COMBUSTION ASSOCIATED NOISE EFFECTS IN FLEX-FUEL ENGINES

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Abstract. *Flex-fuel engines have become the rule in the Brazilian car industry. At the same time car buyers have become increasingly demanding with respect to the acoustic comfort of their vehicles. An adequate knowledge of the noise generated by this new engine type has become therefore of special relevance, The present work describes how calibration parameters of these engines may influence combustion and how this modification may lead to a change in the noise level generated by a given engine. Preliminary results are here described in a discussion mainly concerned with the feasibility of the proposed technique. The influence of the pressure curve, and its relationship with the advance angle, in particular, are associated with the resultant noise level. The study also considers the difference in the noise radiated by the engine and how it is perceived inside the car cockpit.*

Keywords: *Noise, combustion, engine calibration, flex-fuel engines*

1. INTRODUCTION

Road vehicles have become considerably quieter in recent years as a result of applied research, which has become increasingly important to market formed by a more demanding consumer. The traditional noise and vibration sources in a vehicle such have become quieter and improving comfort in modern vehicle now requires a detailed and thorough analysis even to obtain small gains (Guimarães et. al., 2007). In fact the problem is further complicated by the fact that not only traditional noise approach such as in Beranek and Vér , 1992 needs to be considered but also the perception by the vehicle occupants perceive as an indication of quality (Guimarães et al. 2007).

Other environmental related aspects have at the same time become more important, such as those associated with pollutants emission and other important issues such as safety rules now require an integrated approach, where a variety of features has to be simultaneously considered.

1.1. Engine generated noise

The present study is concerned with the noise generated by the power plant of the car, certainly one of the most obvious noise sources in a motor car. In a very broad sense it is possible to classify engine noise into three types of noise, namely: noise due to combustion, noise due to fluid flow and noise resulting from the movement of variety of components. From a purely noise generation point of view, these effects are independent. However, they become integrated effects when the engine comes into operation. For this reason, the engine so-called sound signature is a function which directly depends on the engine set-up. In other words, operational point programming may heavily influence noise emission, and at the same time, conventional pollutant emission. In order to obtain more efficient results these two considerations have to be simultaneously analysed (Alt et. al., 2003).

According to FEV (Wolf et. al. , 2007) the engine noise can be described as the combination of factors indicated in Figure 1.

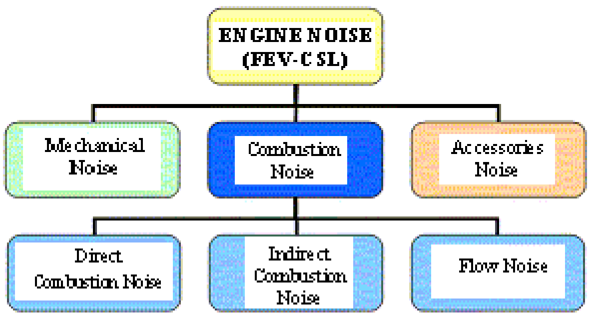

Figure 1. Components of Engine Noise

For the case of the present study where the main concern is how the set-up point influences noise output, accessories noise needs not to be discussed. For the same reason mechanical noise shall only be involved indirectly, and not mentioned in the text which follows.

1.2. The Flex engine

Flex-fuel engines have become by far the preferred choice of Brazilian based car factories. There are many good commercial reasons for that, but also they represent a very important tendency towards increased efficiency, less pollution and reduced dependency on petrol based fuels. However there is still a considerable room for improvement for these engines, as certain design compromises have to be taken to maintain the supply of a growing market. As such, design complexity has increased since fuel changes introduce a variety of operational changes which are inter-related.

Ethanol has provided an interesting alternative in Brazil, for the last thirty years, improving anti-knocking figures, increasing power and torque and reducing pollution. However, it has also introduced difficulties from the point of view NVH (noise vibration and harshness), and also for other issues concerned with wear and fuel, just to mention a few of the issues. Also the designer of a flex engine compensates the differences by changing operational set-up, modifying the calibration curve, the rotational speed and the advance. These parameters also have a decisive influence on the engine performance.

Calibration adjustments have been traditionally targeted only at consumption, performance and gas emissions. Noise emission has been only a matter of concern if a standard figure provided by the regulation institutions are not met. However for a more efficient design these considerations have to be analysed in a more comprehensive way together with NVH figures. The present study is concerned with this analysis.

2. COMBUSTION NOISE GENERATION

Sometimes it may be convenient to separate combustion noise into two different components, namely: direct combustion noise and indirect combustion noise.(Alt et. al. , 2003). Direct combustion noise results from the effects caused by pressure associated with burning and the resultant forces applied to the internal structure of the engine, which results in noise generation. This contribution can be therefore associated with the engine pressure function. Indirect combustion noise, on the other hand is associated with torsion forces in the crankshaft and piston side force.

Engine flow noise is also usually associated with combustion noise, since it appears as a result of the engine operation, what only occurs when the combustion process is running. As such FEV Motorentechnik GmbH (Wolf et. al., 2007) suggests that a convenient way to model the problem is to associate noise generation with the engine pressure curve and the engine torque curve.

3. METHODOLOGY

Since the objective was to associate NVH (Noise Vibration and Harshness) parameters with a given engine calibration experimental measurements have been carried out monitoring noise perceived by the car driver for a certain pressure condition in the combustion chamber. Noise as perceived by the driver has been obtained by positioning a microphone in the head rest, where the drivers right ear would normally be. Combustion chamber pressure has been determined from a pressure transducer positioned in the chamber.

Testing of the vehicle has been accomplished with the use of a roll dynamometer installed an acoustically insulates chamber. The testing procedure encompassed three base conditions, namely: using gasoline, using ethanol and a reference calibration, and using ethanol and the calibration here proposed. The engine rotational speed and load, as well as the engaged gear, have been chosen not only to represent a real condition, but also in a situation where engine noise would be important.

Calibration changes have been effected with the use of a spark advance control. Again this is a suitable strategy, not only because the calibration is modified but also because it represents a typical operational parameter change in a flex fuel engine.

All the measurements sets have been collected in a series of 10 seconds intervals, sufficient time to provide reliability of results.

Typical set of results are to be observed in the following text.

4. RESULTS

Figures 2 to 4 tipify the results which have been obtained. Figure 2 indicates the condition for an engine rotational speed of 2000 RPM, up to measured frequency of 1 kHz. The noise expressed in dB (A) SPL indicates the perceived noise inside the car cockpit. Even though acoustic comfort is normally expressed in terms of dB(A) it is important in this case to quantify the relative contribution to the averaged final result. This data not only helps to identify individual contributions but also provides valuable indication of how to deal with a variety of aspects associated with subjective noise perception, some of them providing information about acoustic features not only relating simply to comfort. Also it helps to identify whether a certain fuel or calibration condition is bound to provide a specific sound quality parameter.

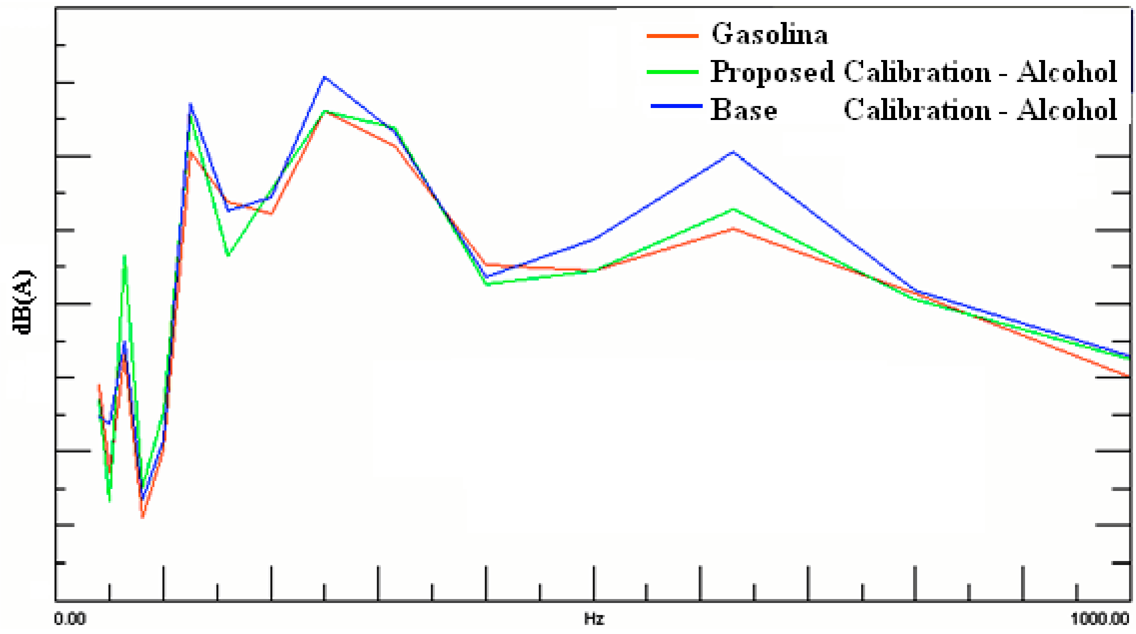

Figure 2. Engine noise and frequency band

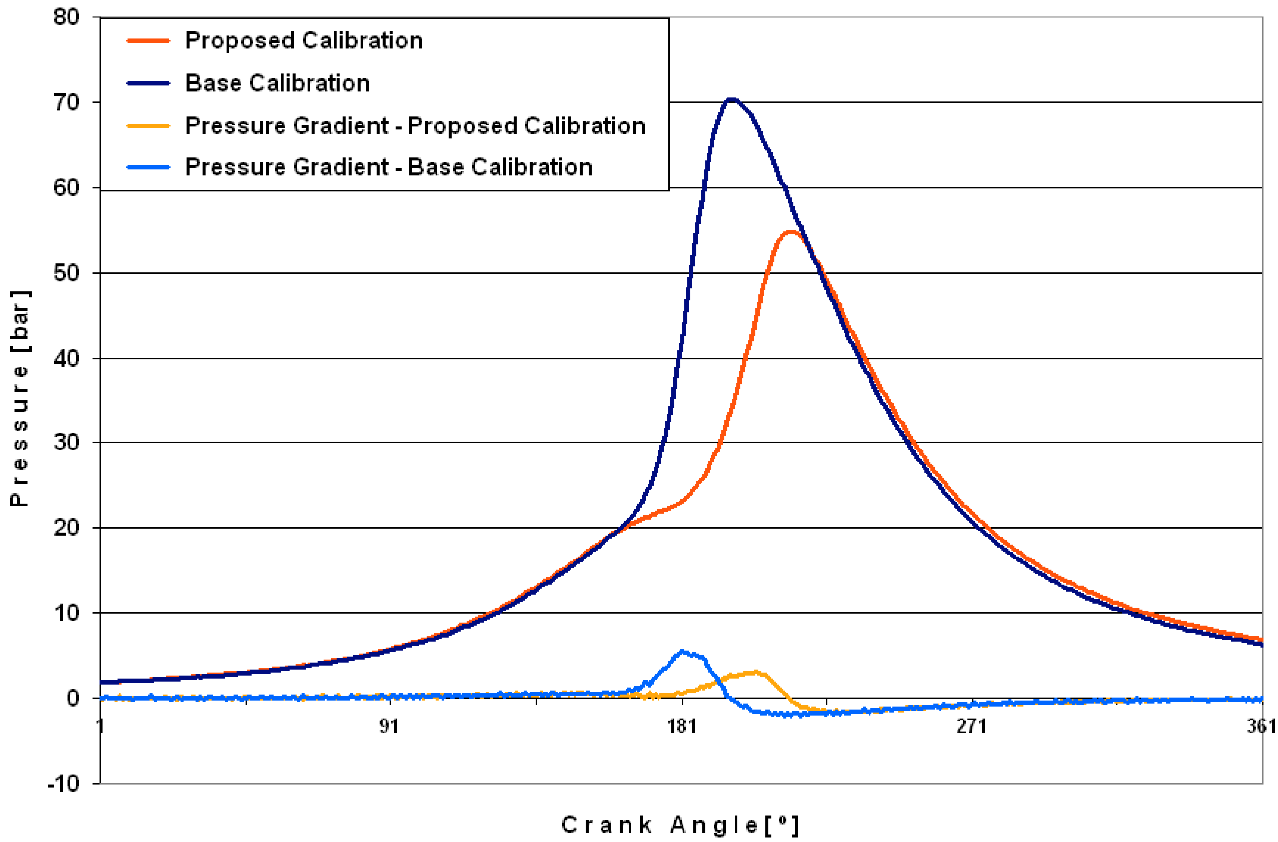

Figure 3. Effect of calibration in combustion chamber pressure

It is possible to observe a fair improvement in noise emission, which is more noticeable for some of the frequency bands, at certain conditions even approaching the observed noise levels when the fuel is gasoline.

Figure 3 provides an inside into a specific engine operation for a given calibration condition, again with the engine running at 2000 RPM. It is possible to observe that the curve becomes smoother for the proposed calibration. Again this confirms the possibility of obtaining a gain in noise reduction, since a smoother pressure curve reduces the forces and torque associated with noise generation. It should be emphasizes however, that at the present stage of development separate contributions associated with each component cannot be expressed in terms of precise values. This part of the study is at the moment under development.

The other part of the present study is associated with fuel consumption and pollutant emission. These results are still being examined and the first impression is that there is not a very significant change for this parameters, for the proposed calibration curve, when it is compared with the base calibration curve. Other tests have been carried out for higher rotational speeds of the engine and again a gain in noise could be observe with hardly any change in consumption and emission values.

Figure 4 presents a general comparison in terms of noise emission for the three main conditions of the present analysis. The advantages in terms of noise for the proposed calibration are rather obvious. However it should be emphasized that the results of the present text only represent a first step of this research, and there is still the need for further refinement in order to obtain a more precise definition of the gain to be obtained.

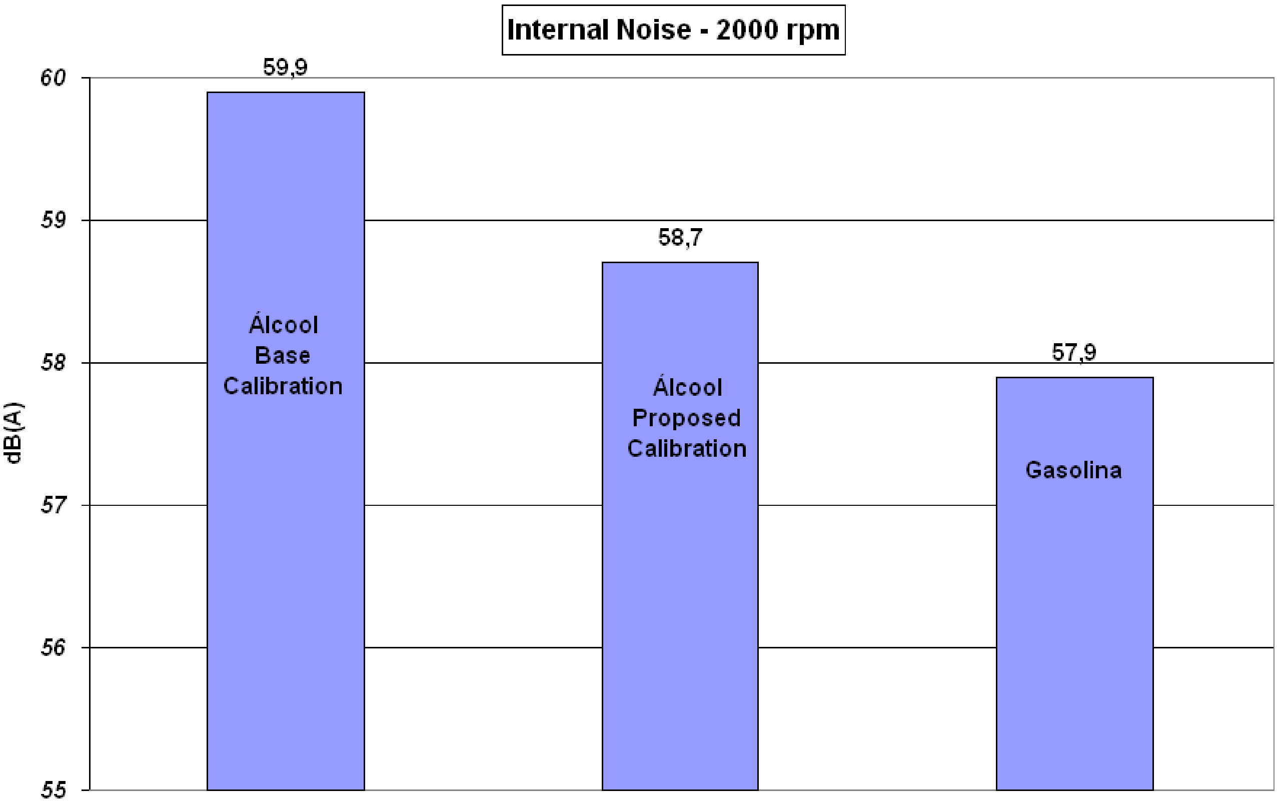

Figure 1. Diagram of shear modulus versus frequency at 303 K

5. CONCLUSIONS

The effects of engine calibration on noise emission have been investigated for a typical flex fuel engine. The calibration changes have been implemented for the “noisier fuel”, that is ethanol, and compared for the base (standard) calibration and for the engine running on gasoline. The obtained noise figures have been associated with the operational condition, here expressed in terms of the observed pressure in the combustion chamber.

The preliminary results here presented indicate that interesting gains are to be obtained in terms both of smoothness and noise, indicating a potential gain in NVH parameters.

Other factors such as fuel consumption and pollutant emission have also been observed but not presented here as further testing is required before more reliable results can be made available.

Finally, it must be emphasized that the present study needs to be implemented in a multiparameter environment, where other parameters such as those associated with performance and endurance are also taken into account. However the present study indicates that the proposed strategy provides the designer with very interesting possibilities which present the possibility of obtained a better and more comfortable vehicle.

6. ACKNOWLEDGEMENTS

The authors would like to acknowledge the support provided by FPT Powertrain Technologies and the staff of the Product Engineering laboratories that has enabled the development of the present work.

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8. RESPONSIBILITY NOTICE

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