WheelWatch
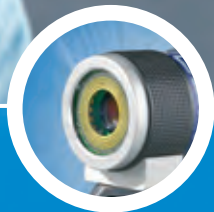
Non-contact high speed monitoring of wheel motion
on a moving vehicle or in a test station

MEASURE THE ADVANTAGE

MoveInspect
TECHNOLOGY

AICON
3d.systems

WheelWatch

Non-contact high speed monitoring of wheel motion
on a moving vehicle or in a test station

Vehicle development for optimal driving characteristics

Chassis design is very important to new car development as it ensures optimal driving characteristics. Choosing the right design parameters requires extensive testing. For example, wheel housing design must allow sufficient clearance for various types of tires and their particular movements, and each wheel must be monitored to see how it behaves under extreme driving conditions or on bad pavements. Past studies have relied on mechanical monitoring devices which are complex in handling and may influence the driving behavior.

WheelWatch provides a revolutionary approach to wheel monitoring. Due to its functional principle, it offers many advantages, facilitates wheel monitoring and delivers more exact measurement results.

High speed camera MoveInspect HF

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

It provides data at a frequency of 490 Hz, ideal for studying and optimizing static and dynamic chassis parameters. Measurements are controlled automatically and may be collected over long periods of time. The triggering function ensures that multiple sensors are fully synchronized.

The camera can be mounted at a distance of less than 500 mm (20 in) from the fender. The camera processor uses TCP/IP protocol to communicate with the laptop computer which controls the system. The computer is placed in the test vehicle. The vehicle 12 Volt power system provides power during the test drive.

WheelWatch is based on a camera system that does not require a mechanical connection between sensor and wheel

Functional principle

For the measurement of wheel movements, one camera for each wheel is mounted so that the wheel as well as part of the surrounding fender is visible. Special optical targets applied to the fender define the vehicle coordinate system. A lightweight carbon fiber wheel adapter is fixed to the wheel.


Carbon fiber wheel adapter

The position of the camera does not have to be stable as WheelWatch recalculates its position continuously using the reference targets on the vehicle fender. The wheel movement measurements are always provided in the vehicle coordinate system. Movements of the camera or camera mount do not influence measurement results, making the system inherently more stable than competing systems.

The driver manually triggers the beginning and end of a measurement session. No other interaction with WheelWatch is required. The high speed camera collects wheel measurements at a rate of up to 490 times per second.

The image processor analyzes the digital images in real time and passes the measurement values to the notebook computer. Wheel target positions and target trajectories are available shortly after the image acquisition. In addition, WheelWatch computes all six degrees of freedom of the wheel in the vehicle coordinate system.
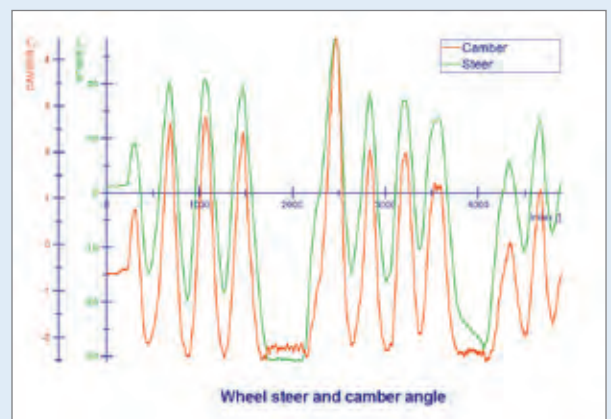
WheelWatch measurement results

WheelWatch advantages

WheelWatch with MoveInspect HF has been developed in close cooperation with the automotive industry, and the system has been designed to provide the features and functionality that are most beneficial for this application.

Short setup time

A major requirement is fast and easy system setup. The MoveInspect HF camera is designed to be mounted quickly on the vehicle without the requirement of sophisticated tools such as tail lifts. Assembly of a four camera system, mounting frame, wheel adapters, and calibration and referencing to the vehicle coordinate system takes less than one hour. The system is ready to begin making measurements immediately after installation.

Measurement accuracy

WheelWatch measures wheel movements for a vehicle traveling at speeds of up to 250 km per hour (160 mph). The system is also capable of observing extreme driving maneuvers. Points are measured to an accuracy of about ±0.1 mm (0.004 in) and angles to an accuracy of about ±0.015°.

Simultaneous measurement of several wheels

Several cameras may be precisely synchronized. WheelWatch may also be synchronized with other measurement devices. In this case, the cameras can either be controlled by an external synchronization signal or they can deliver the master signal themselves for all sensors applied in the test. In addition, each individual measurement value is time stamped. Thus, the synchronized application on several wheels and with other measurement sensors is possible.

Integration into test stations

The WheelWatch system is particularly suited for integration into vehicle test stations. Data acquisition between numerous cameras over multiple axles and even with other sensor types may be precisely synchronized. WheelWatch saves the measurement data digitally, making these suitable for database storage. Data may be converted from digital to analog during tests if real time machine control is required. An optional data router allows the computer to control WheelWatch system functions via TCP/IP.

Work flow: Setup of WheelWatch in a few steps

No mechanical connection between the sensor and wheel

Measurements are non-contact and require no mechanical connection to the wheel. Consequently, driving characteristics of the vehicle are not influenced by the measurement equipment, and steering motion is not restricted in any way. WheelWatch completely overcomes the disadvantage of other wheel monitoring methods because there is no risk of creating erroneous measurements due to the mechanical connection between sensor and wheel.

Low weight

No heavy analysis units, batteries or controllers that may influence driving behavior are required, and the camera mount does not need high stability. Light weight mounting components can be used, which eliminates any significant influence on driving behavior.

One reference for all wheels

With WheelWatch, the four wheels can be captured in a joint coordinate system. Thus it is also possible to detect motion wheel-to-wheel.

Extendable for new measuring tasks

WheelWatch belongs to AICON's MoveInspect Technology, which brings together a wide range of optical measuring technologies into one high-performance modular system. That brings along a vast advantage: By extending the system with additional components and software modules from the MoveInspect Technology, you can simply adapt it to execute new tasks (e. g. door slam testing or recording of engine movements). Follow-up investments for additional complete systems are no longer necessary.

Specifications
for test drives and test stations

System	WheelWatch
System components	per axle 2 MoveInspect HF cameras and 2 CFK wheel adapters, mounting frame, accessory set including targets, sync-box, and controlling computer with WheelWatch software

Camera	MoveInspect HF
Type of camera	high speed CMOS camera
Resolution	1280 x 1024 pixels
Max. vision frequency	490 Hz
Exposure time	10 µs - 1 s
Lens	high performance lens, f = 10 mm, minimal distortion
Flash	high performance LED ringlight, 10 - 100 µs
Data transmission	TCP/IP
Synchronization	digital time stamp / external trigger signal < 5 µs / master for synchronization
Power supply	test drive: 12 Volt vehicle power system; power consumption: 26 W for 2 cameras; test station: 90 - 240 Volt
Weight	1.5 kg

Wheel adapter	
Material	carbon fiber
Diameter	400 mm (16″)
Weight	< 400 g (< 1 lb)
Targets	ANCO on retro reflective film High Gain 7610

Software	Module WheelWatch
	- camera calibration - axle calibration - determination of reference points - transformation in vehicle coordinate system - data transfer via data file, analog or digital (TCP/IP) - calculation of axle and wheel parameters

Controlling computer	
Test drive	notebook (Microsoft® Windows® 7)
Test station	desktop (Microsoft® Windows® 7)

System parameters	
Position accuracy: X, Y, Z	± 0.1 mm (0.004″)
Angular accuracy	± 0.015°
Measurement volume	1 m x 1 m x 0.5 m (40″ x 40″ x 20″)
Distance camera/wheel adapter	approx. 0.5 m (20″)
Measurement range (track/camber)	± 45°
Spin angle range	unlimited
Acquisition frequency	490 Hz

Wheel**Watch**

Non-contact high speed monitoring of wheel motion
on a moving vehicle or in a test station

WheelWatch – a system of AICON's MoveInspect Technology

MoveInspect Technology brings together a wide range of optical measuring techno-
logies into one high-performance modular system. That means that you can combine
the individual components such as sensor, probe and computer with the appropriate
software.

Thus MoveInspect Technology is a powerful and versatile CMM for probing, tracking
and targeting. And as all components are portable, you can always measure right on-site.

A unique investment – in every respect.

M E A S U R E   T H E   A D V A N T A G E

AICON
3d.systems

Headquarters
AICON 3D Systems GmbH
Biberweg 30 C
D-38114 Braunschweig
tel. +49 (0)531 58 000 58
fax +49 (0)531 58 000 60
info@aicon.de

AICON Benelux
Basbellain, Luxembourg
tel. +352 20 88 01 17
benelux@aicon.de

AICON France
tel. +33 (0) 3 63 53 49 00
france@aicon.de

AICON Asia LLC
Seongnam, Gyeonggi-do
(Seoul Area), Korea
tel. +82 31 607 4040
asiapacific@aicon.de

China Showroom
Shanghai, China
tel. +86 21 51079116 ext. 211
china@aicon.de

AICON North America
Plymouth/Michigan, USA
tel. +1 734 787 4799
northamerica@aicon3d.com

www.aicon3d.com
**www.moveinspect-technology.com**

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
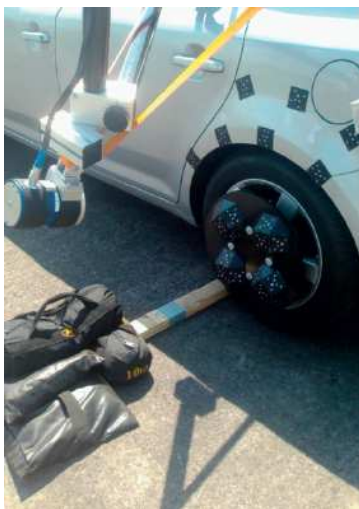
The AICON optical measurement system WheelWatch has been in use at the Hyundai Motor Europe Technical Center (HMETC) since the summer of 2008. The HMETC uses WheelWatch to examine the steering, suspension and bearings of vehicles within the framework of test drives. In this WheelWatch records the wheel 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

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
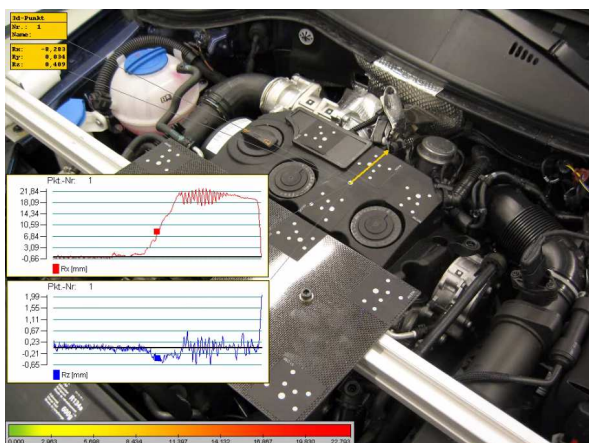
position for measurement we had concerns about camera mounting. For maneuvers on the limit it costs a great deal of time to attach cameras to the vehicle in such a way that they are not exposed to any vibrations. With AICON's WheelWatch system an absolutely stable camera position is not required as it 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.