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Measuring the Capacity of an Engine Combustion Chamber Using Sound

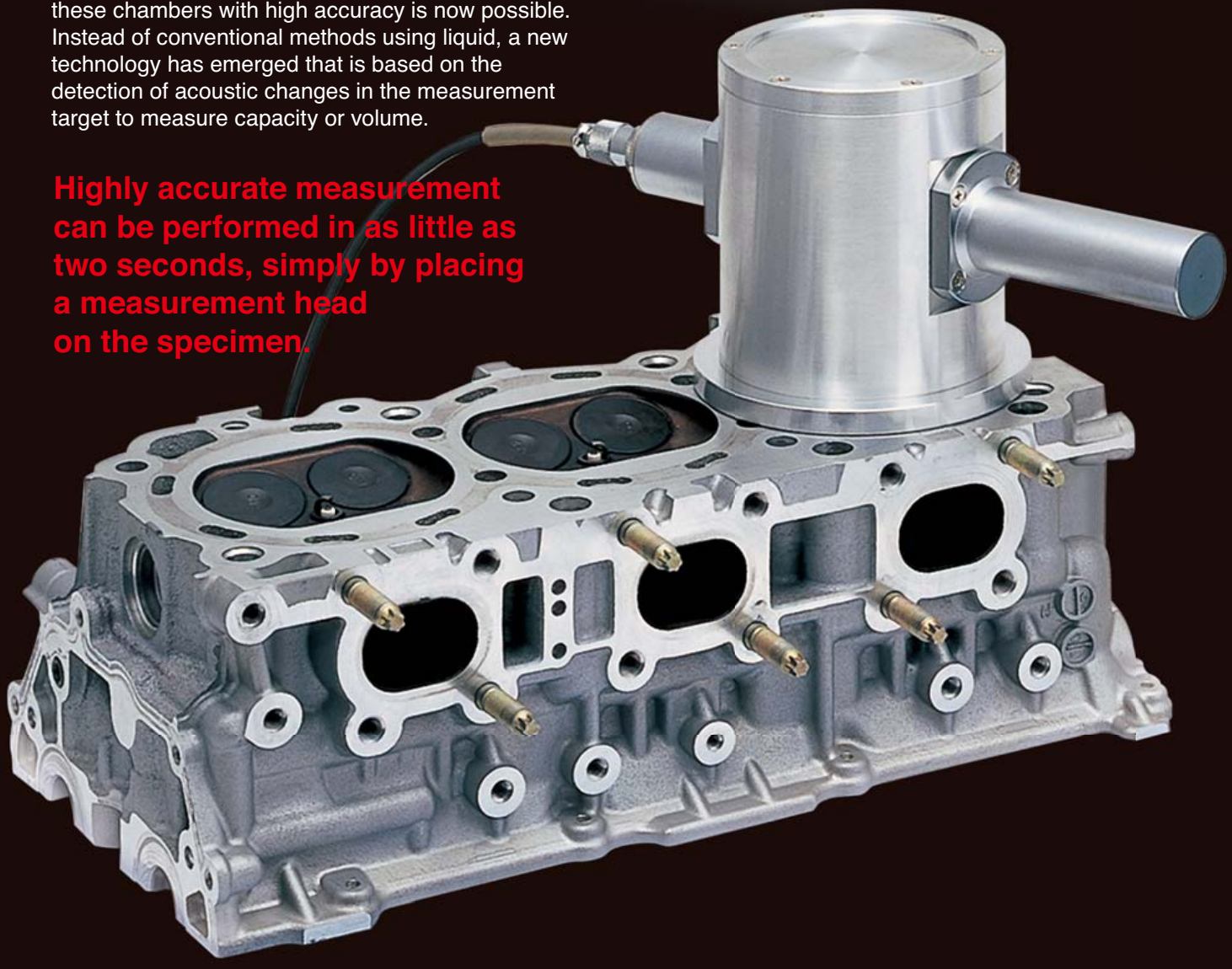
Acoustical Capacity Meter
(Combustion Chamber Capacity Meter)

Acoustical Volume Meter

Measurement time **2** seconds

The combustion chambers in the cylinder head block of an automobile have a large influence on driving performance. Measuring the capacity of these chambers with high accuracy is now possible. Instead of conventional methods using liquid, a new technology has emerged that is based on the detection of acoustic changes in the measurement target to measure capacity or volume.

Highly accurate measurement can be performed in as little as two seconds, simply by placing a measurement head on the specimen.



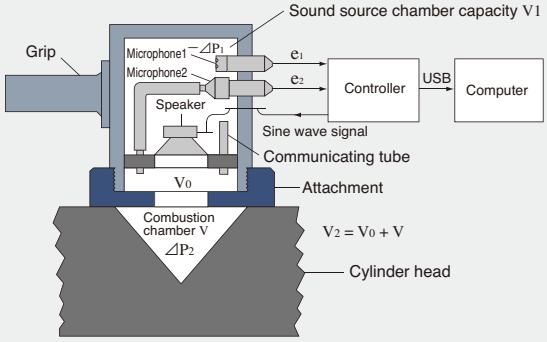
For car manufacturers, competitiveness on the international market is crucial to success. To achieve this aim, engineers constantly aim for improvements in the quality of the various parts that make up an automobile, to further enhance the overall perfection of each vehicle that leaves the assembly line.
Forward-looking manufacturers focus on quality management during the manufacturing process, which includes the application of sophisticated and more accurate measuring methods.

Accurately measuring the combustion chamber capacity of an engine

For example, with regard to the engine that is a central functional component of an automobile, accurately measuring the capacity of the combustion chambers in the cylinder head block is one of the steps in the manufacturing process. The combustion chamber is made of aluminum alloy or magnesium alloy casting and has a complex curved surface. The internal capacity therefore is subject to variations, with subtle differences between individual chambers showing up in the measured values.
As is well known, the four-stroke engine works by repeating four distinct cycles: (1) intake, (2) compression, (3) combustion (explosion), and (4) exhaust. In the case of a four-cylinder engine, the smaller the variations in internal capacity of the four combustion chambers, the higher the explosion efficiency. If there are large variations, incomplete combustion tends to occur which negatively affects fuel economy. Highly accurate measurements are essential to prevent such problems.
Capacity measurement of individual combustion chambers during the engine manufacturing stage has been traditionally carried out by pouring a liquid such as oil into the cavity, a process known as the Biuret method. However, to measure four cylinders with this method is a laborious process that takes about an hour, and the viscous oil or other liquid has to be wiped off afterwards and the chamber has to be dried to return it to a usable condition. As a result, manufacturing efficiency suffers, which posed a technical challenge. For this reason, acoustical capacity meters are being increasingly used for measuring combustion chamber capacity. The measurement head is directly placed on top of the combustion chamber cavity in the engine head block, and the capacity is measured using an acoustical method. ①This has several advantages, such as allowing easy measurement regardless of the shape of the measurement target, and requiring no liquid, so that the specimen can be measured in a dry state. Furthermore, the measurement takes only about two seconds. In view of how measurements are handled during the engine manufacturing process, a spark plug link pipe and link adapter are also available, making it possible to perform the combustion chamber capacity measurement after the engine has been assembled.

The measurement principle of an acoustical capacity meter is as follows. A loudspeaker placed between a reference chamber in the capacity meter and the measurement target chamber is driven by a sine wave signal. As a result, very small changes in pressure with the same absolute value, but of opposite phase, will occur inside each chamber. The amplitude of the pressure change is inversely proportional to the reference capacity value and the capacity of the measurement target. The pressure changes are detected by a pair of condenser microphones, and the capacity is calculated from the ratio of these two signals through application of Boyle's Law and Charles's Law. Such a combustion chamber capacity meter is suitable not only for car engines but for motorcycle or boat engines as well. Recently, the application scope has been further expanded to include measurement of engines used for example in agricultural machinery such as power tillers. In recent years, major car manufacturers have been actively making capital investments aimed at enhanced measurements.

Cross-sectional drawing



Measuring without relying on Archimedes

Along with acoustical capacity meters, acoustical volume meters employing the same measurement principle are also being used. Volume measurements so far mostly applied a principle discovered more than 2,000 years ago by Archimedes (about 287 - 212 BC). This states that when a solid body is fully or partially immersed in a fluid, the upward buoyant force that is exerted is equal to the weight of the fluid that the body displaces. In recent years however, the volume and capacity of objects have increasingly come to be measured using acoustical volume meters.

This innovative technology eliminates the need to immerse the measurement target object in fluid, allowing measurement in a dry state
As outlined above, volume is determined by inserting the measurement specimen into a known container, and determining the difference to the known capacity. The shape of the measurement specimen is not critical, and even objects with very complex shapes can be measured speedily and with high accuracy. In combination with an electronic precision balance, density can be measured as well.

Accurately measuring the combustion chamber capacity of an engine

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During the manufacturing process of an automotive engine, this system allows measurement of combustion chamber capacity simply by placing the measurement head on the combustion chamber cavity, regardless of shape.

For assembled engines, a dedicated adapter can be used to connect the volume meter to the spark plug hole, to measure the combustion chamber volume.

Acoustical Volume Meter

This Acoustical Volume Meter (Densimeter) allows fast measurement of the target object's volume and density in the dry state.

Surprising applications of acoustic technology

The working principle of acoustical capacity meters and volume meters was first proposed by a group of researchers around the late Prof. Ishii at the Acoustic Laboratory of the Faculty of Engineering at the University of Tokyo. Through a fusion of the latest acoustic and computer technology, it has now become possible to configure a measurement system that is easy to use even in a production line. Joint research carried out by Prof. Ishii and the National Metrology Institute (a division of the National Institute of Advanced Industrial Science and Technology) has resulted in the development and commercialization of a measurement device called a weight-only volume meter which compensates for the air buoyancy that tends to produce measurement errors. With this device, a weight of the same type and shape as the weight to be measured and with known volume is used, and the volume difference is measured accurately in air, using the acoustical principle. The device has also been adopted by the International Weight Bureau in France.

Such measurement devices using the acoustical method are utilized for measuring industrial parts to determine whether their volume is within a specified range. For parts that are designed to fit precisely into a given spot, shape accuracy is highly important. Determining the exact shape is technically difficult, but if the volume of a given part is measured and is found to be outside the specified range, the likelihood that the shape of the part is also outside of specifications is high. Such a part can therefore quickly be eliminated as nonconforming. The method is also used to inspect golf balls for variations in dimple size. Dimples not only must be regularly distributed, they also need to have uniform depth and height on the spherical surface. If there are irregular protrusions, air resistance increases and the flight characteristics of the golf ball will be affected in subtle ways. Balls with perfectly uniform dimples can be driven in a low trajectory and also can be driven higher if desired.

A different example for an unusual measurement target is the sugar content inspection of fruit. Sugar content is closely correlated to density, with both values producing straight lines on a graph. If density can be measured accurately, this will enable more precise evaluation of the proper timing for shipping the fruit.

Such measurements therefore were used for example at the national fruit tree test site in Tsukuba and other agricultural experimental stations, and they are now increasingly being introduced at the shipping stations of fruit producing areas.

New measurement principles are making it possible to check for aspects that could not be covered with traditional methods, and this realization is driving further research. Furthermore, based on the same principle as this measurement method, research is also being carried out to enable practical use of a device for measuring the surface area of an object by measuring its acoustic impedance*1, and a device for detecting pinholes in a container*2.

In the automotive field, measuring the combustion chamber capacity of car engines using latest acoustic technology contributes both to product differentiation and to reducing environmental impact, given the fact that the engine forms a crucial part of the final product. In this way, car manufacturing technology is increasingly adopting various new measurement systems that approach the measurement target from a very different angle than traditional methods.

*1 Ippei Torigoe , "Measurement Technology Using Sound" , Souon Seigyo Journal, Vol. 38, p. 6 (2014)

*2 Hirao, Iseki, Iwahashi, Torigoe, "Pinhole Tester Using Acoustic Impedance" , Proceedings of the Acoustical Society of Japan, Sep. 2012, pp. 717-718 (2012)

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