Kastl, Johannes and Remmele, Edgar

Influence of additives on the cold flow behaviour of rapeseed oil fuel

Rapeseed oil fuel differs from fossil diesel fuel amongst others in regard to the cold flow behaviour. The goal of the study presented in the following was to investigate the effectiveness of ten different additives in regard to improve the flow behaviour, especially at temperatures below 0 °C. Therefore a test method has been developed, which uses the measurement of the dynamic viscosity. The temperature of the sample was altered using a defined temperature profile, the dynamic viscosity was measured continuously. The effectiveness of the additives was significantly different, also the influence of the temperature could be seen. Currently nothing can be said about the suitability for daily use.

Keywords
Rapeseed oil fuel, additive, cold flow behaviour, dynamic viscosity

Abstract
Landtechnik 65 (2010), no. 6, pp. 453-445, 2 figures, 1 table, 6 references

The specifications for the use of rapeseed oil as fuel in engines capable of running on vegetable oils are defined in the German standard DIN 51605 'Fuels for vegetable oil compatible combustion engines – Fuel from rapeseed oil – Requirements and test methods' [1]. The use of additives to improve properties of rapeseed oil fuel is explicitly allowed if there are no negative effects on the operating performance or the effectiveness of the exhaust gas after treatment. Also, the water hazardousness of the mixture must still be classified as 'non-hazardous to water' according to the German 'Administrative Regulation on the Classification of Substances hazardous to waters into Water Hazard Classes' (VwVwS, [2]). In contrast to fossil diesel fuels, the use of additives is not common with rapeseed oil fuel.

Rapeseed oil fuel differs from fossil diesel fuel, amongst others, in regard to the low temperature flow behaviour. At room temperature, the viscosity of rapeseed oil fuel is much higher than the viscosity of diesel fuel. When cooling down the oil to temperatures below 0 °C, the dynamic viscosity increases further up to the solidification of the oil. These differences in the flow behaviour can be reduced by warming the fuel in the engine system, but even so the use of rapeseed oil at low temperatures is limited. It has not been thoroughly researched whether the low temperature flow behaviour of rapeseed oil fuel can be improved by the use of additives.

Problems and objective

Compared to fossil diesel fuel, vegetable oils show a different chemical structure and composition. For that reason the existing test methods developed for describing the cold flow behaviour of fossil diesel fuels cannot be used. Because of these differences it is in dispute if additives suitable for fossil diesel fuel can improve the properties of rapeseed oil fuel at all.

Goal of the works was therefore to investigate the effectiveness of additives, which are commercially available for the use in fossil diesel fuel, fatty acid methyl esters (FAME, 'biodiesel') or vegetable oils, in regard to improving the low temperature flow behaviour of rapeseed oil fuel. To achieve this goal it was necessary to develop a test method suitable for describing the flow behaviour of rapeseed oil fuel.

State of knowledge

The few publications on the flow behaviour of rapeseed oil fuel describe a rapid increase in the dynamic viscosity of rapeseed oil fuel at temperatures below 0 °C. Widmann et al. [3] described the influence of time on the flow behaviour at low temperatures. Accordingly, rapeseed oil solidifies after 72 hours at –10 °C, but already after 6 hours at –25 °C. Remmele et al. [4] and Remmele [5] investigated the flow behaviour of rapeseed oil fuel by measuring the dynamic viscosity with a rotational viscosimeter. Experiments showed that the cooling rate influences the dynamic viscosity. Bahl [6] also measured the dynamic viscosity with a rotational viscosimeter; here four additives were examined at seven discrete temperatures. An influence of the additives could be seen, simultaneous measurements of the Pour Point did not show significant differences.
Taking into consideration the literature [3; 4; 5] it seems to be not sufficient to describe the flow behaviour of rapeseed oil fuel by measuring the dynamic viscosity at discrete temperatures.

Material and methods

In the experiments ten additives from different suppliers were used. These will be labelled as K01 to K10 in the following. Three different dosage levels were used for each additive: the recommended dosage given by the supplier (base concentration) as well as twofold and half of the base concentration. The recommended dosage ranged from 0.2 to 3.2 vol%. Attention should be paid to the fact that most of the recommendations were given for the use in fossil diesel fuel.

To investigate the effectiveness of the additives, a test method has been developed, which is based on the measurement of the dynamic viscosity. The sample to be measured is cooled down from 20 to –30 °C and heated up to 20 °C again according to the temperature profile in **table 1**. The measurement device (Anton Paar MCR 101) measures the dynamic viscosity by using the 'controlled shear stress' (CSS) method in a 'cup and bob' geometry. That means the rotation speed is adjusted by the instrument so as to keep the shear stress at a defined level. The higher the dynamic viscosity of the sample, the lower the rotational speed, and thus the less energy is introduced into the sample by the rotation.

The blank sample without additives as well as each one of the additive-rapeseed oil fuel-blends was done in triplicates, and an averaged course of viscosity has been calculated for each sample. The effectiveness of an additive in a specific concentration was rated by comparing the averaged course of viscosity of the respective sample containing the additive with the averaged course of viscosity of the blank sample without additives.

Table 1

Profile for the well-defined alteration of the sample temperature

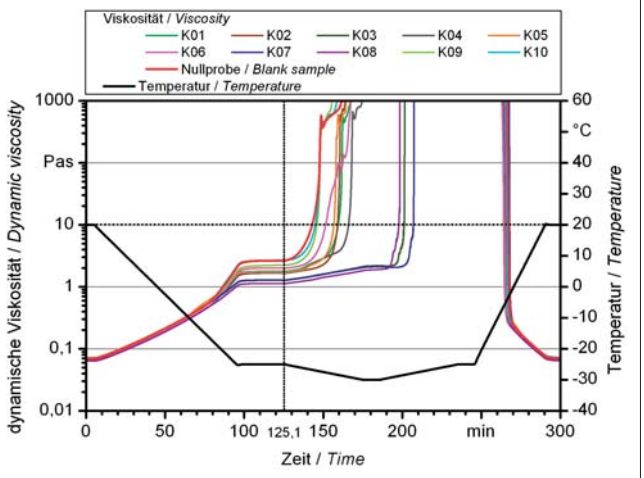
Bezeichnung *Name*	**Dauer in Minuten** *Duration in minutes*	**Beschreibung** *Description*
Stabilisierungsphase 1 *Stabilization phase*	5	konstant 20 °C *constant 20 °C*
Abkühlphase 1 *Cooling phase 1*	90,1	Abkühlrate 0,5 K/min *Cooling rate 0.5 K/min*
Stabilisierungsphase 2 *Stabilization phase 2*	30	konstant -25 °C *constant -25 °C*
Abkühlphase 2 *Cooling phase 2*	50,1	Abkühlrate 0,1 K/min *Cooling rate 0.1 K/min*
Stabilisierungsphase 3 *Stabilization phase 3*	10	konstant -30 °C *constant -30 °C*
Aufheizphase 1 *Heating phase 1*	50,1	Heizrate 0,1 K/min *Heating rate 0.1 K/min*
Stabilisierungsphase 4 *Stabilization phase 4*	10	konstant -25 °C *constant -25 °C*
Aufheizphase 2 *Heating phase 2*	45,1	Heizrate 1 K/min *Heating rate 1 K/min*
Stabilisierungsphase 5 *Stabilization phase 5*	10	konstant 20 °C *constant 20 °C*

Results

Figure 1 shows the averaged courses of viscosity for the blank sample (without additives) and the mixtures of the ten additives in the base concentration. Up to about 80 min into the measurement (sample temperature approx. –17.5 °C) the dynamic viscosity of the mixtures was in good agreement with the blank sample. In the further course up to the end of the second stabilization phase at –25 °C the courses fanned out, the values at the end of the stabilization phase (depicted in the figure by the vertical line) ranged between 1.13 Pas (K08) and 2.68 Pas (K10). The blank sample showed a viscosity of 2.65 Pas at that point in time. Besides the mixture of K03, the mixtures of the additives K07 and K08 showed the biggest difference compared to the blank sample with viscosities of approx. 1.3 Pas. When further cooling down the samples, significant differences appeared, both compared to the blank sample as well as amongst the different additivated fuels. The mixtures of the additives K09 and K10 showed only small variation, whereas the mixtures of K07, K08 and K03 differed the most from the blank sample. The degree of difference becomes apparent when comparing the runtime, until the dynamic viscosity of the samples exceeded a value of 10 Pas. The viscosity of the blank sample exceeded this value at approx. 143 min runtime, the addition of the additives K07, K08 or K03 resulted in retardation to values of approx. 200 min. The mixtures of the additives K09 and K10 varied only slightly from the blank sample with values of about 145 min. The other mixtures exceeded a viscosity of 10 Pas at a runtime of 151 to 166 min. In opposition to the behaviour when cooling the samples, the dynamic viscosity of all mixtures was in good agreement with the viscosity of the blank sample when the samples were being heated up again (heating phase 2).

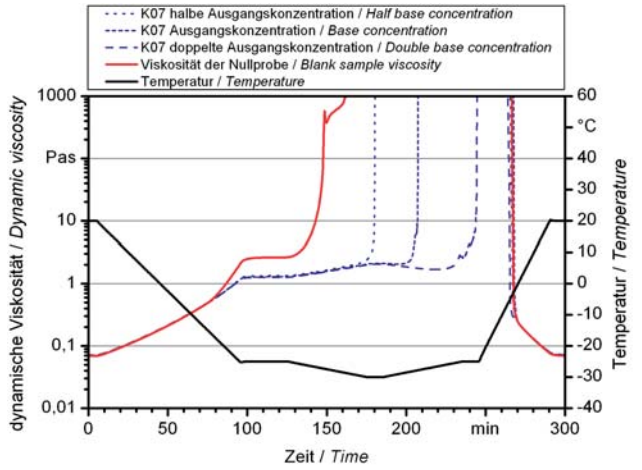
In addition to the dosage recommendation from the suppliers, two more dosage levels have been tested, where the additives have been added in twofold and half of the base concentration, respectively. **Figure 2** shows the courses of the dynamic viscosity of the three mixtures of additive K07. As can be seen the concentration had a big influence on the steep incline of the dynamic viscosity when the sample is cooled down, but there was only a small difference in the viscosities up to the end of stabilization phase 2. The concentration also had only little influence on the rapid decrease of the dynamic viscosity during heating phase 2.

Fig. 1



The temperature profile for the well-defined alteration of the sample temperature plus the courses of the dynamic viscosity of the blank sample without additives and the different additive-rapeseed oil fuel-blends (base concentration)

Fig. 2



Comparison of the viscosity courses of the three different mixtures of additive K07 (base concentration, double base concentration and half of base concentration)

Conclusions

The test method for the examination of the flow behaviour of rapeseed oil fuel that has been developed in this work is suitable to show the influence of additives on the dynamic viscosity. In our laboratory experiments a significant difference in the effectiveness of the tested additives has been shown. The additives K07, K08 and K03 displayed the most promising influence on the cold flow behaviour of rapeseed oil fuel. Apart from the effectiveness of the additives several other aspects have to be examined. First of all the influence on the properties specified in the German standard DIN 51605 has to be investigated, as well as the water hazardousness. Furthermore the influence on the emission characteristics and the effectiveness of the exhaust gas after treatment has to be researched.

Literature

[1] Deutsches Institut für Normung e. V. (2010): DIN 51605 – Kraftstoffe für pflanzenöltaugliche Motoren – Rapsölkraftstoff - Anforderungen und Prüfverfahren

[2] VwVwS (1999): Allgemeine Verwaltungsvorschrift zum Wasserhaushaltsgesetz über die Einstufung wassergefährdender Stoffe in Wassergefährdungsklassen (Verwaltungsvorschrift wassergefährdende Stoffe – VwVwS) vom 17. Mai 1999. Bundesanzeiger, Jg. 51, Nr. 98a vom 29. Mai 1999

[3] Widmann, B. A.; Kaiser, T.; Brand, D. (1994): Technische Eignung von naturbelassenem, nicht additiviertem Rapsöl für den Einsatz als Sägekettenöl. Abschlußbericht zum Forschungsvorhaben für das Bayerische Staatsministerium für Landesentwicklung und Umweltfragen, Stand: 01. Dezember 1994. Hg. Landtechnik Weihenstephan, Freising, und Institut für Energie- und Umwelttechnik, München

[4] Remmele, E.; Thuneke, K.; Widmann, B.; Wilharm, T.; Schön, H. (2000): Begleitforschung zur Standardisierung von Rapsöl als Kraftstoff für pflanzenöltaugliche Dieselmotoren in Fahrzeugen und BHKW - Endbericht zum Forschungsvorhaben. Gelbes Heft Nr. 69. Hg. Bayerisches Staatsministerium für Ernährung, Landwirtschaft und Forsten, München

[5] Remmele, E. (2002): Standardisierung von Rapsöl als Kraftstoff – Untersuchungen zu Kenngrößen, Prüfverfahren und Grenzwerten. Dissertation, Technische Universität München, Lehrstuhl für Landtechnik, Department für Biogene Rohstoffe und Technologie der Landnutzung. Forschungsbericht Agrartechnik des Arbeitskreises Forschung und Lehre der Max-Eyth-Gesellschaft Agrartechnik im VDI (VDI-MEG), Nr. 400

[6] Bahl, B. (2006): Verbesserung der Oxidationsstabilität und des Kältefließverhaltens von Rapsölkraftstoff durch Zusatz von Additiven. Diplomarbeit, Universität Rostock, Institut für Chemie, Abteilung für Analytische, Technische und Umweltchemie

Authors

Dipl.-Ing. Johannes Kastl is member of the scientific staff in the subject group 'Biogenic Fuels, Lubricants and Process Materials' (Head: **Dr. Edgar Remmele**) at the Technology and Support Centre (TFZ), Schulgasse 18, 94315 Straubing, E-Mail: poststelle@tfz.bayern.de

Acknowledgement

The authors would like to thank the Agency for Renewable Resources (Fachagentur Nachwachsende Rohstoffe e.V.) for financing the works (support code 22004607).