Cold start behaviour of regenerative gasoline fuel blends down to -15 °C

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Abstract

As part of the "reFuels- rethinking fuels" project, the focus was on drop-in ready fuels that meet the current EN228 fuel standard. By complying with the fuel standard, the CO_2 emissions of the vehicle fleet can be reduced through a high regenerative share.
In this paper, the focus is on two gasoline fuels, one with a 40 % regenerative and the other with an 85 % regenerative share. The fuels, known as G40 and G85, comply with the EN228 standard and can therefore be refueled directly. The basis of the regenerative share is bioliq®, a fuel based on the biomass-to-liquid process.
G40 is achieved by using 10% EtOH and 30% bioliq® light gasoline. G85 is blended by various other components, for example hydroprocessed bioliq® heavy gasoline.
In earlier studies, the influence of the fuels was investigated on the single-cylinder engine test bench. In the investigations now under consideration, the focus is on cold-start behavior at very low temperatures (down to -15 °C). Both gaseous and solid exhaust emissions are considered, and standard E5 gasoline is taken as the reference.
As a result, it can be seen that both G40 and G85 behave similarly or better in terms of raw exhaust emissions than E5 at low temperatures. The goal of having fuels with high CO_2 potential that at the same time do not worsen exhaust emissions was achieved.

Kurzfassung

Im Rahmen des Projekts „reFuels- Kraftstoffe neu denken" lag der Fokus auf Drop-in fähige Kraftstoffe, die die aktuelle Kraftstoffnorm EN228 erfüllt. Durch die Einhaltung der Kraftstoffnorm kann durch einen hohen regenerativen Anteil die CO2-Emissionen der Bestandsflotte gesenkt werden.
In dieser Arbeit liegt der Fokus auf zwei Benzinkraftstoffe, die zu einem einen 40 % regenerativen und zum anderen einen 85 % regenerativen Anteil besitzen. Die als G40 und G85 bezeichneten Kraftstoffe liegen innerhalt der Norm EN228 und können somit direkt vertankt werden. Grundlage des regenerativen Anteils ist bioliq®, ein Kraftstoff nach dem Biomass-to-Liquid-Verfahren.
G40 wird durch die Verwendung von 10% EtOH und 30% bioliq®-Leichtbenzin erreicht. G85 wird durch verschiedene weitere Komponenten, zum Beispiel hydriertes bioliq®-Schwerbenzin geblendet.
In früheren Studien wurde der Einfluss der Kraftstoffe am Einzylindermotorenprüfstand untersucht. In den jetzt betrachteten Untersuchungen liegt der Fokus auf das Kaltstartverhalten bei sehr niedrigen Temperaturen (bis -15 °C). Dabei werden sowohl gasförmige als auch feste Abgasemissionen betrachtet und Standard E5-Benzin gilt als Referenz.
Als Ergebnis kann betrachtet werden, dass sowohl G40 als auch G85 sich bei tiefen Temperaturen ähnlich oder besser hinsichtlich der Rohabgasemissionen als E5 verhalten. Das Ziel, Kraftstoffe mit hohem CO2-Minderungspotenzial einzusetzen, die gleichzeitig die Abgasemissionen nicht verschlechtern, wurde erreicht.

1 Introduction

The reduction of CO_2 emissions is considered one of the greatest challenges. In Germany alone, the number of registered passenger cars is approximately 48.7 million. Of these, more than 62% are purely gasoline-powered vehicles.[1]
In order to target CO_2 reductions precisely at these vehicles, the project "reFuels- rethinking fuels " was launched in 2019. The aim is to produce drop-in capable fuels within the standard, which have a high regenerative content and ideally better combustion and emission properties.
The regenerative gasoline component used was bioliq®: hydrocarbons obtained from biomass. The process is similar to the methanol-to-gasoline process, but in the first process step, methanol is skipped and dimethyl ether is synthesized directly.[2]
After the gasoline synthesis, two products are available. One is bioliq® light gasoline and the other is bioliq® heavy gasoline. In order to be able to use the heavy gasoline, it must be hydroprocessed in a further process step.[3,4]
With the help of these two fuel components, it was finally possible to produce a blend with an 85% regenerative content that is within the valid EN228 standard.

2 Fuel properties of G40 and G85

	Unit	Norm	Light gasoline bioliq	Heavy gasoline bioliq	E5	G40	G85
RON	-	min. 95	101,7	N/A	95.0	101.0	95.2
Density	kg / m^3	720-775	828.9	891.7	747.8	751.8	762.9
E70	%(v/v)	20-46	1.1	0	33.5	33.6	20.9
E100	%(v/v)	46-71	6.4	0	52.7	46.1	50,2
E150	%(v/v)	min. 75	85.4	0	85.9	91.2	94,4
FBP	°C	Max. 210	171	290	197.1	180.1	173.7
Aromatics	%(v/v)	0.184	76.3	96.5	30.6	31.2	32.7
Ethanol	%(v/v)	max. 5/10	traces	0	4.53	9.76	0.1
Oxygen content	%(m/m)	max. 2.7/3.7	traces	0	1.87	3.58	3.01

Table 1: Fuel properties of E5, G40 and G85 [4,5]

As can be seen, the bioliq light and heavy gasoline fractions are outside the standard. For G40, the light gasoline fraction was used. The aromatics content was one of the limiting factors in order to achieve a higher blending ratio. G40 consists of 30 vol.-% bioliq light gasoline, 10 vol.-% ethanol and 60 vol.-% fossil components.
G85 consists of a larger number of components: Both bioliq light gasoline and hydroprocessed bioliq heavy gasoline were used. Ethanol was also dispensed with. The oxygen content is achieved by methyl tert-butyl ether (MTBE) and ethyl tert-butyl ether (ETBE).
G40 has a very high-octane rating and a high ethanol content. G85 has a very low boiling point.

3 Experimental setup

The fuels were tested on a three-cylinder full engine with near-production configuration and standard exhaust gas aftertreatment. The engine characteristics can be found in Table 2.

	Gasoline three-cylinder engine direct injection
Displacement	999 cm³
Number of cylinders	3
Geometric compression ratio	10.0 :1

Table 2: Technical data ICE

The tests were carried out in a cold test bench at the Institute for Internal Combustion Engines. This test bench can also be cooled down to -20 °C in order to test cold start cycles. Transient cycles, such as WLTC or RDE, are possible. Exhaust gas sampling is performed before exhaust gas aftertreatment to compare fuels. An AMA4000 from AVL and an FTIR from IAG will be used for the gaseous emissions. In addition, the particulate emissions are recorded with a DMS500 from Cambustion.

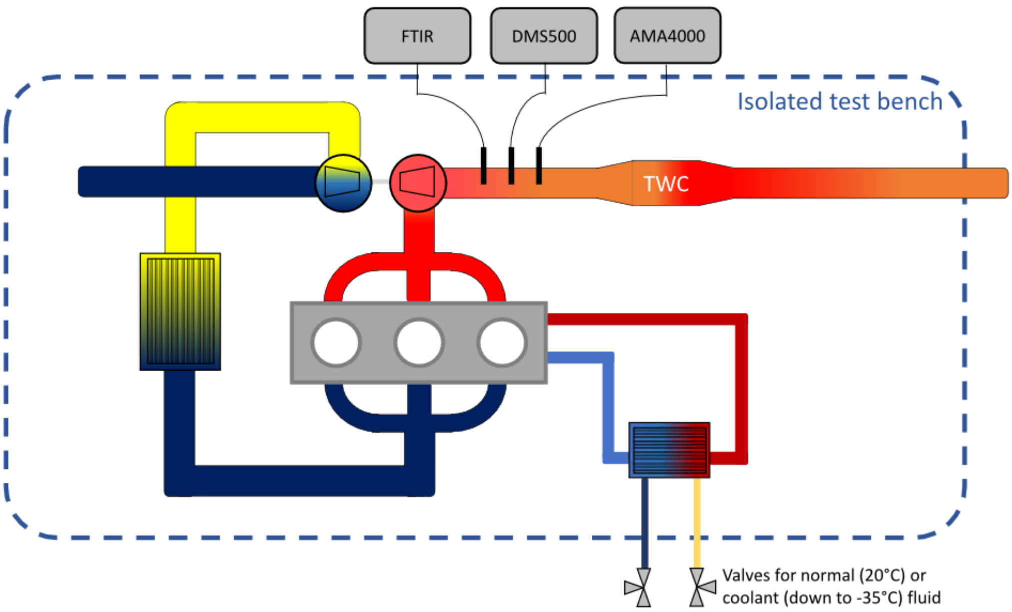


Figure 1: Schematic test bench setup

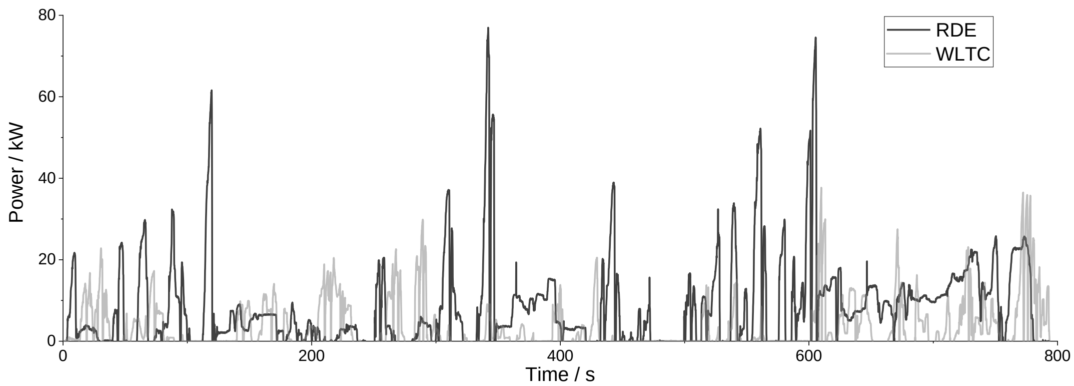


Figure 2: Performed WLTC(Extract) and RDE cycle

4 Characteristic map measurements

In order to draw conclusions about the behavior in transient operating conditions of the fuels, the characteristic map at operating temperature was first investigated. Figure 3 shows the gaseous emissions at 2000 min^{-1}.

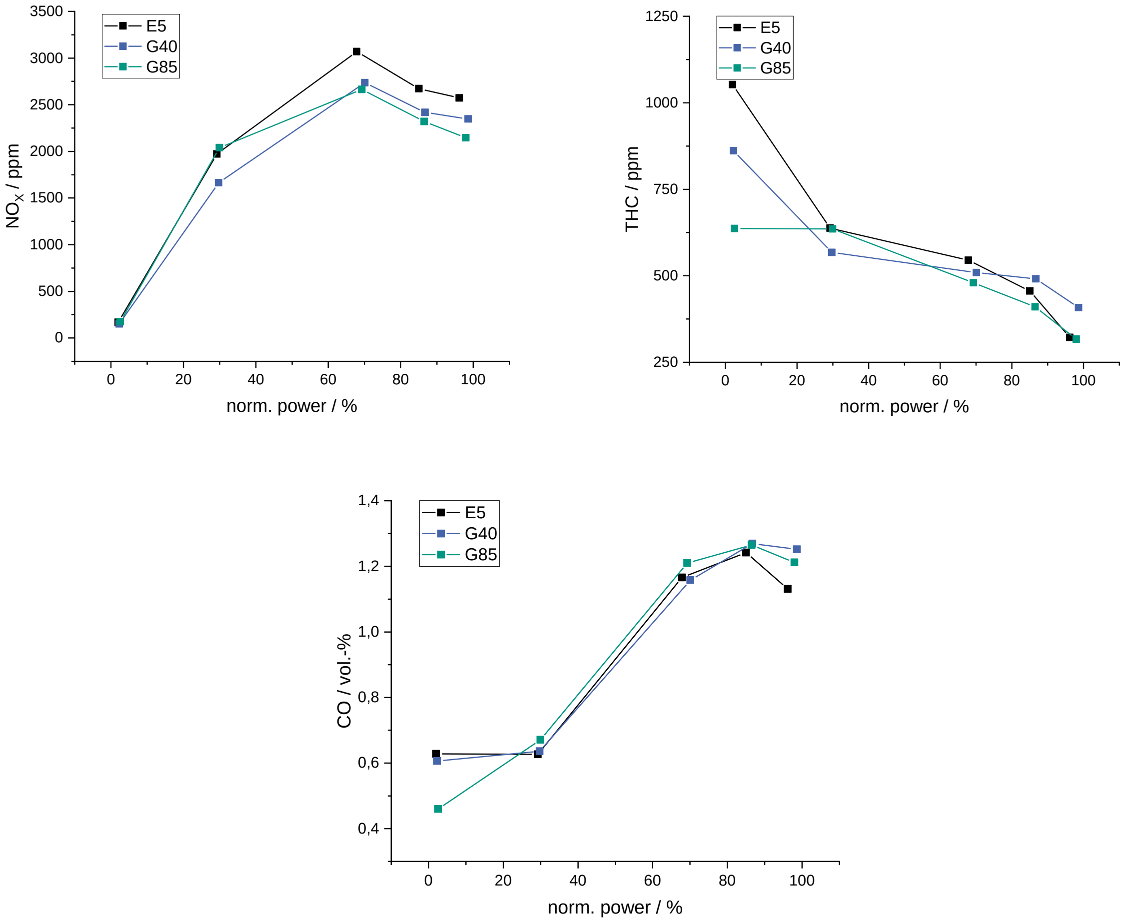


Figure 3: Nitrogen oxide, hydrocarbons and carbon monoxide emissions at 2000 min^{-1}

At the stationary points, the fuels behave very similarly in terms of gaseous emissions. Only G40, with its high ethanol content, shows a slight reduction in nitrogen oxide emissions in the part-load range. This can be attributed to better internal cooling due to the high enthalpy of vaporization of ethanol.
In terms of particulate behavior, the difference between the reference E5 and the two fuels is greater (Fig. 4).

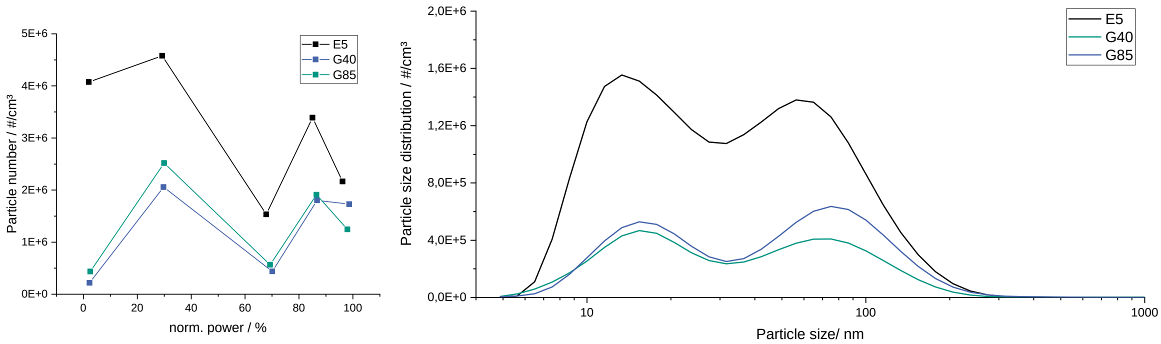


Figure 4: Particle Number at 2000 min-1(left) and particle size distribution at 2000 min-1/75% load (right)

Over wide areas of the map, G40 and G85 behave very similarly in terms of particle number and size. Both are below the reference E5.

5 Cold start behavior

In this chapter, the cold start tests from the WLTC and RDE cycle at temperatures as low as -15 °C are presented. Some of the results from G40 have already been published in another paper [6].
The WLTC cycle has a length of 30 minutes. The RDE cycle is a shortened cycle with a duration of approx. 800 s.

5.1 WLTC

In order to compare the different fuels and temperatures, the exhaust emissions were cumulated over the cycle and related to the distance driven. Figure 5 shows the cumulative gaseous exhaust emissions.

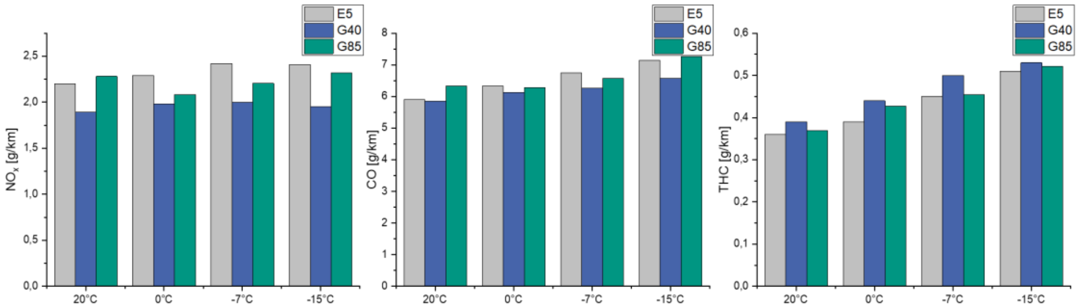


Figure 5: Gaseous emissions of WLTC cycle for different temperatures

In the low-load WLTC cycle, the emission behavior of G40 can be seen again due to the high ethanol content, especially with regard to nitrogen oxide emissions. If the different temperatures within an exhaust gas component are compared, all fuels tend to behave in the same way. In absolute values, the fuels are also close to each other, so that the emissions after an existing exhaust gas aftertreatment should be very similar.

5.2 RDE

In contrast to the WLTC, the RDE cycle has a higher load component and transient driving conditions.

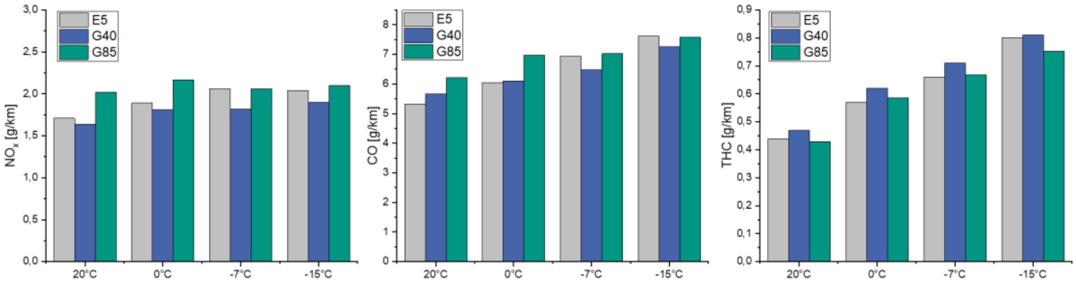
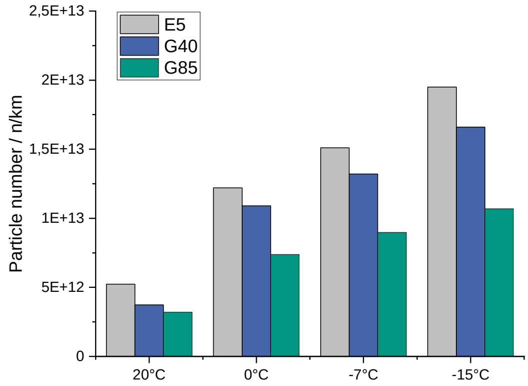


Figure 6: Gaseous emissions of RDE cycle for different temperatures

However, the gaseous emissions behavior is similar to that of WLTC. G40 shows a slight advantage with regard to nitrogen oxide emissions. All other emissions are again close to each other, so that there are no disadvantageous emissions with G40 or G85.
The upper figure in Fig. 7 shows the particulate emissions over the different temperatures. Low temperatures play an even greater role in particulate emissions.
G40 is in a similar range to the reference. Slight advantages can be seen, however. This may be due to the increased oxygen content and the resulting better oxidation. The low boiling point also plays a positive role.
At 20 °C, G85 behaves very similarly to G40. However, when temperatures get even colder, it shows further advantages. The lower boiling point of G85 could be used to its full potential there. The oxygen content of G85 is in the same range as G40, but the high ethanol content of G40 may explain the difference.



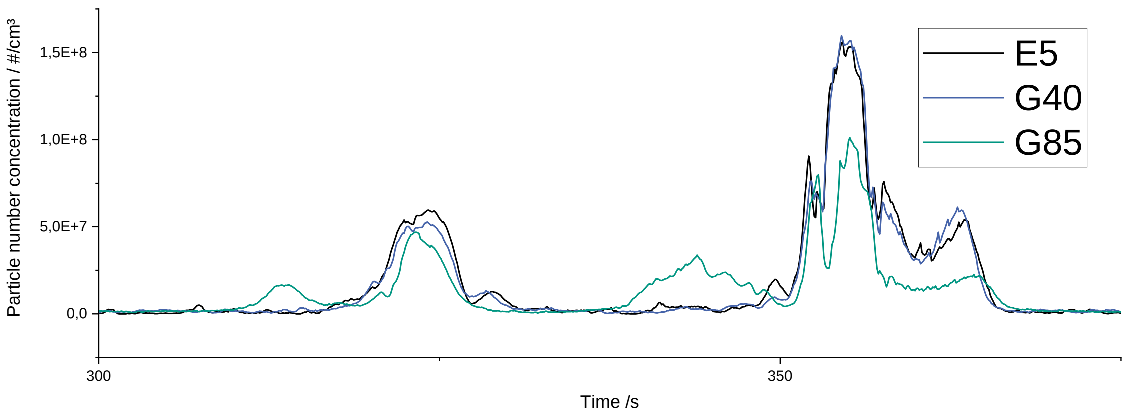


Figure 7: Particle emissions of RDE cycle for different temperatures(top) and an extract of particle number concentration at a -15 °C cold start

6 Summary & outlook

The focus of the investigations was to examine the emission behavior of drop-in gasoline fuels at low temperatures. With G40 and G85, two regenerative fuel blends were presented that showed no worsening in both gaseous and solid exhaust emissions during transient cycles.
G40, 40% regenerative with 30% bioliq® light gasoline and 10% ethanol, impresses with its high-octane rating of over 101.
G85, 85% regenerative, consisting of a mix of bioliq® light gasoline, hdyroprocessed bioliq® heavy gasoline and other regeneratively produced components.
With this regenerative share of 40% and 85%, respectively, the fuels can contribute to CO_2 reduction in the transport sector without requiring any modifications to the vehicle and without any worsening of exhaust emissions.

7 References

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