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Material vibration propagation in floor pan

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ABSTRACT

Purpose: The article provides a discussion on the studies on material vibration propagation in floor pan of the passenger car. The purpose was to analyse the vibration signals in multiple measuring points. The time-frequency distribution of the signals allows to identification the dominant component of the signal useful for material natural frequency calculation.

Design/methodology/approach: The investigations were conducted based on the modified method of experimental and operating modal analysis. The investigation comprised 3 steps: research and measurements of vibration accelerations in a vertical direction perpendicular to the horizontal surface of vehicle in four selected points (impact excitation), analysis of the time courses of the vibration response, signal processing and analysis of the time-frequency distribution of the vibration

Findings: The distribution of the signal allows to identify the dominant frequency band. For the floor pan it is low frequencies, between 20 and 40 Hz. In this band the natural frequencies of the floor pan material can be identification

Research limitations/implications: Number of the acceleration sensors and impossibility of the impact excitation signal recorded.

Originality/value: Application of the modified method of experimental and operating modal analysis for the vehicle frame and car body. Research on the material properties influence on the vehicle vibration research. Comparison of the vibration structure at floor pan under the place of the driver and passengers feet as the vibration propagation path from frame and car body to the human body.

Keywords: Automotive materials; Floor pan vibration; Material vibration propagation

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PROPERTIES

1. Introduction

Propagation of the vibration is very important phenomenon in every machine and technical or engineering objects. There are many of elements and systems for vibration absorbing or isolation [1]. The material structure has some properties responsible for the damping and propagation of the vibration [2,3,4]. During study the vibration of the technical systems it should be taking into consideration material vibration propagation. For the driving safety and comfort it is very important what kind of vibration are transferred from road roughness and others vibration sources of the vehicle to the human body. Exposure to vibration and the human perception are strongly connected with comfort or discomfort feeling of the driver and passengers. In some situation it can influence on the driving safety. Of course there are many of others phenomenon, including wear [5-7] or repair technologies and quality [8-10], which are strongly related with comfort and safety of the vehicles.

Under study many research it can be observed that mostly the suspension system and shock absorbers are researching for the vehicle vibration propagation [11]. It is significant for the car vibration research during drive. Some preliminary research was conducted on vehicle vibration during parking. This paper opens the discussion on influence of the materials properties in vibration research of the vehicle.

2. Relation between requirements for a car structure and new materials

The requirements for a car body are constantly increasing but ecology, safety and comfort are always main goals of innovations and improvements. For the ecology and safety an important aim of the automotive industry is to decrease the fuel consumption by reducing the weight of the vehicle without loss of security to enlarge the agility. Automotive companies are constantly improving technologies and build vehicles from materials that offer improved user comfort and safety. The requirements for materials intended for automotive use are: easily formable, weldable, coatable and repairable. Vehicle weight reduction has been considered as one of the most important solutions to improve fuel economy. One solution to these problems is to reduce a vehicle's weight, because 57 kg weight reduction is equivalent to 0.09-0.21 km per litre of fuel economy increase [12].

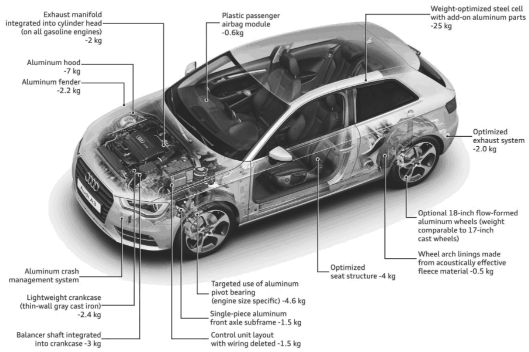

Fig. 1. Weight reduction in the Audi A3 [20]

It is possible that the vehicle body weight can be reduced by using multiple materials without cost increase. Lightweight automotive bodies and elements have been developed using high strength steels, aluminium alloys and composite materials. There is many research conducted on novel metallurgical technologies [13-18]. The multi-material concept is that the right material types are used in the right locations for the desired product functions. The possibilities for reducing the weight of the vehicle body start with an optimised all-steel body and span all the way to an all-aluminium car. More lightweight designs can only be obtained by using fibrous composite materials. Between the extremes of all steel and all-aluminium cars, there are solutions that combine steel with lightweight materials (Fig. 1) [19].

The first and most commonly used material is high strength steel. It has higher yield strength and failure strength than mild steel. The car weight can be reduced by using high strength steel sheet of a lower depth to replace the mild steel sheet of body parts. One of the most interesting HSS materials is Boron Steel (UHSS - Ultra High Strength Steel). The boron steel type used in the automotive industry today has extremely (ultra) high strength. It can have a yield point of about 1350-1400 MPa. Perspective materials that could fulfil most of the relevant requirements include dual-phase steel. Also high manganese TWIP and TRIPLEX alloys represent new perspective material types, with high strength properties, toughness and ductility in wide temperature range and high energy absorption on impact. The next group of materials is light metals. One may observe increasing use of metals such as aluminium and magnesium in the automotive industry (Fig. 2).

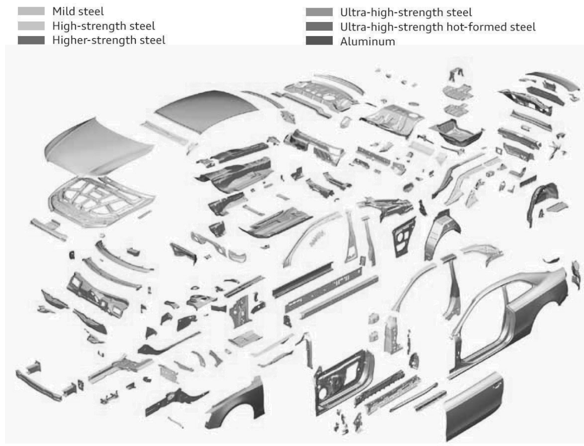

Fig. 2. Audi A5 multiple materials body structure [20]

The Fig. 3 shows technologies of forming and manufacturing elements made of the boron steel. The boron blank is hotted up to before it is stamped. By adding heat to the stamping process the B-Pillars can have the tensile strength increased by 500 MPa. Standard steel B-Pillars are in the 500-700 MPa range whereas this process will make a part into the 1500-1650 MPa range.

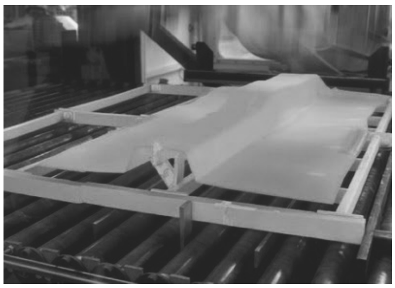

Fig. 3. Technologies of forming and manufacturing B-Pillars made of the boron steel [20]

For the comfort requirements it is very important what kind of the vibration are transferred on the human body. It cause the vibration and noise exposure. The paper describe the investigation on vibration properties of the floor pan in passenger car.

3. Methods of research on material vibration properties

Vibroacoustics is the science discipline describes the possibilities of vibration and acoustics signals useful for diagnosing and research purpose. The paper [2] presents some preliminary research on possibilities of vibration signal application in research on materials. During the research the vibration accelerations in a direction parallel to the symmetry axis of disks in two selected points were measured (Fig. 4). The vibrations in the disk material structure were excited by impacts in specific points.

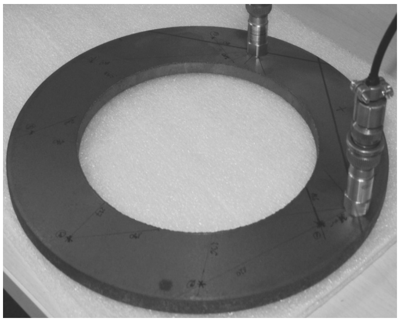

Fig. 4. Experimental research on material properties on the propagation of vibrations excited with a single force impulse [2]

The qualitative impact assessment for the structural material the disk was made of was performed by establishing the correlograms of time sections of the wavelet coefficient matrices. The time sections applied in the analysis were chosen bearing in mind the free vibration frequencies of the components examined. For the analysis the autocorrelation function for the chosen wavelet sections were used. The results has been depicted in Fig. 5.

a) b)

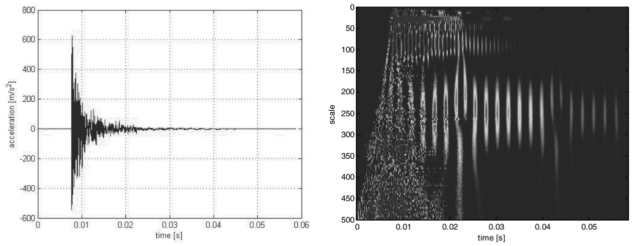

Fig. 5. Results of the research: a) time course of vibration accelerations and b) distributions of wavelet coefficients [2]

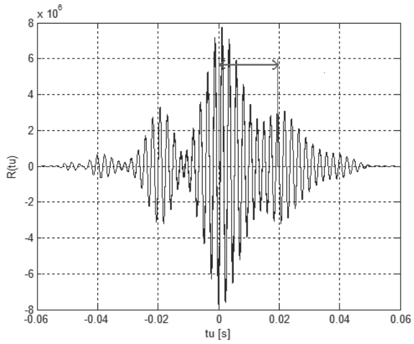

Fig. 6. Correlogram of wavelet sections with the time shift value marked on which the local maximum of the intercorrelation function occurs [2]

The main phenomenon useful in vibration research is resonant. Resonance vibration of materials is caused by an interaction between the inertial and elastic properties of the materials within a structure. Resonance vibration amplifies the vibration response more than the level of deflection, stress, and strain caused by static loading (Fig. 6).

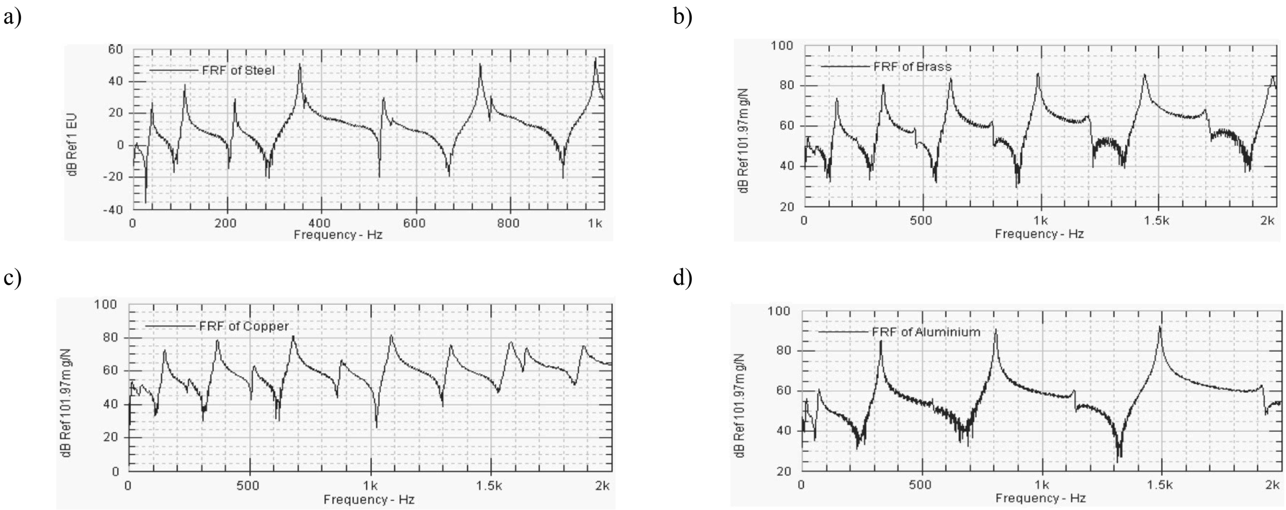

Fig. 7. Frequency response function of: a) steel, b) brase, c) copper, d) aluminum [4]

The modal research allows the frequency response function (FRF) to be determined. This describes the input-output relationship between two points on a structure as a function of frequency. The characteristics of a system that describe its response to excitation as the function of frequency is the Frequency Response Function H(f) defined as the ratio of the complex spectrum of the response to the complex spectrum of the excitation. Nowadays the modal testing is an effective means for identifying and simulating dynamic behavior and responses of structures. A very useful group of this research is experimental modal analysis (EMA) because this is an example of non-destructive testing. Modal research is based on vibration responses of the structures. New methods of the signal processing allows the vibrational response of the structures to the impact excitation (instrumented hammer impact excitation), which are measured, transformed into frequency response functions using Fast Fourier Transformation (FFT) [3,4].

The paper [17] presents some experimental modal analysis of beams made with different materials such as steel, brass, copper and aluminum. The beams were excited using an impact hammer excitation technique. Some of their results were presented on figures below (Fig. 7).

4. Research methods

Vibration propagation in solid structures depend in main condition on material properties and quality. For identification the mapping of vibration measuring in multiple points is very useful. Under the studies in question, active experiments were undertaken featuring measurements of vibration accelerations in a vertical direction perpendicular to the horizontal surface of vehicle in four selected points the positions of which have been depicted in Fig. 8. The subject of the study was floor pan of passenger car. It was chose for the case study because of the importance of the vibration transfer to the human in car as the vibration exposure. The arrangement of measurement points was set for the places where driver and potential passengers put feet on the floor pan. It is the natural vibration propagation path to the human body.

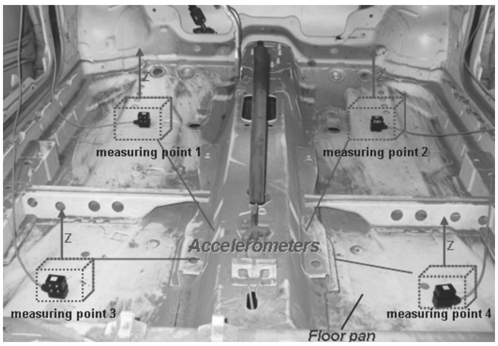

Fig. 8. Subject of studies and arrangement of measurement points

For identification of the vibration propagation and material natural frequency the method of impact excitation were examined. The phase of the response, in general case, will be different than that of the excitation. The phase difference between the response and the excitation will vary with frequency. The study subject does not need to be excited at one frequency at the time. The same applies if the system is subjected to a broadband excitation comprising a blend of many sinusoids at any given time, such as in the white noise or an impulse. There are some application of modal analysis. For example: theoretical, experimental and operating. Theoretical modal analysis based on identified structural model. Experimental analysis requires measuring of excitation and response. Operational based on active experiments and measuring only the responses in multi points.

According to the goal of the research the modified method of experimental and operating were applied. It were measured only the response signals but caused by the impact excitation, which is not full correlated with operational excitation of passenger cars. It was assumed the isolation from influence of the suspension system on vibration propagation and separation for the material damping properties. At the same time the research scope doesn't contain the Frequency Response Function calculation. The scheme of the research method have been depicted in Fig. 9.

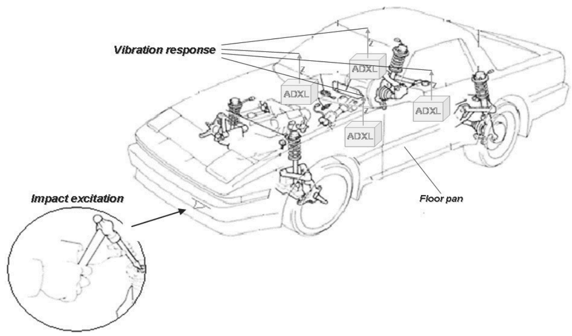

Fig. 9. Scheme of the research method of impact excitation

5. Material vibration propagation in floor pan

As the results of the research the time courses recorded for the vibration accelerations were established. For the analysis of material vibration propagation in floor pan it was decided to transform recorded signals to time-frequency domains.

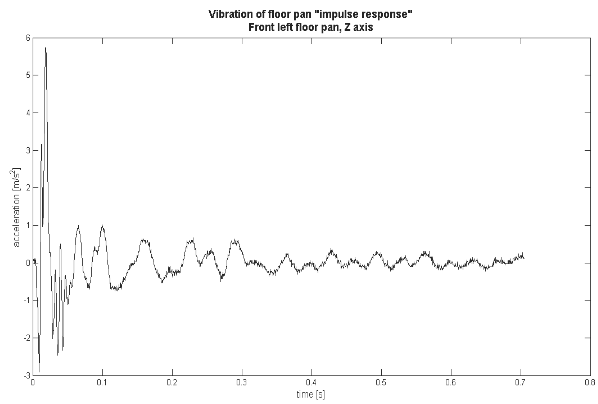

Fig. 10. Vertical vibration signal of impulse response of the floor pan, measuring point 1 - front left

The distribution of the signal simultaneous in time and frequency allows to observe changes of the frequency component of the signal during time period. It is very helpful for identification the natural frequencies of the material structure. The results has been depicted in Figs. 10-17.

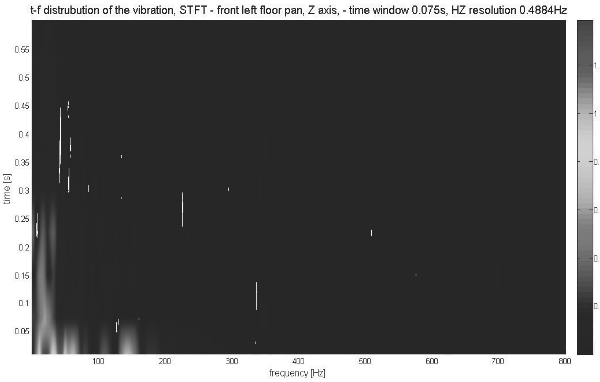

Fig. 11. Map of vertical vibration signal of impulse response of the floor pan, measuring point 1 - front left

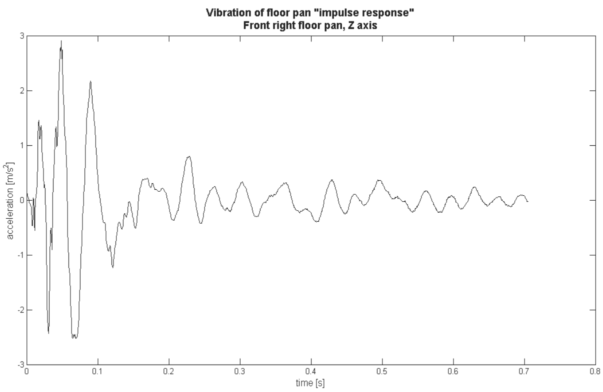

Fig. 12. Vertical vibration signal of impulse response of the floor pan, measuring point 2 - front right

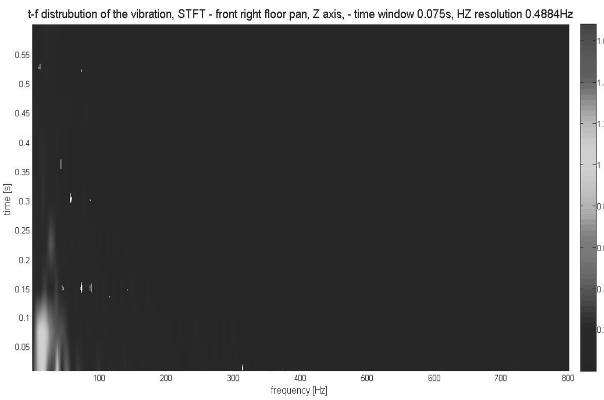

Fig. 13. Map of vertical vibration signal of impulse response of the floor pan, measuring point 2 - front right

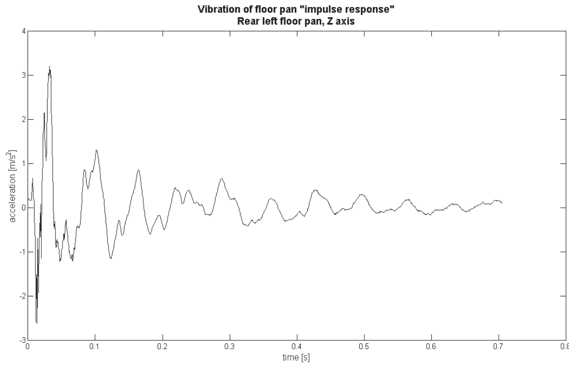

Fig. 14. Vertical vibration signal of impulse response of the floor pan, measuring point 3 - rear left

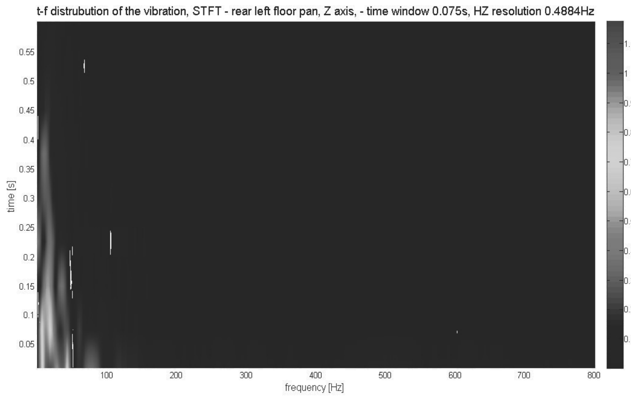

Fig. 15. Map of vertical vibration signal of impulse response of the floor pan, measuring point 3 - rear left

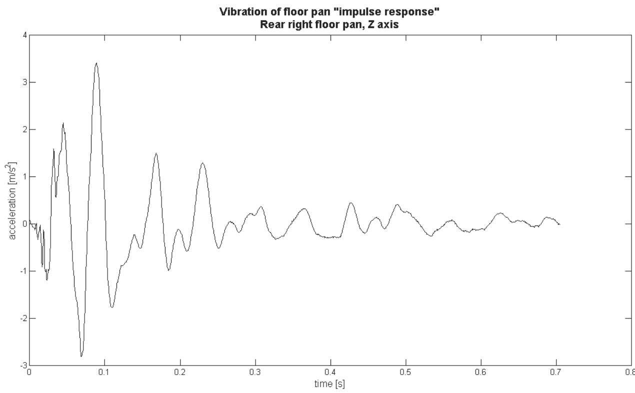

Fig. 16. Vertical vibration signal of impulse response of the floor pan, measuring point 4 - rear right

6. Conclusions

The paper presents some preliminary research on material vibration and analysis of material vibration propagation in floor pan. For identification the mapping of vibration measuring in multiple points were recorded. The distribution of the signal allows to identify the dominant frequency band. For the floor pan it is low frequencies, between 20 and 40 Hz. In this band the natural frequencies of the floor pan material can be identification. The obtained results have to be compare and analyse with complex signals of the vibration under many of different excitations.

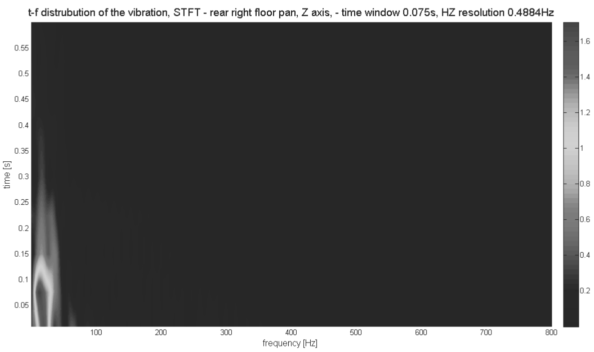

Fig. 17. Map of vertical vibration signal of impulse response of the floor pan, measuring point 4 - rear right

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