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Investigations and comparison of noise signals to useful signals for the detection of dents in vehicle bodies by sound emission analysis

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Abstract

The context of this paper is the German research project KESS (Konfigurierbares Elektronisches Schadensidentifikationssystem) funded by the Federal Ministry of Education and Research. In this Project, an entire system from sensing structure-borne sound up to Car-2-Infrastructure communication for the minor damage detection of car sharing vehicles is under development. Therefore, the suppression of noise signals is essential for the further algorithms to classify minor damages.

Minor damages in vehicle body parts create structure-borne sound which overlaps with additional oscillations of the vehicle. In the ordinary usage of vehicles, those additional oscillations are mainly caused by road and engine noise. Within this paper the differences of such noise signals and signals of structure damages will be described. Therefore, an analysis method to calculate spectrally decomposed envelope signals of structure-borne sound signals is given and the analysis results will be presented. A digital filter method to attenuate the majority of noise signals and to preserve the useful signals for the detection of minor damages will be given at the end of this paper. This digital filter method has been successfully designed and implemented into the algorithm of the sensor by using model based design techniques.

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Keywords: KESS; structure-borne sound; minor damage; vehicle body; dent; scratch

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1. Introduction

The automatic detection of vehicle body damages like dents and scratches is one key factor of modern fleet condition monitoring. During the lifetime of a fleet vehicle several damages of its vehicle body occur, henceforth referred to as minor damages. Even though such minor damages do not affect the technical functionality of the vehicle, fleet owners are interested in good-looking cars as they give customers a feeling of high-quality. Thus, especially the outer appearance of the vehicle has to be in a good shape and even minor damages must be repaired. Therefore, it is necessary to know if a costumer was responsible for a minor damage or if the damage has been created by vandalism or accident when the car was not lent to a customer. An entire system from detecting minor damages of the vehicle body up to forwarding the data to a fleet disposition server of a car sharing company is currently under development in the governmental funded research project KESS. In this system a network of structure-borne sound sensors [1] is mounted to the vehicle body. The sensors analyze the structure-borne sound to detect the type of damage, the severity of damage and the location of the damage on the vehicle body part the sensor is mounted on [2]. All information from the single sensor nodes are then collected and combined in a central electronic module inside the vehicle [3]. This module decides whether the incoming messages fit to a plausible damage pattern or not. If the damage seems to be plausible a wireless encrypted GPRS message is then sent from the vehicle to the disposition server of the fleet management system.

One aim of the KESS project is to provide such damage messages when the vehicle is parked as well as when the vehicle is driving. Especially in the driving state heavy oscillations by road and engine noise are introduced to the vehicle body which overlap with the structure-borne (SB) sound waves of a possible minor damage.

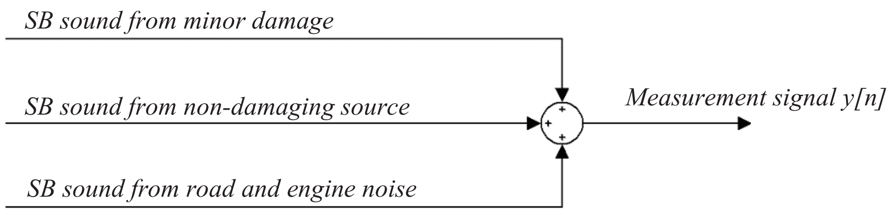

Fig. 1. Composition of the measurement signal *y[n]* by a SB sound sensor.

So, when the vehicle is in a driving state, it is obvious that the structure-borne sound from road and engine noise will be added to the measurement signal. This paper is providing a spectral separation method to suppress the majority of such noise signals in the measurement signal. This is very important for the subsequent classification of minor damages, because the classification method is then independent of the driving state of the vehicle, what enables the system to detect minor damages not only when the vehicle was parked but also when it was driving.

2. State of the art

The detection of damages and defects in the vehicle body has been investigated by different research groups. In 1999, Karbacher, et al. [4] presented a method to detect dents in the vehicle body by an automatic camera system. This was very helpful for an end-of-line test of the vehicle-body after the car has been guided though a production line. Their system is based on a camera gate where the car needed to be passed though. Hence, the system is completely separated from the car and a detection of damages in real-time is not possible. Similar approaches to detect damages optically are published in the work of Lilienblum, et al. [5] and Yogeswaran, et al. [6].

Another system, which is much more similar to the here described one, is published by Müller [7] in his doctoral thesis. He is although using piezoelectric film elements for the detection of structure-borne sound signals of damage events. In contrast to our work, he is continuously forwarding the raw voltage signals of the piezoelectric elements to a central calculation unit. Due to this circumstance, his central calculation unit needs to process the signal data all time through, even though the car is parked. That causes a very high current consumption of the entire system. The