AUTOFORE

WP 330 - Actual Situation of Remote Sensing

Contents

1. Abstract

Function of Remote Sensing (RS)

Remote Sensing (RS) is the key word for measuring exhaust gas in the flowing traffic (roadside exhaust gas evaluation). The Remote Sensing-Device (RSD) consists of four parts: the Transmitter/ Receiver device, the Reflecting Mirror, Speed/Acceleration device and a Camera. The RSD has to be positioned at a location that has to fulfil some special characteristics. Is the measuring set-up correctly installed, it is possible to measure the exhaust emissions of passing vehicles via spectral analysis. The RS exhaust gas evaluation allows an estimation of gas values measured by stationary emission testers.

Advantage and Disadvantage of RS

<u>Advantages</u>

Technical:
- allows to measure the exhaust gas of passing vehicles
- results of vehicles in use
- allows to gather gross data of location/fleet (statistical data)

Cost:
- high throughput lower costs (measurement capability: a vehicle every two seconds)
- measurement is on site, no additional expenses for test facilities if RS is used exclusively (or lower if it is used as pre selection for a stationary test)

<u>Disadvantages</u>

Technical:
- restrictions to locations: only in one-way-streets, no oncoming traffic/not over several tracks)
- engine has to operate under loaded conditions (accelerate/upwards)
- no control of engine temperature (faults by measurement in cold start mode)
- measurement only under dry conditions (high error rate at bad weather)
- not valid results: at laboratory conditions more than 10%, "in traffic" measurements about 40%
- driver can take relevant influence on measurement results

Cost:
- initial costs (device 75K €, and additionally a vehicle for housing the electronics and for transportation)
- large bureaucratically apparatus needed (if not only used as a screening tool for vehicle identification and documentation of test)
- additional costs may result from building an adequate sensing location (e. g.: construct/prepare a single lane)

Legislation:
- no exhaust gas limit values for RS defined
- no direct possibility of identifying the vehicle (all details) clearly by VIN
- no proceeding for vehicles that exceed the limit values
- no proceeding for vehicles that never pass a RS-station (RS only)
- any step of documentation at the vehicle (e.g. sticker), will be an additional step (RS only)

Usage for PTI

Today just a few RS systems are operating, mostly in the field of research. Potential can be seen in the use as a screening tool to reduce measurement expenses for stationary tests. Replacing stationary tests is not in sight because RS is not reliable enough. The main reasons are that the driver can affect the measurement, the large fail rate even under best conditions and the lack/incomparability of defined limit values for RS. Dealing with limits for RS will always be of difficulties because the measurements are taken more practical influenced conditions than in a standardised process.
Nevertheless, RS has a large potential for future applications e.g. screening of extraordinary polluted areas or for additional inspection between the obligatory stationary tests for evaluating the quality of PTI.

2. Introduction

In the past, emission control was introduced to prevent air pollution and to increase life quality especially in urban areas. The large emission of carbon monoxide (CO), hydrocarbons (HC) and oxides of nitrogen (NO_X) in areas with high frequentation from mobile sources impacts the health and the environment. Nowadays vehicle exhaust gas measurement is an important part of the environmental protection concept.

However different methods for the evaluation of exhaust gas has been developed. The exhaust gas of vehicles are usually measured stationary in Europe. In some non-European countries another test procedure for vehicle exhaust gas measurements was developed and introduced, because of differences in the local legislation in contrast to Europe. The framework in these countries, e.g. no PTI, low number of inhabitants, had made an exhaust gas measurement with stationary tester very costly. Therefore RS was developed.

Remote Sensing (RS) is the key word for measuring exhaust gas in the flowing traffic via spectral analysis. The RS-Device (RSD) is emitting several beams in a height where the exhaust pipes of the most vehicles are expected. Typically an infrared beam is used for the analysis of CO, CO_2, respectively HC and an ultraviolet beam for the analysis of NO_X, respectively HC (depends on the manufacturer system). The beams penetrate the gas and are reflected back via a mirror to the gas analyzer. While passing the exhaust gas, the beams were partially absorbed by the contents of the gas. With the absorption rates of the beams the specific composition of the gas can be computed and the distribution of CO, CO_2, HC, NO_X can be evaluated. In this study the function, the in use experiences and the conclusions for roadworthiness now and in the near future will be discussed.

3. Remote Sensing

3.1 Components

The Remote Sensing-device (RSD) consists of four parts:

- Emitter/Receiver Module (Gas Analyser)
- Reflecting Mirror
- Speed/Acceleration Detection Module
- Camera

The sizes and weights are chosen exemplary from one manufacturer to show the dimensions. Systems from other manufacturers can deviate from these values.

The Emitter/Receiver Module houses two internal modules. The Emitter Module consists of the UV/IR-source. The Receiver Module consists of a rotating mirror-wheel with 12 single mirrors and a detector-unit with 5 detectors for analysing the gas content.
Size: 49 x 24 x 52 cm
Weight: approx. 29 kg

The Deflecting Mirror Module is a simple reflector of the source light beam. It reflects the beam back to the detector side of the analyzer.
Size: 46 x 16 x 18 cm
Weight: approx. 5,5 kg

The Speed/Acceleration Detector Module is providing information on the driving conditions of vehicles tested.

The Video Camera captures a digitized picture of the licence plate of the vehicle in order to identify the car/owner.

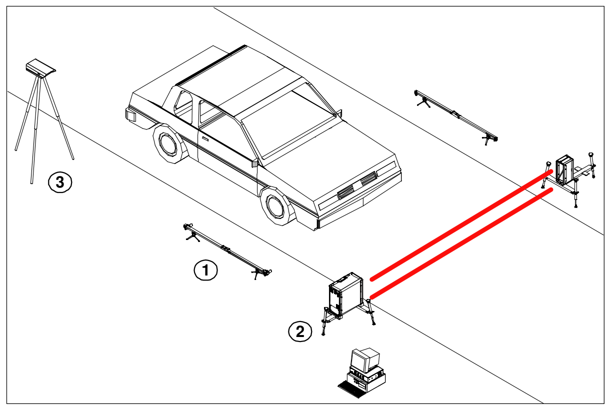
Presently only one manufacturer offers RSD commercially. The price for the system is about 75 k€. Additionally a van for the evaluation electronics and an operator for the roadside installation, calibration and supervising is needed.

3.2 Locations and Device Set-up

In order to get valid results with the RSD, the engines of the analysed vehicles have to operate under loaded conditions. To achieve this, the RSD has to be placed at an upward gradient or at a position, were the vehicles have to accelerate. Oncoming traffic and sensing over several tracks will interfere the accuracy of the measurements, e.g. because the exhaust plume of the measured vehicle will be dispersed. Therefore experiences showed that best results were received at single track one-way-streets.
Another aspect of the measuring position is the operating temperature of the vehicle. A valid measurement can only be achieved if the vehicle reached the operating temperature. Measured vehicles, which are running in the cold start mode, appear to have high emissions, without having problems with the exhaust system. Therefore several areas, were RS basically make

sense, e.g. residential areas, are not acceptable for measuring, because the operation time of the vehicles engines are often to short to reach the necessary temperature. A further aspect for site selection is the vehicle speed at the sensing location. With increasing vehicle speed the dispersion of the plume increases, too. Therefore the vehicle speed at the sensing site should not be to high.
If an adequate location has been selected, a trained operator has to install the road components of the RSD first. After that the electronic components of the detector has warmed up for about 30 minutes. Then the detector has to be calibrated with a test gas with a known blend of CO, CO_2, HC and NO_X.

3.3 Measuring Procedure



If a vehicle is entering the calibrated measuring set-up, it first crosses the light barrier of the speed/acceleration module (1), where the exact speed and acceleration of the vehicle is determined. This data is needed for the estimation of the emission values. After that, the vehicle crosses the light beam of the emitter-module (2). Within 0,5 seconds the detector is analysing the exhaust plume of the passing vehicle. After computing the exhaust gas values and checking their plausibility, the camera (3) will photograph the licence plate to identify the car and the owner.

3.4 Measuring Conditions

To get valid data with the RSD, the results are depending on several factors. Important factors that can affect the accuracy of the measurement are the environmental conditions. The RSD is capable to operate under almost all temperatures (-7 to +49 °C). In studies all across Europe the device showed that temperatures have no influence on the accuracy. Also the effect of ambient wind on the results can be seen as minor. The faster the vehicle, the smaller the influence of ambient wind on the results. But weather conditions that are interfering the analysing beam of the detector, has a major influence on the accuracy of the measurement.
The humidity may not be over 85%. The RSD can handle light rain conditions, but only by accepting an increased error. Heavy rain, snow and fog impairs the sensitivity of the device negatively, so that all measurements under these conditions have to be seen as critical.

3.5 Human effects on the accuracy of measurement

Another important aspect that can affect the accuracy of the RSD is the human factor. A valid measurement can only be achieved, if the engine works under loaded conditions. If the driver is recognizing the RSD, he can affect the sensing by stopping the acceleration process or braking. Therefore the driver is in the position to decide if he wants to have a valid or invalid measurement. For this reason an independent measurement is not possible.

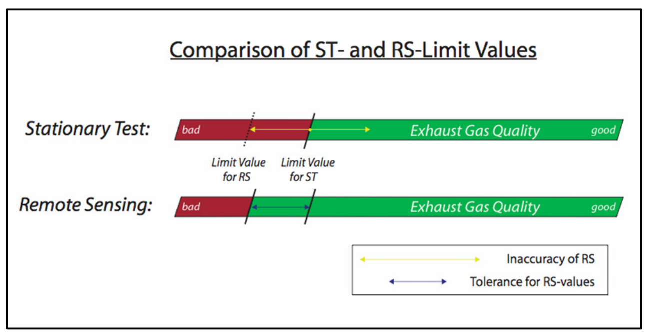
4. Discussion

RS was introduced years ago in several non-European countries as a pilot project for roadside inspections. The national vehicle inspection characteristics included, these countries decided to use RS for their requirements. The fact that RS is preferred in comparison to stationary tests, shows that RS is a serious alternative for stationary exhaust gas measurement. Meanwhile the collected experiences of these countries can help to compare this technique with the usual stationary tests in Europe. The arguments pro and contra RS can be arranged into three categories: Technical, Costs and Legislation.

4.1 Technical

In contrast to stationary test, which evaluates the gas content via probe inside the exhaust system, RS is based on a totally different concept, measuring outside the exhaust system. The advantage of the RS concept is that it allows measuring the gas concentrations, "real-time", in the flowing traffic with a smaller expense than with stationary tests. If both systems will be used for roadworthiness simultaneously, it must be guaranteed that a vehicle don't gets a valid test result with only one of the test methods. The basic problem will be the comparability of the measuring results of these two different concepts, because different measuring methods can show different results on the same source.

Two solutions are thinkable for the problem. On the one hand the direct comparability of RS values and stationary test values and on the other, the introduction of a tolerance for RS values. The direct comparability should be targeted for a simultaneous use. But to match the stationary test values, a correction factor has to be applied, that outweighs the differences of the test methods. But the large number of influences on the RS method makes this option very complicated, maybe not solvable.



RS can be used to have a quick distinction between very good from very bad emitting vehicles. The difficulty is the comparison in the range of the limit values, because of the large dispersion of the readings caused by external influences. Nevertheless, to use RS, the other solution is to introduce a tolerance for RS values, thus detach these values from the reference of stationary values. This tolerance is necessary to handle the dispersion. Measurements can be used to identify gross polluters on the one end of the scale and a clean screened area on the other side. To clarify the emission behaviour around given limit values will need additional measurements, e. g. stationary tests.

Another advantage of RS that has to be mentioned is, that the technology allows a high throughput of vehicles. The device is test-ready every 2nd second, so the theoretical throughput is 1800 vehicles per hour. In contrast to that, the throughput of stationary tests is significant below this value.

On the other hand, there are major disadvantages of the RS technique. Finding an adequate test site is one of the problems of RS. To get valid data from the roadside measurements, extensive requirements on the sensing site have to be placed. The difficulty is that the sites

have to fulfil the criterions mentioned in 2.2, but it also needs a high frequentation of vehicles. Positioning the RSD at a location that is not fulfilling all the criterions, an increased error rate is the consequence. A major problem, related with the sensing location, is depending on the different characteristics of the sensing site. Has an adequate location been found that matches all the mentioned criterions, nevertheless the local characteristics are differing from location to location. The measured exhaust gas quality of a vehicle in the flowing traffic depends on the situation where the vehicle is in the moment of the test. Deviating to ST, were the test criterions are always very similar, the differences in the characteristics of the location influences the measured exhaust gas composition of the vehicle. Therefore it was suggested to define limit values for every sensing location. Experiences in former studies showed that up to 50.000 vehicles have to be measured per location to set these values. Additionally it has to be considered that the measured vehicles average depends on the time of day, i.e. on the traffic density at the sensing location.
An additional aspect is, that in some countries it is not possible to combine the RS-technology with a "real-time" database connection, in order to get the emission classification of every passing vehicle. This would be necessary if the measurement should concern different limits for different vehicles.
But not only the location problem can take influence on the error rate of the RSD. The weather is another aspect that affects the accuracy. The interferences caused by rain or fog disturbs the beam of the gas analyser, so that the error rate under these conditions is increasing additionally to the normal error rate by around further 50%. This fact limits considerably the use of this system in a broad application. A further major problem of RS is, that the driver can take influence on the measurements, so that an independent result cannot be guaranteed. With going off the accelerator pedal or tipping the brake pedal, the driver affects the sensing, so the accuracy of the measurement is very low and thus the test has to be seen as not valid.
All these mentioned aspects are the reasons why the valid "in traffic"-measurements with RS are only around 60% of all passed vehicles. But even under perfect conditions, so called "laboratory" conditions, the error rate is still around 10%. The mentioned problems are showing that the RS technology is nowadays not in the position to achieve the same measuring quality like stationary exhaust gas tests.
But the advantages of RS and the ongoing development of the RS-technology possibly bring RS into the position to be an equivalent measuring system for future applications.

4.2 Costs

The factor "costs" is a major argument for a broad application of devices. State of the art stationary exhaust gas devices cost about 8000 €. In comparison to that, the initial costs of a RSD are about 75K €. Additionally to that, a vehicle for the transport and operation (housing the evaluation computer) might be needed. In the comparison of the initial costs, the RSD is significantly more expensive than the cost for a stationary device. In a broad application the price of a RSD will fall, but is not expected to reach the price level of stationary tester.
The high initial costs can be levelled down through the high throughput of vehicles, so that the costs per vehicle are low and the device will amortized itself rapidly.
Nevertheless, the costs can be an obstacle for a broad application, because not only the RSD and the technical infrastructure (initial costs) are needed, but also a large bureaucratically apparatus must be installed and maintained e.g. for one or more operators, the infrastructure

for identification of the vehicle, the documentation of the test, to bring the results to the owner of the vehicle. All these aspects complicate the "RS-only" variant and raise the bureaucracy and the costs. In a variant where RS is used additionally as a screening tool, it might reduce costs for stationary test, but by establishing and maintaining a second measurement technology.

4.3 Legislation

From legislation side, several questions on RS are not answered. The first basic aspect is, that until today no limit values for RS have been defined, so that RS can not be performed, neither as replacement of stationary tests nor in addition. Especially the definition of limit values for RS in addition to stationary tests could be very complicated, because the definition of new limit values of a complete different measuring method, needs to be comparable to an existing system.

Furthermore, before an official test can be performed, a vehicle has to be identified clearly. This is not the case, if relying only on the licence plate, used for identification by the RSD. The manipulation possibility is significant higher, than identifying a vehicle with VIN used in stationary tests. Generally more information are given to the tester in stationary tests, because the tester has the complete documentation of the vehicle with additional data and can check for modifications, that influence the exhaust gas content.

Other questions in a "RS-only" variant are unresolved. What happens with vehicles that never pass a RSD? Do they get a request from authorities, that they have to perform the test? What happens with vehicles that exceed the RS exhaust gas limit? Do they have to perform a stationary retest to confirm the RS data or to prove later for repair and maintenance?

A certificate for a passed test has to be introduced. For example, this could be a sticker on the windscreen, so that the vehicle is marked as OK. To handle this in a RS only scheme will afford additional measures.

In summary limit values for RS have to be defined first. For an "RS-only" variant several legislation questions have to be answered before a broad application of RS can take place.

5. Conclusions for Roadworthiness

As discussed in the report, the RS technique has some advantages compared to the stationary test. But today the disadvantages outweigh the advantages. Summarized the major problems of RS are the location, the weather, the large fail rate even under best conditions, the comparison of the limit values and the influence of the driver to the measurement. But this is only a on-the-spot notation. Today RS is suitable for the identification of gross polluters and statistics, e.g. overview of the fleet/street characteristics.

The ongoing development of the RS technique can maybe solve the technical problems, so that RS has perhaps a large potential for the tasks of screening in the future. Another operational area for RS could be as additional inspection between the obligatory stationary tests, to evaluate the quality of PTI. Therefore RS seems to be helpful as an additional (screening) tool for PTI or for roadside inspections. Here the advantages of RS of a quick measurement and result may be very useful.

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6. Literature

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