

Development of Exhaust Sound Quality on Aston Martin V8 Vantage

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ABSTRACT

The Aston Martin V8 Vantage represents a new chapter in the company's development. In line with brand image the new product was required to exhibit a powerful and sporty yet sophisticated sound which would become a leader against competitors.

The exhaust orifice sound was tuned via a combination of CAE simulations and iterative modifications coupled with subjective assessments.

The final product exhibits a strong, linear, firing-order dominated sound which is unique to the vehicle and unlike many other traditional V8 soundtracks. The exhaust sound quality can be seen as a vehicle feature affirmed by the positive feedback from customers and press.

INTRODUCTION

As the demand for vehicles to become more and more refined increases, sound quality is becoming a greater concern to manufacturers. Increasingly it is not only the sound level that is considered in noise control, but also sound quality. Pang et al [1] have shown that sound quality is an important attribute that relates strongly to customer satisfaction. Furthermore, sound quality can be used to enhance the brand image of a manufacturer [2], being used as a competitive advantage over other brands.

Powertrain NVH is an extensive subject covering both error states and sound quality tuning of the whole engine, driveline and associated systems. Exhaust and intake sound are two of the major contributing elements to vehicle noise that a driver responds to. Consequently, the sound quality of the exhaust note is an important factor for the vehicle's customer appeal [3].

This paper gives an account of the target setting, design process and iterative tuning steps employed within the development of the exhaust sound quality.

BRAND DNA

Traditionally there are two main vehicle sound classifications: the limousine/cruiser with a quiet and discrete sound, whereas for sports cars a more rough and powerful sound is requested. The company's brand image is of a luxury sports car, and as such, it crosses the boundary between the above two classical groupings. It is desired that the product displays a powerful, sporty image, and therefore sound, but at the same time, the vehicle should be capable of cruising comfortably and luxuriously.

This contradiction was achieved successfully on other company products by utilising the exhaust bypass valves. A similar system was to be used for this new sports car, but it was key to incorporate brand images;

Exhaust sound quality should be:

- Sophisticated sound
- Lightweight, free revving character
- Leader amongst competitors

It should not be:

- Large, lazy, rumbling
- Highly stressed, racing engine
- A silent, super refined luxury engine

TARGET

As part of the target setting process each attribute is split into individual sub-system and component level targets. Figure 1 details a high level generic breakdown of the overall vehicle sound quality through to exhaust sound quality.

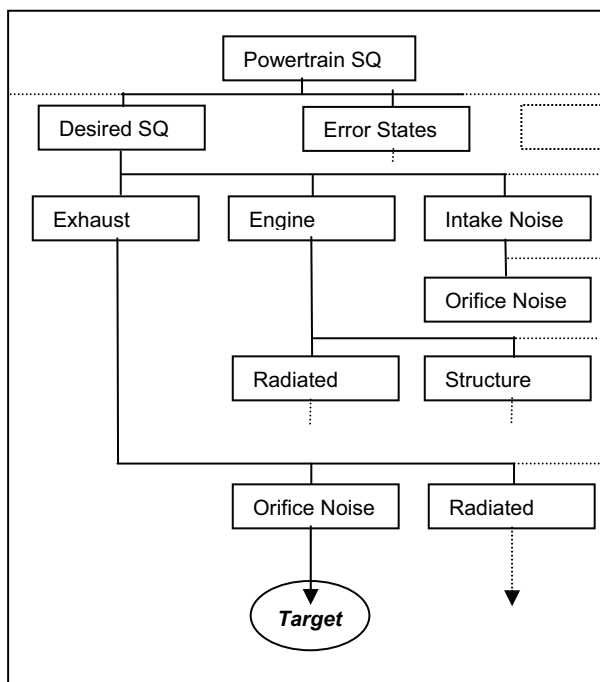


Figure 1: Example of high level breakdown of sub-systems and component targets.

Within the company brand image, much emphasis is placed on the exhaust orifice noise contribution above other attributes to create the overall sound quality. This is partly as a result of a strong brand image in this field, but also due to the difficulty of allowing only desired noises from the engine bay into the cabin without added devices.

In order to achieve a desirable exhaust orifice noise, the target sound needs to be carefully planned. Firstly it is important to establish and understand the type of vehicle, its image and product placement within the company and also market place. Figure 2 demonstrates where the sports car will sit within the company's model range.

It is clear from the graphic below that there should be an aggressive and sporty sound quality in line with the vehicle. Evoking this quality involved the tuning of many systems within the vehicle (as highlighted in figure 1), but it is the tuning of the exhaust orifice noise that is the subject of the following.

	Sports car	GT	'Halo' product
Concept Styling	Benchmark sports cars	Sportiest GT	Prestigious Flagship
P/T Performance	380bhp	450bhp	520bhp
Engine	V8	V12	V12
P/T Sound Quality	Sporty, Powerful Unique	Powerful Comfortable Smooth	Powerful Strong Exciting

Table 1: Sports car positioning within the brand.

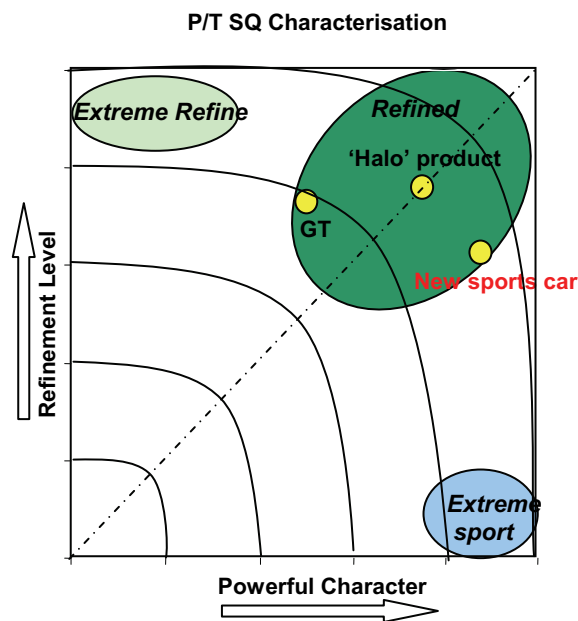


Figure 2: New sports car product position within company portfolio.

Defining the target sound for a sporty vehicle is key. Many studies have been performed on what makes a sporty exhaust sound. Generally it is accepted that the firing order of the engine should be dominant [1]. However it is often stated that in addition to this, it must also contain multiples of the fundamental firing order, as well as a degree of sub-harmonics, or half orders [3].

The first basic method for giving a performance or sporty impression to the customer is volume. Surveys have shown that loudness has a distinct effect in the performance impression, with louder sounds giving a higher performance impression. [4]

However, simply increasing the volume alone is not enough to generate a sporty quality sound. Naylor et al [3] have demonstrated that for a sound to be perceived as sporty it should in addition to the firing order have a sub-harmonic sound content. For a V8 engine they demonstrated that three components were found to correspond to an improved 'sporty' sound. These were: rumble (half orders); deepening of sound (amplified 4th & 6th orders); hollow sound (amplified 8th, 10th & 12th orders)

The amplification of sub and half orders provides a roughness to the sound which is usually perceived as sporty. This is as a result of increasing the periodicity of the combustion waveform which creates a modulation – perceived as roughness. The amount of roughness is dictated by the levels of the sub and half orders [4 & 5]. If the modulation is too much, the sound can be unpleasant, therefore the level of half orders need to be very well balanced otherwise the sound will become unpleasant.

With this said, the desire was to exhibit a sporty, powerful, and unique sound, identifiable with the brand. However, key to the product is its everyday usability, and in line with this, the sound should also be comfortable for daily use, and not too extreme. In line with the findings above and benchmark data from current products and competitors, the target sound was specified as shown in figure 3:

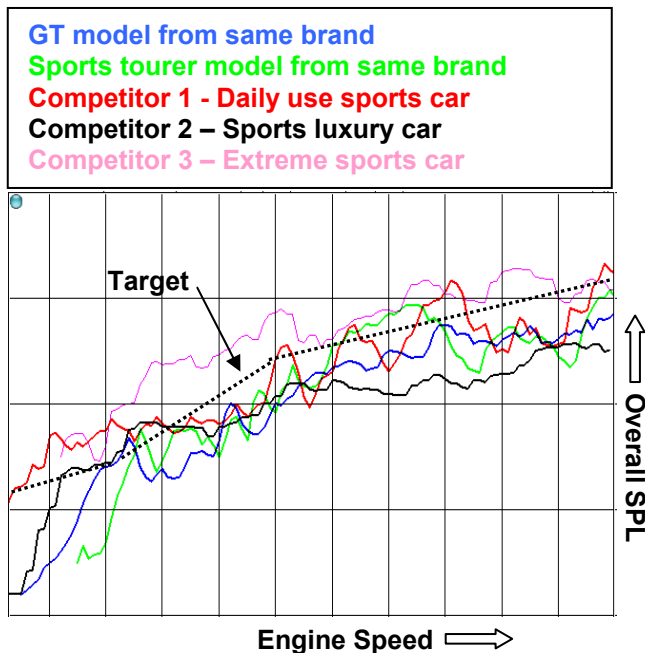


Figure 3: Overall cabin noise during 3rd gear WOT run up for several European competitors.

Target Sound:

- 3dB higher than current GT product overall SPL.
- Firing order dominated (4th EO)
- Minimum half and odd order contents (10dB lower than 4th EO), but enough to contribute to a sporty sound.
- Linear transition under acceleration.
- Comfortable sound to cruise with and for everyday use at low engine speeds.
- Exciting sound at high engine speeds.

As a production vehicle, it also required to pass all legislative noise control tests such as the drive-by cycle test.

DESIGN PROCESS

For sound quality development a prototype vehicle was assigned for use with development mufflers. Traditionally the exhaust orifice sound was tuned via iterative steps in modification to prototype hardware and on vehicle subjective assessment of each design.

Throughout development of this product a sound quality CAE tool was fully used for the first time within the

company to assist with the development. Ricardo WAVE allowed many design iterations to be quickly assessed which previously would have not been considered. The CAE capability was not intended to replace subjective assessment but to aid the direction of development. As this was the first programme within the company to use acoustic CAE, much of the early work was concentrated on correlation and building up confidence in the techniques and results with the intention of its use on future programmes.

CAE MODELLING

Ricardo WAVE is a 1D CAE code used to analyse the dynamics of pressure waves, mass flows and energy losses in ducts. It can be used to model engine systems including intake and exhaust manifolds, pipes and mufflers. It provides a fully integrated treatment of time-dependant fluid dynamics and thermodynamics. [6]

Using the 3D builder add-on package, an air-to-air (induction-engine-exhaust) CAE model was built up for the entire engine system from clean air ducts through to muffler exit orifice. A post processing element was then used to simulate the sound from the modelled system. This allows changes to be made quickly and efficiently to the model and the effect on the sound analysed.

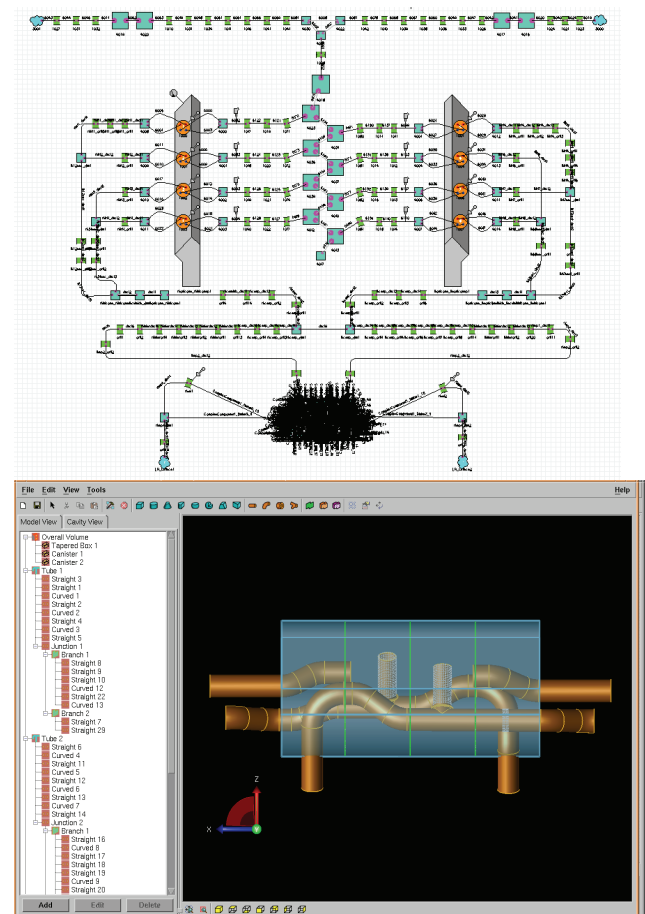


Figure 4: Screen grabs of the model used and the 3D build element within WAVE.