of a functionally graded material (FGM) under the influence of thermomechanical load at different specified temperatures has been carried out. Stress analysis of brake discs were carried out by using ANSYS program [20]. In one of the two different studies; They used Cast iron, Stainless steel and Carbon-carbon composites materials to choose the optimum one against deformation, temperature and stresses for better performance. In another study; The stresses occurring in the carbon/carbon composite brake disc were investigated. The obtained results were shared with the literature [21-22]. In a different study; A three-dimensional thermoelastic stress analysis was carried out for an automobile disc brake mechanism.

According to obtained results: it was determined that the pad material properties are significantly affect the temperatures and stresses for the disc/pad pair. It has been concluded that the use of an ax material with high heat transmission coefficient, density and heat capacity can play an important role in preventing conditions such as wear and breakage by reducing the stresses on the disc [23]. The effect of friction in the disc brake system with respect to time was investigated. The obtained results were shared with the literature by using graphics [24].

On the other hands, brake discs are the part of the brake system. The brake discs, against which the brake pads rub, are part of the braking system. In this way the car can slow down properly. Brake discs are one of the most wearable parts in the automobile and these parts must be checked in certain routines. The literature review reported that there were many reasons for the damage and cracking of the Brake Discs. The most important reason for these negativities are Cracks because of the overheating and cooling. In addition, reasons such as very strong shoe pressure and the lack of maintenance of the brake system cause the brake discs to crack. Discs show different properties against temperature. Figure 1 shows the damages on the brake disc due to temperature [25].



**Figure 1.** Damaged brake disc [25].

Hassani and Gholami analytically studied stresses occurring in functionally graded rotating discs of

certain thickness [26]. Kayıran has done two different studies; The stresses in the boron carbide ( $B_4C$ ) material disc, the Aluminum-boron carbide ( $B_4C$ ) disc of different diameters, and the thermoplastic discs are reinforced with steel wires were investigated. Obtained results were calculated in agreement with the literature [27-28]. Figure 2 shows a brake disc.



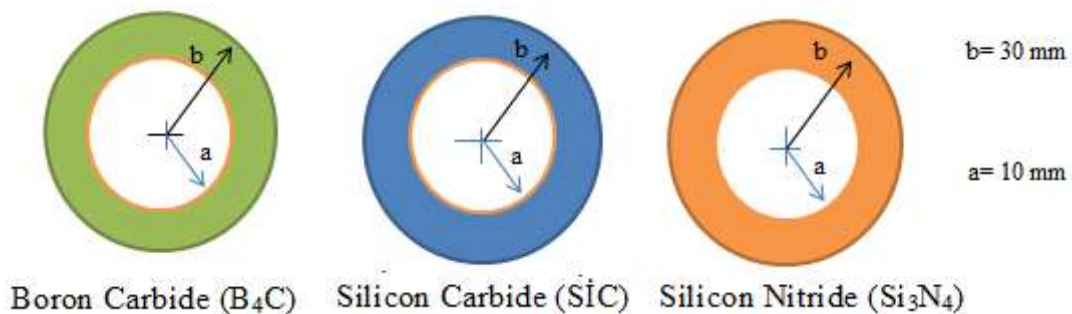
**Figure 2.** Example of brake disc

In previous studies, it was seen that the displacement changes of the discs were not considered alone, only the stresses occurring in the discs were analyzed. In this study is aimed to share the results obtained by investigating the displacements in the radial direction at the determined optimum temperatures in the discs modeled from Silicon carbide ( $SiC$ ), Silicon nitride ( $Si_3N_4$ ) materials together with Boron Carbide ( $B_4C$ ) material, which is vital in the aviation, defense and space industry in our country.

In other studies, radial displacements and stresses have been studied. In this study, only the radial displacements were the main subject of investigation. In the literature research, According to literature reviews Stress analysis is generally–in examined for some–materials such as discs and cylinders, while the radial displacements occurring in materials are not determined.

**2. Material And Method**

In this study, three independent discs were given heat load and the changes of radial displacement conditions with the effect of temperature were investigated. By performing a numerical study, the optimum temperatures were determined and the stress conditions at 40 °C, 50 °C, 60 °C, 70 °C, 80 °C, 90 °C were examined, respectively.



**Figure 3.** Showing the radius of the discs

Suitable radius for the discs are determined (fig. 3). The materials that make up the disc were selected appropriately. One of the discs consists entirely of Boron Carbide ( $B_4C$ ), the others are Silicon carbide (SiC) and Silicon nitride ( $Si_3N_4$ ), respectively.

## 2.1 Analytical Solution

For a thin disc  $\sigma_z = 0$  general equilibrium equation [29].

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

It is given in the form. In equation (1),  $r$  is the radius of the disc at any point,  $\sigma_r$  is the radial stress, and  $\sigma_\theta$  is the tangential stress. Here the disc material is taken as  $i = 1$ .

$$\varepsilon_{ri} = \frac{du}{dr} \quad (2)$$

$$\varepsilon_{\theta i} = \frac{u}{r} \quad (3)$$

Where  $u$  is the displacement in the radial direction.  $\varepsilon_r$  stands for radial strain,  $\varepsilon_\theta$  refers to the tangential strain. Strain-stress relationship (Timoshenko and Goodier, 1970);

$$\varepsilon_{ri} = \frac{1}{E_i} (\sigma_{ri} - \nu_i \sigma_{\theta i}) + \alpha_i T_r \quad (4)$$

$$\varepsilon_{\theta i} = \frac{1}{E_i} (\sigma_{\theta i} - \nu_i \sigma_{ri}) + \alpha_i T_r \quad (5)$$

$$\sigma_{ri} = \frac{F}{r} \quad (6)$$

$$\sigma_{\theta i} = \frac{dF}{dr} \quad (7)$$

in the form. If equations (6) and (7) are applied in equations (4) and (5);

$$\varepsilon_{ri} = \frac{1}{E_i} \left( \frac{F}{r} - \nu_i \frac{dF}{dr} \right) + \alpha_i T_r \quad (8)$$

$$\varepsilon_{\theta i} = \frac{1}{E_i} \left( \frac{dF}{dr} - \nu_i \frac{F}{r} \right) + \alpha_i T_r \quad (9)$$

obtained. The fitness equation for elongation;

$$r \frac{d\varepsilon_{\theta i}}{dr} + \varepsilon_{\theta i} - \varepsilon_{ri} = 0 \quad (10)$$

It is obtained that the equilibrium equation where the stress function can be defined as  $F$  and equations between (1-7) are used to obtain the general Equation (11).

$$r^2 \frac{d^2F}{dr^2} + r \frac{dF}{dr} - F = -r^2 \alpha_i E_i T_r' \tag{11}$$

Since the discs are different from each other,  $i = 1$  for each disc.  $T_0$  is the first temperature value,  $T_r'$  is the temperature value of any point in the radial direction. If  $T_r'$  is substituted in equation (11) for stress analysis;

$$r^2 \frac{d^2F}{dr^2} + r \frac{dF}{dr} - F = -r^2 E_i \alpha_i \frac{T_0}{(b - a)} \tag{12}$$

$$F = C_1 r^1 + C_2 r^{-1} + A_i r^2 \tag{13}$$

It is obtained that Radial and tangential stresses,

$$\sigma_r = C_1 + C_2 r^{-2} + A_i r = \frac{F}{r} \tag{14}$$

$$\sigma_\theta = C_1 - C_2 r^{-2} + 2A_i r = \frac{dF}{dr} \tag{15}$$

Radial and tangential stresses are written as above. Using the boundary conditions  $r = a$  for case  $r = a$  if  $\sigma_r = 0$ ,  $r = b$  for case  $\sigma_r = 0$  the integration constants,  $C_1, C_2$  and the final term  $A_i$  are determined as follows:

$$A_i = -\frac{E_i \alpha_i T_0}{3(b - a)} \tag{16}$$

$$C_1 = -A_i(a^2 + a * b + b^2)/(b + c) \tag{17}$$

$$C_2 = A_i(a^2 b^2)/(a + b) \tag{18}$$

is found as,  $u$ : radial displacement is obtained as in (19) below;

$$(U_r)_i = \left[ \frac{1}{E_i} \left( C_1 r(1 - \nu_i) - \frac{C_2}{r}(1 - \nu_i) + A_i r^3(3 - \nu_i) \right) + \alpha_i r T \right]_i \tag{19}$$

### 3. Findings And Discussion

In the study; For discs are made of Boron carbide ( $B_4C$ ) and Silicon carbide ( $SiC$ ) and Silicon nitride ( $Si_3N_4$ ), thermal stresses from inner surface to outer surface under parabolic increasing temperature distributions were investigated. The disc is fixed and its dimensions are taken as  $a = 10$  mm,  $b = 30$  mm. Solutions were prepared by using different temperature values of  $40^\circ C$ ,  $50^\circ C$ ,  $60^\circ C$ ,  $70^\circ C$  and  $80^\circ C$ ,  $90^\circ C$ , respectively. The material properties of the disc are given in table 1. The analysis result was obtained assuming that the modulus of elasticity does not change with temperature (remains constant).

**Table 1.** Mechanical properties of discs [30-31-32].

Disc No	Disc Materials	E (GPa)	$\alpha$ ( $1/^\circ C$ )	$\nu$
1	Boron Carbide ( $B_4C$ )	472	$4.4 \times 10^{-6}$	0.21
2	Silicon Carbide ( $SiC$ )	420	$9.4 \times 10^{-6}$	0.15
3	Silicon Nitride ( $Si_3N_4$ )	210	$3.6 \times 10^{-6}$	0.22

Table 2 shows the radial displacements that occur inside the discs.

**Table 2.** Displacements in the radial direction occurring inside the discs

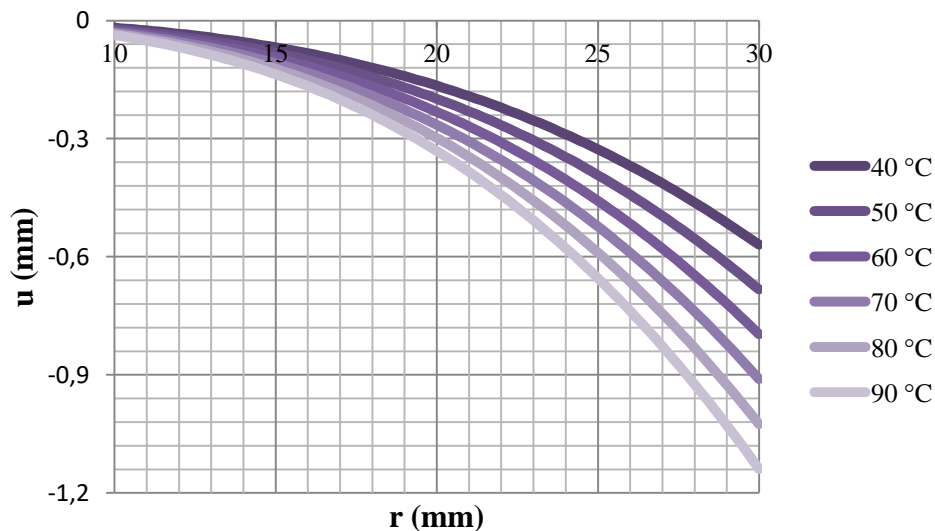
Material	r	40 °C	50 °C	60 °C	70 °C	80 °C	90 °C
<b>Boron Carbide (B<sub>4</sub>C)</b>	r=10	-0.018	-0.022	-0.026	-0.030	-0.033	-0.037
<b>Silicon Carbide (SiC)</b>	r=10	-0.009	-0.010	-0.012	-0.014	-0.016	-0.017
<b>Silicon Nitride (Si<sub>3</sub>N<sub>4</sub>)</b>	r=10	-0.007	-0.008	-0.010	-0.011	-0.013	-0.014

Table 3 shows the radial displacements that occur on the outer part of the discs.

**Table 3.** Displacements in the radial direction occurring on the outer part of the discs

Material	r	40 °C	50 °C	60 °C	70 °C	80 °C	90 °C
<b>Boron Carbide (B<sub>4</sub>C)</b>	r=30	-0.569	-0.683	-0.797	-0.911	-1.025	-1.139
<b>Silicon Carbide (SiC)</b>	r=30	-0.272	-0.327	-0.381	-0.436	-0.49	-0.545
<b>Silicon Nitride (Si<sub>3</sub>N<sub>4</sub>)</b>	r=30	-0.217	-0.261	-0.304	-0.348	-0.391	-0.435

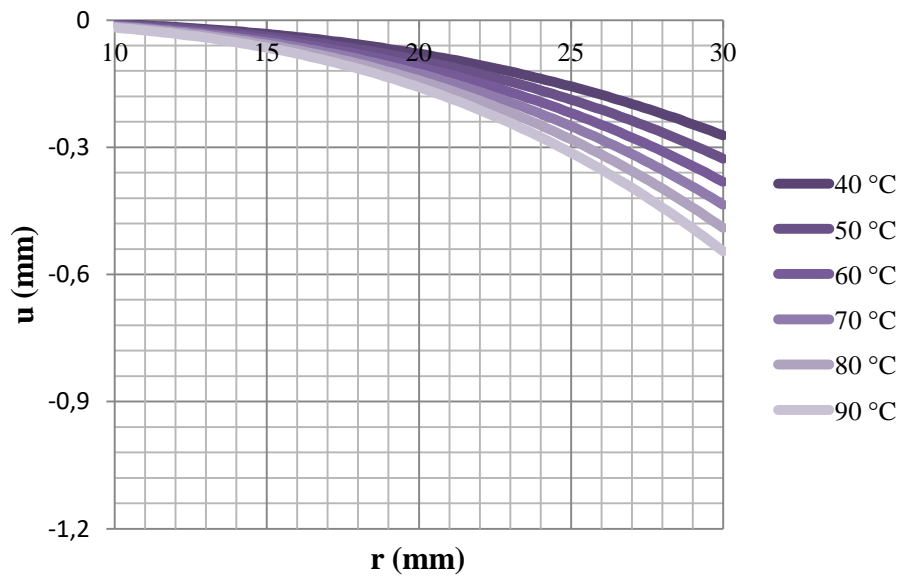
Figure 4 shows the linear increase of the temperature from the inner region to the outer part of the disc. In the case of boron carbide (B<sub>4</sub>C), there is displacements in the radial direction formed on the disc.( u= displacements)



**Figure 4.**The radial displacements of the boron carbide (B<sub>4</sub>C) disc

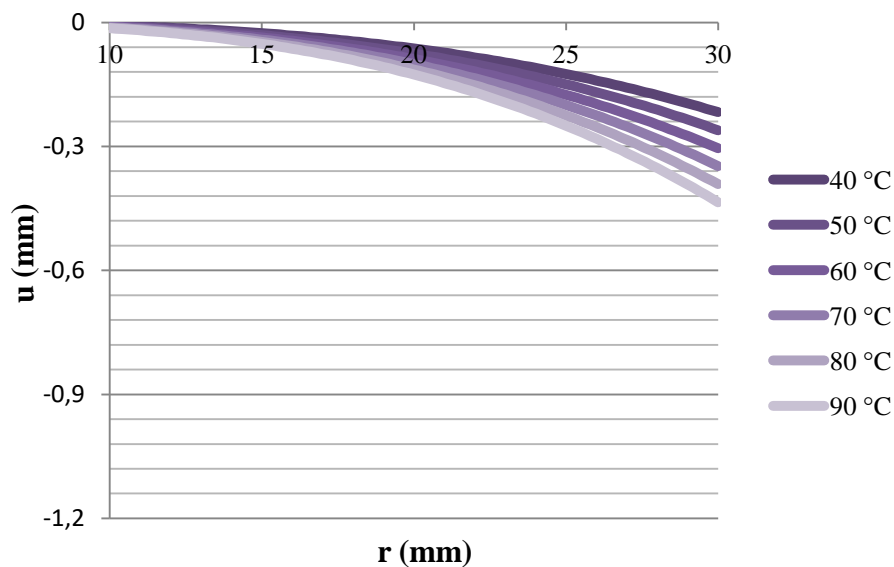
Figure 5 shows the radial stress on the Silicon carbide (SiC) disc. In the figures above, the displacements in the radial direction are given in graphs. For example, in the Boron carbide (B<sub>4</sub>C) disc, it was observed that -0.018 mm radial displacement occurred in the inner part of the disc at 40 ° C, while the radial displacement at the outer part was -0.569 mm. At 40° C, the radial displacement occurred in the inner part of the silicon carbide (SiC) disc was -0.009 mm, while the radial displacement occurred in the outer part was -0.272 mm. It has been determined that the radial displacement of the inner and outer parts of the Silicon nitride (Si<sub>3</sub>N<sub>4</sub>) disc is -0.007 mm and -0.217 mm. For high temperatures, for example, at 90 ° C, the radial displacement that occurs inside the boron carbide disc is -0.037 mm, while the silicon carbide disc displacement is -0.017 mm. For the radial displacements for the outer parts of the discs, it was observed that the radial displacement occurred on the outer part of the boron carbide disc was -1.139 mm, and the radial displacement occurred at the outer part of the silicon carbide disc was 0.545 mm. It was determined that the radial

displacement occurred in the inner and outer regions of the silicon nitride ( $\text{Si}_3\text{N}_4$ ) disc was -0.014 mm and -0.435 mm, respectively.



**Figure 5.** Radial displacements in the silicon carbide ( $\text{SiC}$ ) disc

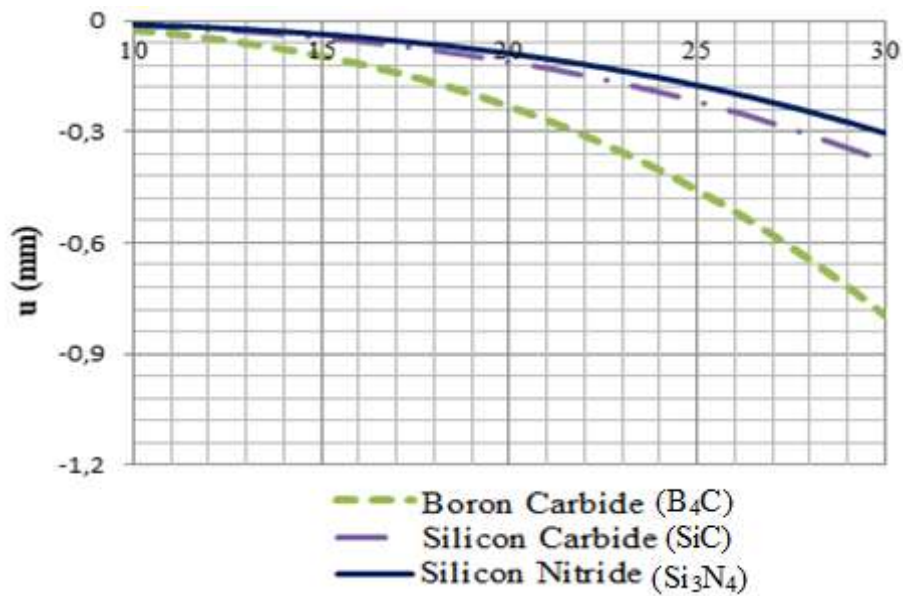
Figure 6 shows the radial stress on the Silicon Nitride ( $\text{Si}_3\text{N}_4$ ) disc.



**Figure 6.** The radial displacements in the silicon nitride ( $\text{Si}_3\text{N}_4$ ) disc

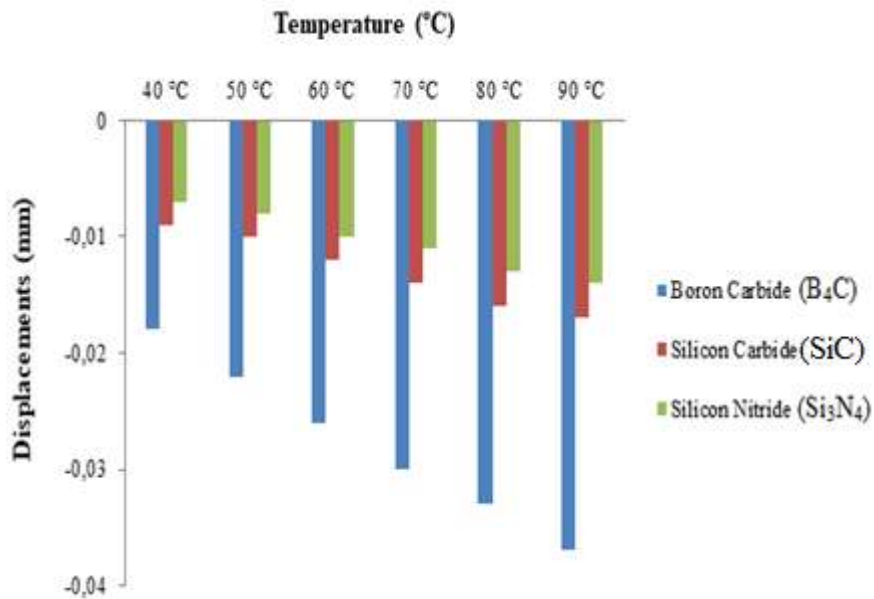
It is seen that the findings obtained in this study are compatible with those obtained in the literature study. For example; In the study conducted by Çallıoğlu and Karakaya; It has been observed that the radial displacement was obtained by assuming that the temperature decreases parabolically from the inside to the outside in the disc consisting of superimposed and isotropic material, is low at low temperatures and increases as the temperature increases. It was also observed that the displacement increased linearly [33]. This study is compatible with the studies in the literature. In a different study, stresses and radial displacements occurring in the disks were analyzed. The results calculated in this study were similar [33-34-35]. In Figure 7, radial displacements occurring in all materials for 60 ° are shown in a single graphic.





**Figure 7.** Displacement of discs at 60 ° temperature

In Figure 8, the displacement values occurring on the inner surface of the discs are given in the graphic.



**Figure 8.** Displacement values occurring on the inner surface of the discs

In Figure 9, the displacement values occurring on the outer surface of the discs are given in graphics. In Figure 10, radial displacements occurring at temperatures of 40 °C and 90 °C are given in a single graph. (Region of discs  $R=14.8$  mm to  $R=15.2$  mm) . The radial displacement is obtained from ANSYS commercial finite elements analysis program and their numerical results are depicted in Figures 11 to13.

It is seen that it is compatible with the results of the ANSYS aspect analysis for all disc materials. In another study by Callioglu; It is concluded that the displacement of a disc on the outer surface is greater than the displacement on the inner surface. Similar results emerged in this study; It has been observed that the radial displacement on the inner surface of the disc is less than the displacement on the outer surface of the disc [36].

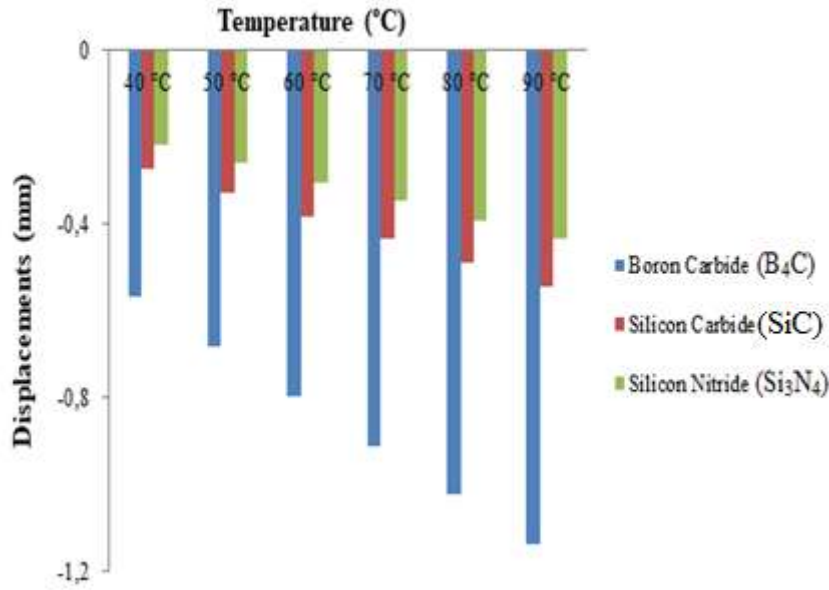


Figure 9. Displacement values occurring on the outer surface of the discs

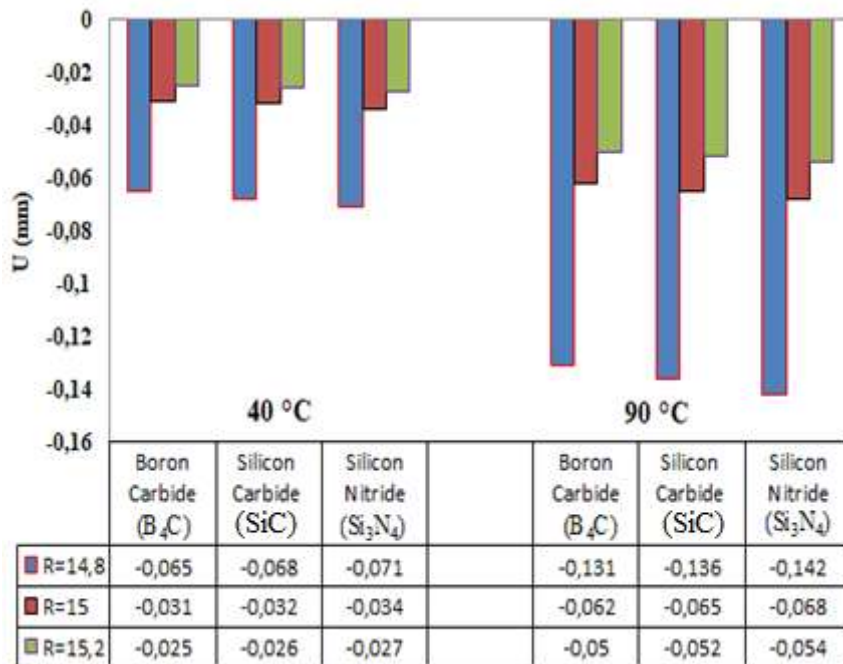


Figure 10. Radial displacements occurring at temperatures of 40 °C and 90 °C (Region of discs R=14.8 mm to R=15.2 mm)

In a different study by Ondurucu and Kayıran; radial, tangential stresses and displacements in the radial direction were investigated numerically for the bimaterial disc exposed to linear decreasing temperature. At the end of the research; It was concluded that significant decreases occurred between the radial displacements due to material change in the discs and the radial displacement occurred in the aluminum material was 51.86% higher than the cast iron material. In addition, it was concluded that the radial displacements that occur when the elasticity modulus changes with temperature, decreases according to the radial displacements when the modulus of elasticity remains constant with temperature [37].

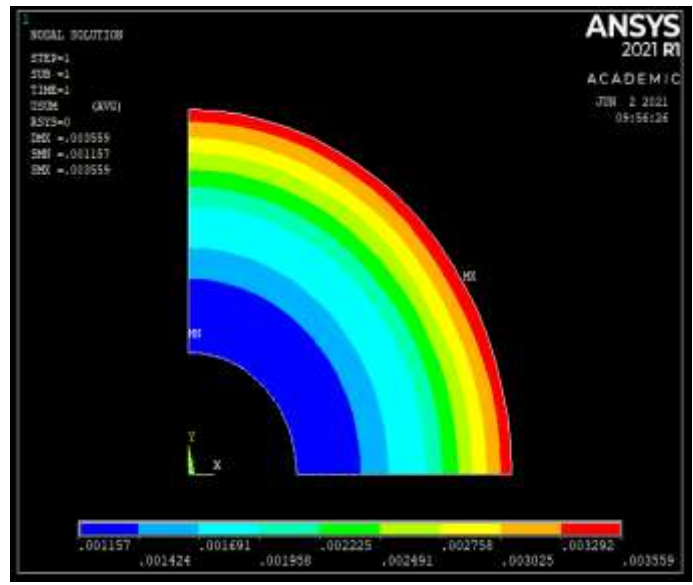


Figure 11. Radial displacement was obtained from ANSYS Code ( $B_4C$  disc)

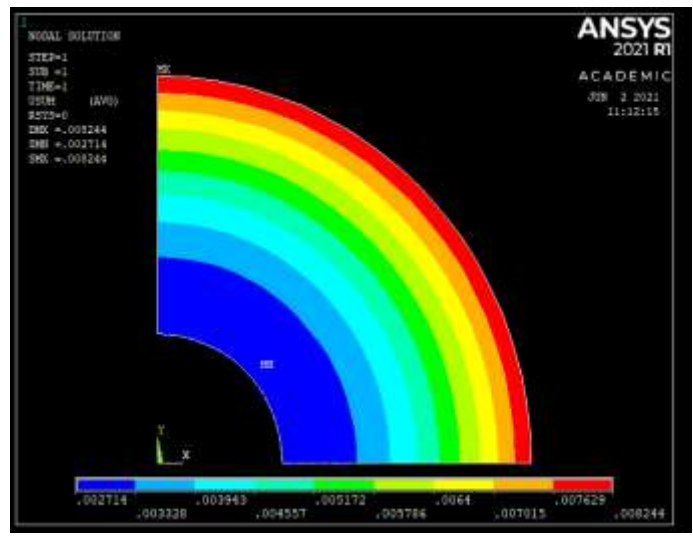


Figure 12. Radial displacement was obtained from ANSYS Code ( $SiC$  disc)

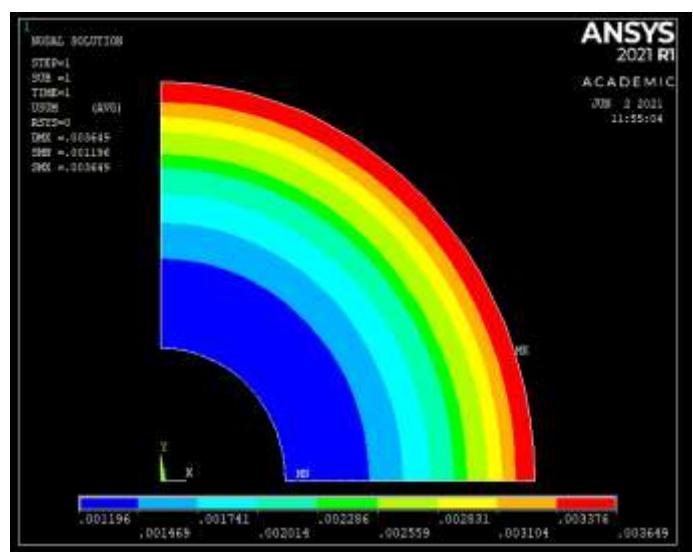


Figure 13. Radial displacement obtained from ANSYS Code ( $Si_3N_4$  disc)

It is seen that disc materials are frequently used differently, especially in brake systems. Disc materials are in general; They are manufactured from Aluminum, titanium, aluminum matrix composites, ceramic and cast iron materials. In these materials, However, Al-MMK materials are widely used in brake systems, some problems could not be prevented. Al-MMK-is widely preferred as a brake disc material, which has a heating problem between the matrix material and the reinforcement material. Another obstacle in this regard is; shown as a cost issue Another obstacle is that its cost [38-39-40-41].

In this study, it was determined that the hardness ratio of Boron carbide ( $B_4C$ ) was higher than Aluminum and showed better mechanical properties. In addition, Boron carbide ( $B_4C$ ) exhibits high wear resistance. On the other hand, SiC material, a high thermal shock resistance and thermal conductivity. SiC is not as hard as Boron carbide ( $B_4C$ ), it has more hardness than metallic materials such as Aluminum. Silicon nitride ( $Si_3N_4$ ); material, on the other hand, SiC has an ideal composition of material properties. These materials are as light as silicon carbide (SiC) and also exhibit impact and shock resistance thanks to their excellent thermal shock resistance and high hardness. It is thought to be used as disc material [42-43-44-45].

## 5. Conclusion and Recommendations

Since the elasticity modules and thermal expansion coefficients of the materials forming the discs are different, the radial displacements (displacements) are different from each other.

1. It was concluded that the maximum absolute displacements are on the outer surface of the disc, while the minimum absolute displacements are on the inner surface of the disc.
2. It was concluded that the disc material directly affects the displacements that occur on the disc.
3. It was observed that when the temperature in the disc increases linearly from the inner region of the disc to the outer region, the radial displacements increase as compression stress.
4. For example, at 40 °C, the radial displacement value was calculated in Boron Carbide ( $B_4C$ ) material in the middle part of the discs ( $R=15mm$ ) was calculated to be 109.67% higher than the displacement calculated in Silicon Carbide (SiC) material, and 160.00 % higher than the displacement value occurring in silicon Nitride ( $Si_3N_4$ ) material disc. In the same region: it was determined that the radial displacement in Silicon carbide (SiC) material was 24.00 % greater than the displacement in silicon Nitride ( $Si_3N_4$ ) material disc.
5. For example; At 50 °C It was determined that the displacement value occurring at the innermost part of the Boron Carbide ( $B_4C$ ) disc-was 120 % higher than the Silicon Carbide (SiC) disc.
6. It was determined that the displacement value occurring at the outer part of the Boron Carbide ( $B_4C$ ) disc was 175% higher than the Silicon Carbide (SiC) disc.
7. It was determined that the displacement value occurring at the innermost part of the Boron Carbide ( $B_4C$ ) disc was 25% higher than the Silicon Nitride ( $Si_3N_4$ ) disc.
8. For example at 90 ° C; It was determined that the displacement value occurring at the outermost part of the Boron Carbide ( $B_4C$ ) disc was 108.99 % higher than the Silicon Nitride ( $Si_3N_4$ ) disc.
9. It was determined that the displacement value of the inner part of the Silicon Carbide (SiC) disc was 161.83% higher than the silicon nitride ( $Si_3N_4$ ) disc.
10. It was determined that the displacement value occurring at the outermost part of the Silicon Carbide (SiC) disc was 25.28% higher than that of the Silicon Nitride ( $Si_3N_4$ ) disc.
11. It was observed that the displacements (displacements) occurring in the radial direction increased as the temperature increased.

In this study, the displacements in the radial direction occurring in the disc with Boron carbide ( $B_4C$ ) material were higher than that of Silicon carbide (SiC) and Silicon Nitride ( $Si_3N_4$ ), and also the displacements occurring in the Silicon carbide (SiC) disc are compared to the Silicon Nitride ( $Si_3N_4$ ) disc. It is concluded that there is more.

It is concluded that it may be common to design durable discs subject to less displacement by choosing the appropriate material.

Since the hardness of Boron carbide ( $B_4C$ ) was higher than Silicon carbide (SiC) and Silicon nitride, the radial displacement is thought to be higher. It is thought that the amount of hardness of the material and the radial displacement can be related inversely.

In this study; Thanks to the combination of good tribological properties and excellent hardness properties of Boron carbide ( $B_4C$ ), Silicon (SiC) and Silicon nitride ( $Si_3N_4$ ) selected as disc material; light and very sensitive bearings are thought to be ideal for use in bearing applications of heavy vehicles and automotive components exposed to high pressure. In general, the disc materials used in this study were found to be more applicable than other metallic and composite materials used in the literature. It is believed that this study will be a reference to other studies in the form of the study of radial displacements occurring in discs.

### Authors' Contributions

HFK carried out the study and wrote up the article.

### Competing Interests

The authors declare that they have no competing interests.

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