EngineWatch

6D measurement of engine motion

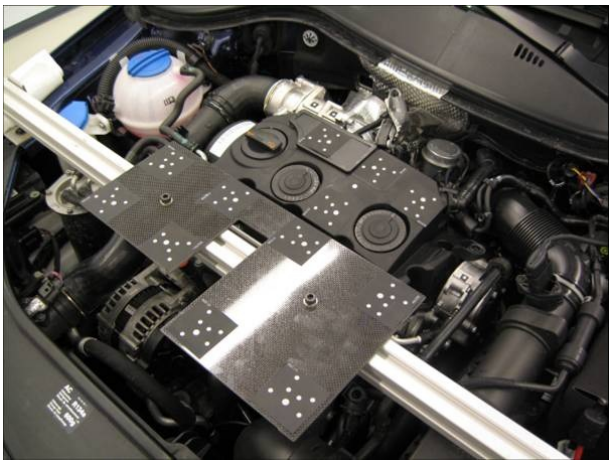
MEASURE THE ADVANTAGE

In vehicle development, exact information about engine-to-body clearance is necessary to ensure an optimal design of the available space. For example, the engine must not collide with other parts in the engine bay when the driver changes gears or deals with difficult driving maneuvers. AICON's optical measuring system EngineWatch is now available to measure engine movements precisely.

The system acquires engine movements in six degrees of freedom (6-DOF), both during a test drive and in a test station. Thus it replaces traditional devices such as mechanical travel sensors. The position and orientation of the measured points is depicted with absolute values in the vehicle coordinate system.

At the same time, it is also possible to monitor movements of other relevant parts in the engine bay, for example movements of the battery box. The optical measuring system EngineWatch works on a non-contact base i.e. without a mechanical connection between sensor and engine block. Therefore EngineWatch delivers reliable measuring results, also under extreme dynamic conditions. The measuring frequency goes up to 490Hz, and measuring data can be recorded for an unlimited period of time.

EngineWatch



reference points on the engine block

Advantages at a glance

- short setup time
- 6-DOF measurements of movements in real time
- high accuracies (X, Y, Z: ± 0.1mm, angular accuracy ± 0.015°)
- measuring frequency up to 490Hz at unlimited measuring time
- measuring results are shown as absolute values in vehicle coordinate system
- no mechanical connection between sensor and engine block
- camera mount does not need high stability
- used for test drive and test station
- high speed camera also applicable for motion analysis of any other object

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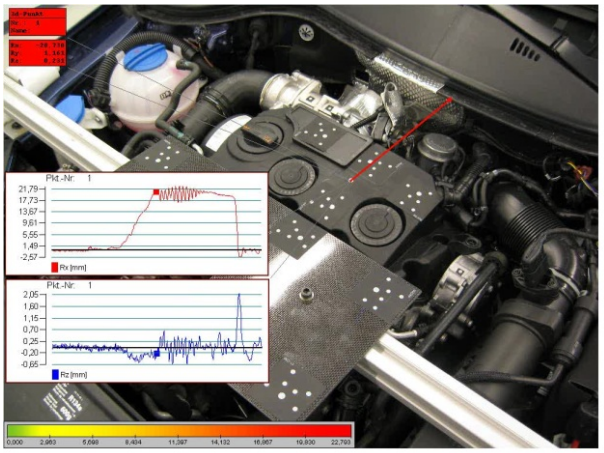
Functional principle

EngineWatch is built around a high speed camera. The camera consists of a high resolution CMOS sensor, an integrated high performance flash, and an image analysis processor. The camea features extremely short shutter speeds of just a few micro-seconds that are necessary for long-duration tests.
It also ensures the system is robust and stable over time.

Mounted on a fixture, the camera directly focuses the engine block. The measuring principle is based on the detection of relative movements of two solid bodies. Therefore reference targets are placed on the engine block and on the car body in a way that the camera will focus all targets at the same time. Setup and calibration of the system take less than 30 minutes. The position of the camera to the engine block does not need to be stable as EngineWatch recalculates its position continuously using the reference targets. Hence, camera movements cannot influence the measuring results.

The measuring images are analysed in the sensor. Thus only the digital data are transferred to the notebook computer in real time, not the entire images. EngineWatch calculates the positions of the measuring points in X, Y, Z, and the rotation angle (alpha, beta, gamma) as absolute values in the vehicle coordinate system. For the presentation of the results, a path-time-diagram is created showing the X, Y, Z movements in the vehicle coordinate system. In order to visualize the measured movements in a CAD system, the measuring results can be exported to post-processing software via an interface.



result presentation path-time-diagram for XYZ movements in vehicle coordinate system

Further areas of application - MoveInspect

The applied high speed digital camera can also be used for other motion analyses dealing with a big number of measuring points. When conducting a 3D analysis of other objects than the engine, at least two cameras are necessary that monitor the part from different viewing angles. The repertoire comprises e.g. door slam tests, closure tests of hoods, convertible tops, and windows, or material tests. Detailed information is available in our product brochure MoveInspect.

MoveInspect for 3D measurements of dynamic processes

Specifications

System	**Engine**Watch
System components	MoveInspect basic system with high speed camera, syncbox for 1-4 cameras (cascadable), laptop computer with EngineWatch software, one set of coded targets (ANCO-code), thereof 50 on magnetic mount, callibration panel with transportation case
Operating system	Microsoft® Windows® XP
Power supply	test drive: 12 Volt vehicle power system, test station: 90 - 240 Volt
max. acquisition frequency	490Hz
Synchronization	20 mA Loop / TTL clock & enable IN/OUT
EngineWatch data set	X, Y, Z, alpha, beta, gamma, number of picture, time stamp (ASCII-Format)
Measuring volume (X, Y, Z)	1,000mm x 1,000mm x 500mm
Accuracy XYZ	± 0.1mm
Angular accuracy	± 0.015°

Testing vehicle dynamics with the help of optical metrology

Prototypes have a tough time. A hard program awaits them almost immediately after coming into life: they need to complete test drives which push them to breaking point and endure lengthy checks on the test stand. These wide ranging examinations are however necessary for vehicle development so that the production vehicle ultimately has optimum drive characteristics. Therefore detailed examinations of wheel behavior during extreme driving maneuvers are undertaken among other things. Ultimately the vehicle will have to overcome bumps or strong steering movements without any difficulty later on, during sudden evasive maneuvers for example. Great significance is also attached to the optimization of the design envelope. For example the wheel case of a vehicle requires a particular size in order to provide the wheel with sufficient space during extreme driving maneuvers. Examinations for unit movement are vital so that the engine has sufficient space and does not collide with other components during operation.

In the past these studies were carried out with the help of mechanical processes. These are however laborious in terms of handling and only the instruments fitted on the vehicle can influence driving behavior under certain circumstances. For this reason many companies are switching to optical measuring processes which make the three dimensional measurement of movements easier. They thus provide extremely accurate results which are then suitable for a comparison with previously carried out simulation calculations.

Practical example: optical measurement of wheel movement at Hyundai

The AICON optical measurement system WheelWatch has been in use at the Hyundai Motor Europe Technical Center (HMETC) since the summer of 2008. The HMETC uses WheelWatch to examine the steering, suspension and bearings of vehicles within the framework of test drives. In this WheelWatch records the wheel movements with the help of high speed cameras with a frequency up to 490Hz. Prior to the acquisition of WheelWatch, the HMETC exclusively used systems which could measure vehicles in a stationary position and not during travel. Vehicle development did however more and more frequently demand examinations of the elastokinematics of vehicles which can in principle only be carried out during a test drive. On the basis of this requirement a decision was finally taken to

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purchase the WheelWatch measuring system which provides reliable measurement data both on a test stand and on a moving vehicle.

The high speed camera used for the WheelWatch system consists of a high resolution CMOS sensor, an integrated high power flash and a FPGA image evaluation processor. With this camera, any number of points can be recorded within the dynamic processes without any time restriction. External triggering means a time synchronous linking to other sensors is guaranteed.

What experiences has the HMETC had with AICON's optical measurement system WheelWatch?
Kevin Parker, Vehicle Dynamics Engineer at HMETC, reports: "With WheelWatch we can for example analyze how the track of the rear wheels changes when the vehicle drives over an obstacle. In order to record the unintended changes of direction of the vehicle we carry out test drives at various speeds. The test results are of great importance for us and they are directly involved in vehicle development. We can always rely on the results of WheelWatch. They are reliable and precise."

Functional Principle

In order to measure the wheel movements a camera is fitted in such a way for each wheel that it records the fender and the wheel to be measured at the same time. Specially coded measurement targets on the bodywork characterize the vehicle coordinates system. The wheel is signalized with an adapter in lightweight construction (CRP). The position of the camera to the vehicle does not have to be stable as WheelWatch references itself to the vehicle in the measurement cycle. The measurement values derived from the relative movement of wheel to fender are thus provided directly in the vehicle coordinates system. Camera movements thus do not influence the measurement results in contrast to other systems.

The driver triggers start and stop of the measurement himself. Additional interactions with the system are not necessary. The measurement images are analyzed directly in the sensor and the digital data are sent to the evaluation notebook in real time. The results (the wheel position in X, Y and Z, track, camber and roll angle and trajectories) are available shortly after the recording. The position accuracy is at approx ± 0.1mm, the angle accuracy at approx. ± 0.015°. WheelWatch provides all six degrees of freedom of wheel movement absolutely in the vehicle coordinates system. In this way wheel movements can be recorded up to a speed of 250 km/h. The quality of the WheelWatch data is so high that these can be passed on to measurement value recording unfiltered as raw data. In this way any possibility of the actual measurement results being distorted by automatic filtering is avoided.

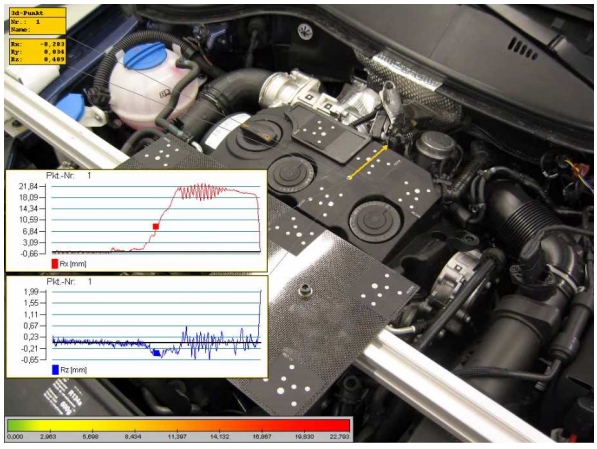
Vehicle Tests vs Virtual Prototyping

AICON's WheelWatch system is also used in the "Engineering Services" department at LMS International in Leuven (Belgium). LMS examines dynamic vehicle behavior for various companies from the automotive sector. Even if virtual prototyping gains in importance in vehicle development, tests on a real development vehicle will continue to play an important role. This opinion is shared by Theo Geluk, a test engineer at LMS. "Tests provide realistic information on the operating and driving behavior of vehicles. They provide feedback to the development teams to validate theories", Geluk states.

LMS uses WheelWatch in order to examine the effect of bodywork flexibility on vehicle dynamics. This involves testing which types of deformation have an influence on dynamic driving behavior. In these tests LMS uses WheelWatch in addition to other measurement sensors. Theo Geluk explains: "For us it is important to know the actual wheel movement in relation to the bodywork. We have already carried out more than 100 test drives with WheelWatch and we see the data generated by WheelWatch as a valuable complement to other measurement data. It is really easy to combine it with other sensors."

BMW validates simulation models with the help of optical metrology

BMW in Munich also uses AICON's WheelWatch within the framework of test drives. Here the wheel positions on both axles are measured, compared with the results of simulation calculation and the simulation models are thus validated. Helmut Zender who works in the vehicle dynamics development section at BMW recalls: "In our first test drives with WheelWatch we analyzed the wheel position on a BMW 3 series model when crossing over bumps. Previously we used an optical system for measuring wheel position which was based on the recording of uncoded markers. This was however very sensitive to the ingress of sunlight. In addition the sensors were relatively heavy which can influence driving behavior. The WheelWatch system provides us with measurement data which are clearly more accurate today even if there is strong sunshine. Of course we looked at optical measurement appliances from various manufacturers during the selection process. However with other systems which required a very rigid camera position for measurement we had concerns about camera mounting. For maneuvers on the limit it costs a great deal of time to attach cameras to the vehicle in such a way that they are not exposed to any vibrations. With AICON's WheelWatch system an absolutely stable camera position is not required as it is supported optically by a reference system on the vehicle. For us that is a decisive advantage." As BMW also requires data from other measurement sensors at the same time, measurement takes place in offline



mode at present. In connection with the test drive, data of all sensors are brought together via synchronization signals. In this the WheelWatch system specifies the measurement cycle. Depending on the test, the measurement frequency amounts to between 100 and 490 Hz.

Suitable for many other dynamic applications due to its modular structure

The cameras used for WheelWatch are also able to take on completely different dynamic measurement functions alongside the recording of wheel movements. A building block principle means that the user can put together a measurement system specifically for his own requirements: only one high speed camera with accessories for recording engine movements ("EngineWatch"), two or four cameras with vehicle mounting for measurement of the wheel movements on one or two axles ("WheelWatch") or two cameras on one camera bar fitted for examining deformation and movement of any object points ("MoveInspect"). In total the cascadable controller is designed for up to four cameras.

At BMW a high speed camera is thus also used for the measurement of engine movements. Helmut Zender comments on the use of AICON metrology in this area as follows: "The available space in the engine bay has continued to decrease in recent years as more and more units need to be incorporated. It is important to know the movement of the engine units exactly as it is only in this way that the installation space can be designed optimally. For example the engine should have sufficient clearance to other components in the engine bay even for drives on the limit. Thus we require more precise measurement data today which must be fully capable of interpretation. That means that not only must the form of the body geometry be known but we must also know how precisely this body geometry lies in the vehicle coordinates system. This must be precise to the millimeter. AICON's EngineWatch measurement system helps us to meet these high requirements for accuracy."

Prospects

In coordination with existing users the dynamic measurement systems are optimized regularly in order to meet the constantly growing demands even better. In this way AICON fundamentally revised the WheelWatch software and presented the new version at the Automotive Testing Expo Europe in Stuttgart in June 2010. The user interface was newly designed in order to present the individual work stages even more clearly. In addition the user can now define an axle related vehicle coordinates system as is demanded for examinations of vehicle dynamics. The identification of WheelWatch camera, wheel adapter and reference point field occurs automatically in this. Finally the link to other data recording systems can additionally be assured via CAN bus with the revised software. New findings will also be incorporated into the further development of the dynamic measurement systems in the future and make daily working life easier for the test engineers at least even if not for the prototypes.