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# Working Range Optimization of Bearing Discs with 3 Axis Dynamic Testing

Talha İkbal Çığır [1*], Adem Erdem[1], Melih Hakan Samur [1], Hasan Savat[1] and Taragay Miraç Akgül[1]

[1]*AYD Automotive Industry Inc, R&D Center, Konya-Selçuklu, Türkiye*

[*]*cigir.talha@aydtr.com*

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***Abstract*** – All motor vehicles must have braking systems to stop and stabilize the vehicle. Brakes are systems that control the movement of vehicles, slow them down, stop them or fix their position by absorbing kinetic energy. The main parts of the braking system of automobiles are the brake disc, brake pad, piston and brake caliper. Brake discs are a widely used brake type in the automotive field due to their ease of getting rid of heat and providing the same braking torque in both directions of rotation. In this study, the durability and life test of the bearing and hub part of the bearing discs with 3-axis dynamic test is the subject. Test parameters were determined by examining the operating conditions of the brake discs under the vehicle. Dynamic testing was carried out by applying axial, radial and rotational axis loads according to real under-vehicle conditions. During the test, instant cracks, errors and temperatures were monitored. Axial and radial load was given by hydraulic actuators, and rotational movement was given by the engine. In the test system, load and distance limits were defined for the hydraulic actuators, ensuring that the system would stop in case of any error. During the test, load and distance data were monitored and recorded. The temperature monitoring of the bearing and hub section was done via laser sensors. Temperature data measured with laser sensors were collected by taking data second by second. A limit of 99 °C has been placed on the temperature system. If the temperature of the hub and bearing section exceeds 99 °C, the system stops. Axial and radial loads were also recorded in the system second by second and data was collected. 6 samples were tested. According to the test data, the maximum temperature was determined as 41.2 °C and the average temperature was 38.3 °C. In this study, the effect of loads on bearing discs under real under-vehicle conditions was examined. As a result of the tests, all 6 samples completed the test without any errors. Thus, the suitable working range of the part is optimized. In the next process, different bearings will be tested and compared.

*Keywords – Brake System, Disc with Bearing, Dynamic Test, Hub, Laser Temperature Sensor*

## I. INTRODUCTION

Although disc brakes are not a new design, they did not become common for use in passenger vehicles until the 1960s. At that time, many vehicles used drum brakes on the front and rear wheels. Disc brakes began to become standard equipment in domestic vehicles in the 1970s. Since then, disc brakes have become standard equipment for most vehicles sold today. Disc brakes for the front wheels have become standard on all passenger cars and light trucks. The use of disc brakes for the rear wheels has also become widespread. If disc brakes and drum brakes are compared, advantages such as resistance to brake fade, faster shedding of water from friction surfaces and self-cleaning of dust debris can be mentioned. The disadvantage of drums is that they require significant force to compress the pads against the brake rotor. This force requirement causes the driver's effort to slow down and stop the vehicle to increase. Due to this disadvantage, a power assist system must be used to reduce driver effort in vehicles with disc brakes. Disc brakes are similar to each other in terms of operating system. Generally, pressurized brake fluid forces the caliper piston out of the caliper bore, which puts pressure on the brake pads. Two brake pads are compressed against the disc, as shown in Figure 1.1. The pads pressing on the disc create friction and heat. This friction force slows down the disk, and the slowing down of the disk slows down the wheel and tire. The heat is dispersed by spreading into the air.

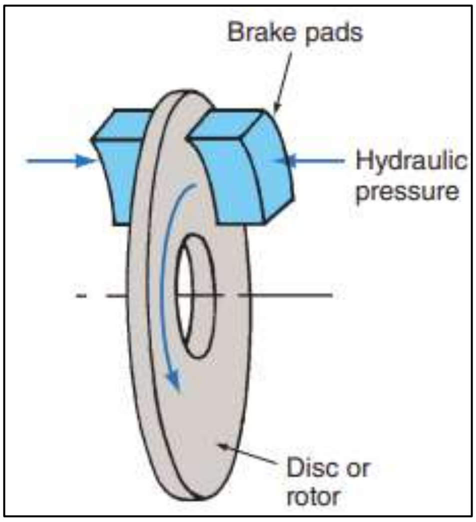


Figure 1.1 Basic Working Principle of Disc Brake System

Friction components; It consists of two main elements: disc and pad. Rotors, also called brake discs, are mounted in the hub and rotate with the wheels. Since the caliper clamps the brake pads to the rotor, significant friction occurs between the pads and the rotor. This friction is the force that slows the wheel and also causes the intense heat produced by the brakes. Due to braking stress and heat generated, brake rotors must be manufactured to be strong and resistant to high operating temperatures.

The most common brake discs are discs produced by the casting method and have two friction surfaces separated by ventilation holes. Air channeled brake discs are produced as high-performance discs and have holes or channels of different shapes on them. They were first tested in racing cars in the 1960s [1].

Antanaitis and Rifici opened 90 circular channels on a brake disc and achieved a change and increase in the heat transfer on the disc from 8.8% to 20.1%, depending on the vehicle speed. At the same time, thanks to these holes, the gas resulting from the burning of the pad dust formed between the disc and the pads is expelled. However, when braking in wet conditions, these holes prevent the formation of a water film between the disc and the pads, thus removing water particles from these areas and ensuring a drier braking process. Discs with air cooling channels crack over time due to the stresses on them. However, it also causes the amount of wear on the brake pads to increase. However, despite all this, it also increases the slowing and stopping performance of the vehicle [2].

When the pads are pressed against the rotor, heat is generated on all surfaces of the rotor. As the rotor rotates, air is drawn through the ventilation holes to remove and dissipate heat from the friction surfaces and cool the rotor. Front brake rotors in today's passenger cars and light commercial vehicles generally consist of ventilated discs.

Non-ventilated solid discs, such as the rotor in Figure 1.2, can be found on the rear wheels of some vehicles or the front wheels of older model vehicles. Since the rear brakes do less work than the front brakes, solid discs can be used in the rear.

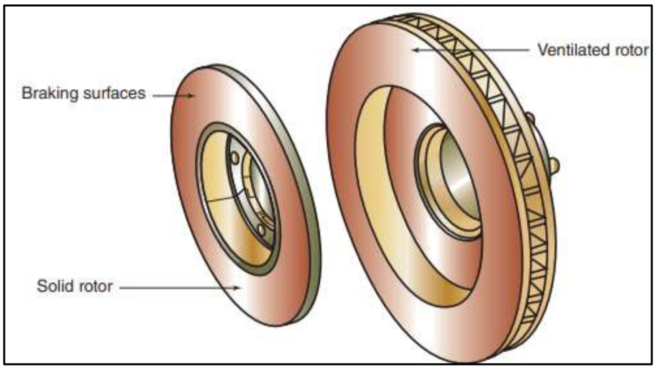


Figure 1.2 Solid Disc and Vented Disc Example

During the braking process, the kinetic energy of the vehicle is converted into heat energy. And approximately 90% of this energy is stored as heat energy in the brake discs. Some of this energy is transferred to the environment. Solid discs without cooling channels carry out this heat transfer process slowly. Brake discs with cooling channels cool this heat transfer faster thanks to the air circulation in the internal channel structures [3].

It has been determined that the heat transfer coefficients of brake discs with cooling channels are twice as high as those of solid discs [4].

Bearing discs are called discs that have a bearing inside the disc. The basic working principle of these discs is that the inner ring of the bearing is fixed by means of a nut and the outer ring rotates with the disc. One of the main elements tested in this study is the bearings in the roller discs. Another main element is the part of the disc called the hat part.

## II. Materials and Method

The technical drawing and rendering image of the brake disc test sample used in the study are given in Figure 2.1. In order to understand more clearly the points tested in this study, a simple image devoid of bearing assembly is given in the technical drawing.

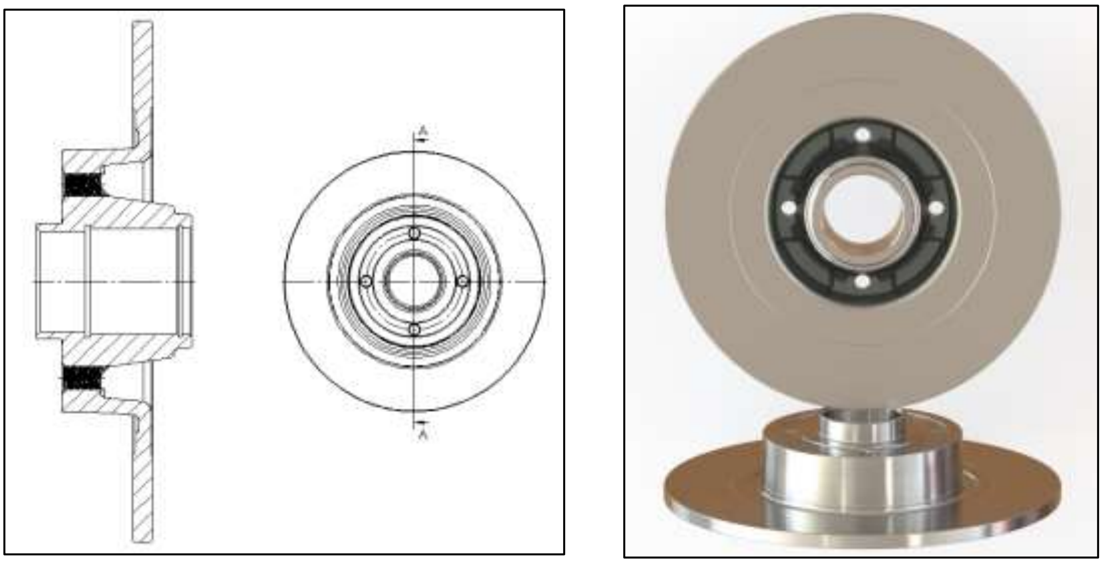

Figure 2.1 Technical Drawing and Render Images of the Test Sample

### A. *Test System and Parameters*

The main purpose of the testing system is to test the bearing in the disc and the durability of the disc hub. It was designed for this purpose. As a result of the research, it was decided to apply axial, radial and rotational forces in the test system. In the test system, two hydraulic actuators, 1 rotation motor, 1 engine rpm adjustment screen, 1 system cooling fan, 1 laser temperature sensor to instantly capture the bearing temperature, and 1 temperature recording screen to record and monitor temperature data were used. .

The hydraulic actuators used in the test system can perform up to 50 kN force and 15 Hz frequency. The rotation motor can reach 600 rpm rotation power. The design of the test system was designed in 3D in the SolidWorks program. The 3D design image is given in Figure 2.2.

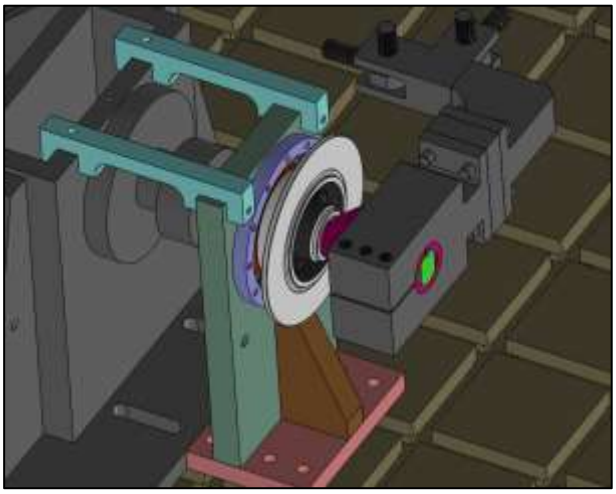

Figure 2.2 3D Image of the Test System

After the 3D design was completed, the production of the apparatus to be used in the test system started. In order to get accurate results from the test, 2379 cold tool steel was preferred in the material of the apparatus. After the production of the apparatus was completed, the assembly of the test system began. After the installation was completed, system runout was measured using a comparator. When the secretion decreased to 0.03, the assembly of the test system was completed. The general state of the test system and the elements used in the test system are given in Figure 2.3.

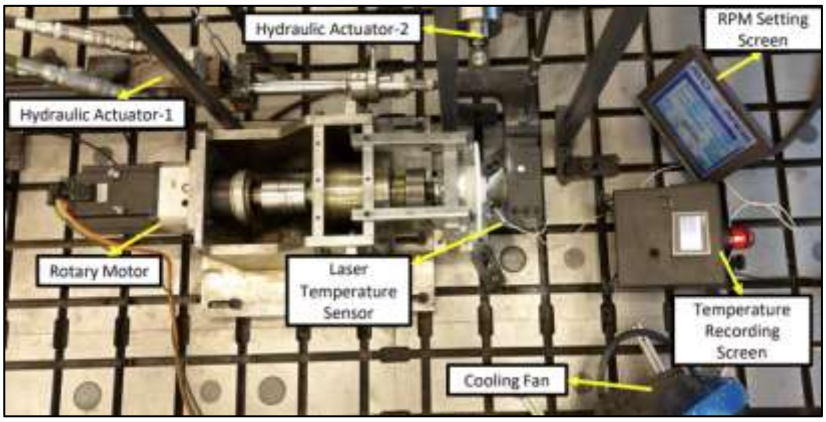


Figure 2.3 Test System Equipment

In the test system, the forces to be applied to the disk and bearing were calculated. In line with the calculations, an axial load of 4.688 kN, a radial load of 7.414 kN and 400 rpm were applied on the rotation axis. The representation of the test parameters is given in 2.4.

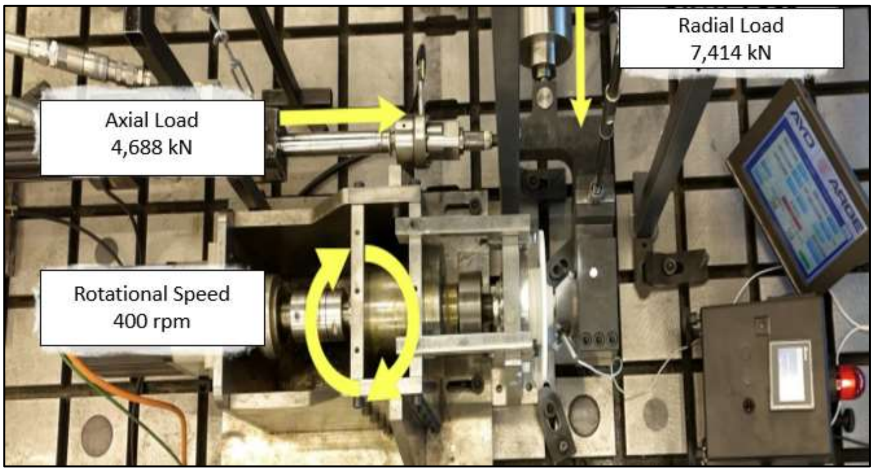


Figure 2.4 Test Parameters

A test plan was created using the determined parameters. The radial load was kept constant throughout the test, taking into account the movements under the vehicle. The axial load operated with a nine-second load cycle. The engine rotated continuously at 400 rpm. A test plan was prepared for 10,000 cycles. The test plan is given in Table-1.

Table 1. Test Plan

| | **Action** | **Axial Load** | **Radial Load** | **Time (seconds)** |
|---|---|---|---|---|
| **1** | Free Rotation | 0 | 0 | 10 |
| **2** | Axial and Radial Load Increase from 0 | 33% | 33% | 15 |
| **3** | Axial and Radial Constant Load | 33% | 33% | 150 |
| **4** | Return to 0 | | 0 | 5 |
| **1** | Free Rotation | 0 | 100% | 9 |
| **2** | Axial Load Increase from 0 | 0-100% | 100% | 1 |
| **3** | Constant Radial Load | 100% | 100% | 9 |
| **4** | Return to 0 | 0 | 100% | 1 |
| | Free Rotation | 0 | 0% | 10 |

## III. Results

The graph obtained during the test is given in Figure 3.1. All 6 parts have successfully completed 10,000 cycles.

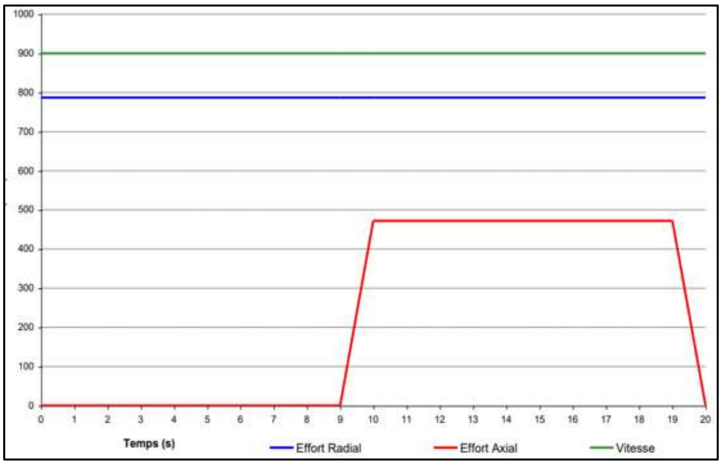


Figure 3.1 Test Instant Data Graph

At the end of the test, only a small amount of oil leakage occurred in the disc bearings. The general photo after the test is given in Figure 3.2, the front surface photos after the test are given in Figure 3.3, and the back-surface photos after the test are given in Figure 3.5.

Figure 3.2 Post-Test General Image

During and after the test, the disc was sprayed to identify any small cracks or breaks. Apart from this, the test system is set to stop itself if the smallest limit is exceeded. No cracks or defects were found on the front surface.

Figure 3.3 Front Surface Photos After Testing

In the dynamic tests, all 6 samples successfully completed their tests and no defects were found on their front surfaces, as seen in Figure 3.3.

Figure 3.4 Back Surface Photos After Testing

In dynamic tests, all 6 samples completed the tests successfully and no defects were found on their back surfaces, as seen in Figure 3.4.

## IV. DISCUSSION

If we talk about the test photos added in the findings; There was no error in the bearing or discs. In previous studies, parameters such as instant monitoring and recording of bearing temperature could not be applied. Thanks to this study, temperature, load and millimeters were monitored. This test system can be used to compare different bearings in future studies.

## V. CONCLUSION

In this study, the testing of 6 discs samples was completed. No errors occurred in the tests, except for a small oil leak in the disc bearings. The highest temperature was determined as 44.3°C and the average temperature was 37.8°C. In this way, the testing of discs and bearings has been completed.

## ACKNOWLEDGMENT

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