LUNDS UNIVERSITET
Lunds Tekniska Högskola

Department of Energy Sciences
Division of Combustion Engines

Study of SweaX in an Optical Diesel Engine

Postadress Box 118, 221 00 Lund *Besöksadress* Ole Römers väg 1 *Telefon* 046-222 85 25 *Fax* 046-222 4717

LUNDS UNIVERSITET
Lunds Tekniska Högskola

1.Background

Because RME (rapeseed methyl ester) is made from vegetable oil, its carbon dioxide contribution to atmosphere is very low compared to fossil diesel. While RME is an excellent fuel for diesel engines, it sometimes provides inferior start characteristics compared to fossil diesel.

This study investigates ignition and soot formation characteristics in the two fuels Verdis Polaris and SweaX. Although both consist of RME, SweaX also contains an extra component, namely EuroAd. The two fuels are referred to as RME och SweaX throughout this report.

A diesel engine fitted with a glass window was used to study injection and fuel combustion in the cylinder. The processes were recorded at high temporal resolution using a fast video camera. Ignition characteristics were studied in conditions corresponding to cold start in winter temperatures, while soot formation was studied in conditions equivalent to an engine at operating temperature.

2. Test Equipment

The tests were carried out on a Scania D13 engine fitted with optical access to one of the cylinders. The injection system was the same XPI common rail-system Scania uses in production. The engine was fitted with brand-new injectors for the tests.

Figure 1 shows a schematic diagram of the optical access to provide an impression of how the images were recorded. The cranking mechanism and the original piston (parts D, I and H) are installed in the engine block. Above the original piston there is a piston extension (C) on top of which there is a transparent piston (B). The angled mirror, which is placed inside the piston extension (G), provides a view of the combustion chamber from below.

The combustion chamber images were captured via the mirror using a high-speed camera at 15,000 frames per second. Figure 2 provides an example of the camera view. The picture shows that the injector is mounted centrally in the combustion chamber and eight regular fuel sprays propagates from the injector to the cylinder walls. The lighter, irregular areas at the end of each spray are flames. Because Scania uses vertical air circulation in the combustion chamber, the flames have a tendency to shift anticlockwise from the spray.

Postadress Box 118, 221 00 Lund *Besöksadress* Ole Römers väg 1 *Telefon* 046-222 85 25 *Fax* 046-222 4717

LUNDS UNIVERSITET
Lunds Tekniska Högskola

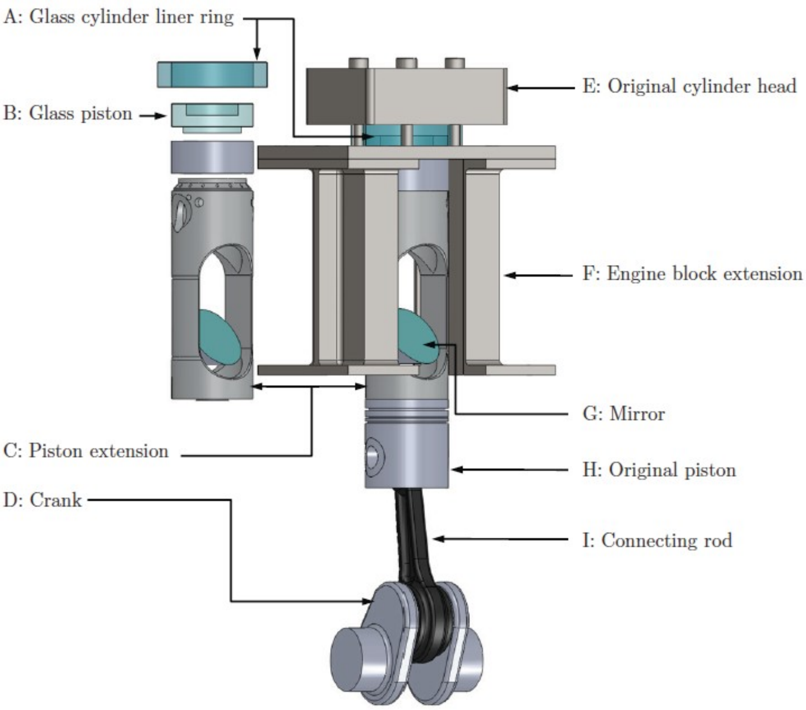

Figure 1: Schematic diagram of the optical access fitted to the test engine.

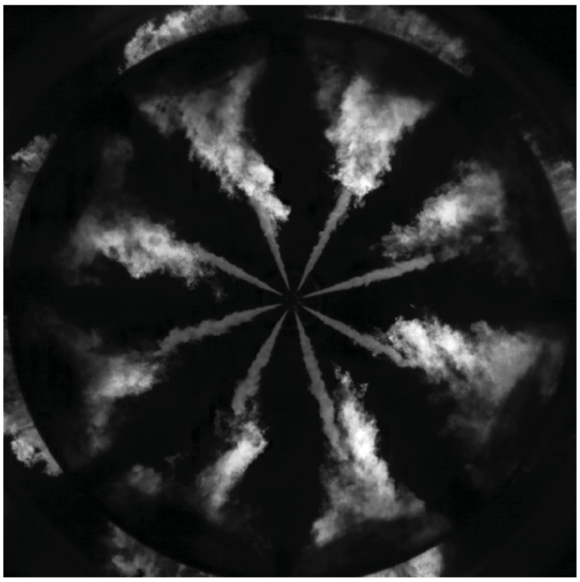

Figure 2: Camera view of the combustion chamber. All regularly shaped fuel sprays spread from the centrally mounted injector. The lighter, irregular areas at the end of each spray are flames.

LUNDS UNIVERSITET
Lunds Tekniska Högskola

3. Ignition Characteristics

Figure 3 provides an example of the ignition process when the two fuels are injected in conditions equivalent to cold start in winter temperatures. The numbers at the bottom right indicate how far the crankshaft has rotated following the commencement of injection. (One revolution equals 360°, thus 30° equals 1/12 of a revolution.)

The images in the top row were taken from a high-speed recording of an RME injection. In the first frame it is possible to discern that eight sprays begin to spread from the injector. (The two exhaust valves and the two induction valves can be seen around the injector.) The fuel is injected just before the piston reaches top dead centre, and this fuel does not ignite until 30° later. By way of comparison with normal operational conditions, ignition typically takes place 5° after the commencement of injection in an engine at operating temperature.

The lower row of pictures shows SweaX injection under identical conditions. In this case the fuel already ignites after 15°, which is a significant improvement compared to RME.

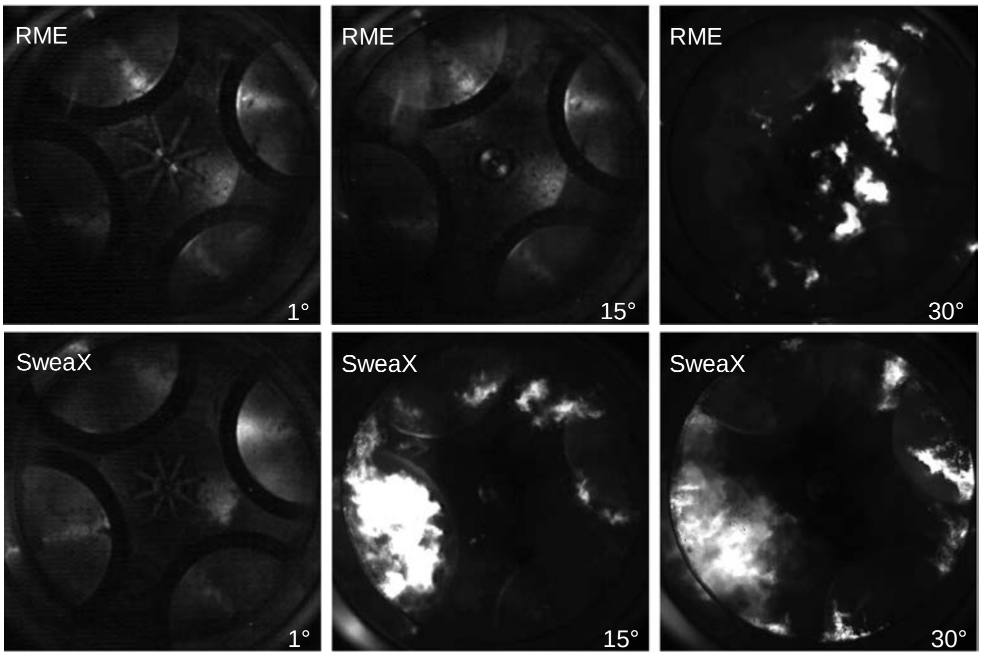

Figure 3: Figure 3 provides an example of the ignition process when the two fuels are injected in conditions equivalent to cold start in winter temperatures. The numbers in the bottom right-hand corners show how many degrees the crankshaft has rotated following commencement of injection SweaX ignited 15° after commencement of injection, while RME ignited later.

LUNDS UNIVERSITET
Lunds Tekniska Högskola

The tendency for SweaX to ignite earlier than RME is confirmed by the diagram in figure 4. Here ignition time is calculated in milliseconds. With the engine running at 1200 rpm, one degree equals 0.14 milliseconds The pie charts correspond to average values of 30 to 50 combustion cycles and the error bars represent variations in the ignition time that always occurs between cycles.

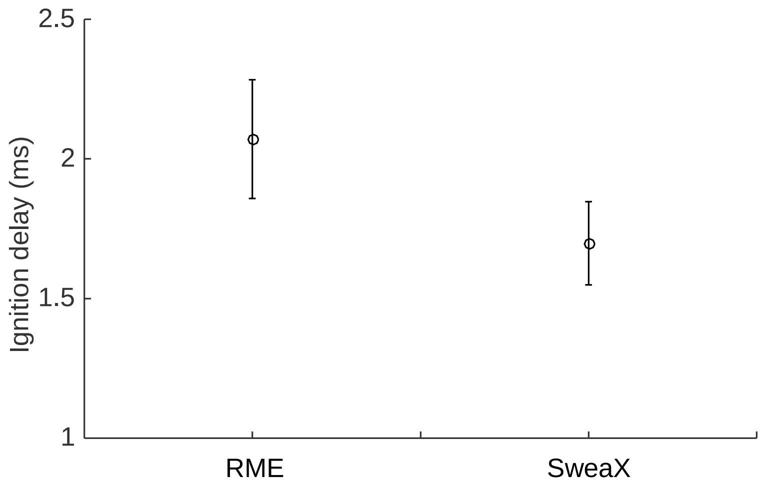

Figure 4: Ignition lag, or ignition time, is the time that passes between the commencement of injection and the fuel's self-ignition in the cylinder. SweaX provides a quicker, more stable ignition process.

Two important conclusions can be drawn from Figure 4. Not only does SweaX ignite 20% earlier than RME, it also displays less variation between the cycles. In other words, SweaX provides quicker, more stable ignition than RME.

4.Soot Formation

In order to investigate whether SweaX and RME differ regarding soot formation, the flame intensity of each fuel was measured in the cylinder. The intense yellowish-white light emitted from the spray flames comes from heated soot particles that incandesce brightly. The intense yellowish-white light emitted from the spray flames comes from heated soot particles that incandesce brightly. Light intensity is determined by the amount of soot and flame temperature. If we study flame intensity at the moment of operation where the temperature is the same, it will provide a good idea of how much soot is formed in the flame.

The example in Figure 5 shows that RME emits a brighter light from the flame than SweaX, confirming that RME produces more soot during combustion. The images were taken in conditions corresponding to an engine at operating temperature and 30 % full load.

Postadress Box 118, 221 00 Lund *Besöksadress* Ole Römers väg 1 *Telefon* 046-222 85 25 *Fax* 046-222 4717

LUNDS UNIVERSITET
Lunds Tekniska Högskola

The photographs in Figure 5 were taken 10 degrees after the commencement of injection. The diagram in Figure 6 confirms that what we see in the photographs applies throughout the entire combustion cycle. Flame intensity was calculated by adding together the signals from each frame of the recording. It is noteworthy that SweaX displays lower flame intensity throughout the combustion process. Accordingly, the cylinder contained less soot at any given time when the engine was run on SweaX.

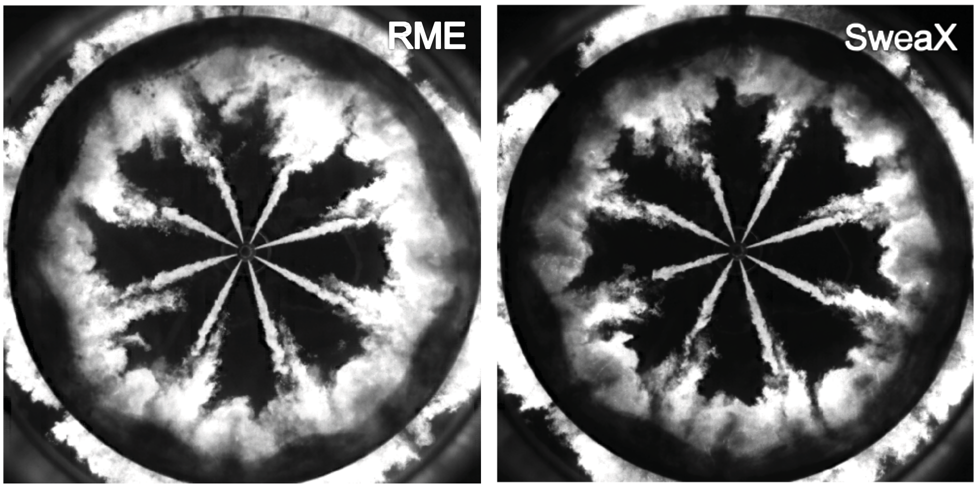

Figure 5: Flame brightness or intensity provides a measure of the amount of soot formed during combustion. We see that pure RME has a higher intensity and thus produces more soot than SweaX.

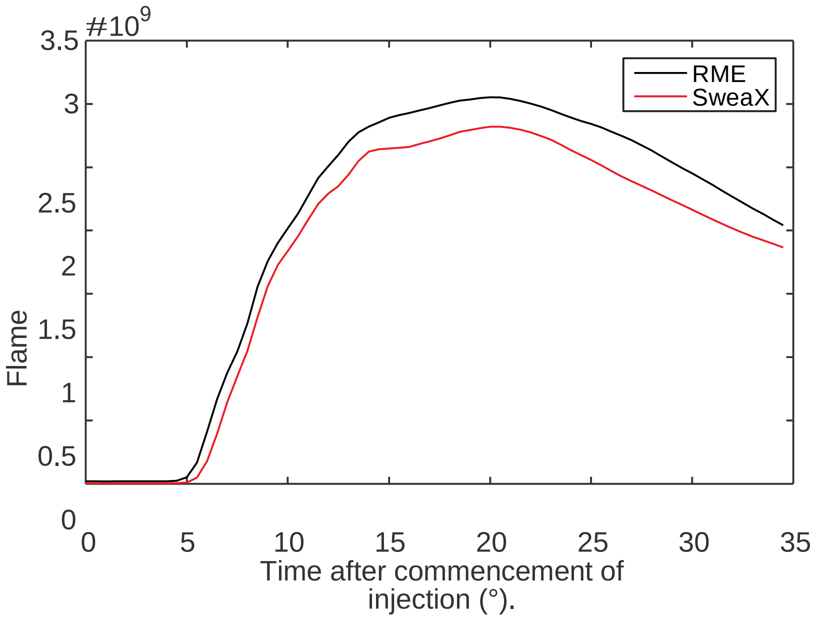

Figure 6: Flame intensity is a measure of the amount of soot formed during combustion. The result shows that soot formation is reduced with SweaX compared to RME.

Postadress Box 118, 221 00 Lund *Besöksadress* Ole Römers väg 1 *Telefon* 046-222 85 25 *Fax* 046-222 4717

LUNDS UNIVERSITET
Lunds Tekniska Högskola

Conclusions

The results of this study lead to the following conclusions:

- SweaX provides a 20% faster ignition and a more stable ignition than RME at low temperatures.
- In conditions that correspond to an engine at operating temperature, SweaX reduces soot formation compared to RME.

2015-04-24

Öivind Andersson, Professor

Department of Energy Sciences,
Combustion Engines Division,
Öivind Andersson, Professor

Postadress Box 118, 221 00 Lund *Besöksadress* Ole Römers väg 1 *Telefon* 046-222 85 25 *Fax* 046-222 4717