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Contributions in developing advanced engineering methods for researching the N.V.H. aspects in Porsche Cayman operation conditions at Technical University from Cluj-Napoca

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Abstract. Noise is one of the most important parameter that influences the artificial and especially automotive pollution. Developing new motor vehicles, widely known as cars, respectively their auxiliary systems is now difficult to be done without considering noise, vibration and harshness (N.V.H.) aspects in testing and operation. N.V.H. criteria facilitate the appreciation made by testers, owners and users in relation with vehicle's general behaviour and also in correlation with their auxiliary systems. Main objective of the present paper is to outline the innovative and advanced method in computer aided testing of N.V.H. parameters in a sporty car Porsche Cayman model at Technical University from Cluj-Napoca. Redefining the standards in comfort and tuning is close related to the N.V.H. research. These parameters are not acting as isolated factors in some isolated environment. They should be considered in relation with the complex whole which is the operating motor vehicle in the road traffic environment. Experimental testing results were achieved and properly analysed and interpreted. There were outlined some trend lines in each case. Development possibilities and perspectives were also pointed out in order to facilitate and encourage the further research of the specific problems.

1. Introduction

Considering noise, vibration and harshness (N.V.H.) aspects we aim to achieve a specific level of testing and to improve measuring capabilities as well as to develop some innovative and advanced research methods.

Increased expectations and regulations concerning noise, vibration and harshness (NVH) levels are inherent in automotive engineering and specific design. Optimal refinement is in this case one of the significant technological and design attributes to be looked at in the process of perfecting a motor vehicle and its specialized systems.

Noise emissions of traction drives and the coupling of structure-borne sound to surrounding technical devices is increasingly becoming a key performance indicator (KPI) in the automotive industry and is also used as an indicator for condition monitoring e.g. of production machines [1]. The present day automotive industry searches for any option to attract the customers with products which will be generating lower noise and consume less fuel but also be equally powerful. This unique requirement drives the motivation for building each and every aspect of a dynamical system to be represented in the math model. The car should be durable, less noisy, powerful, as well as elegant [2].

In order to develop new vehicle products with well-refined noise performance, vehicle noise measurements and analysis have to be conducted to validate designs and acoustic refinement [3].
High standards of NVH (Noise, Vibration and Harshness) performance are expected by consumers of all modern cars. Refinement is one of the main engineering and design attributes to be addressed in the course of developing new vehicle models and vehicle components [4].
By applying a specific methodology and materials the paper aims to achieve experimental results.

2. Methodology and materials

The best results in research are gained by applying scientific method and using adeqauted materials as it is shown in the next paragraphs. Environmental requirements of the recording equipment: operating ambient temperature 0° to 35° C; nonoperating temperature -20° to 45° C; relative humidity: 5% to 95% noncondensing; operating altitude up to 3000 m.

Methodology was developed at Technical University from Cluj-Napoca and materials were made available at the Automobile Laboratory from Automotive and Transportations Department.

2.1. Methodology

By measuring the noise level, considering the vibration critical range and analyzing harshness we can assess and evaluate the comfort level. The present paper shows an engineering method (Figure 1) for computer aided testing and appreciation in the field of N.V.H. parameters concerning the operation of sporty Porsche Cayman car.

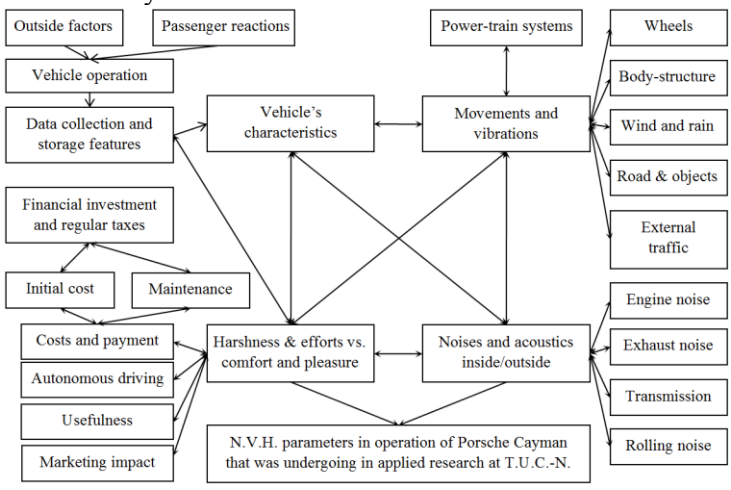

Figure 1. Short methodology in determining noise, vibrations and harshness.

The tested and evaluated car is a fully operational model, which was studied in relation with noise emissions, in-use vibrations and harshness level. An innovative method of advanced engineering research was sketched out. The interaction between computer processing power and N.V.H. evaluation effort is consistently highlighted.

The new design methods are starting to consider NVH issues throughout the whole design process. This involves integrating extensive modelling, simulation, evaluation, and optimization techniques into the design process to insure both noise and vibration comfort. New materials and techniques are also being developed so that the damping treatments are lighter, cheaper, and more effective. Noise, Vibration and Harshness, more commonly known as NVH, is an all-encompassing engineering discipline that deals with the objective and subjective structural dynamic and acoustic aspects of automobile design. The NVH engineer is interested in the structural dynamic response of the vehicle from the complete assembled system down to the normal modes of the individual components. As a vehicle is a moving dynamic system, its response to stochastic, time varying inputs is important for safety, quality, and comfort of the passengers. One specific area of study within NVH is vehicle acoustics. Sound plays an important part in the development of a motor vehicle [5].

2.2. Materials

Used materials consist in one full operational motored vehicle (Figure 2) Porsche Cayman model year 2016 and the auxiliary equipment and devices necessary for experimental testing.

As experimental equipment used in the developed tests were two mobile devices for noise measuring (md367fd/a) and data recording (A1367EMC2407 IC579C-E2407), also there was a test bench for vibration measurements (PF N750) as well as digital post-processing stations.

Figure 2. Available motored vehicle for experimental measurements concerning N.V.H. aspects.

2.3. Mathematics and calculus

Noise is a special category of sounds and it is defined as complex sound which generates an audible harshness. The elements which define the noise analyze are a part of the physiologic acoustics. The study of the link between the excitation and sensation intensity is made by Weber-Fechner law. According to this empirical law, for a hearing sensation variation in geometrical progression there is a correspondence in received hearing sensation variation in logarithmic progression, as in the next model [6][7]:

$$S = \frac{l}{k} * \ln \frac{I}{I_o} \quad [\text{Np}] \tag{1}$$

where: S is hearing sensation, in Np; k – integration constant; I – sound intensity, in W/m^2; I_o – minimal reference intensity perceptible in sound field, in W/m^2.

Taking into consideration the physical relation between intensity and acoustic pressure there may be determined the level of sound pressure level N_p, as mathematical model [6][7][8]:

$$N_p = 20 \lg \frac{p}{p_o} \quad [Np] \text{ (theoretical)} \quad N_p = 20 * \log_{10} \frac{1.7*10^3}{2*10^5} = 85 \quad dB \text{ (applied for close proximity)} \quad (2)$$

where: p_o is minimal acoustic pressure coresponding to the reference intensity, which has the value of $2 \cdot 10^{-5}$ N/m^2; p – instant pressure, in N/m^2.

3. Experimental setup and results

The vehicle and testing equipment were interconnected via contact or contactless technical devices. The vehicle was brought in the Automobile laboratory from the Technical University were is a specialized vibration test bed available in order to monitor the Porsche Cayman behavior in some frequencies range of motion, especially the wheel train.

Beside that there was also installed specialized equipment (microphone stand alone bench and software operated device) to measure the noise level multiple locations and various distances in 15 meters range from the inspected sporty car as it is shown in figure 3.

3.1. Experimental setup for testing

In order to get accurate testing results and to make some interesting observation in relation with the sound waves generated by the operational systems and powertrain there were implemented some innovative and advanced engineering strategies in following the research protocol on Porsche Cayman (Figure 3).

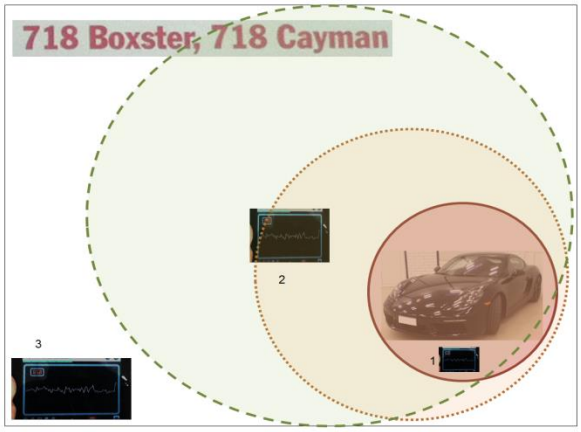

Figure 3. Points for measuring the noise level variation in motored vehicle car range.
1-in close range<5m; 2-medium range, 5÷10 m; 3-distance of 15 m.

The vibrations are analyzed on a specialized test bed available at Technical University from Cluj-Napoca as shown in figure 4, considering them in a cumulative protocol.

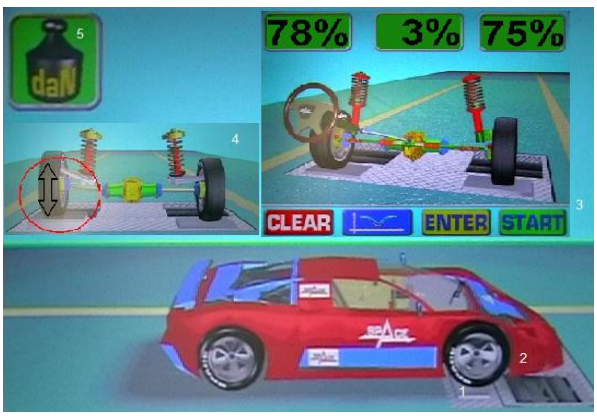

Figure 4. Schematic image of vehicle on vibrational test bed.

1-vibrational plates of test bench; 2-tested vehicle for vibrations and harshness; 3-vibration damping testing results on vehicle's front axle; 4-vibration damping testing results on vehicle's rear axle.

Other main sources of noise and vibrations are vehicle speed, engine speed and transmission as they are plainly presented in figure 5 and figure 6, mentioning the locations for n.v.h. generators.

Figure 5. Sources of N.V.H. in vehicle operation.

1-vehicle speed meter on board of tested vehicle; 2-tahometer for engine speed on board of Cayman tested model; 3-complex cutaway transmission model with 7 + 1 gears and multi disc dual clutch for both input shafts.

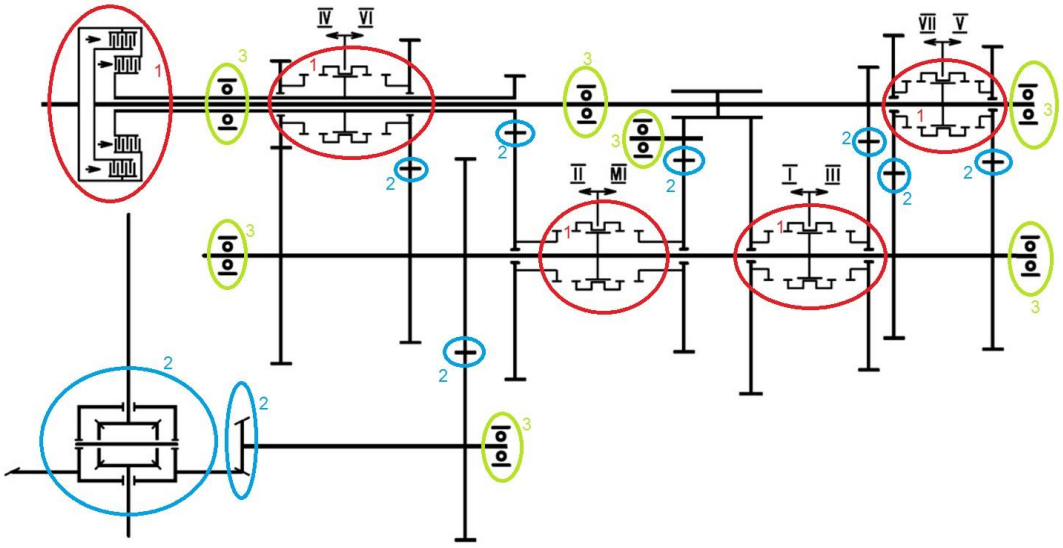

Figure 6. Simplified model of complex Direct Shift Gearbox 7 + 1 as a N.V.H. source.

1-main sources for noise and vibrations at gear change; 2-secondary sources of noise and vibrations; 3-lowest N.V.H. generation sources.

3.2. Experimental testing results

By setting up a computer assisted experimental model (Figure 7) and measuring the noise level (Figure 8), considering the vibration critical range and analyzing harshness we can assess and evaluate the comfort level. The present chapter shows a synthesis of some results collected with an engineering method for computer aided testing (C.A.T.) and appreciation in the field of N.V.H. parameters concerning the operation of sporty Porsche Cayman car (see table 1), with specific applicability on optimization process of the studied vehicle. The tested and evaluated car is a fully operational model, which was inspected concerning noise emissions (Figure 9 and Figure 10), in-use vibrations and harshness level. An innovative method of advanced engineering research was sketched out. The interaction between computer processing power and N.V.H. evaluation effort is consistently supporting the evaluation process.

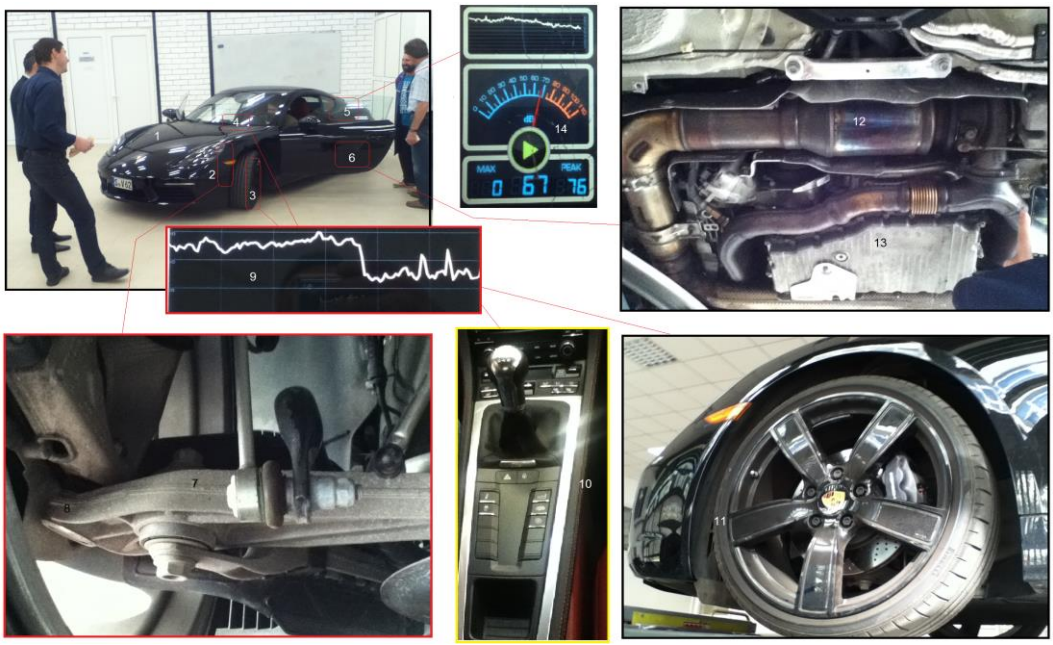

Figure 7. Research equipment from Technical University and studied Porsche Cayman.
1-Tested car; 2-front suspension; 3-wheels; 4-on-board recording equipment; 5-engine sound measurement; 6-power train; 7-lower suspension arm; 8-joint; 9-sound curve; 10-gear change; 11-tire; 12-exhaust; 13-gearbox; 15-software app.

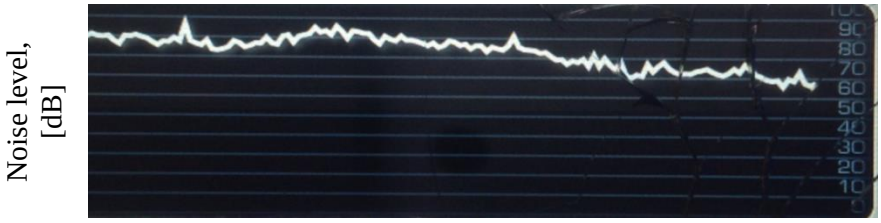

Figure 8. Noise variation from start in accelerating process of tested car.

Table 1. Vehicle technical date.

Parameter	Value
Manufacturer	Porsche
Model	Cayman
Code	982
Fuel	Gasoline
Pollution standard	Euro 6

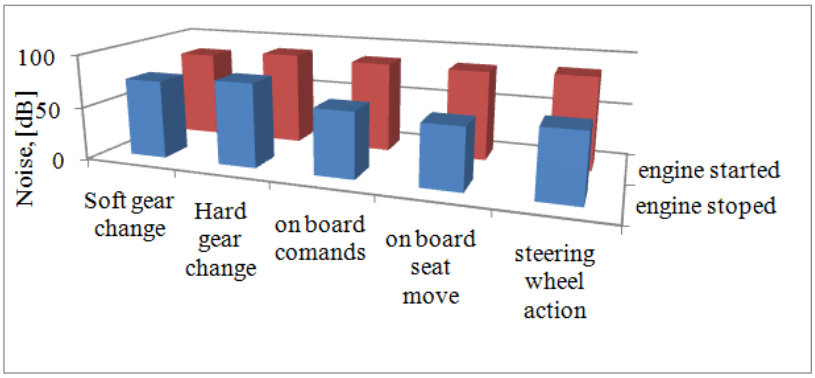

Figure 9. Noise values in various conditions of Porsche Cayman.

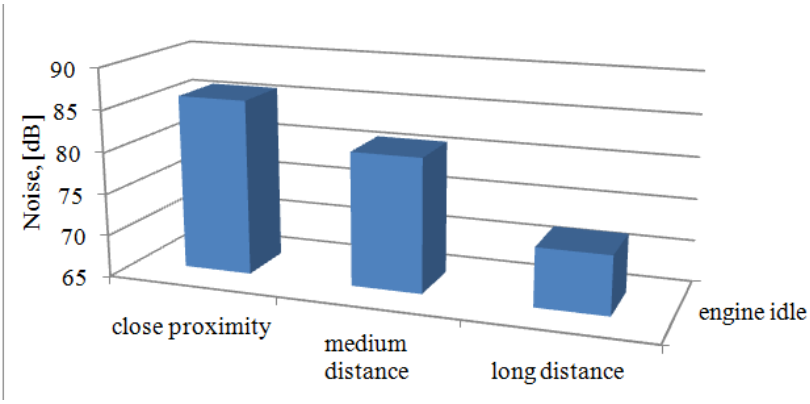

Figure 10. Noise values at various distances from Porsche Cayman.

3.3. Limitations of the proposed study

The research is restricted to the development and validation of an innovative affordable engineering method in computer aided testing or evaluating the N.V.H. parameters for Porsche Cayman sporty motor vehicle and it surely may be extended and applied in other cases and situations also.

The proposed personalized analysing method worked adequately in the developed work for Porsche Cayman, but needs to be highly defined in order to apply it for large series of motor vehicles.

3.4. The novelty of the achievement

The research crew members are experienced in internal combustion engines, transmissions, pollution, alternative energy sources for green vehicles and mechanical construction technologies. The consideration of N.V.H. aspects in operating conditions represents a synthesizing endeavour of capabilities, technologies and experiences. Even if there were also considered in the previous work some particular tests of vehicle's mass oscillations, this is the first integrating process of so many important aspects that define N.V.H. evaluating criteria and advanced engineering methods based on computer processing power available today. Originality of the paper consists in research method and applied protocol, while the applicability is both in acoustics engineering and automotive development.

4. Conclusions

Redefining the standards in comfort and tuning is close related to the N.V.H. research. N.V.H. parameters are not acting as isolated factors in some isolated environment. They should be considered in relation with the complex whole which is the operating motor vehicle in the road

traffic environment. The N.V.H. aspects have an engineering influence in the vehicles development and operation, but also they have a financial impact when it comes to car marketing.
Noise levels of analysed sporty car are higher than regular series BMWs or other usual motored vehicles, an aspect which influences both user's satisfaction and attention.

Close range measurements of noise show actual values between 75 to 130 dB, when the engine is running and speeds up at high revs level, with applicability in car design and operation optimization.

By departing from the operating vehicle the sound level is ranged from 45 to 68 dB.
The initiated study creates development possibilities and perspectives which facilitate and encourage further research of the specific problems.

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