TEST CENTER FOR ENGINES & LUBRICANTS

DEVELOPMENT & TESTING

DSi offers complete services for research, development, and evaluation of engines and lubricants.

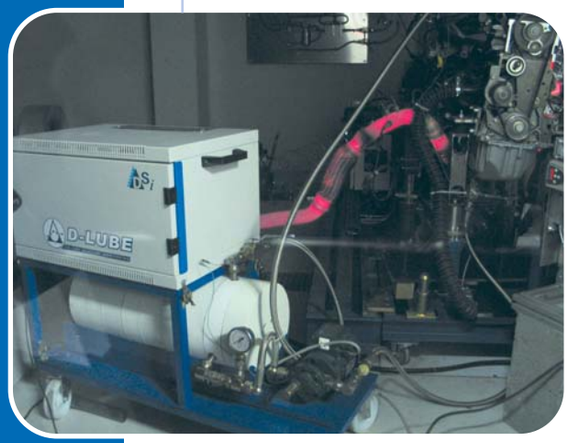
DSi has installed dynamometer and innovative bench test methods to evaluate engines and lubricants. The facilities are available to evaluate diesel and gazoline engines with respect to wear (camshafts, followers, piston rings, piston liners, connecting rod bearings,...), oil consumption, fuel dilution & evaporation, oil aeration, fuel economy, etc. New design engine components and special coatings are also evaluated to determine compatibility with modern lubricants.

OUR FIELD OF EXPERTISE:

Engine & lubricant testing with on-line measurement of:

- engine wear (impact of lubricant, additive content, dilution,...)
- oil consumption
- fuel dilution and evaporation
- lubricant aeration
- poisoning and clogging of after treatment systems (catalysts & DPFs)
- impact of soot contamination on engine wear
- study of lubricant formulations and compatibility with new material coatings
- radio-labelling of engine parts, base oils and additives for on-line measurement

NEW ENGINE TEST CENTER WITH RADIOTRACING TOOLS



- A 1,300 sqm new test facility in Tournai-West, Belgium
- Standard test bed monitoring tools (fuel flow meter, blow-by, ...) and data acquisition @ 100Hz
- Radiotracing tools for on-line measurement of wear, oil consumption, fuel dilution, lubricant aeration & DPF clogging
- Radiochemistry laboratory for fuel and lubricant labelling
- Dedicated area for 3-D inspection of After Treatment Systems (ATS)
- A 220 keV X-ray system for inspection of engine parts and ATS
- Energetic optimisation of the test facility with heat recycling
- A competent technical team
- A fully independent contract service center

engines aircrafts

YOUR BENEFITS

- Your access to complete services including test tools and innovative methodologies
- Your access to real-time results
- Short test durations compared to conventional tools
- A significant reduction of your development & testing costs
- Real operating conditions
- Our highly qualified and experienced technical staff
- Customer oriented solutions and high flexibility

DSI CUSTOMER REFERENCES

- Renault SAS (F)
- Renault F1 Team (F & UK)
- TOTAL France
- P.S.A. - Peugeot SA
- Volvo Trucks (RVI)
- I.F.P. (Institut Français du Pétrole)
- Le Moteur Moderne (A.V.L.)
- Sodemo Racing
- Case New Holland (B)
- Federal Mogul (F)
- E.D.F. (Electricité de France)
- Cossworth (UK)
- C.E.A. (Commissariat Energie Atomique)
- Ricardo Consulting Engineers (UK)
- BP Castrol (UK)
- Prodrive - Tickford (UK)
- Land Rover / Jaguar (UK)
- M.I.T. (USA)
- Magna (USA)
- GM (USA)
- SK Corp (South Korea)
- Maruti - Suzuki Group (India)

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LUBRICANT AERATION

FICHE 2

THE OIL AERATION ISSUE

The presence of air in the fluid of a working hydraulic system can cause significant performance problems. Mixed air may be in an entrained or dissolved state and it can directly affect such fluid parameters as density, bulk modulus, sonic velocity, etc.

Consequences can be the following:

- **Loss of lubricity**
- **Higher oil temperatures**
- **Wasted horsepower**
- **Cavitation problems**
- **Noisy operation**
- **Etc.**

MEASUREMENT PRINCIPLE

Air-X is a new instrument designed for on-line monitoring of oil aeration in a running mechanical system (engine, gear box, etc.). The operating principle is based on an accurate density measurement using X-ray transmission. An oil sample coming from the mechanical system is circulated continuously into a compact measuring chamber where the density measurement is performed.

The specific chamber design of Air-X allows the instrument to perform on-line measurements using a very low activity X-ray source. The chamber is self-shielded so that no radiation at all comes out from the unit whatever the operating conditions.

The total volume of oil sampled in "Air-X" is less than 0,5 liter for a minimal impact on the operating mechanical system.

The chamber includes probes that are used for automatic temperature and pressure compensation. Therefore, the air content can be computed and displayed at standard conditions (i.e. T = 20°C and P = 1 bar).

WHERE TO INSTALL THE DEVICE ?

Air-x equipment, standard version

Air-X, is able to sample and evaluate oil from atmospheric or pressurized lines in an operating hydraulic system. For fired engines, the oil is typically sampled from the sump at a location which is close to the input of the oil pump. The sampling unit of Air-X includes an internal oil pump with accurate and variable flow control.

All operating parameters are selected from the user's interface (a PC).

For applications on fired engines oil can also be sampled directly from the gallery. The sampling unit includes a precision valve that limits the pressure drop in the gallery to an acceptable value.

Air-X, equipment includes 2 subsystems:

- The sampling unit, a rectangular box to be installed in the vicinity of the running hydraulic system. It contains the measuring chamber with its X-ray transmission system, an hydraulic pump with its controller, and the temperature and pressure measuring probes;
- The data acquisition system (a PC with dedicated acquisition boards), which is typically installed remotely, in a control room.

The two units are linked via a single USB cable.

SOFTWARE

A software package is supplied with Air-X, that offers the following functions :

- Setting-up of equipment
- Calibration
- On-line measurement
- On-line visualization of the oil flow in the measuring chamber (compressed video signal)

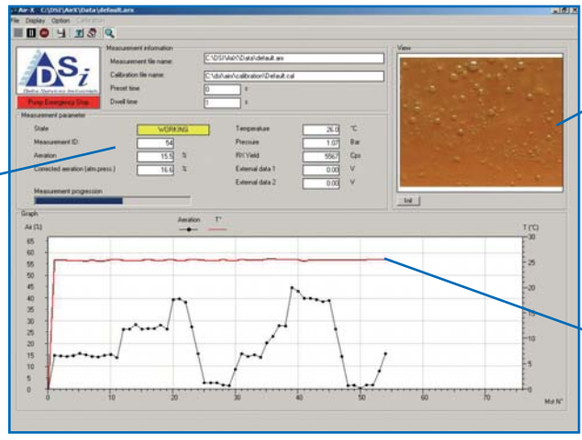
Calibration:

- As the operating principle of Air-X is based on a density measurement it is necessary to identify the law that describes density variations according to temperature. This is easily done using a calibration routine included in the software package. Such calibration must be done once for each type of oil to be used during the tests.
- Then, before starting a new measurement, a single calibration point is done by launching the acquisition while the air content is 0% (engine stopped).

On-line measurement:

The oil is sampled continuously in the measuring chamber but the dwell time for data acquisition can be selected between 1s up to several mins. Short dwell times allow visualizing aeration during transient operating phases of the engine, while longer dwell times provides a high accuracy on the absolute air content.

All measurement data (oil temperature, oil pressure and aeration level) are recorded and can be visualized on a graphic during operation of Air-X. A dedicated routine is also provided, which allows converting the results to a .csv format.



Operating parameters (P, T°, dwell, …) & on-line aeration results

Visualisation of the aeration process in the measuring chamber

External signals (T°, RPM…) can be superimposed graphically to aeration results

NOT A BLACK BOX !

All calibration and measurement parameters can be selected by the user. Moreover, the flow of oil circulating in the measuring chamber can be directly visualized on the PC screen through compressed video signal. This allows the operator to get a better feeling and understanding of the aeration process, which is also an appreciable information. Pictures can be taken at any moment during acquisition, and saved on hard disk.

OIL CONSUMPTION

REAL-TIME OIL CONSUMPTION MEASUREMENT

C-Lube, real-time oil consumption measurement on combustion engines

On-line measurement of oil consumption is of interest, in light of the new environmental regulations imposed on today's high-performance engines.

Lubricant consumption has a negative impact on the environment, but it also reduces the life-time of post-treatment systems by poisoning catalysts and clogging particle filters.

A new method was recently developed and patented by DSi Belgium and TOTAL France for monitoring oil consumption on running engines. It is based on lubricant labeling using new radiotracer compounds, which are made representative of the distillation interval of the base oil.

Oil consumption measurement is performed in the exhaust line where tracer residues are trapped and monitored during engine operation.

The only real-time method that takes into account both burned and unburned oil fractions

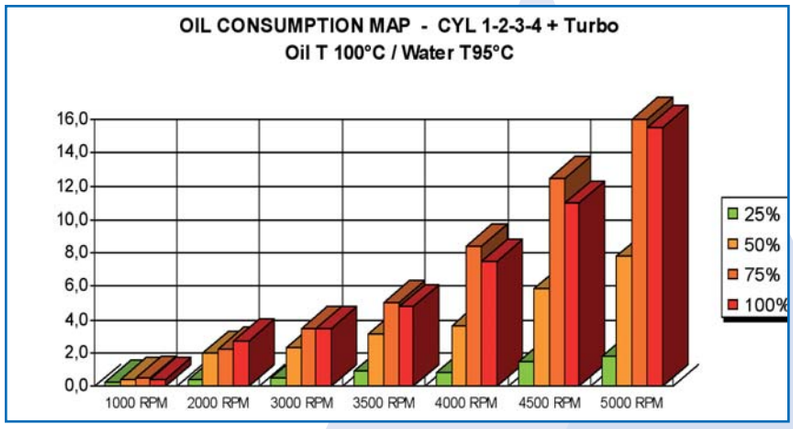
MEASUREMENT PRINCIPLE

Engine oil is labeled by adding a radiotracer to the engine oil, and a monitoring system is installed near the exhaust line where the marker will be trapped. During engine operation the tracer is burned proportionally to the lubricant. The measurement consists of monitoring, in real-time, the amount of tracer trapped in the exhaust line. The amplitude of the detected signal is proportional to the oil consumption.

C-lube equipment installed in a test cell

The new methodology is simple, very sensitive and repeatable. It offers significant advantages over other methods, including:

- **On-line / Real-time results.** Oil consumption for one operating condition is typically acquired within minutes. Analysis of short transient phases is also possible by increasing the amount of tracer mixed in the oil, or by using repeatable transient data.
- **Engine oil consumption mapping within 1 day**. A real-time, steady-state map is generated within 4 to 6 hours for typical oil consumption rates of 1 to 10 grams/hour.



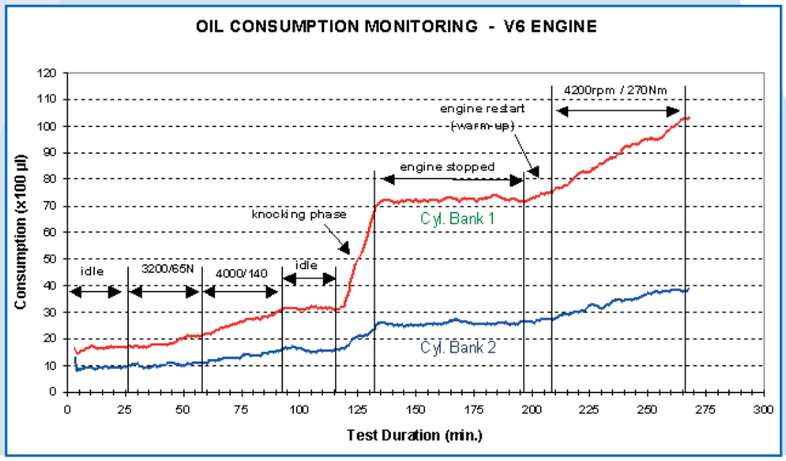
OIL CONSUMPTION MAP ON A 4-CYL TURBO-DIESEL ENGINE

- **No change in oil properties.** Less than 100 µl of tracer is added to the engine oil pan. The tracer shows no particular chemical affinity with the lubricant.
- **Representative of oil distillation interval.** Several tracer compounds are available, with various boiling points spread over the oil distillation interval. A single tracer can be used for measuring consumption of a particular oil fraction (light, medium or heavy), or a mixture of tracers can be also be used in order to be representative of the actual oil distillation interval.

The only real-time method that takes into account both burned and unburned oil fractions

- **The oil consumption methodology can be combined with a dilution measurement.**
- **Possibility to differentiate oil consumption of a unique cylinder, or of a cylinder bank.**

OIL CONSUMPTION MAP ON A V6 PR GASOLINE ENGINE



- **No need for low-sulphur fuel.** The use of special fuels is not required.
- **Measuring equipment is compact and easy to use**. Only a filter has to be installed in the exhaust line to trap the tracer. The measuring probe is installed close to the filter and its local data acquisition unit is linked to a remote PC via a USB cable.
- **Applicable on test beds and on moving vehicles.** Two equipment configurations are available, including a compact system for on-board installation on passenger cars, with local data logger for acquisition during road tests.
- **Not affected by the presence of fuel in the lubricant**

For more information on this product : SAE paper ref. SAE 2005-01-2172

OIL DILUTION

FICHE 4

THE OIL DILUTION ISSUE

On-line measurement of oil dilution is of interest in light of new environmental regulations imposed on today's high-performance engines.

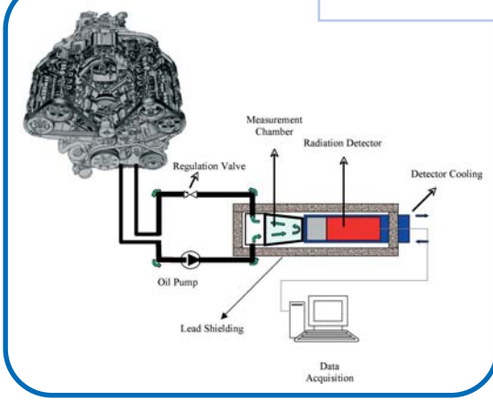
In particular, after-treatment devices such as diesel particle filters (D.P.F.) need to be periodically re-generated in order to eliminate their soot content. Such re-generation process is typically performed by using post-injection cycles that can induce a transfer of fuel to the lubricant, resulting in oil dilution.

Oil dilution has a negative impact on engine wear parts such as bearings, camshafts, cylinder sleeves, etc.

A new methodology was recently developed by D.S.I. sprl and TOTAL France for monitoring oil dilution on running engines. It is based on lubricant labelling using a new radiotracer compound, which is representative of lubricant.

Bearing wear caused by a dilution problem

MEASUREMENT PRINCIPLE



Operating principle of D-Lube

Before starting a measurement, a radiotracer compound is added to the lubricant. A few ml of labeled compound is mixed to the oil when the engine is started.

During engine operation, a small volume of the engine oil is circulated continuously into a measuring chamber where specific activity is monitored.

The **dilution measurement** consists in monitoring the signal (gamma-rays) emitted by the radiotracer and in converting any variation in terms of oil dilution. Temperature effects are corrected automatically.

The new methodology applies to both gasoline and diesel engines: optimisation of cold start procedures, development of post-injection strategies and of evaporation cycles. It offers significant advantages over other methods, including:

- **On-line / Real-time results:** Oil dilution is monitored continuously during engine operation, at a rate of 1 measurement per minute.
- **Short Test Durations:** dilution rates are accurately measured within short runs from <1 hour to max. 4 hours, depending on dilution rates.
- **High sensitivity:** sensitivity is of 0.05% per hour (in terms of dilution rate).
- **No change in oil properties:** Less than 100 µl of tracer is added to the engine oil pan. It does not interact chemically with oil and additives.

D-lube equipment in a test cell

- **Measuring equipment is easy to install:** Oil is sampled directly from the sump. 2 hoses are easily connected to the engine.
- **Applicable on test beds and on vehicles.** Our standard equipment is dedicated to test bench applications. Another version is available, for on-board installation on passenger cars.

EXAMPLE 1 : OIL DILUTION MEASUREMENT - LABORATORY SET-UP FOR CALIBRATION

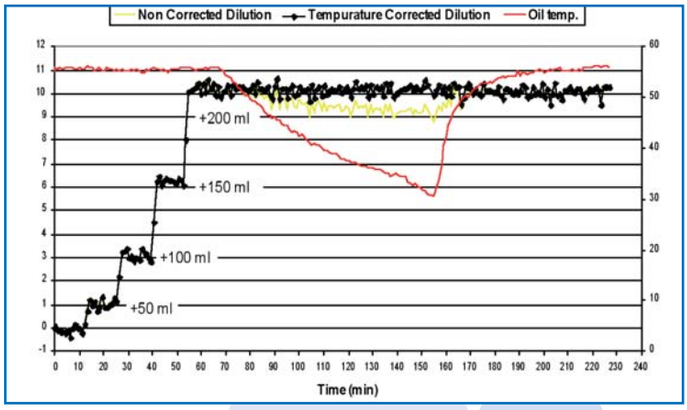
This first example shows a typical calibration procedure.

Oil from a thermostatic bath, is circulated in a D-lube measuring device at a rate of ~1 litre/min.

Small quantities of diesel fuel are added to the lubricant in order to dilute artificially the lubricant, corresponding to dilution levels of respectively 1%, 3%, 6.25% and 10%.

The yellow curve here above gives dilution results without temperature correction.

The dark curve corresponds to the corrected values obtained during the same experiment.



Laboratory set-up

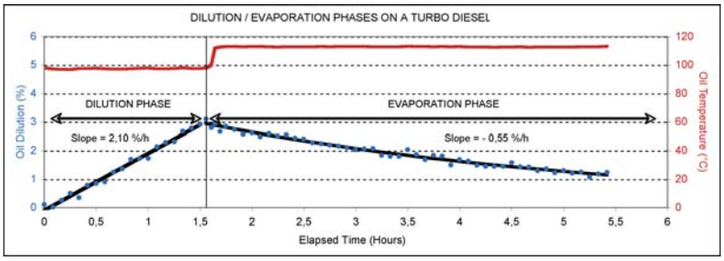
When dilution has reached ~10%, temperature of the oil bath is lowered from 55°C to 28°C in order to verify the efficiency of the automatic T° compensation routine.

This short experiment can be repeated periodically in order to check that the D-Lube equipment works properly, as part of your Quality Assurance program.

EXAMPLE 2 : REAL-TIME DILUTION MEASUREMENT ON A FIRED ENGINE

This second example shows on-line results obtained during engine operation.

During a first run (t=0 to t=1.5h), the engine is operated at normal oil temperature (~95°C) with permanent post-injection cycles for re-generating the after-treatment system. These post-injection cycles induce a high dilution rate of ~2.1 % per hour.



On-line dilution measurement on a fired engine

During the second phase (t=1.6h to t=4h) post-injection cycles are stopped and the engine is operated at higher temperature (oil temp ~115°C) in order to facilitate evaporation. Such operating conditions allowed to evaporate part of the previously diluted fuel, at a rate of ~0.55 p.c. per hour.

Similarly, other engine operating conditions can be tested in order to study their impact on dilution or evaporation processes.

The new method reduces significantly the time needed for optimizing post-injection strategies, reducing accordingly the development costs.

BENEFITS

D-Lube is an innovative tool for studying the impact of engine parameters and post-injection strategies on the dilution process.

The main benefits associated to the new method are:

- Results are available on-line, during engine operation;
- It offers a high sensitivity of ~0.05% per hour (in terms of dilution rate);
- It offers an excellent discrimination between fuel and lubricant, which is the weakness of the GC method where superposition of the heavy fuel fraction and the light oil fraction can induce uncertainties.

For more information on this product: SAE paper ref. SAE 2005-01-2170

SCANFAP

FICHE 5

NEW METHODOLOGY FOR MEASUREMENT OF POISONING AND CLOGGING OF AFTER-TREATMENT DEVICES

Lifetime of after-treatment systems (ATS) is influenced by engine oil consumption and by the nature of the lubricant, in particular its additive content.

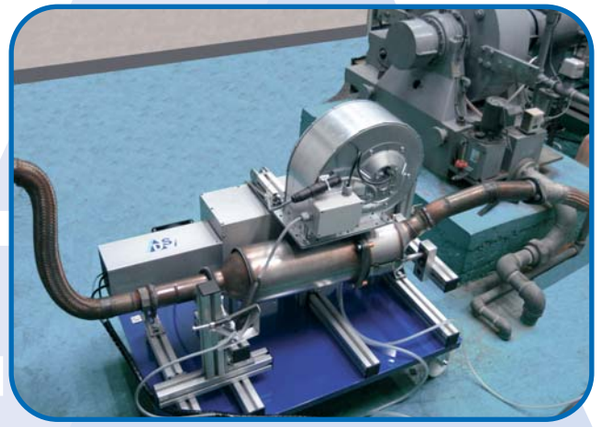
Long term performance tests on ATS include measurement of accumulated residues (ashes) in the ceramic structure.

DSi has developed a non-destructive radiotracer technique based on labelling of specific elements contained in engine oil (e.g. zinc and calcium). The new method offers on-line measurement of ash deposits in the ATS, and visualization of their distribution along the filter. The new method is extremely sensitive since it can detect extremely low quantities of ashes in the range of 1mg. Therefore, accurate measurements can be performed within very short running times.

MEASUREMENT PRINCIPLE

The new method(*) consists in labelling one or more elements contained in the lubricant, for example zinc, calcium, or phosphorus. During engine tests, a fraction of the lubricant is burned in the combustion chamber and ash residues are transferred through exhaust gases to the ATS where deposits are formed.

A radiation monitoring system is installed close to the ATS. It measures continuously, through the ATS, the radiation emitted by the ashes issuing from combustion of the labelled elements. As the detected signal is proportional to the amount of ashes trapped in the ATS, ash accumulation is quantified on-line during engine operation.



Ash Deposit Monitoring Equipment

SCANNING SYSTEM FOR 2D-3D MAP OF ASH DISTRIBUTION

A scanning device is also available for 2D/3D measurement of ash distribution in the ATS. The system is used without destroying the ATS since the radiotracer signal (gamma rays) passes through the canning.

(*) International patent by DSi and Total France

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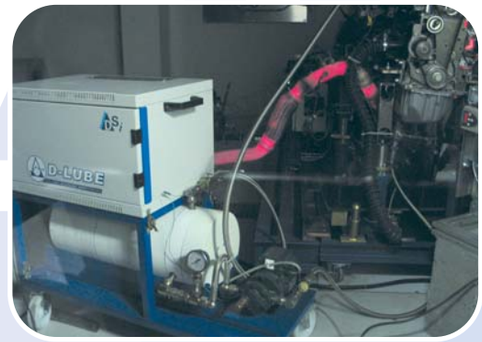
YOUR BENEFITS:

- **On-line results:** ash accumulation in the ATS is measured in real-time during engine operation. Engine parameters can be changed at any time during tests to study their impact on the ATS;
- **Real Operating Conditions:** measurements are performed under real operating conditions of the ATS and the lubricant (i.e. additive concentration in the sump, evaporation of volatile oil fractions, formation of oxides, sulfates, phosphates…);
- **Extremely high sensitivity:** the radiotracing method allows detecting less than 1 mg of ash deposit in the ATS. Such sensitivity allows shortening significantly test durations;
- **Excellent selectivity:** several organic compounds can be labelled simultaneously in the lubricant to evaluate their respective impact on ATS poisoning and clogging. Contribution of each element to ash deposit is evaluated during a unique test.
- **3-D map of ash deposition:** the scanning system measures automatically ash deposit profiles in the ATS;
- **No change in oil properties.** Radiotracers are of the same chemical nature as the lubricant. Therefore, lubricant properties remain unchanged.
- **No need for special fuel**
- **Non Destructive Measurement:** no need to open or to destroy the ATS since the radiotracer signal is detected through the canning;
- **Measuring equipment is compact and easy to use:** It is easily installed in the test cell, or in a vehicle. The local data acquisition system communicates with a PC via a single USB cable.
- **Available as service measurement:** DSi is also able to offer this radiotracer technology as a service package that includes engine testing services and radiotracing tools.



SAE INTERNATIONAL award for DSi

This new method is the fruit of a cooperative research program between DSi and Total France. The methodology is fully described in SAE paper 2005-01-2178, which received a "SAE Award for Research on Automotive Lubricants". This paper is entitled "An innovative On-Line measurement Method for studying the Impact of Lubricant Formulations on Poisoning and Clogging of After-Treatment Devices."

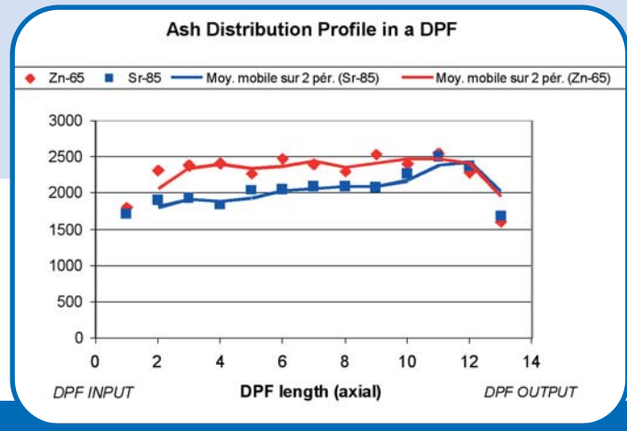
EXAMPLE : ASH DEPOSIT PROFILE IN A DPF

The graph hereunder shows how calcium (blue curve) and zinc (red) have accumulated in a DPF during a 10-hours engine test on a diesel engine operated at max. output power.

These results were obtained using Zn-65 as radiotracer for labelling ZDDP additive, and Sr-85 for labelling organic compounds containing calcium.

These profiles were obtained using the automatic scanner system.

The same measurement can be repeated with various lubricant formulations. In particular, one can study the impact of mid-ash or low-ash additive packages on the deposit process.



WEAR MEASUREMENT (TLA/RNT)

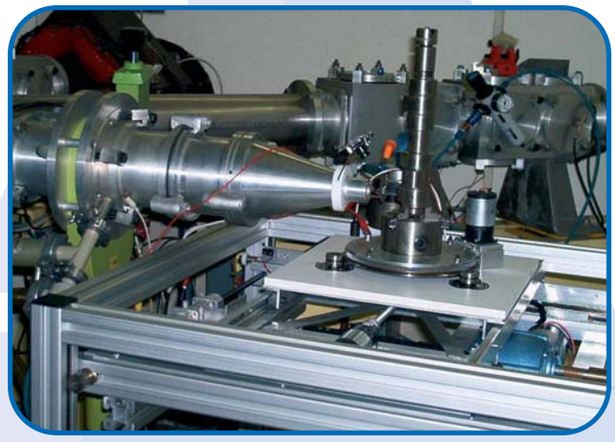
For more than 15 years, DSi has used radiotracer techniques to offer accurate and real-time wear measurements.

TLA (Thin Layer Activation) is our key product. The method allows performing on-line wear measurements on running engines without dismantling parts (i.e. camshafts, cylinder sleeves, piston rings, valves & seats, bearings, etc.). TLA is also applied for studying the impact of lubricant formulation, fuel dilution and soot content on wear.

TLA OPERATING PRINCIPLE :

TLA is based on the labelling of mechanical parts using a particle accelerator. Our client's engine components are despatched to an activation center where they are treated using the high energy beam of a cyclotron.

We provide TLA measurement services as a full package that includes activation services, equipment sales & renting, and qualified manpower. TLA services can be performed either at your site or at our test center in Belgium.



BENEFITS

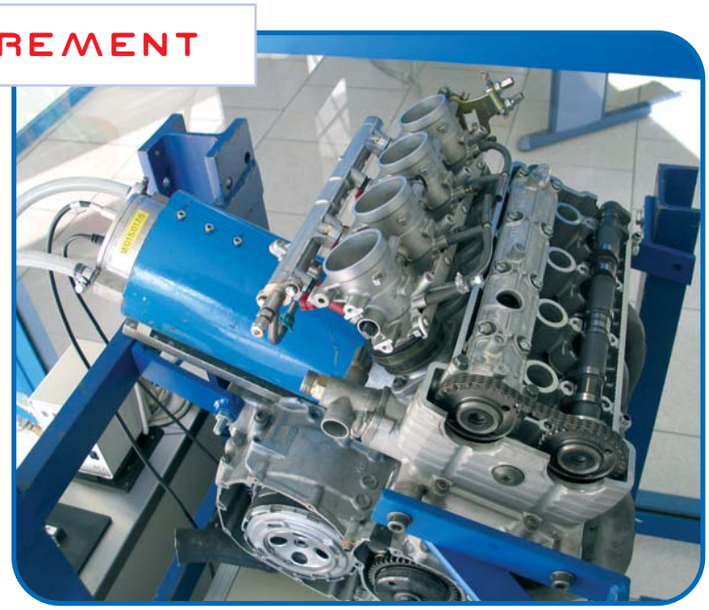
- On-line results
- Extremely high sensitivity
- Real-operating conditions without dismantling parts
- Non-destructive measurement
- Short test duration
- Fully qualified and trained personnel
- Full package service measurement

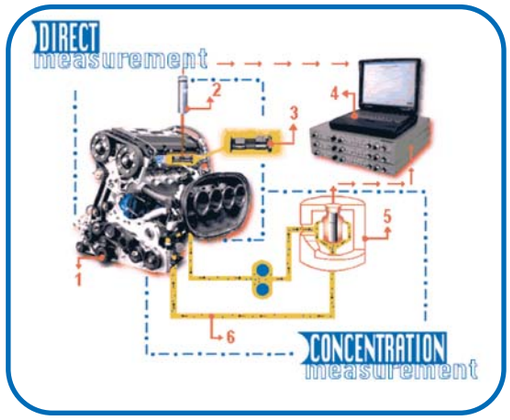
Two measurement methods are available. The choice depends on the type of component undergoing wear and on the configuration of the mechanical system to be studied:

DIRECT MEASUREMENT

A measuring head is installed in the vicinity of the part for monitoring of the signal emitted by the labelled area. Any loss of signal is automatically converted in material loss.

The probe is installed externally to the engine since the gamma radiation emitted by the labelled part(s) can easily penetrate engine walls.





Inspect-Wear equipment performs on-line measurement of wear by applying both "residual" and "flow-through" measurement methods

1 Running engine
2 Detector for « direct » or « residual » measurement
3 Activated wear part (camshaft)
4 Signal processing, data acquisition and software
5 Chamber for « flow-through » or « concentration » measurement
6 Circulating oil

CONCENTRATION METHOD

Also known as "flow through method", it consists in monitoring the increase of signal in a fluid (lubricant or coolant) that transports worn particles.

The detection head is installed in a measuring chamber where the fluid is circulated. A particle trap (a filter or a magnet) can also be installed in the chamber to collect efficiently worn particles.

For more information on this product :
SAE paper ref. SAE 2000-01-1990

X-RAY INSPECTION

FICHE 7

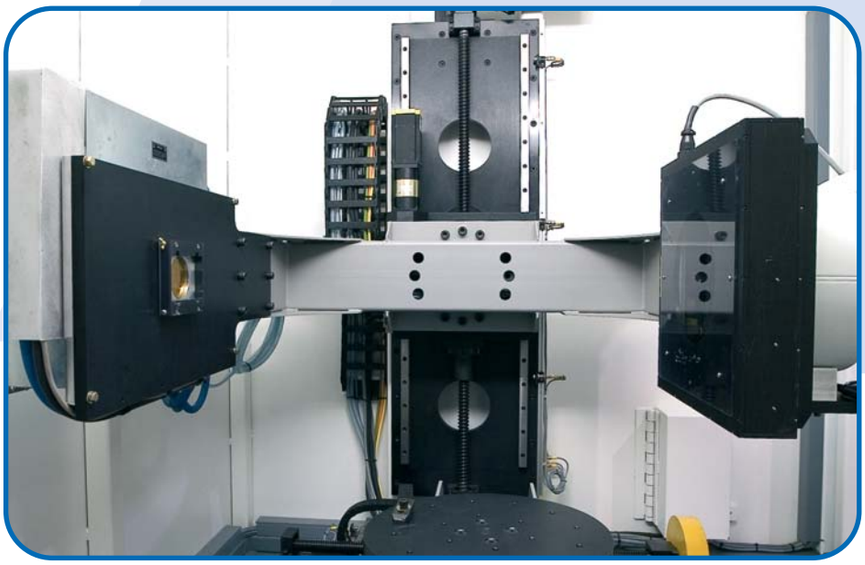
DSi now offers x-ray inspection services to meet your needs in terms of quality control of mechanical components. Our state-of-the-art X-ray system provides reliable and high resolution imaging.

The new X-ray equipment includes a programmable handling system for automatic inspection of a batch of components, and automatic storage of digital radiographs.

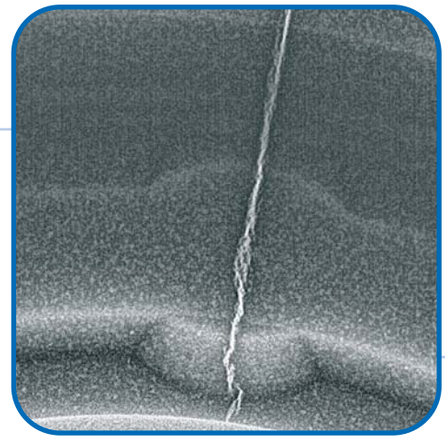
Applications cover casting/foundry components, automotive and aeronautical parts, cable beams and connectors, sealed electronic equipment, art objects, etc.

CHARACTERISTICS

- latest generation digital imaging system
- 5-axis manipulator system enabling views from a rotating volume
- full automatic, semi-automatic or operator assist mode
- real-time digital image archival



APPLICATIONS



- Quality control and inspection of mechanical components : evaluation for metal fatigue, porosity, shrinkage and cracks from manufacturing processes or operating conditions
- Casting defects such as cavities, gas, inclusion, tearing, foreign material, and sponge
- Real-time visualisation of electrical components, connectors and weldings
- Real-time visualisation of internal mechanisms
- Visualisation and inspection of internal structures of art objects
- Measurement of internal distribution of deposits in exhaust systems (soot, ashes in DPFs)
- Computed 3-D tomography

YOUR BENEFITS

- non-destructive inspection
- high resolution, real-time imaging
- convenient for a wide range of materials and components
- Fully qualified and trained personnel
- Very fast response time of our technical team

Ideal choice for customers requiring high-performance quality assurance

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