NVH Challenges for Two- and Three-cylinder Engines

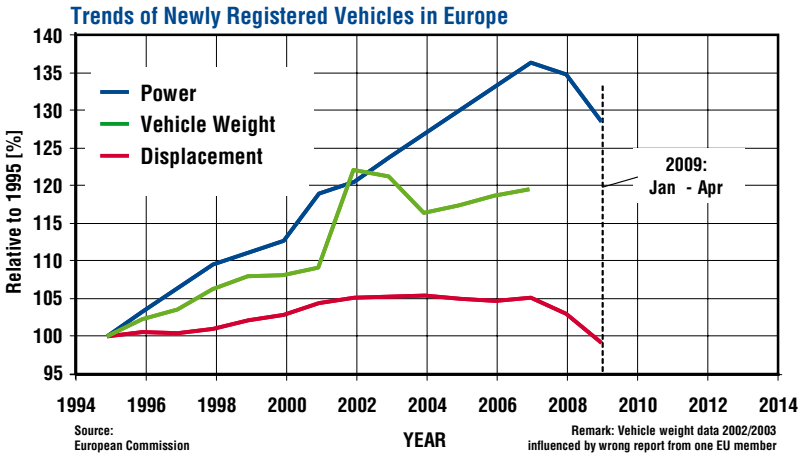

Fig. 4: European Passenger Car Trends Regarding Performance, Weight and Displacement

Engine designs from the 1990s strived to achieve improved performance and reduced cost, while adhering to emissions regulations. Recently, the focus has shifted towards extremely fuel efficient, yet affordable engines. This development is the result of rising consumer demands for smaller, low-fuel consumption and low-cost vehicles and by the legislation of increasingly stringent fuel consumption standards around the globe.

Figure 4 depicts these developments in consumer behavior and illustrates this trend. The drastic turnaround in 2008 was provoked by the German government's scrapping bonus program and overstates the general trend. The trend towards powertrain downsizing will lead to considerable market share gains for three-cylinder engines in the smaller vehicle segment up to medium-sized cars. Two-cylinder engines, on the other hand, will only be used as basic powertrains in the very smallest class of vehicles. However, these two-cylinder engines will be more attractive in the even more cost-conscious emerging markets.

Since the use of two- and three-cylinder engines will increase in the future, the special NVH challenges that arise from this trend should be examined more closely. Based on the knowledge gained in many projects that have been conducted in this field, three-cylinder engines do not generally lead to an increase in the vehicle's interior noise level. In fact, from mid-rpm levels and up, the dB(A) level is lower than with comparable four-cylinder engines [Fig. 5]. The sound character is, however, often perceived as rough. This is due to a different ratio of the gas and mass forces in the cranktrain drive, as well as high structure-borne noise induction via the engine mounts. To be effective, counteractive measures must address these issues. Three-cylinder engines with carefully designed NVH vehicle integration will receive high customer acceptance.

The fundamental question that arises with three-cylinder engines is whether a balance shaft is necessary. FEV investigations on three-cylinder engines have shown that the impact of a balance shaft on interior noise is only marginal. Only at very high speeds (>5,000 rpm) is there an audible difference in the interior noise with and without the shaft. Thus, eliminating the balancing shaft for engines with a displacement of less than 1.3 L seems quite feasible and can lead to further weight, cost and fuel economy advantages. The decision on whether or not to use a balance shaft should be evaluated by experts for each individual case during the concept phase. Reliable predictions during early stages of the development cycle have been facilitated through the use of extensive databases, combined with fast NVH tools that have been tried and tested.

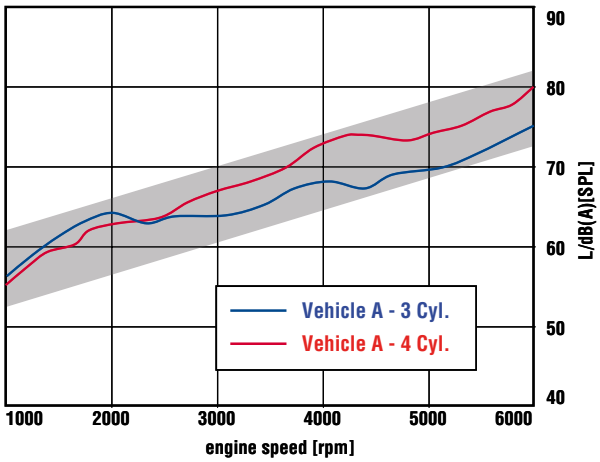

Fig. 5: Interior Noise Levels of a Vehicle with three- or four-cylinder Gasoline Engines

In the case of two-cylinder Engines, the design of the basic engine concept is much less restricted. Design concepts, such as flat engines, in-line and v-engines are already being used in regular production motorcycles.

Similar to the manner in which these different concepts impact packaging and cost, they also considerably influence NVH behavior. Sound characteristics can be produced that resemble a motorcycle engine used in a BMW (flat engine), Ducati or a Harley Davidson. All of the evaluation criteria must also be considered in order to arrive at a decision that is suitable for the particular application. At FEV, a decision matrix is created through the use of extensive databases, as well as tried and tested calculation tools, which yield reliable evaluations within a few weeks.

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