자동차 클러치 디스크의 불규칙 진동에 의한 디스크 파손 연구
Study on the Fracture of Automotive Clutch Disk due to Abnormal Vibration

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Key Words : Automotive Clutch Disk(자동차 클러치 디스크), Abnormal Vibration(비정상 진동), Fracture(파손), Fatigue(피로).

ABSTRACT

In this study, the failure of the automotive clutch disk was investigated. During the process of power transmission, clutch disk plates did repeated work of releasing and engaging the pressure plate. The effects of unbalance rotation in the abnormal vibration and torque amplitude under engaged state were measured from this experiment. In order to reduce the unbalance,a modified clutch disk shape was developed. With a three-dimensional model of the stopper pin, to predict fatigue fracture, finite element analysis was carried out and evaluated the improvement of the new clutch disk.

1. Introduction

Stopper pins failure can be attributed to several causes. However, mechanical fatigue failure is probably the most common cause of stopper pins failure. In a mechanical system, one of the major reasons of damage and failure is fatigue. Fatigue failures usually occur under high cycle fatigue but sometimes low cycle fatigue failures can also be observed. In the case of stopper pins failure in a clutch disk, we can find low cycle (below 250 cycles) fatigue failures. Fatigue failure occurs in the following steps (a) In the process of power transfer from a cushion plate to stopper pins, abnormal vibrations occur, (b) A gap between the cushion plate and the stopper pin is generated due to the vibrations, (c) Unbalance rotations of the clutch disk are caused by the gap, (d) Stress concentration is developed on the neck of stopper pins. (e) Fatigue failure occurs.

In this paper, experimental analysis using by dynamo tester is performed to examine the reasons of the fracture damage in practice. To enhance fatigue life of stopper pins, a modified clutch disk is suggested. Finite element analysis is used to predict fatigue life of a stopper pin in the modified clutch model under the 13Hz frequency repeated force and compared its maximum stresses with original ones which have unbalance rotation. The results of fatigue analysis are discussed. The modified clutch disk has 8 cushion rivets in total, to reduce unbalance rotation.

2. Experimental Analysis

To examine the reasons of low cycle stopper pins failure, a dynamo tester is used. During the process of power transmission, clutch disk plates do repeated work of releasing and engaging the pressure plate. So, by using the dynamo tester, this mechanism can be realized. The amount of unbalance rotation of the clutch disk can be controlled and torques are measured under each unbalance rotation for 550,800, 1,800,300rpm, respectively. The effects of unbalance rotation in the abnormal vibration and torque amplitude under engaged state are measured from this experiment. Test modes for reappearance experiment are expressed in Table 1.

To examine the improved performance of

Table 1 Test modes for experiment.

Test Object	Unbalance 550gmm / 110gmm C/C ASSY
Engage rpm	Idle ~ 3000 *rpm*
Inertia	0.295 $kgms^2$

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the modified clutch disk against stresses, stresses are experimentally calculated by using strain gage. In total, four strain gages are attached. Figure 1 shows an experimental setup for strain measurements.

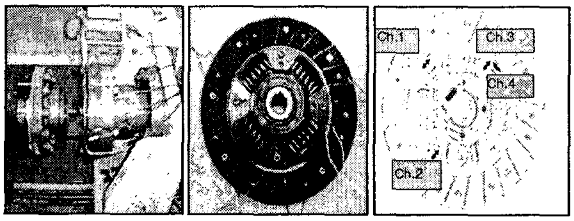


Figure 1. Strain measurements in the disk plate.

3. Numerical Analysis

By using the torque data from experimental analysis, numerical fatigue analysis is performed, by using finite element method. Examined torques are converted into forces to be adopted in the FE model. From the finite element analysis, fatigue life of the modified clutch disk is predicted and maximum stresses under fatigue loading are also calculated.

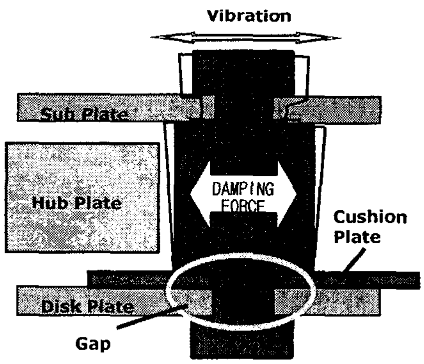


Figure 2. Schematic view of a stopper pin movement.

3.1 Modeling and Boundary Conditions

FE model of a stopper pin for fatigue analysis is developed. The used program for FE analysis is FEMFAT Ver.4.5b. In the part of the neck, sub-plate is contacted and sub-plate applies repeated force to the neck (Figure 3). In the contact part between a stopper pin and disk plate, a gap element is used between solid and shell for considering gap effect due to unbalance rotation. Shell element in the FE model is used for applying contact loadings. As the boundary conditions, x, y, z-direction constraints are applied on the shell elements.

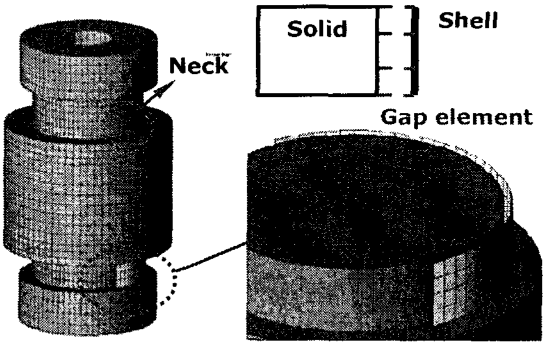
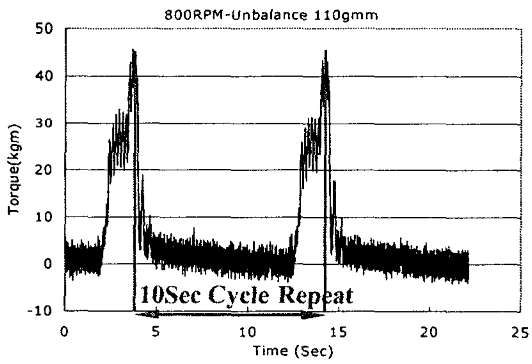


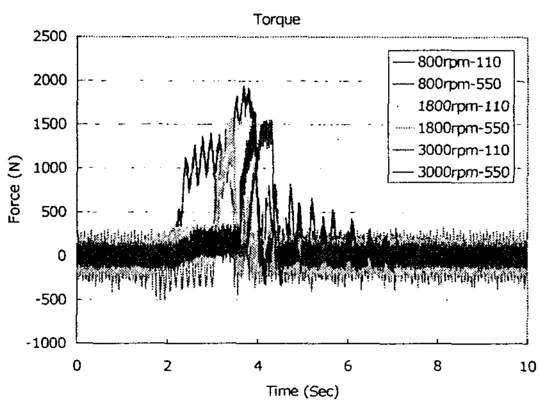
Figure 3. Finite element model of a stopper pin : applied shell and gap element.

3.2 Load history

For fatigue analysis, torques at time 0 to 10sec are converted into forces to utilize load history. The repeated frequency is 13Hz.



(a)



(b)

Figure 4. (a) Adopted torque-time load history of 800 rpm with 110gmm unbalance. (b) Adopted force-time load history according to its rpm and unbalance.

Figure 4(a) shows adopted torque–time load history of 800rpm with unbalance 110gmm and noted 130cycle repetition during 10sec. Figure 4(b) shows adopted force–time load history according to its rpm and unbalance.

4. Result and Discussion

4.1 Experimental results

To confirm the reason of stopper pins failure, abnormal vibrations are reproduced through repeated engage and release movements likewise a real clutch disk. The torques are measured under the unbalance rotation and the results are shown from figures 5 to 10. Time domain results are converted into frequency domain results to verify low cycle fatigue effects. The upper part is time domain and the lower part is frequency domain torque results in each figure. In the upper part graph, small box express magnified graph of peak part of red circle.

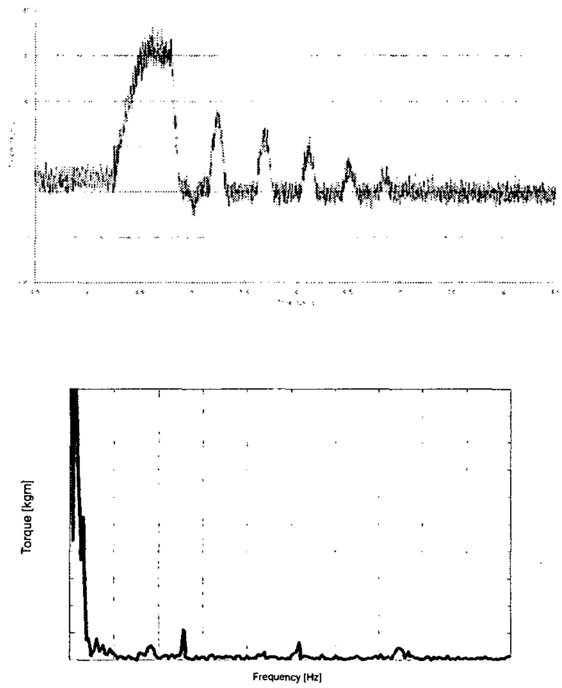


Figure 6. Unbalance 110gmm under 3000rpm.

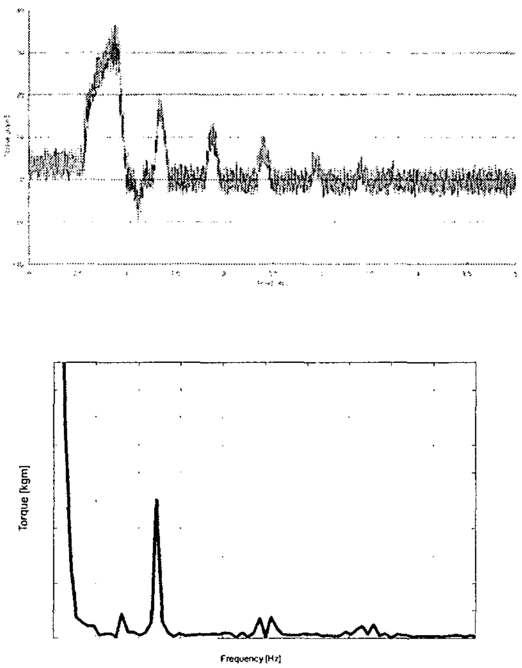


Figure 5. Unbalance 550gmm under 3000rpm.

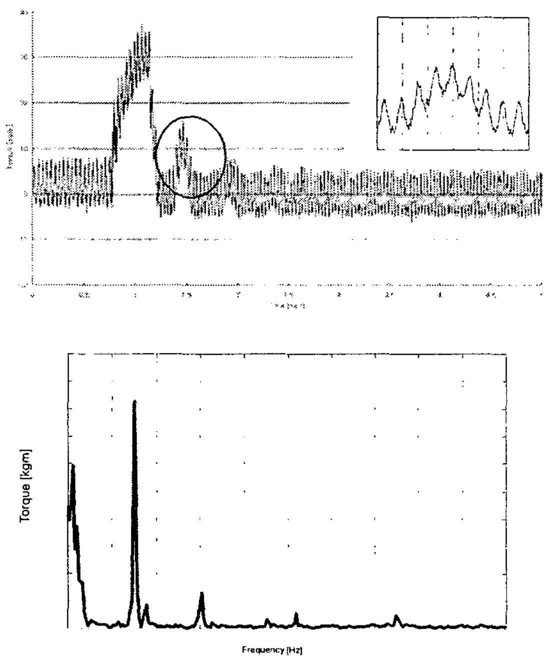


Figure 7. Unbalance 550gmm under 1800rpm.

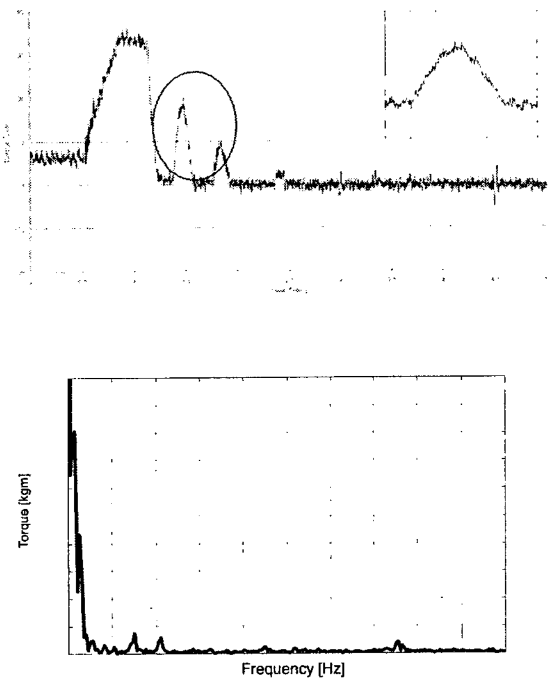


Figure 8. Unbalance 110gmm under 1800rpm.

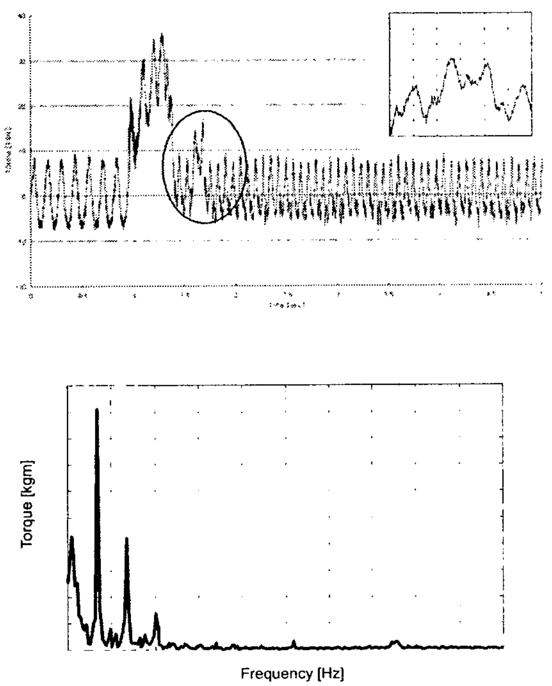


Figure 9. Unbalance 550gmm under 800rpm.

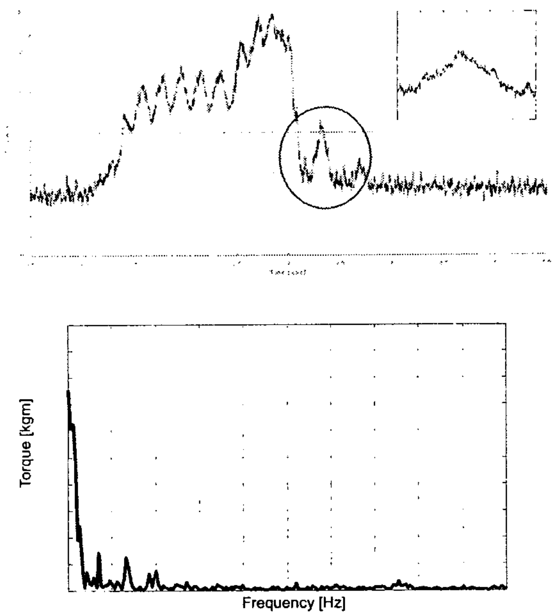
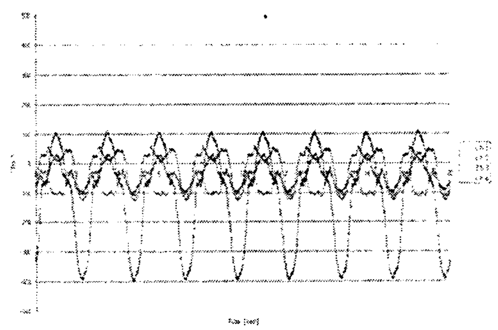
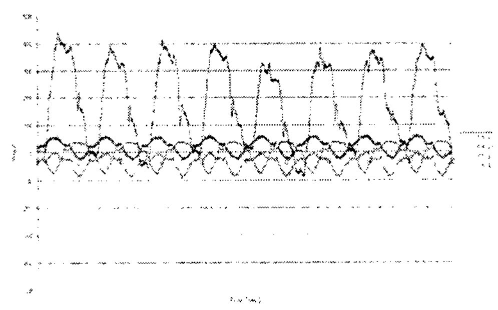


Figure 10. Unbalance 110gmm under 800rpm.

The measured strains in each channel (Figure 1) are expressed in Figure 11. Through the results, it can be deduced that the strain variation is reduced in the modified clutch disk and calculated stresses are also reduced.



(a)



(b)

Figure 11. Strain variations according to time in each part. (a) Original model. (b) Modified model.

Table 2 shows the improved performances of the modified clutch disk through stress distribution.

Table 2 Stress distributions in each channel.

	Original (kg/mm^2)	Modified (kg/mm^2)
Ch.1	4.98	4.34
Ch.2	1.33	1.12
Ch.3	1.92	0.89
Ch.4	0.87	0.75

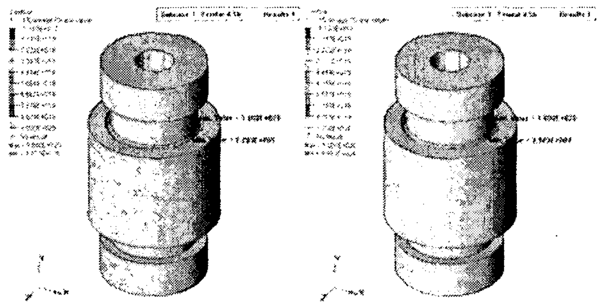


Figure 12. 8000rpm Unbalance 110gmm and 550gmm.

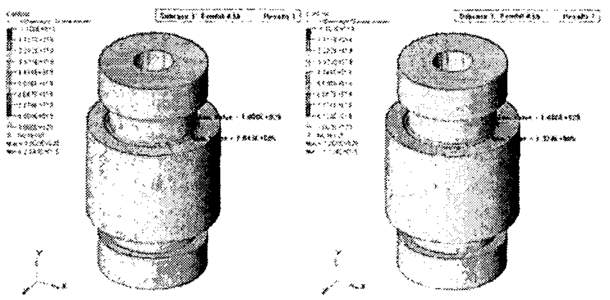


Figure 13. 1800rpm Unbalance 110gmm and 550gmm.

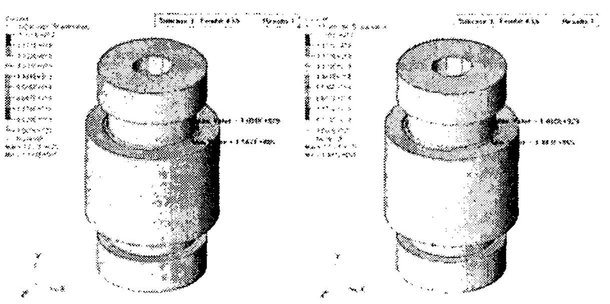


Figure 14. 3000rpm Unbalance 110gmm and 550gmm.

4.2 Finite element analysis result

When the unit load is applied to the stopper pin, stresses are concentrated in the notch part of the neck of the pin. The maximum stress value of stopper pin in the modified clutch disk is illustrated in Figure 12.

Fatigue test on stopper pin has also been conducted and its results are illustrated from Figures 12 to 14. Fatigue life is predicted for each unbalance and rpm and the results are shown in Table 3.

Table 3 Calculated fatigue life cycle.

	800rpm	1800rpm	3000rpm
PP Unbalance 550gmm	12,893,900	17,212,000	19,279,000
PP Unbalance 110gmm	15,639,000	26,559,000	20,306,000

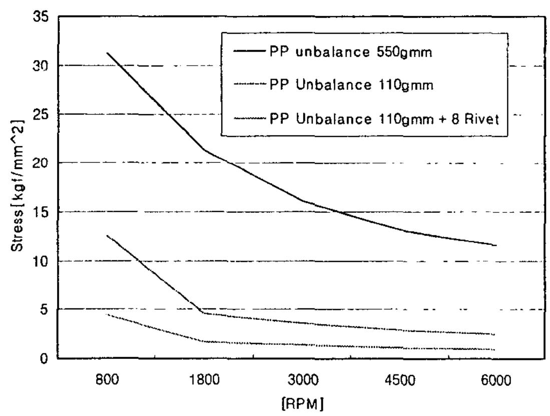


Figure 15. Stress analysis result.

5. Conclusion

To prevent stopper pins failure, especially fatigue fracture, experimental analysis by using a dynamo tester has been performed. Through the experimental analysis, the effects of abnormal vibration on the torque are represented and low cycle fatigue is also examined. In the numerical analysis, finite element model is used to predict fatigue life and stress distribution. Obtained stress results are compared with the modified clutch disk results. In this paper, the modified clutch disk with 8 additional rivets is suggested to overcome fatigue failure. The performance of the modified clutch disk is also analyzed and compared with the original one.

후 기

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