SI Engine Downsizing – The Potential and Limitations for Two- and Three-Cylinder Concepts

In the compact vehicle segment, three-cylinder engines are becoming increasingly more common. As engine swept volumes continue to decrease, the question will eventually arise, whether cylinder displacement should be further reduced or if the introduction of 2-cylinder engines makes more sense.

A simulation of the NEDC shows that for a typical base vehicle using an SI engine (3-cylinder, VH = 1.1 L, 44 kW, 5 MT, 1130 kg), for a variety of different engine displacements, a range of variants regarding the number of cylinders, and charged versus naturally aspirated versions, a CO_2 advantage from 4-6 % can be realized with downsizing [Figure 3]. Thermodynamically, the two-cylinder versions have a relative advantage of approximately 1.6 %, compared to the three-cylinder variants, because the specific cylinder volume is more favorable.

Achieving equivalent vehicle performance requires a change to 4-valve technology and variable valve timing for the downsized, naturally aspirated variants; 2-valve technology is appropriate for the charged versions. The CO_2-reduction potential of the charged concepts is greater because of their inherently better downsizing potential, as well as the possibility of reducing the rated speed in combination with an appropriate optimization of the gear ratios.

Conversely, the air charged versions, especially the two-cylinder variant, are at a disadvantage in terms of dynamic behavior compared to the naturally aspirated versions. As a result, a charged version of the two-cylinder engine with a small swept volume is not a viable option. In addition, the increased expense of the charging system is a reason to avoid charging in this price-sensitive vehicle segment.

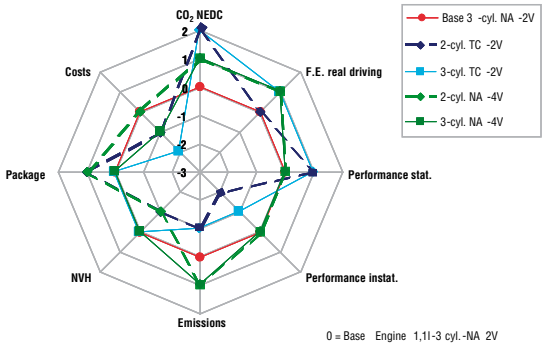

Fig. 4: Overall Evaluation of 2- and 3-Cylinder Concepts

The naturally aspirated variants [Fig 4] do not present any significant advantages or disadvantages. The three-cylinder naturally aspirated engine has advantages in terms of noise character and a comparable absolute NVH level. However, the naturally aspirated two-cylinder is more attractive in terms of cost and offers a higher potential for CO_2-reduction. Both of the naturally aspirated versions must be equipped with variable cam timing and a variable intake system to compensate for the required range of vehicle performance. The two-cylinder engine could also be a good solution as a base engine for a "Range Extender" in a future electrically-driven vehicle.

The determination of which downsized version is most appropriate also has to consider criteria such as integration into an engine family or the potential for variants with increased performance. Evaluations of the potential for further CO_2-reduction in the compact vehicle segment, using measures such as optimization of tire rolling resistance or a start/stop system, suggest that it is possible to realize NEDC CO_2-levels of about 100 g/km with conventional gasoline engines.

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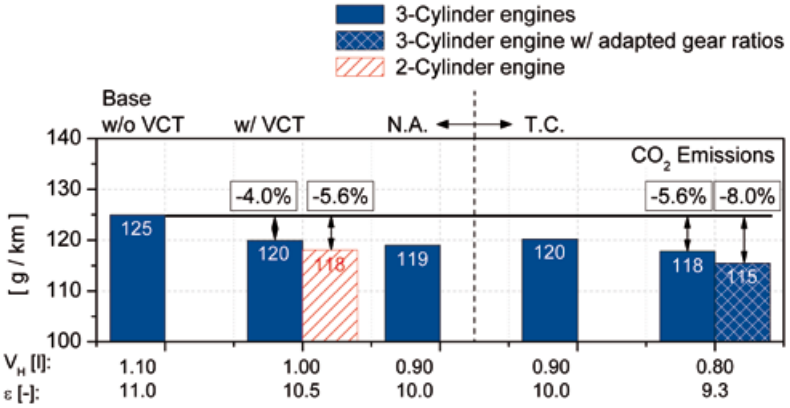

Fig. 3: CO_2 Emission Reduction in NEDC – Charged and N.A. Variants