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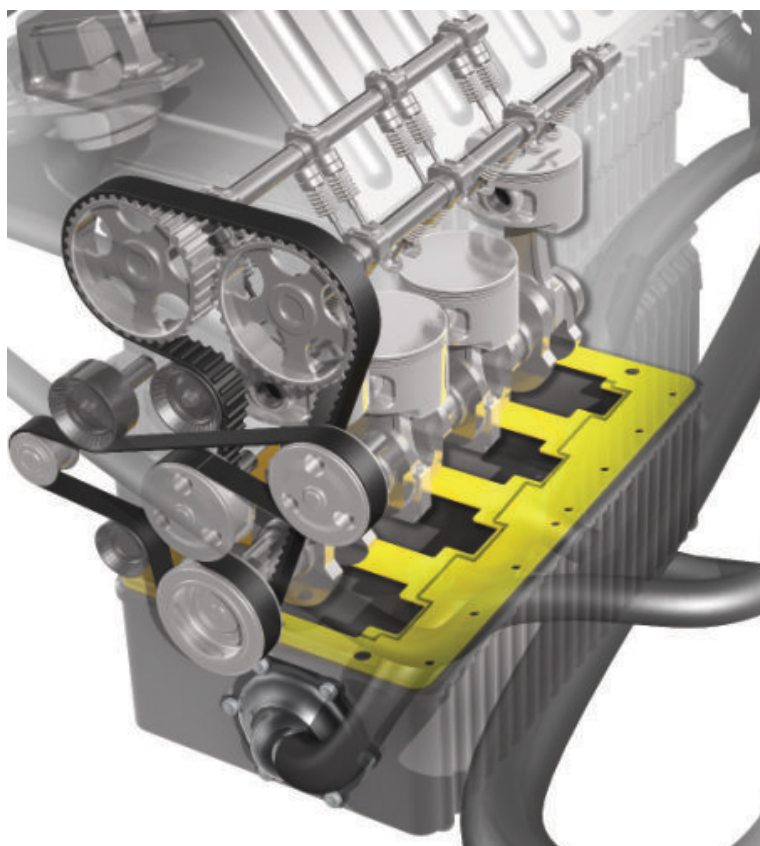
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Shear plate reduces diesel-engine noise

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This CAD model shows the placement of the engine shear plate (yellow), the introduction of which helps to damp fundamental engine-block "breathing modes."

In 2007, more than 50% of all passenger vehicles sold in Europe were diesel powered, amounting to a total of 15 million sales, according to the **European Automobile Manufacturers' Association** (ACEA). In France and Belgium, more than 70% of passenger cars sold are diesels.

The diesel engine's well-known and often criticized "noise" has been heavily treated with acoustic countermeasures to reduce knocking to an acceptable level on today's passenger vehicles. However, diesel-engine noise is expected to increase with the introduction of new Euro 5 and 6 emissions regulations.

Designing high-performance engines that meet the new standards will require increased combustion pressure, which can result in vastly increased levels of high-frequency engine-block vibrations and radiated noise. Vibration transmitted from the block to other engine parts, such as the oil sump and transmission cover as well as to the car body through engine mounts, adds to the NVH challenge.

With Euro 5 scheduled to come into force in September 2009, and Euro 6 five years later, it is clearly time for car manufacturers to rise to the challenge of meeting the new emissions standards while still providing further improved levels of vibration and noise, both in diesel and gasoline engines. This is exactly the challenge that French manufacturer **PSA Peugeot Citroën** has been meeting head on.

"Diesel knocking is, to a very high degree, dependent on the combustion pressure," said Léon Gavric, a senior expert in acoustics at PSA who is also responsible for the Powertrain NVH (noise, vibration, and harshness) Department. "To meet the new Euro emission standards, a lot of people will concentrate on optimizing the combustion, resulting in very disappointing engine acoustics."

For the last 10 years, PSA has been studying what causes the acoustic radiation specific to diesel knocking. The conclusion is that there are specific "breathing modes" on the engine block excited by combustion, and that these are responsible for the sound radiation and diesel knocking.

"We had the idea to put a damping plate, cut in a smart way, inside the engine," said Gavric. "We patented our idea, which was based on a sandwich (constrained layer) shear plate where the deformation in the middle layer attenuates the knocking. We already had a good relationship with **Trelleborg Rubore** AB and knew that they had the vibration-damping expertise that we needed, so it was quite natural that we turned to them for the development of this shear plate."

Trelleborg Rubore, based in Kalmar, Sweden, is the global market leader in NVH solutions in brake applications, but it also has a thorough knowledge of noise and vibration damping solutions for powertrain and chassis parts. Early on, the company saw that, in the design of shear plates, it could make good use of its Duru-LAM (durable rubber laminate) material, which consists of two steel layers with a rubber layer in between.

"When PSA contacted us," said Arvid Norberg, R&D NVH Manager, "we immediately joined the project. Even though we did not know what the end results would be, the idea of introducing a high-damping material inside the engine was particularly suited to our expertise. Soon we realized that this could be a very effective solution to damp the fundamental engine block 'breathing modes.' The conventional solution to reduce vibrations is to increase engine block stiffness, but in many cases this only shifts the noise to higher frequencies." With the introduction of the shear plate, vibration and noise levels are reduced, resulting in considerably improved sound quality.

"Our argument for choosing Duru-LAM is the fact that it is a proven material for damping sound and vibrations in internal engine applications, for example producing damped windage trays," Norberg said. "At the moment, its properties are quite unique. No other

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material currently on the market is as resistant to heat and oil. Based on the Trelleborg Group's core competency, we're using rubber in the middle layer, vulcanized together with two steel layers. This makes it so much tougher than the conventional sandwich materials, where the polymer just can't handle the oil. Duru-LAM is very durable and has high shear strength."

The shear plate can be positioned differently to suit the packaging requirements of different core engine designs. For example, in case of a deep-skirt cylinder block, the plate will be placed between the engine block and the oil pan below the crankshaft.

"The first prototypes we delivered to PSA Peugeot Citroën were of this type," Norberg said. The Duru-LAM shear-plate prototypes had milled grooves in the steel layers held together by the middle polymer layer. When the upper steel layer is fastened to one side of the engine block and the lower layer to the other, it makes for ultimate shearing—and thus damping—in the middle layer.

PSA started rigorous testing of the prototypes in January 2007. "We did a lot of acoustic research and simulations," said Claire Chaufour, one of the experts on Gavric's team. Testing included fitting the shear plates between a block and oil pan during an engine bench test inside an anechoic chamber using an acoustical head to analyze sound quality.

"We achieved considerable improvements of sound quality with the shear plates, and a really bad noise quality would improve to acceptable or very good," Gavric explained. "We were really impressed by the results. One PSA Peugeot Citroën NVH senior expert called the shear-plate concept 'a revolution for diesel-engine noise.'"

Not only does the shear plate filter out unwanted vibration and knocking noise, Gavric said the real gain is "that by reducing the constraints concerning the noise and vibrations issues, you're able to tune the combustion to reduce emissions, pollutants, and fuel consumption. It is really possible to design higher-performance eco-friendly engines."

Reducing engine block weight is desirable, but this would be another source of increased noise and vibration. "This will also be targeted with the shear plate," said Sylvain Chérourge, key account manager, Trelleborg Rubore France. "The shear-plate solution may also reduce costs as it removes the need for other more expensive and heavier damping solutions."

However, more testing needs to be conducted. "The acoustic performance tests are one aspect," said Gavric. "Since the shear plate is inside the engine, thorough durability testing is absolutely crucial. Durability is the biggest issue inside the oil pan. Once this testing is completed to our satisfaction, we'll apply shear plates to our new generation of diesel engines. This means the Euro 6-compatible engines, which will be on the market in 2010-2011."

"The thing is, though, that this is not a 'one size fits all' solution," said Chérourge. "Not only do engine types differ in design, the frequencies that should be damped by the shear plate vary with each engine type. Depending on the engine, the shear plate has to be tuned differently, which calls for more tests and experimenting with the Duru-LAM layer thicknesses."

"The shear-plate technology is not an off-the-shelf product," Norberg agreed. "The whole concept is based on close cooperation between us and the car manufacturer to reap the benefits. In the early stages, we have to describe how the shear plate works and the benefits of using computer simulation tools. It's an enormous advantage, both for us and the customer, being able to calculate the effect of damping early in engine design."

Ulf Wiman of Trelleborg Rubore AB wrote this article for AEI.

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