Ignition of automotive HID lamps

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This work considers the ignition process of high intensity discharge (HID) lamps used for car headlights. Due to their high background gas pressure of 15 bar xenon, ignition voltage becomes very high. Without any ignition aid, the ignition voltage reaches values of the order of 20 kV. Current research considers the possibility to reduce the ignition voltage by optimizing ignition aids, namely antennas and the so-called outer-bulb discharge.

1 Introduction

Since many years, HID lamps are used in many fields of applications; one of these fields is car head lighting. A new generation of automotive HID lamps with a reduced power input of 25 W helping to save energy is considered within this work. The lamps have a luminous flux of about 2000 lm to avoid automatic levelling and headlamp wash systems. The D5 lamp combines burner, igniter and electronic controlled gear (ECG) in a compact chassis to make system small and low in costs. This aims to bring HID head lighting to cars quipped with incandescent halogen lamps today.

Due to safety reasons, these lamps must run-up instantaneously. Fast run-up is reached, amongst others, with a high background gas pressure of about 15 bar xenon in the cold state. The pressure is two orders of magnitude higher than in lamps used for general-lighting applications. The high filling pressure has the disadvantage that ignition voltage increases significantly. Without any ignition aid, ignition voltage reaches values of about 20 kV. A high ignition voltage is disadvantageous since igniter electronics becomes more complex and expensive. Therefore, a reduction of the ignition voltage is an aim of current research. There are several methods to reduce the ignition voltage of HID lamps. For automotive HID lamps, we investigate the outer-bulb discharge, a dielectric barrier discharge (DBD) within the outer bulb, and antennas. Antennas are conductive coatings or wires on the outer burner wall.

2 Investigated HID lamps

The lamps consist of an ellipsoidal shaped quartz tube, in which two tungsten electrodes are melted oppositely to each other. The inter-electrode gap is about 4 mm, in which the light-producing arc takes place. The lamp bulb is filled with about 15 bar xenon in the cold state and further with a composition of metal halides, especially sodium and scandium iodine to adjust the light properties, e.g. colour rendering index (CRI) and correlated colour temperature (CCT). Additionally, they improve the efficacy to 80-90 lm/W by inducing the
gas-phase emitter effect. A so-called model outer bulb is applied to vary the electrical contacts, O-ring, clamping ring (PEEK), return wire, and KF 16 flange to the vacuum pump and gas filling system.

Figure 2: Technical 3D drawing of the model outer-bulb.

gas type and gas pressure within the outer bulb. A technical 3D drawing of the model outer bulb is shown in figure 2. The geometry is comparable to the normal outer bulb of a commercial lamp. The model outer bulb consists of a quartz tube, having an additional quartz pipe with a KF16 flange to connect it to a pumping unit and a gas-filling system. The model outer bulb is made of quartz to be able to withstand the high thermal load produced by the lamp during operation.

3 Diagnostics

To investigate the ignition of HID lamps used for car headlights, several electrical and optical methods are used. The central element of the experimental setup is the model outer bulb with the HID lamp described in the previous section. The ignition voltage of the lamp is measured with a high voltage probe. It mainly consists of a capacitive voltage divider with a division factor of 1000. The ignition current is measured with a passive current probe consisting of a Rogowski coil and an integrator circuit (Pearson probe). Its conversion factor is 1 V/A and has a rise time of 2 ns. Furthermore, the luminous flux coming from the lamp is recorded with a silicon photo diode detecting the visible spectral range in combination with a transfer impedance amplifier with a conversion factor of 20 kV/A. The system supplies a voltage signal proportional to the detected light. All electrical signals are recorded with a four channel digital oscilloscope having an analogue bandwidth of 1 GHz. To observe the development of the outer bulb discharge during ignition, an image of the lamp is focused on an ICCD camera. By means of a triggered igniter and a pulse delay generator, the setup is synchronized. The pulse delay generator takes into account delay times of the camera, measuring probes and cables.

All measuring data, electrical signals measured with the oscilloscope as well as the photos taken with the ICCD camera are processed and saved by a PC using a LabVIEW program.

4 Selected results

Figure 3 shows a measurement example of the ignition of an automotive HID lamp (D5 lamp). The electrical measurements, namely the ignition voltage $U_{ign}$, the ignition current $I_{ign}$ and the photo current, represented by $2U_{PD}$, are shown in figure 3a. Additionally, the trigger signal for the ICCD camera $U_{trigger}$ is shown indicating the beginning of the exposure time, whereas the corresponding ICCD image is presented in figure 3b.

The ignition voltage represented by the blue curve starts to rise after triggering the igniter. At $t \approx 130$ ns the voltage slew rate decreases indicating the ignition of the outer-bulb DBD. The ignition of the DBD is correlated with an increase of the electrical current (red curve) and the photo diode signal (green curve). Black arrows indicate these moments in figure 3a. The voltage amplitude supplied to the lamp at this moment is defined as ignition voltage of the outer-bulb DBD $U_{ign, DBD}$. After that, the voltage ramp increases further but with a reduced slew rate until the maximum is reached at $t \approx 160$ ns. The inner bulb ignites at this moment. The maximum voltage represents the ignition voltage of the lamp $U_{ign}$. Shortly after that moment, the increasing electrical current as well as the increasing photo current indicates the breakdown within the inner bulb.

Figure 3b presents an ICCD photo of the outer-bulb DBD at $p_{outer} = 5$ mbar argon in the outer bulb. The powered anode is located on the left and the grounded cathode on the right side. The exposure time $t_{exp}$ is 50 ns and begins before the DBD ignites as shown by two black bars in figure 3a. Therefore, the ICCD camera records the whole phase, in which the DBD is active, and the exposure stops before the inner bulb breaks through. However, the beginning of the ignition of the inner bulb is visible in figure 3b, i.e. the initiation of surface streamers can be seen. These surface streamers propagate along the inner wall of the
burner and form a closed discharge channel. If the power supply to the discharge is further increased, an light-producing arc discharge is formed.

References

This information are mainly taken from the following publications, in which further information on the topic can be found:


Figure 3: Exemplary electrical measurement (a) and corresponding ICCD image (b) of the ignition of an automotive HID lamp with an outer-bulb pressure of 5 mbar argon