2nd VegOil

Demonstration of 2nd Generation Vegetable Oil Fuels in Advanced Engines

Workpackage WP4

Engine Oil Development

Deliverable N° 4.10b:

Sensor Provision and Data Interpretation Publishable

Version: 2

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1 Summary

Information on the installation of the sensors and a description of how operate has been reported under Deliverable No 4.10b on 20th August 2009.

The data gathered so far is summarised as follows:

LVK TU-Munich test

- Data from January 28,2009 to April 22, 2009
- Approximately 26 hours of data

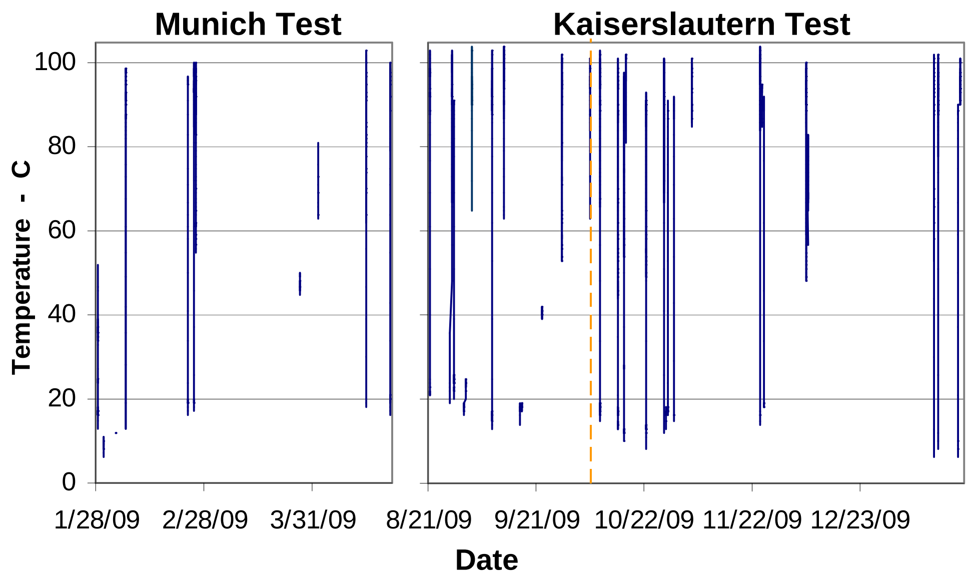
John Deere - TU-Kaiserslautern Test

- Data from August 21, 2009 to January 20, 2010
- Engine run with bio-fuel under prescribed protocols to investigate emissions
- Approximately 89 hours of data

2. Data Interpretation

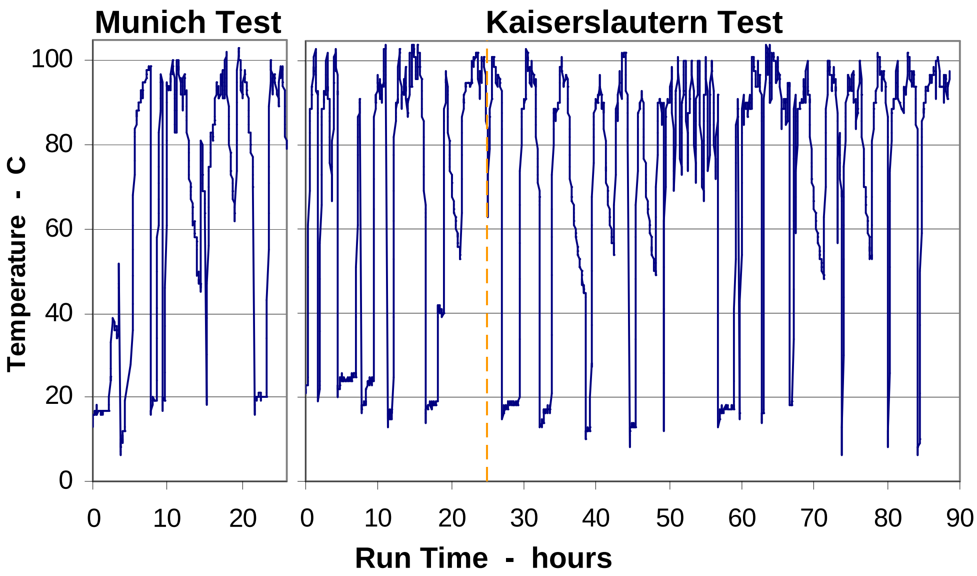
Oil Temperature vs Date

This shows when lubricant data were taken for the two tests. All data periods were less than 8 hours with many periods being less than 3 hours. Note that the initial oil temperature of a data period was not always ambient; hence, data may be missing at the start of some periods. The vertical dashed orange line marks where the MFI data indicates an oil change occurred during the Kaiserslautern test.



Oil Temperature vs Run Time

Shows the lubricant temperature as a function of time for the two tests. Note the periods when the lubricant was at ambient temperature or appears to be cooling to ambient. The engine was probably not running during those times; however, no attempt was made to eliminate those data. The vertical dashed orange line is the same as above.

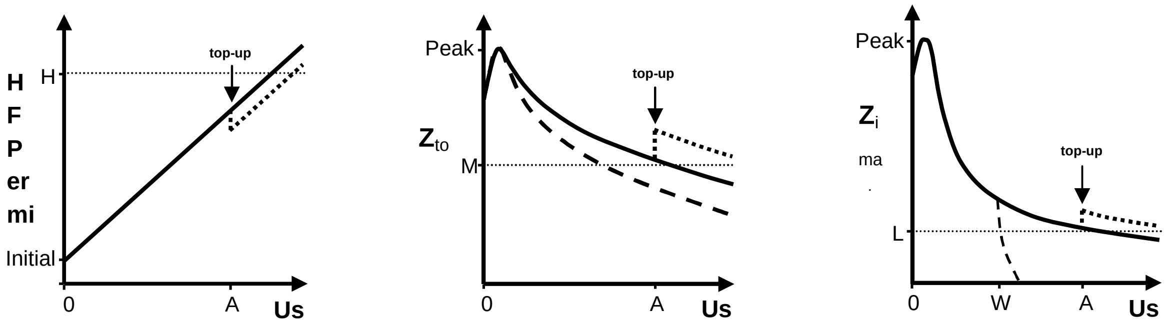


Electrochemical Impedance Trends Associated with Lubricant Functionality Changes

High frequency (HF) ~100kHz
Bulk fluid properties associated with contaminants
- friction reduction

Medium frequency (MF) ~100Hz
Bulk fluid properties associated with detergent and dispersant additives
- contaminant control

Low frequency (LF) ~0.1 Hz
Surface properties associated with antiwear, etc. additives
- surface protection

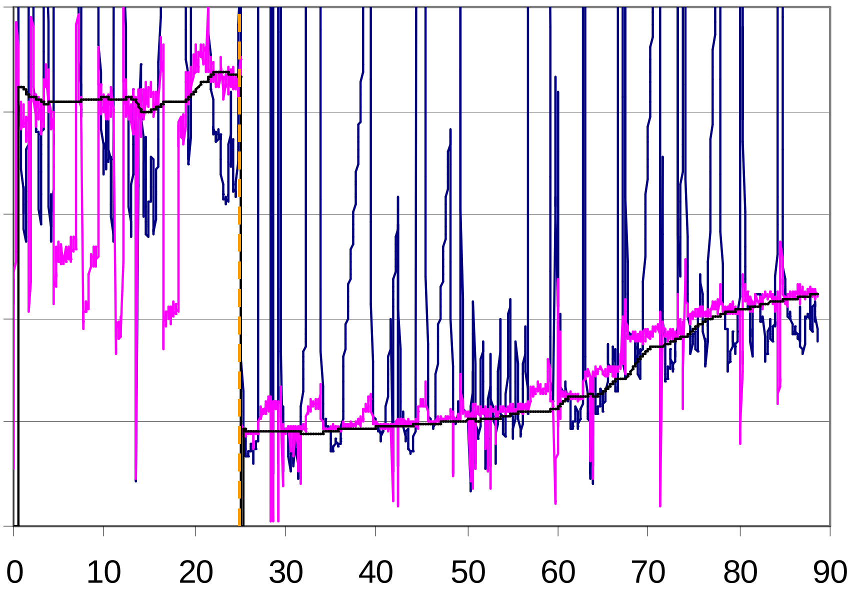


The HF permittivity trends the lubricant's contaminants. Permittivity typically increases with use (run time) for a diesel lubricant as polar contaminants such as soot increase, with the lubricant being condemned when the percentage permittivity increase from initial reaches a HF threshold ("H"). Permittivity can decrease for a diesel engine usually due to the engine sump being "dirty" from a previous drain interval or due to fuel dilution occurring. Condemnation thresholds can be set to protect the engine against these occurrences.

The MF total impedance (Ztotal) trends the contaminant control functionality of the lubricant's detergents and dispersants, with the trend ascending to a peak followed by a decrease with use. A typical MF condemnation threshold is 50% of peak ("M").

The LF imaginary impedance (Zimaginary) trends the surface protection functionality of the lubricant's surface active additives, with the trend ascending to a peak followed by a decrease with use. A typical LF condemnation threshold is 30% of peak ("L").

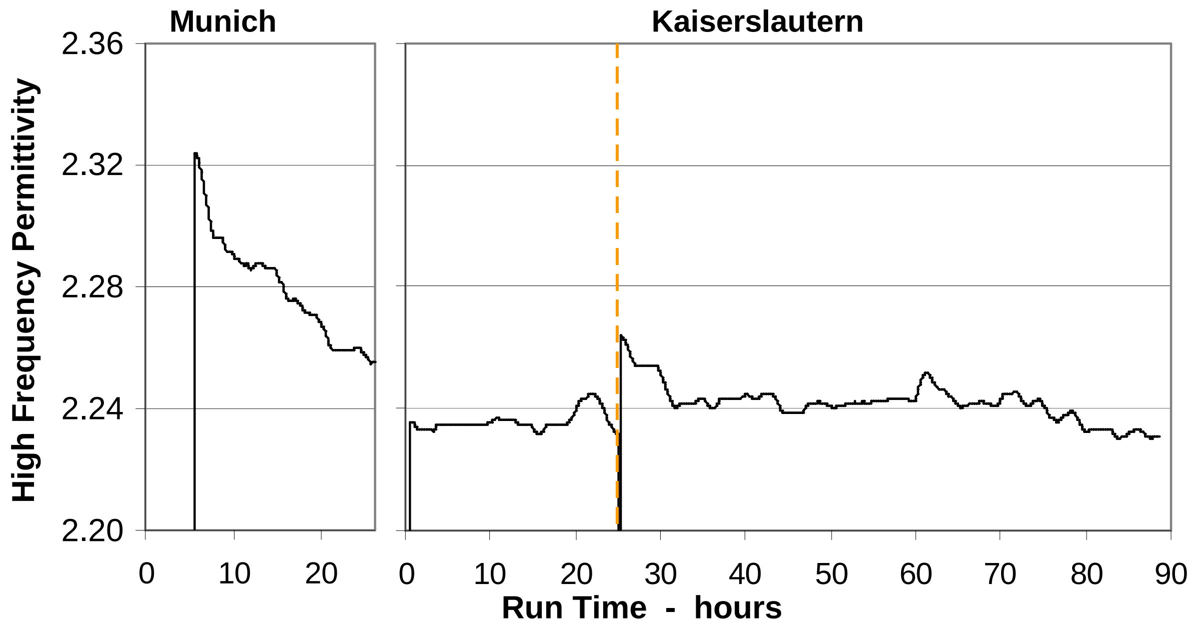
<u>Example of Data Processing</u>



The MFI sensor outputs high, medium and low frequency (HF, MF and LF respectively) impedances and temperature every ~3 minutes. The raw outputs were logged and an off-line MFI algorithm uses the temperature data to normalize/compensate the raw data to a single temperature and then filters for temperature range and rate and for noise. The algorithm compares the filtered data trends to thresholds to determine lubricant condition and to identify when oil changes are needed.

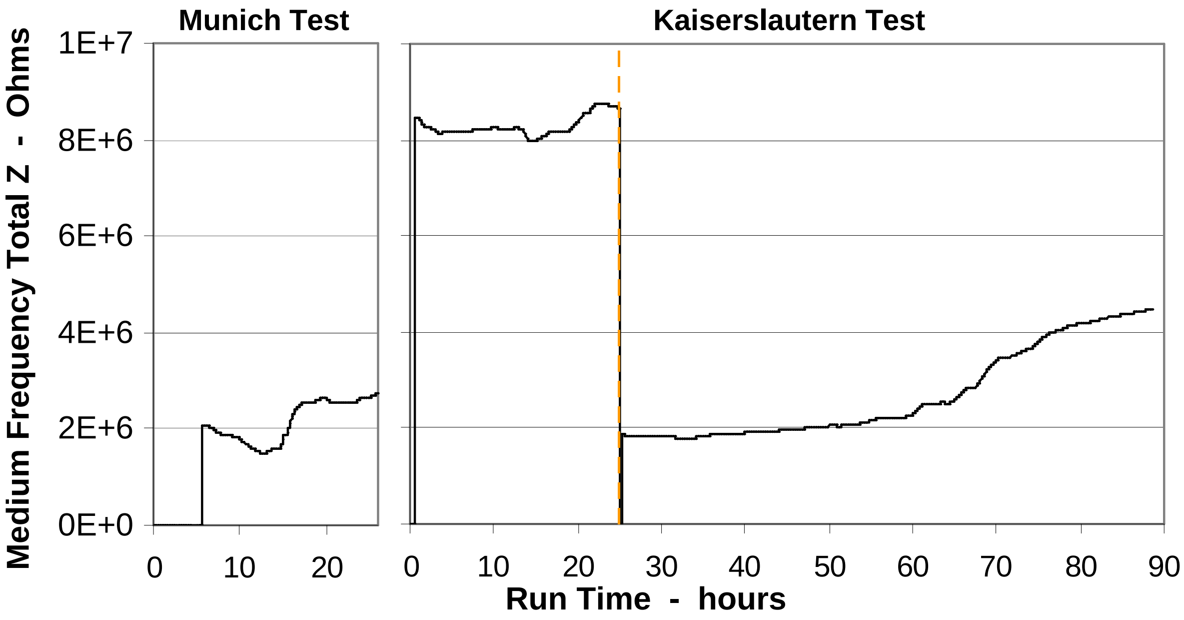
The above plots show the MF raw, temperature compensated and filtered data for both tests. Compensation temperature was 90ºC, and data taken with temperature between 60 and 120ºC, and rate of change ≤5ºC per minute were accepted. The impedance decrease at ~25 hours in the Kaiserslautern test (marked by the dashed orange line) is diagnosed as an oil change. The conclusions on the lubricant condition from the sensor are documented on Page 10 of this report, but in summary the evaluation of the sensor output confirmed that the lubricant had good contaminant control and surface protection functionality.

High Frequency Permittivity



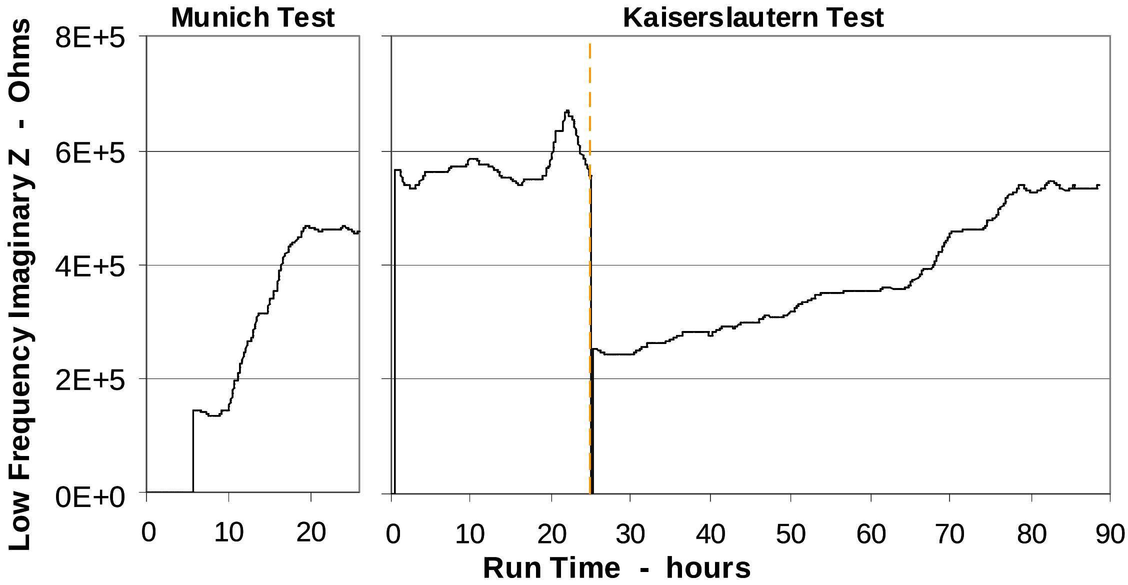
The plot shows the filtered High Frequency permittivity for both tests. The permittivity decrease seen in the Munich test suggest that were contaminants present in the engine at the start of the test or that there was significant fuel dilution during the test period. The slight permittivity decrease after the oil change marked by the dashed orange line in the Kaiserslautern test may also be indicative of a minor amount of fuel, which often occurs with biofuels are used. This is consistent with the low permittivity at the end of the first drain period which suggests that soot generation rate is quite low as is the fuel dilution rate, which may be zero. More information about the engine, including laboratory oil analysis, is needed before a better diagnosis of the results can be made and appropriate condemnation thresholds for the MFI algorithm's trend analysis can be set.

Medium Frequency Total Impedance



The plot shows the filtered Medium Frequency total impedance for both tests. Since the peak was not reached for the one drain interval of the Munich test or for either drain interval Kaiserslautern test, the contaminant control functionality of the lubricants remained very good throughout both tests.

Low Frequency Imaginary Impedance



The plot shows the filtered Low Frequency imaginary impedance for both tests. At worst the peak was only just reached for the two drain intervals; hence, the surface protection functionality of the lubricant remained good during both intervals. Assuming the same lubricant use for both tests, the more rapid impedance rise in the Munich test suggests that surface protection functionality was degrading faster during that test. This may be due to harsher engine operating conditions, such a shorter run periods (more starts), or due to contaminants. If fuel, in particular oxidized fuel, is a contaminant, a more rapid depletion of bulk antioxidants, which are in chemical balance with the surface antioxidants, is known to occur and may be the cause for the first period's more rapid rise.

Conclusions

Munich Test

- The lubricant had good contaminant control and surface protection functionality as of April 22, 2009.
- The HF permittivity decrease indicates that contamination may have been an issue with the lubricant; however, since appropriate HF thresholds are not set for this engine the degree of lubricant degradation is not clear.

Kaiserslautern Test

- A lubricant change was made October 6, 2009.
- The first lubricant, drain on October 6th, still had good contaminant control and surface protection and contaminant levels appear to be low assuming the same lubricant was used for both drain intervals.
- The second lubricant had good contaminant control and surface protection functionality, and contaminants were low as of January 20, 2010.

The Munich test was degrading the lubricant more quickly mostly due to operating conditions or contaminants. The Munich test was conducted under harsher engine operating conditions. These harsher engine operating conditions included shorter engine running periods and operation under low loads. This would subject the lubricant to more engine starts under colder conditions both of which are likely to introduce more contaminants (i.e. soot, fuel dilution and water) into the lubricant. The introduction of increased levels of contaminants into lubricants will accelerate the degradation of the lubricant.