Thermal stress analysis of teeth exposed to parabolic increasing temperature distribution

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1. Introduction

Stress analysis of machine elements according to temperature Temperature is very important for the behavior of the material. Temperature changes can cause unwanted stresses on machine parts due to negative stresses. In this case, permanent damage to the machine part is possible. In structured iterative screening; thermal stress analysis and thermal analysis.

The thermal stresses of the brake discs were investigated and it was concluded that there were cracks in the disc at high temperatures and the temperature was a very important parameter [1]. In another study, they determined the stresses at high temperatures determined for rotating discs [2]. The effect of different temperatures on the composite disk was investigated [3]. In a study conducted by Kayıran (2012), thermal stress analysis in a bimaterial disc consisting of two different materials was analyzed analytically. The results were compared with the literature [4]. In another study, they performed thermal stress analysis of metal matrix composite disc under the effect of uniform temperature [5]. In a different study he made, he made thermal stress analysis of a disc and shared his results with the literature. [6]. In the study conducted by Kayıran and Öndürücü (2018), the radial and tangential stresses occurring in the cast iron and ceramic disc under parabolic increasing temperature distribution from the inner surface to the outer surface of a disc were investigated [6]. In a study conducted by Pan and Cai, (2018), thermal stress analysis of the ventilated disc brake based on the moving heat source was examined [7]. Discs are used in aviation industry, especially in areas that vary according to the temperatures they work in, which facilitate energy and human life. In this study, three different discs are considered and it is necessary to conduct thermal stress analysis on a disc exposed to heat effect. It was assumed that the temperature from the inner surface to the outer surface of the discs increased parabolically.

Disc-1 was determined as aluminum (6061-T6), disc-2 silicon carbide, disc-3 titanium. It was assumed that the temperature from the inner surface to the outer surface of the discs increased parabolically. The results obtained by making solutions for all three discs were determined in tables and graphs.

2. Body of abstract

In this study, thermal stress analysis was performed for three different discs subjected to increasing parabolic temperature distribution in the region from inner surface to outer surface of aluminum (6061-T6), titanium and silicon carbide discs. Assuming that the modulus of elasticity does not change with temperature, the stresses in the radial direction of the discs are obtained. It was concluded that the stresses occurring in aluminum (6061-T6) disc were higher than the stress values of silicon carbide and titanium and discs, stresses occurring in silicon carbide disc were more than stresses in titanium disc, it was concluded that the mechanical properties of the selected material effected the stresses exactly. .

3. MATERIALS AND METHODS

In this study, by applying heat load which has parabolic increasing function on three different discs, the changes of radial, tangential and radial displacement conditions formed by discs are investigated numerically. Thermal stress analysis was performed for 50 ° C, 100 ° C, 150 ° C, 200 ° C, 250 ° C. Figure 1 shows a disc subjected to thermal stress analysis.

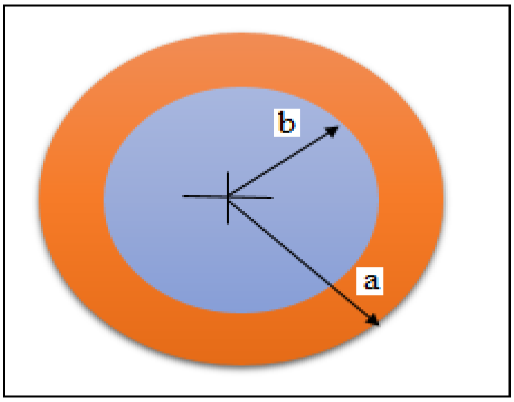

Figure 1. A disc subjected to thermal stress analysis

3. Equations, figures, and tables

$\sigma_z = 0$ general equilibrium equation for a thin disk [8].

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

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

$$\varepsilon_{ri} = \frac{du}{dr} \tag{2}$$

$$\varepsilon_{\theta i} = \frac{u}{r} \tag{3}$$

Here u is the displacement in the radial direction. ε_r denotes radial deformation, ε_θ denotes deformation in the tangential direction. Strain-stress relation [8].

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

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

$$\sigma_{ri} = \frac{F}{r} \tag{6}$$

$$\sigma_{\theta i} = \frac{dF}{dr} \tag{7}$$

It shaped. (6) and (7) are applied in equations (4) and (5);

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

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

obtained. Eligibility equation for elongation;

$$r\frac{d\,\varepsilon_{\theta i}}{dr} + \varepsilon_{\theta i} - \varepsilon_{ri} = 0 \tag{10}$$

as obtained. The general equation (11) is obtained by using the equilibrium equation (1-7) in which the stress function can be defined as F.

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

as obtained. The general equation (11) is obtained by using the equilibrium equation (1-7) in which the stress function can be defined as F.

$$T_r = T_0\frac{(a^2 - r^2)}{(a^2 - b^2)} \tag{12}$$

$$\frac{dT}{dr} = \frac{2rT_0}{(b^2 - a^2)} \tag{13}$$

If T_r' 'is substituted in equation (11) for stress analysis

$$r^2\frac{d^2F}{dr^2} + r\frac{dF}{dr} - F = -r^2E_i\alpha_i\frac{-2rT_0}{(a^2 - b^2)} \tag{14}$$

$$F = C_1r^1 + C_2r^{-1} + A_ir^3 \tag{15}$$

as obtained. Radial and tangential stresses,

$$\sigma_r = C_1 + C_2r^{-2} + A_ir^2 = \frac{F}{r} \tag{16}$$

$$\sigma_\theta = C_1 - C_2r^{-2} + 3A_ir^2 = \frac{dF}{dr} \tag{17}$$

Radial and tangential stresses are written as above In the case of $r = a$, in the case of r=b $\sigma_r = 0$ using the boundary conditions, the integration constants C_1, C_2 and the final term Ai are determined as follows:

$$A_i = -\frac{E_i\alpha_iT_0}{4(b^2 - a^2)} \tag{18}$$

$$C_1 = -A_i(a^2 + b^2) \tag{19}$$

$$C_2 = A_i(a^2b^2) \tag{20}$$

Table.1 Mechanical properties of discs (Aerospace Specification Metals Inc, 2019, Periodictable, 2019, International Syalons, 2019)

Discs	Disc materials	Elasticity Module (GPa)	Thermal Expansion coefficient ($1/°C$)
Disc-1	Aluminum	68,9	13x10-6

	6061-T6		
Disc-2	Titanium	116	8.6x10-6
Disc-3	Silicon Carbide	360	4,9x10-6

Figure 2 shows the radial and tangential stresses that occur on the Aluminum 6061-T6 disc.

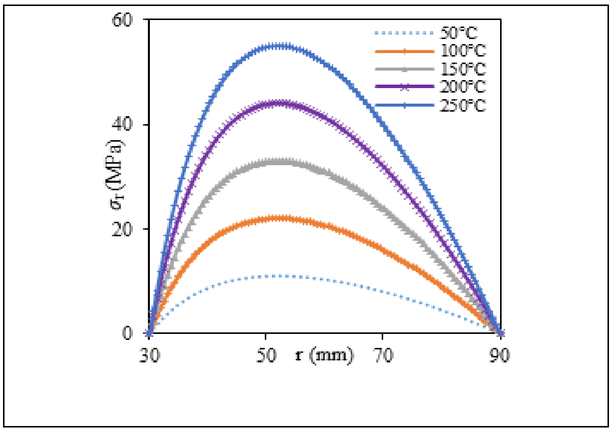

Fig.2 Radial stresses on the aluminum 6061-T6 disc

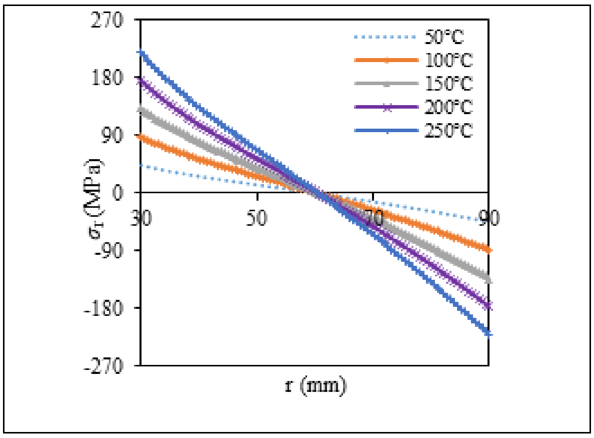

Fig.3 Tangential stresses on the aluminum 6061-T6 disc

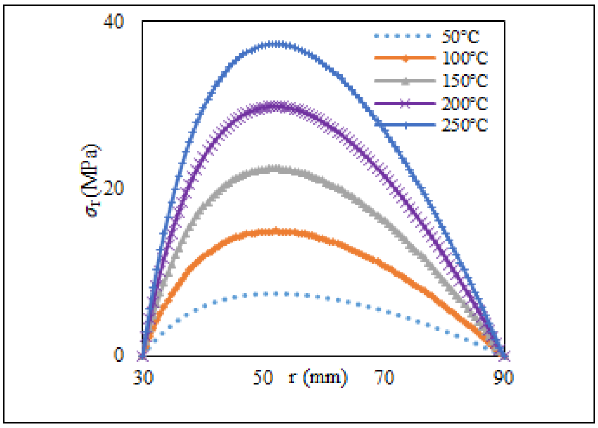

Fig.4 Radial stresses in silicon disc4

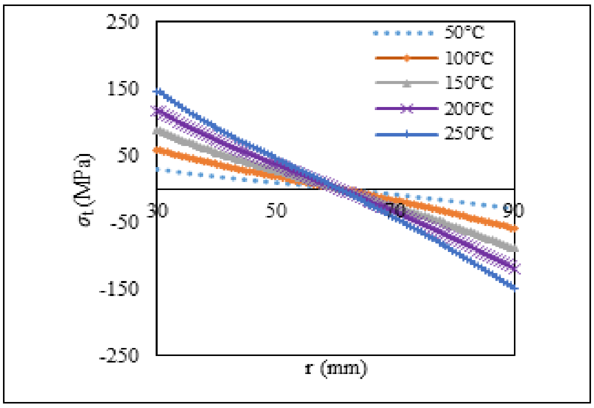

Fig.5 Tangential stresses on silicon disc

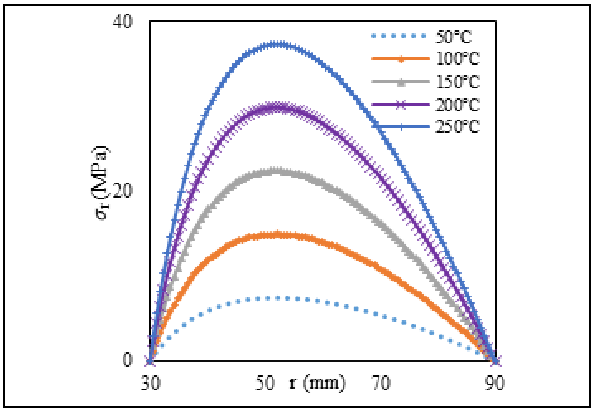

Fig.6 Radial stresses in titanium disc

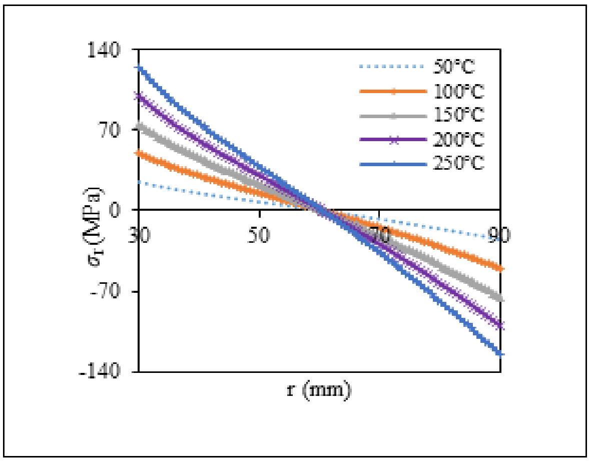

Fig.7 Tangential stresses on titanium disc

As it can be seen from the figures, it has been found that the radial and tangential stresses of the different materials are different from each other

Table.2 Stresses when the modulus of elasticity does not change with temperature

Temperature	Radial	Disk1 (Aluminum	Disc 2 Silicon Carbid	Disc-3 (Titanium)	For both discs

(° C)	surface of the disc	6061-T6)	e		
		σt (MPa)	σt (MPa)	σt (MPa)	σr(MPa)
50	İnner	44,10	29,85	24,94	0
	Outer	-44,10	-29,85	-24,94	0
100	İnner	88,20	59,71	49,88	0
	Outer	-88,20	-59,71	-49,88	0
150	İnner	132,30	89,57	74,82	0
	Outer	-132,30	-89,57	-74,82	0
200	İnner	--176,40	119,42	99,76	0
	Outer	-176,40	-119,42	-99,76	0
250	İnner	220,50	149,28	124,70	0
	Outer	-220,50	-149,28	-124,70	0

As can be seen in Table 2, the tangential stress at Disk-I at 50 ° C was determined as 44.10 MPa as the tensile stress at the innermost part of the disk and -44.10 MPa as the compressive stress at the outermost part of the disk. For Disc-II, the tangential stress is 29.85 MPa as the tensile stress at the innermost part of the disc, and -29.85 MPa as the compressive stress at the outermost disc, 24.94 MPa as the tensile stress at the innermost part of the disc, The compression stress on the outermost part of the disc was -24.94 MPa. The tangential stress at Disk-I at 50 ° C was determined to be 220,50 MPa as the tensile stress at the innermost part of the disc, and -220.50 MPa as the compressive stress at the outermost part of the disc. For Disc-II, the tangential stress is 149.28 MPa as the tensile stress at the innermost part of the disc, and -149.28 MPa as the compressive stress at the outermost disc, 124.7 MPa as the tensile stress at the innermost part of the disc, The compression stress on the outermost part of the disc was -124.70 MPa. At 250 ° C, the tangential stress in Disk-I was found to be 47.70% higher than Disk-II and 16.46% higher than Disk-III.

4. RESULTS

As a result of this study, the following results were obtained:Aluminum 6061-T6, Silicon Carbide and titanium disc forming materials have different modulus of elasticity and thermal expansion coefficients.It has been observed that radial stress, tangential stress and displacement in radial direction increase with increasing temperature. Tangential stresses for three different discs were found to be larger than radial stresses. At different temperatures, the radial stress is zero at the innermost and outermost part of the disc. Radial stresses are in the form of tensile stress, tangential stresses in the form of tensile stress from the inner part of the disc to the middle region, compression stress from the middle to the outer region. Radial stresses have the highest value in the regions near the inside of the disc. The tangential stress in the outermost region of the aluminum disk was found to be 47.71% higher than Silicon carbide and 76.82% higher than Titanium. The tangential stress occurring in the inner region of the silicon carbide disc was found to be 19.71% higher than Titanium carbide. The radial displacements occurring in the outermost part of the aluminum disc were approximately 173.3% compared to the silicon carbide disc and 36.66% more than the titanium. The radial displacements occurring on the outermost part of the silicon carbide disc were found to be approximately 100% relative to the titanium disc. With this study, it can be concluded that Aluminum 6061-T6 disc is more resistant to thermal stress than silicon carbide disc and silicon carbide disc is more resistant than titanium disc

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