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Durability Study of Subway Brake Disc and Wheel-type Brake

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지하철의 브레이크 디스크와 차륜방식브레이크의 내구성 연구

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ABSTRACT

In this study, as part of the subway braking system, the structural analysis was performed with the fatigue analysis by comparing subway brake disc and wheel-type brake. When structural analysis was performed, it was possible to verify that the wheel-type brake were higher than the brake discs in case of total deformation. As the same loading conditions were given to the subway brake disc and wheel-type brake, wheel-type brakes was shown to have more deformation than brake disk but lower damage than the subway brake disc. Comparing with each fatigue loading condition, the maximum fatigue life for 'Sample history' is found to be about 60 times longer than for 'SAE bracket history'.

Keywords : Wheel Type Brakes(차륜방식브레이크), Disc(디스크), Structural Analysis(구조해석), Fatigue Loading Condition(피로하중조건), Fatigue Life(피로수명), Durability(내구성)

1. Introduction

There are now several types of brake discs on the market. There are many different shapes and various types of places to be mounted. But the purpose is the same. The brake discs and brake pads work together by friction. In case of unning subway, the wheels have rotating energy. In order to stop or lower the rotation, the brake disc and pad cause friction which is converted from friction energy to heat energy. In this paper, we compared several types of discs used on the market with the brake discs used on the subway train with the wheel-type brakes. ANSYS program was used to analyze which type of shape is ideal or good for each application. We can investigate and understand what is vulnerable to the brake disc. There are the different types of subway brake disc and wheel-type brake in car and the brakes at the subway have been familar used for public transportation. By doing this research, we may understand the reason why vibration is so loud and noisy when the subway slows down. This approach is also useful because it is similar to the one used in automobile. The results of this study show that the brake disc

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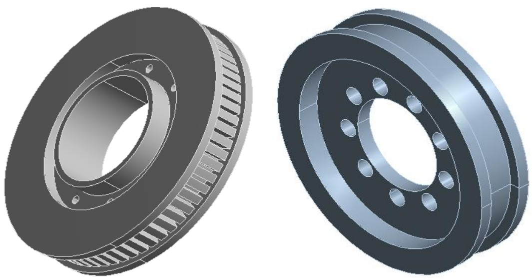
method is less deformed but more damaged than the wheel-type brakes, so the design is thought to help the durability increase[1~9].

2. Result of This Study

2.1 Research models

In this paper, since the brake discs and wheel-type brakes for subway are braking by the brake pads coming into contact with the wheels directly, the wheel is modeled by using CATIA program and forces and moments are applied to the brake discs of two models to investigate and analyze the structural changes of the models. The models were designed to almost match the size of the wheel with the actual subway brake disc. The difference between the shapes of metro brake disc and wheel-type brake is clearly different from the visual view, the subway brake disc has a hole and is tight inside. It can be verified that both sides are exactly alike, and the wheel-type brake comes into contact with into the wheel, so the operation is significantly different. In this paper, the models are designed with the CATIA program. Through ANSYS program, the structural analysis is carried out when force or moment is applied and the safety and fatigue life are obtained by the fatigue analysis. The actual configurations of models 1 and 2 are (a) and (b) of Fig. 1. Fig. 2 are shown as the meshes of models 1 and 2.



(a) Subway brake disc (b) Wheel-type brake

Fig. 1 Models of subway brake disc and wheel-type brake

(a) Mesh of disc (b) Mesh of wheel

Fig. 2 Meshes of subway brake disc and wheel-type brake

Table 1 Material properties

Item	Values
Compressive yield strength	250 MPa
Poisson's ratio	0.3
Young's modules	2×10^5 MPa
Tensile Ultimate strength	460 MPa
Density	7850 kg/m^3
Tensile yield strength	250 MPa

Table 2 Numbers of elements and nodes at models

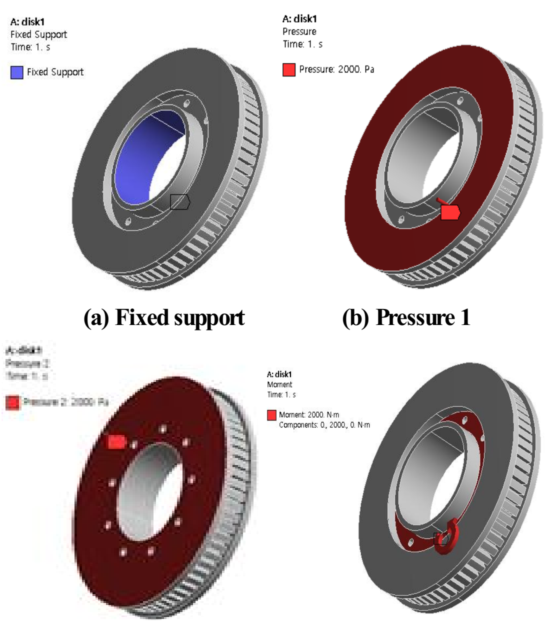
Model	Nodes	Elements
Subway brake disc	94373	55698
Wheel-type brake	87129	50097

Table 1 shows the material properties of cast steel and Table 2 shows the numbers of elements and nodes by model[10~12].

2.2 Analysis conditions

2.2.1 Constraint condition for disc

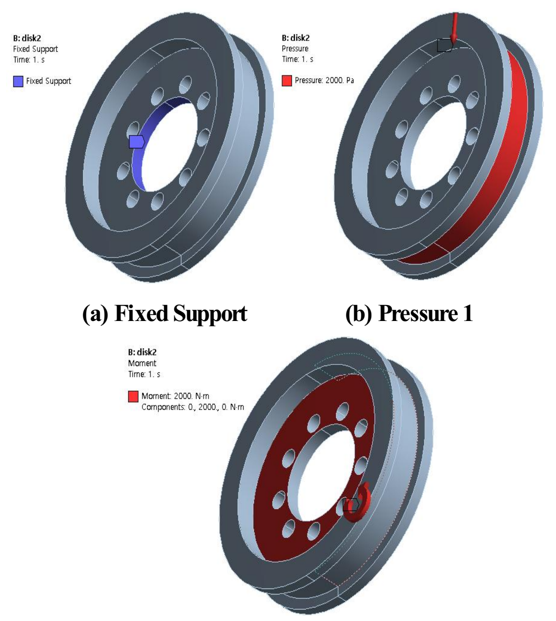
As brake pad tightens up wheel, the part come in contact with on the wheel axle is fixed. The constraint condition is shown at Fig. 3 (a), The pressure and moment are applied at brake at braking



(a) Fixed support (b) Pressure 1

(c) Pressure 2 (d) Moment

Fig. 3 Constraint condition of subway brake disc



(a) Fixed Support (b) Pressure 1

(c) Moment

Fig. 4 Constraint condition of wheel-type brake

as shown by Figs. 3 (b), (c) and (d). Because the forces applied on both sides of the brake discs for subway are almost equal, both sides are applied with the same pressure of 2000 Pa as Figs. 3 (b) and 3 (c). The moment of 2000 N·m by the wheel rotation is applied to the disk model as shown by Fig. 3 (d).

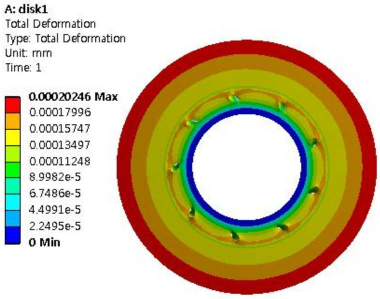
2.2.2 Constraint condition for wheel

In case of wheels, the part come in contact with the axis of subway is fixed as shown by Fig. 4 (a) like the subway brake disc. The pressure of 2000 Pa is applied on the contact area of the pad as shown by Fig. 4 (b). In addition, the moment of 2000N·m is applied to the part where the axis rotation force is given as shown in Fig. 4 (c).

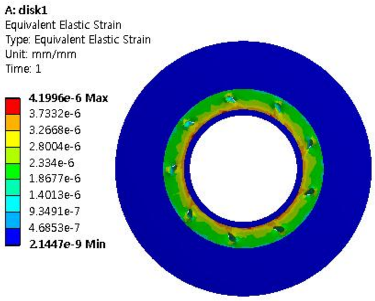
2.3 Analysis results

2.3.1 Structural analysis result

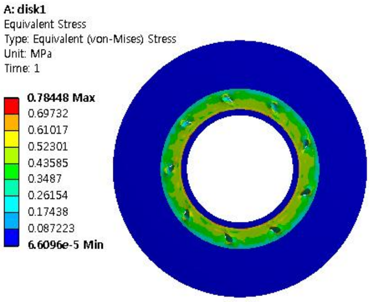
As shown in Fig. 5 and Fig. 6, the contours of total deformation, equivalent elastic deformation, and equivalent stress are shown respectively in cases of the disc and wheel. At Fig. 5, the disc shows a maximum total deformation of 0.00020246 mm, a maximum equivalent elastic strain of 4.199610×10^{-6} mm/mm, and a maximum equivalent stress of 0.78448 MPa. At Fig. 6, the wheel shows a maximum total deformation of 0.0010329 mm, a maximum equivalent elastic strain of 7.5228×10^{-6} mm/mm and a maximum equivalent stress of 1.4935 MPa. These values make it easier to compare the wheel-type brake discs with the wheel-type brakes. Since the disc has a maximum total displacement of 0.0010329 mm, the wheel-type brake discs are approximately 20 times more deformed than the subway-brake discs. In addition, the maximum equivalent elastic deformation of disc is 4.1996×10^{-6} mm/mm and the maximum equivalent elastic deformation of the wheel is about 7.5228×10^{-6} mm/mm, resulting in a difference of approximately two times. And the wheel will be given by a



(a) Total deformation

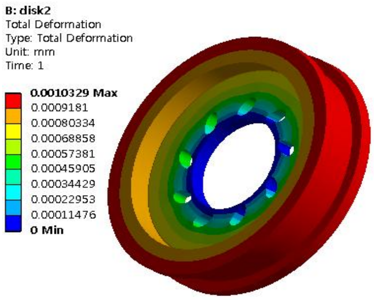


(b) Equivalent Elastic Strain

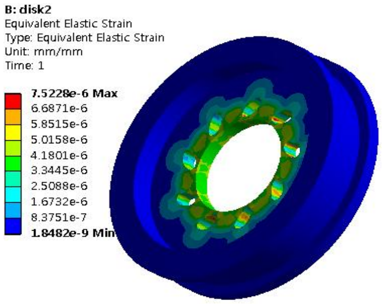


(c) Equivalent Stress

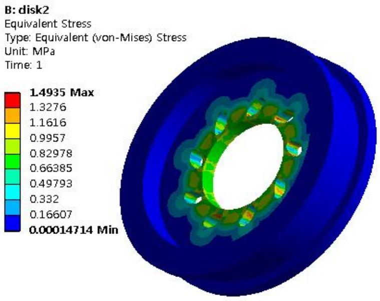
Fig. 5 Structural analysis of subway brake disc



(a) Total deformation



(b) Equivalent Elastic Strain



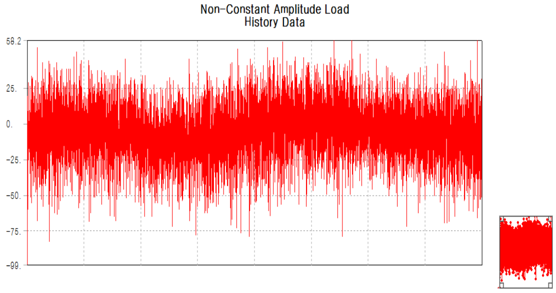
(c) Equivalent Stress

Fig. 6 Structural analysis of wheel-type brake

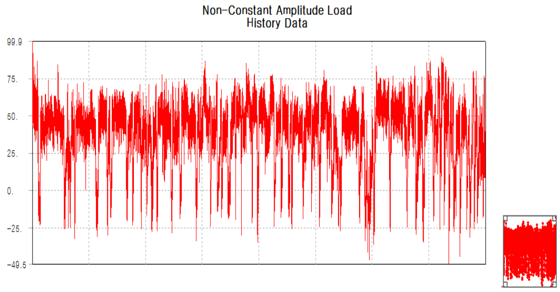
maximum equivalent stress about twice as high as the disc. These study results at two models show that there are a lot of applied force and a lot of damage to the axle parts of wheel, regardless of the subway brake disc or wheel, which indicates that the friction surface when the brake pads hold the wheel remains as it is but the parts attached to the axle will given by a lot of force[13~15].

2.3.2 Result of fatigue analysis

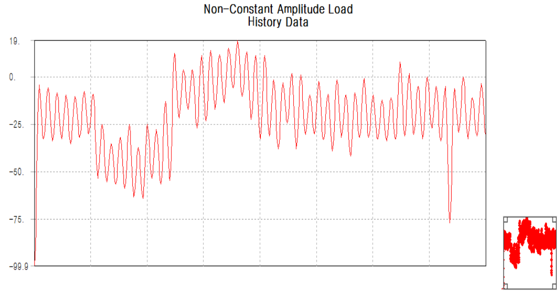
The boundaries of the model are the same as those of Fig. 3 and Fig. 4. The fatigue results at the wheel in cases of subway brake disc and wheel-type brake are analyzed. Fig. 7 shows the stress amplitudes about one cycle and three kinds of fatigue loads are used as shown by Fig. 7. At Fig. 7, SAE bracket is the worst fatigue loading condition on rail. SAE transmission is the condition used in bad load on rail and the sample history is



(a) SAE bracket history

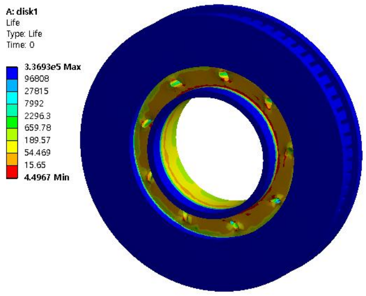


(b) SAE transmission

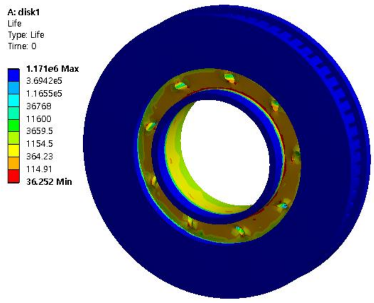


(c) Sample history

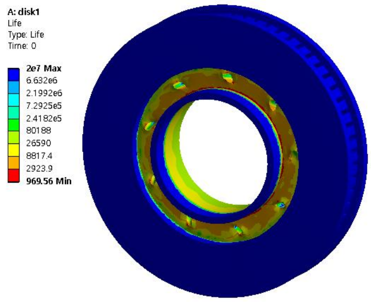
Fig. 7 Fatigue loading history



(a) SAE bracket history



(b) SAE transmission



(c) Sample history

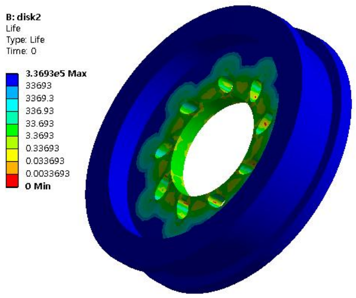
Fig. 8 Fatigue lives of subway brake disc

the good condition used in moderate load on rail.

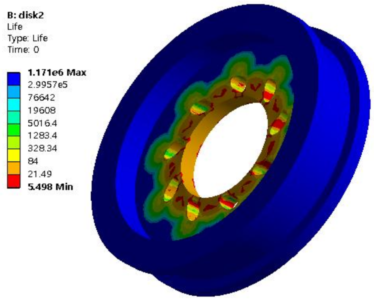
Fig. 8 and Fig. 9 show the contours for fatigue lives about three kinds of fatigue loads in cases of subway brake disc and wheel-type brake respectively. Fig. 8 shows the shortest maximum life of 3.3693×10^5 Cycles under the severe worst loading condition of‘SAE bracket’and the longest life of 2.0×10^7 Cycles is shown under the moderate loading condition of ‘Sample History'. In the case of Fig. 9, the same maximum fatigue lives are also shown as in case of Fig. 8. By Comparing with each fatigue load, the maximum fatigue life for 'Sample history' is found to be about 60 times longer than that for 'SAE bracket history'.

3. Conclusion

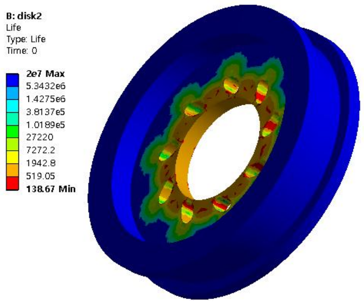
By designing the two configurations of the subway brake disc and the wheel-type brake, the structural analysis and fatigue analysis are performed in this



(a) SAE bracket history



(b) SAE transmission



(c) Sample history

Fig. 9 Fatigue lives of wheel-type brake

study and the following results are derived;

1. When comparing the maximum total deformations of the subway brake disc with the wheel-type brake, it can be seen that the wheel is deformed 20 times more than the disc.
2. The maximum equivalent stress and the maximum equivalent elastic deformation of wheel become about twice as high as those of the disc.
3. There are a lot of damage to the axle parts of wheel, regardless of the subway brake disc or wheel, which indicates that the friction surface when the brake pads hold the wheel remains as it is but the parts attached to the axle will given by a lot of force.
4. Through the results of this study, the wheel-type brake by covering the wheel at the large area are shown with more deformation but lower damage than the subway brake disc.
5. SAE bracket is the worst fatigue loading condition on rail. SAE transmission is the condition used in bad load on rail and the sample history is the good condition used in the moderate load on rail. Comparing with each fatigue loading condition, the maximum fatigue life for 'Sample history' is found to be about 60 times longer than for 'SAE bracket history'.

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