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*Original Article*

# A Study on the Diagnosis of Timing Belt Failure Noise in Automobiles

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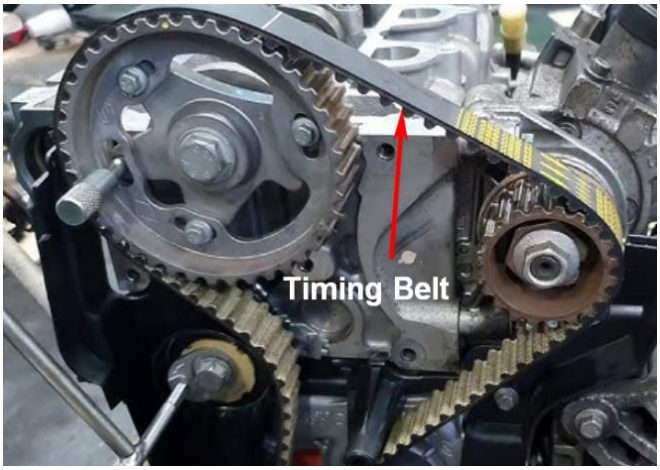
***Abstract -*** *Automobiles provide various signs to drivers when a specific part is broken or is about to break down. They send out various abnormal signs through unusual vibrations transmitted to the body, symptoms that can be identified with the naked eye, abnormal phenomena that can be detected by smell, and sounds generated from the start of the engine. In this study, This paper studied a method to diagnose the sound generated when a timing belt of an automobile breaks down and use it to immediately repair the same sound when it occurs in the future. Of course, abnormal sounds can be detected not only when a timing belt of an automobile breaks down but also when various parts of the automobile break down. This paper suggests the need to study sounds related to automobile failures occurring in various parts. An automobile diagnosis program through sound can be provided to the owner-driver when the automobile is released, installed in the vehicle to perform self-diagnosis, or can be applied in a smart environment and put into practical use. Ultimately, this program is to enable automobile manufacturers to create a manual for vehicle failure diagnosis through sound and provide it when the vehicle is released or to install a self-inspection system that analyzes sound and warns the driver so that drivers can check and repair matters related to failure diagnosis on their own and prevent major accidents in advance.*

***Keywords -*** *Automobiles, Timing belt failure sound, Breaks down, Repair, Diagnosis, Manufacturers.*

## 1. Introduction

Currently, leading automobile manufacturers around the world are improving the performance of their automobiles and expressing various warning sounds and indicator lights to facilitate repairs in the event of a breakdown. Until now, these systems have mainly adopted methods using sensors. This study aims to prepare for the same breakdown that occurs in the future by collecting data on the breakdown sound when a timing belt fails among automobile diagnostic methods using sound. Existing automobile breakdown diagnostic methods are based on automobile design drawings. However, in the repair field, in addition to textbook repair methods, mechanics often use unique methods that reflect their know-how. In particular, humans have the ability to utilize their five senses. The five senses are sight, touch, smell, taste, and hearing. Humans actively utilize their five senses in automobile breakdown diagnostics. Rather, even the sixth sense that surpasses the five senses is utilized, but among them, there is a diagnostic method using four senses in a realistic automobile diagnostic method. The diagnostic method using the four senses uses sight, touch, smell, and hearing, excluding taste, and it is said that some mechanics sometimes use taste. First, visually, when stopped, you can check the exterior of the car, the condition of the wheels, whether there is insufficient oil in the engine room, the condition of the battery, etc., and when the standby switch is on, after starting, and while driving, you can first visually diagnose the indicator lamps on the instrument panel. Second, tactilely, from the vibration transmitted to your hands from the steering wheel while starting the car and the tactile sensation transmitted to your whole body through the seat, it is enough to check the condition of the car that is different from normal. Third, olfactorily, the smell coming from the car provides more certain confirmation than a suspicion of a breakdown. However, since the smell often implies that the breakdown has progressed beyond the preventive level, you should stop and check immediately when you feel the smell. Fourth, auditory diagnosis, which this paper will deal with, is an aural diagnosis. A vehicle is a culmination of advanced science and technology in which more than 25,000 parts are interlocked and operated. In addition, interest in the sounds made by those parts is valuable data for automobile diagnosis and inspection. In order to diagnose timing belt failure through sound, the engine noise before and after the failure was first analyzed, and then the repair procedure was studied through diagnosis. This study will play a major role in digitizing the sounds of failure signs occurring in various parts of automobiles in the future and using them as practical automobile maintenance manuals. Automobile maintenance manuals utilizing sounds must establish unique data for each vehicle model.




a. Timing belt

b. Diesel SUV automobile

**Fig. 1 Diesel SUV automobile timing belt**

This is because each automobile has a different mechanism. For this study, the engine sound of a 4-wheel drive SUV with a diesel engine with a broken timing belt was recorded, and the normal engine sound was recorded after repair, compared, and analyzed. The recording was done using a Zoom H2 digital recorder, and the analysis was done using the Adobe Audition program.

## 2. Timing Belt Fault Diagnosis Through Sound

This paper is a study on a method for diagnosing a timing belt of automobiles using sound. Since timing belt fault diagnosis research using sound requires a lot of time and labor for an individual to conduct, cooperation from a maintenance shop or an automobile research institute of a vehicle manufacturer is necessary. Since each vehicle has a similar basic structure and principle, even if the vehicle type is different, they generate similar sounds when the timing belt fails. Since it is the same type of failure, the type of sound is similar, but there may be slight differences depending on the vehicle type, so unique sound data must be constructed for each vehicle. These sounds can be utilized as self-diagnosis programs or smart environment applications. Efforts should be made to obtain precise diagnosis results depending on the vehicle type by making good use of sound (voice) recognition technology. The most correct way is for the vehicle manufacturer to plan and implement a fault diagnosis method using sound simultaneously as the new vehicle planning. [3, 4]. This paper recorded the sound generated when the timing belt of a diesel SUV vehicle failed and compared it with the sound of a timing belt that was operating normally. Although this study is limited to timing belt failure, it opens up the possibility that the sound generated by various vehicle parts can be used to diagnose vehicle failures. Figure 2 is a diagram that illustrates the procedure for diagnosing timing belt failure using sound. The car must always be ready to receive external sounds or sounds generated by the car itself. Then, it must be digitized and compared with the data modeled and accumulated through the same process and analyzed.

Since the driver cannot detect external sounds well while driving the car, the sound generated when the external mechanism fails must be displayed on the instrument panel inside the car. The sounds that can be detected inside the car while driving is mostly likely to be related to the electronic circuit. If the sound of the external mechanism failure is audible inside, it is likely a very serious failure. Also, each car trim produces its own unique sound, so each car requires a precise sound diagnostic program. After the diagnosis is completed, the repair procedure must be carried out so that the car can be operated normally.

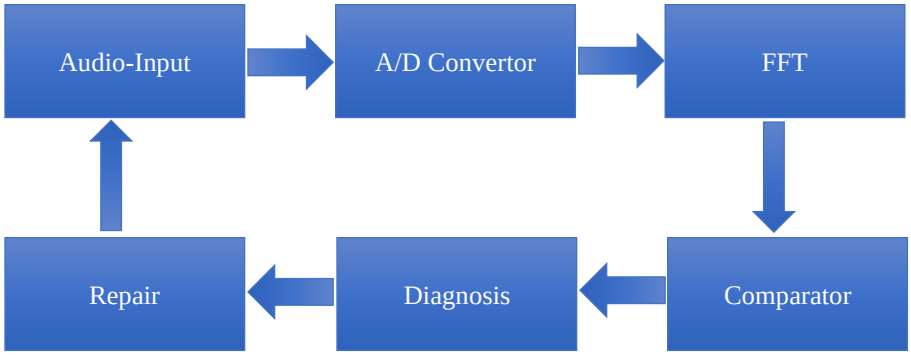



**Fig. 2 Diagram for timing belt fault diagnosis using sound**

### *2.1. Purpose of the Experiment*

Timing belt failures occur frequently and can cause major accidents, so it is important to check them in advance to prevent failures. Timing belts can stretch or break as they age. If the timing belt stretches or breaks, it can come off the wheel and damage other parts. In the automotive environment, many accidents occur due to various failures, but the purpose of this study is to prevent accidents caused by timing belts in advance. Furthermore, it is necessary to establish a method to diagnose failures in various parts by sound. [1]

### *2.2. Experimental Method*

In order to diagnose vehicle timing belt failure using sound, the sound of the vehicle timing belt was recorded by dividing it into normal and faulty cases. For the study, the sound characteristics were investigated by comparing the normal engine sound of a stopped SUV vehicle with the engine sound of a similar vehicle showing signs of failure. The order is as follows. [2, 3]

- First, record the engine sound of a normal vehicle and convert it into data.
- Second, record the engine sound of a similar vehicle showing signs of failure and convert it into data.
- Third, the normal sound and the failure sound are analyzed with an acoustic analysis program, and the difference is converted into data.

The engine sound of a normal vehicle idling is called the reference sound, and the engine sound of a vehicle showing signs of failure is called the failure sound. Figure 3 is a spectrum graph comparing the operating noise of a normal vehicle and a malfunctioning vehicle for timing belt fault diagnosis.

The timing belt noise was recorded directly using a digital recorder (ZOOM, H2), and Adobe's Audition program was used to compare and analyze the malfunction noise and normal noise. The spectrum graph helps to understand the difference in the average frequency by comparing the sound changes in each frequency band. Looking at the graph, the timing belt noise does not show much difference between a normal vehicle and a malfunctioning vehicle in the low-frequency band A section based on 2,000 Hz, but a large difference appears as it goes into the high-frequency section. In particular, the malfunctioning vehicle expresses the sound as irregular and rough. [4, 5]

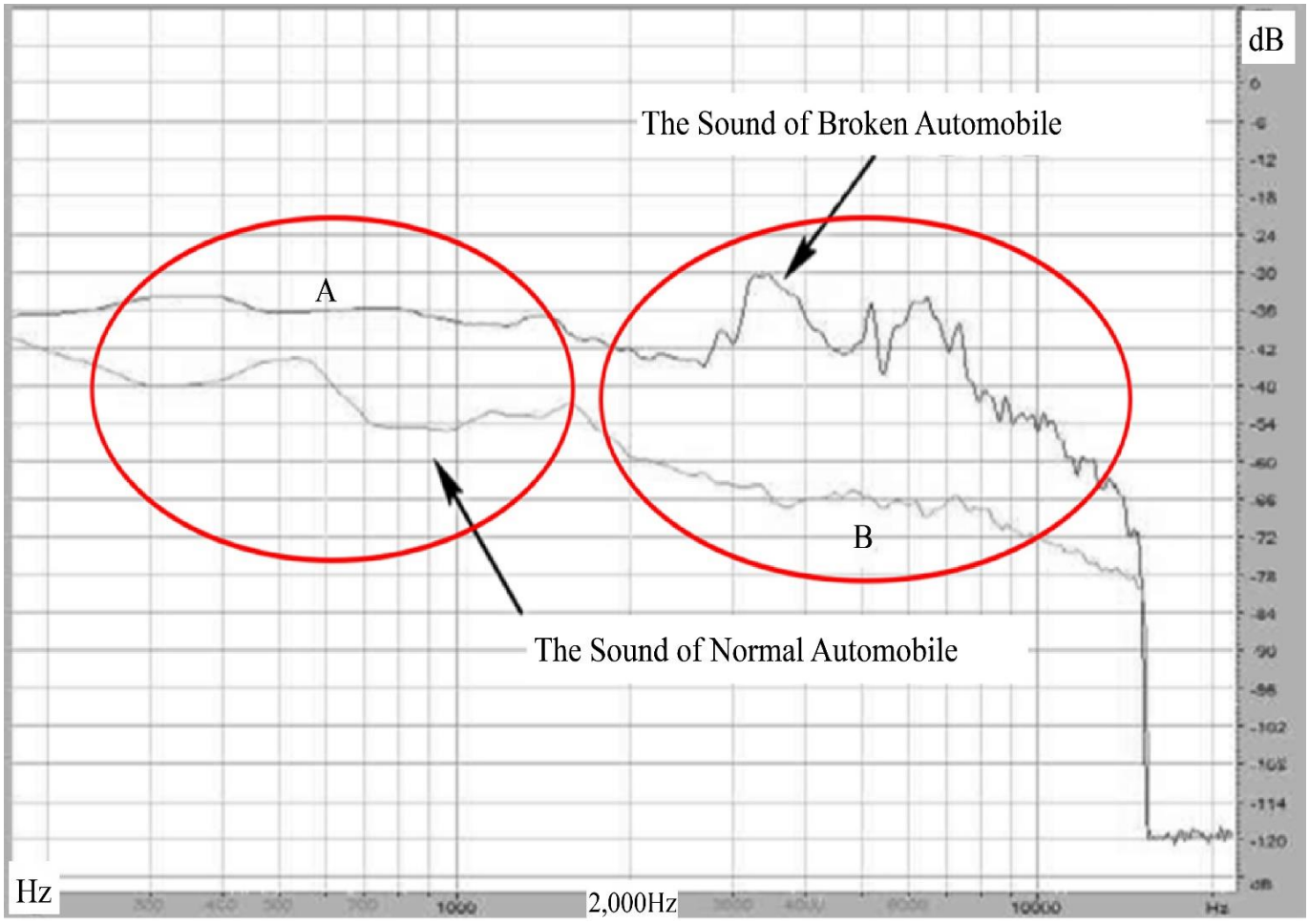



**Fig. 3 Comparative analysis of spectra of normal and broken automobiles**

### *2.3. Analysis of Experiment*

A study was conducted to compare and analyze the operating sounds of normal and faulty vehicles to diagnose timing belt failures. The research process can be explained through the flow chart in Figure 4 below. The procedure is to constantly monitor the vehicle's starting sound, engine sound, and driving sound through a microphone installed in the vehicle, and if a failure sound occurs, compare and analyze it with existing failure sound data; if a failure is determined, notify the driver with an indicator light on the dashboard or with a warning sound or voice. Failure signals determined through this process can be prevented and maintained in advance by drivers and mechanics to prevent accidents caused by vehicle failures. [6]

#### *2.3.1. Malfunction Symptom*

A repetitive grinding noise occurred and got worse, and the steering wheel and brake pedal suddenly stopped working, almost causing a major accident.

#### *2.3.2. Cause of Malfunction*

The timing belt had poor clearance, causing noise and worsening the condition.

#### *2.3.3. Troubleshooting*

Replaced the timing belt and checked the clearance.

The normal operating sound and the operating sound showing signs of failure showed a clear difference through spectrum analysis. The engine sound of a normal car is soft and rhythmic, mainly in the mid-low range. However, the engine sound generated when the timing belt is broken showed a prominent friction sound in the range of 3,000 Hz to 8,000 Hz. The flow chart in Figure 4 helps to build a timing belt failure diagnosis system using sound. In addition, through this study, the possibility of practical application of a vehicle failure diagnosis program using sound was found by datafiguring common sounds that appear according to the same type of failure situation. [7] Table 1 is a table that records the contents of the sounds generated by the car from the perspective of cause and solution.

This paper records the contents of the timing belt failure of diesel SUV cars, but the sounds generated when various parts fail can also be digitized. Diesel SUVs are basically louder and more dynamic than gasoline engines. In situations where such loud engine sounds occur, the sound generated when the timing belt fails is louder and can be sufficiently detected. Such loud failure sounds can be detected by the car itself and displayed on the dashboard and also notified with a warning sound. In particular, failure of important parts such as timing belts can lead to major accidents, so it is necessary to repair the failure immediately when the sound is detected.

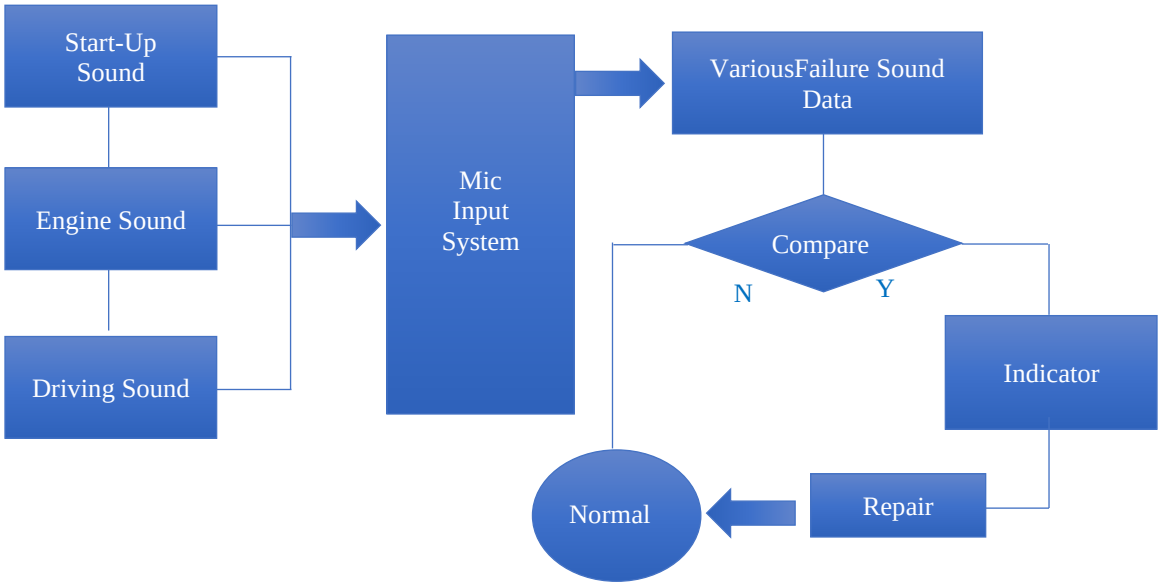



**Fig. 4 Flow chart of automobile self-diagnosis system through sound**

**Table 1. Fault diagnosis contents and solutions through automobile sound**

| Situation | | Sound that occurs | Troubleshooting contents | Solution |
|---|---|---|---|---|
| During driving | | Periodic friction noise that increases | Fan belt tension stretching and aging | Fan belt replacement and tension adjustment |
| While stopped | When starting | | Parts that move according to engine rotation (various pulleys and belts). In particular, timing belt abnormality | Check (tension, wear, cracks, alignment) and replace the timing belt and drive parts |
| | When idling | | | |

## 3. Conclusion

A car is a moving machine and a necessity of life. All operating mechanisms generate sounds. Cars are no different. In particular, cars generate various sounds in each part because they have about 25,000 parts that mesh together and rotate. When a car malfunctions, the sounds generated by the car become louder and more unique. Cars are machines that move at high speeds, so they are useful but also very dangerous. Currently, various methods are used to predict and diagnose malfunctions in advance. In this study, we studied the procedure for diagnosing and repairing a timing belt malfunction using sound. For the study, we recorded timing belt failure sounds from diesel SUVs and recorded normal sounds after repairs. This research can be applied to various areas, not just timing belts. Since a car is a mobile machine in which mechanisms mesh together and rotate, it cannot help but generate sounds from the moment it starts operating. However, there is a difference between the sound of normal operation and the sound that shows signs of malfunction. Sound is the fastest early diagnosis among human senses for diagnosing cars. Since drivers cannot help but be sensitive to sound, they quickly catch abnormal changes in sound. The fact that the catch is fast means it can prevent serious failures in advance, proving that sound is excellent data for diagnosing automobile failures. Of course, methods for precisely diagnosing car malfunctions using sensors have been developed, but sound helps us make realistic judgments of the situation. Accordingly, it is suggested that automobile manufacturers in the future study vehicle diagnosis programs using sound while creating arbitrary failure states with the vehicle before releasing a new car and providing the manual to the driver along with the vehicle. In the future, data on sounds related to automobile failures that have been studied in various ways should be collected to accumulate and develop a vehicle failure diagnosis system using sound. Such actions can be considered an attitude of automobile companies fulfilling their own responsibilities and obligations while pursuing profits.

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