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Light Flicker Frequencies in the HID lamps

Application to CDM-T Elite 50W/930

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Abstract: In order to reduce the electric consumption for high intensity discharge lamps (HID), the use of high frequencies electronic ballasts represents both a solution and many advantages such as, the decrease in the congestion, low costs and weak losses, approximately 10%. However it is not regarded as perfectly reliable, this is due in a great part to the appearance of Acoustic Resonances inside the arc tube which can result in low frequency light flicker and even lamp destruction. Experimentally we used a HID lamp of 50 W and we determined, light flicker frequencies and the arc motion frequencies using a photodiode which detects the light intensity fluctuation and a camera to record the arc motion. The experiment was done in the Department of Mechanical Engineering and Production, Hamburg University of Applied Sciences.

Keywords: Acoustic resonance, Fast Fourier Transform FFT, photodiode, Arc Motion, CMOS image sensors.

1. INTRODUCTION

The electric discharges play an important role in numerous applications and especially those of lighting. Among the first invented artificial luminous sources, lamps functioning with low pressure dominated the market at the time, in parallel the development of high intensity discharge lamp allowed the creation of light sources, which produce an important luminous flow beneficial for lighting wide public spaces. However the high intensity discharge lamps presents an improvement in the volume which is very reduced in regard to that of low pressure lamps, in the photometric performances of the system, in the lamp life, and finally a better control of its functioning so as to reduce electricity consumption [1].
They emit light at high lumen output levels with high color quality. Currently, HID lamps are operated by low frequency drivers. Operating these lamps at high frequency of 300 kHz achieves an efficiency enhancement. However, the alternating current (ac) generates a periodic heat source in the form of a plasma discharge arc [2 - 4].
The fluctuating temperature field implies pressure oscillations. When the driving current is tuned to an acoustic eigenfrequency of the arc tube, standing pressure waves are induced, generating material flow via an acoustic streaming phenomenon, which can affect the buoyancy driven velocity field and thus cause arc motion or high intensity fluctuations. In order to determine the acoustic resonance frequencies, we have measured current, voltage, electric power, photodiode, and even sound spectrum. At this level, just a few investigations have been done on the flicker itself [5 - 6].
In our paper, we investigate the frequency of light intensity flicker as well as discharge arc motion. Measurements with a photodiode determine the high frequency at different operating parameters and its time-dependent behaviour. Simultaneously arc motion is recorded with a camera to identify the position and the shape of the arc, therefore to determine the arc motion frequency.

2. EXPERIMENTAL SETUP DESCRIPTION

The LFSW setup used to measure the Acoustic Resonance (AR) spectra of the HID lamps uses a Square Wave plus Ripple (SWPR) signal as power supply. A low frequency (LF) square signal is modulated in amplitude by a high frequency (HF) sinusoidal signal at different modulation depths. This kind of signal leads to different power components associated to different frequencies. The dependency of the power of each frequency component depending on the modulation depth wants to be measured in order to characterize the system [6 - 11]. Figure 1 displays the setup that we used for measurements. Function generator (FG1, Yokogawa FG300) generates a sinusoidal HF signal that acts as modulation for the LF square signal generated by FG2 (Agilent 3312A). At the output of FG2 the SWPR is created, this signal is then amplified by the power amplifier and the

amplified signal is delivered to a resistor that simulates the presence of the HID lamp (Philips 50W 930 Elite). The input of the resistor is measured by both a power analyzer (Yokogawa PZ4000) and an oscilloscope (LeCroy 6030A). Both of them monitor the current and the voltage. We use the oscilloscope to create the fast Fourier transform of the power signal (obtained by direct multiplication of the current and the voltage input channels). We measured the power in the frequency domain of the DC signal (frequency 0), the modulation frequency (HF) and the carrier frequency (LF). For measurement of the brightness fluctuations during discharge arc flicker, a high speed silicon photodetector (TorLabsDET100A/M) with
a rise time of 43 ns is used. The photodiode converts the incident light into a current. A digital oscilloscope (Tektronix TDS2022B) transforms this electrical signal continuously into the frequency domain by fast Fourier transform (FFT). The resulting frequency is called flicker frequency, and the results are saved every 5 s for post processing [12 - 14].

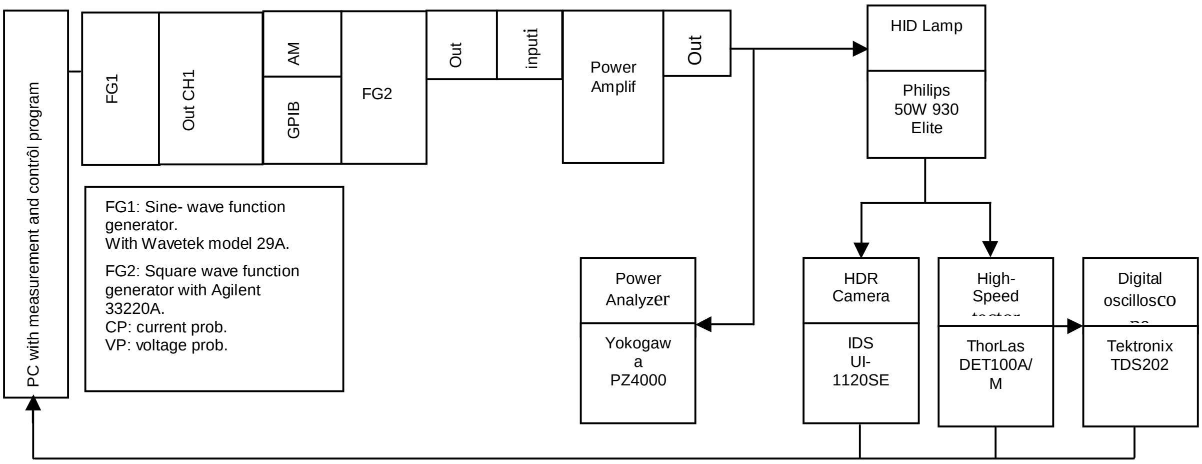

Fig.1: LFSW setup characterization of discharge arc flicker in HID lamps.

Simultaneously, a camera records a video of the brightness distribution of the discharge arc in order to measure the time dependent arc deflection. Due to the high brightness differences between the electric arc and the surrounding, a camera with a high dynamic range is used. SiCMOS chip measures electromagnetic radiation in the range of 400-900 nm with resolution of 768 x 576 pixels. The arc deflection in the center of the arc tube is calculated for each frame and use as a marker for arc motion. The time signal is then split into 5s segments and converted into the frequency domain by FFT [15].
The resulting frequency is called motion frequency. Devices, camera and photodetector are located at a distance of 0.2 m from the HID lamp at the same horizontal level. A computer records the data and controls the experimental setup [16].
Before the measurement, the lamp is operated at stable condition for 2 min. then the sinusoidal excitation frequency is set to a frequency near the first acoustic eigenfrequency of the arc tube. The amplitude of the sinusoidal signal is expressed relative to the amplitude of the square wave voltage (modulation depth) and is set to a value high enough to simulate fluctuations of the arc discharge. To limit the power input during discharge arc flicker, the HID lamp is operated at 90% of its nominal power. The experiment is then conducted for 40 s these conditions [17 - 18].

3. EXPERIMENTAL RESULTS

The first acoustic Eigenfrequency was known by most previous investigations for this kind of lamps approximately at 42 kHz. Therefore, the frequency range for the flicker characterization is set to 42 ± 2 kHz. We presented at the first, both flicker and motion frequency at fixed excitation frequency of 42 kHz and a modulation of 15%. Secondly, we present discharge arc flicker around the first acoustic eigenfrequency as a function of excitation frequency and modulation depth.
In order to determine the motion frequency, a 2D brightness distribution of the discharge arc is used in Fig.2. The black lines in the figures high light the course of maximal brightness. The vertical distance of this curve to the horizontal symmetry line (Z=0) is defined as arc deflection.

In Fig.2.b we show the arc at the moment of maximal arc deflection, the light intensity is depicted 50 ms later in the instant of minimal arc deflection. This time difference is equivalent to a sinusoidal half cycle and therefore results in a periodic time of 100 ms and a motion frequency of 10Hz. In the same experiment conditions and kind of lamps but for smaller power than 50 W, we have easily noticed that the deflection for the lamp of 50 W lamps was Larger. This difference is essentially due to the ohmic effect within the arc discharge, the difference in ohmic losses plays an important role in elevation of the temperature within the plasma. When the temperature of the arc increases, the buoyancy caused by the gravitational force increase. Consequently the discharge arc deflection will be larger.

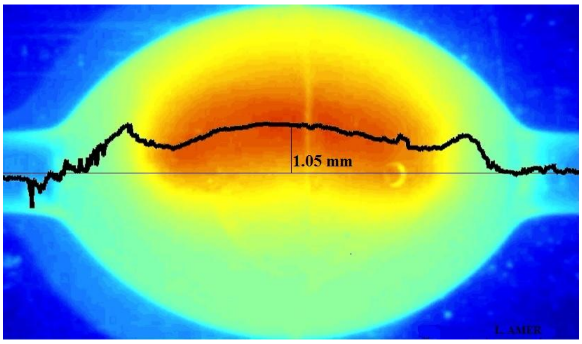

Fig.2a: Distribution of light intensity for an excitation frequency of 42 kHz and 15% of the modulation depth in stable condition.

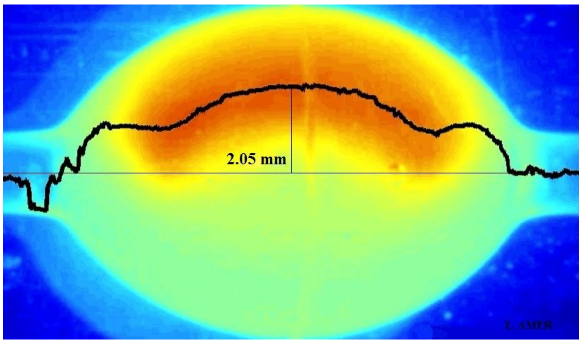

Fig.2b: Distribution of light intensity for an excitation frequency of 42 kHz and 15% of the modulation depth after 2 min.

Figure 3 displays the time-development of flicker frequency and motion frequency from the onset of flicker up to 40 s. both frequencies concurrently increase over time from under 10 Hz to 11Hz. This increasing flicker frequency over time can be observed in nearly all measurements. And we observed that both measurements are in very good agreement, the arc motion frequency and the light intensity flicker frequency are obviously identical.

In the aim to characterize arc flicker near the first acoustic eigenfrequency, the excitation frequency is turned from 35 to 50 kHz in 500 Hz steps. The modulation depth is set to values between 10% and 12% in steps of 2%.

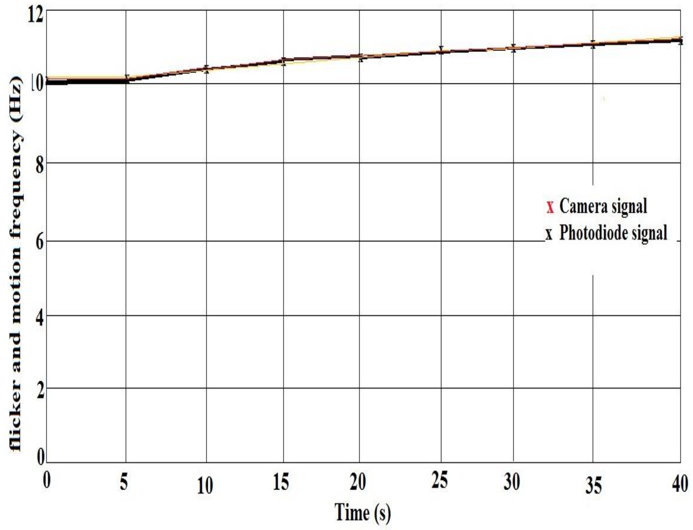

Fig.3: Motion frequency and flicker frequency in the frequency domain for HID lamp 50W.

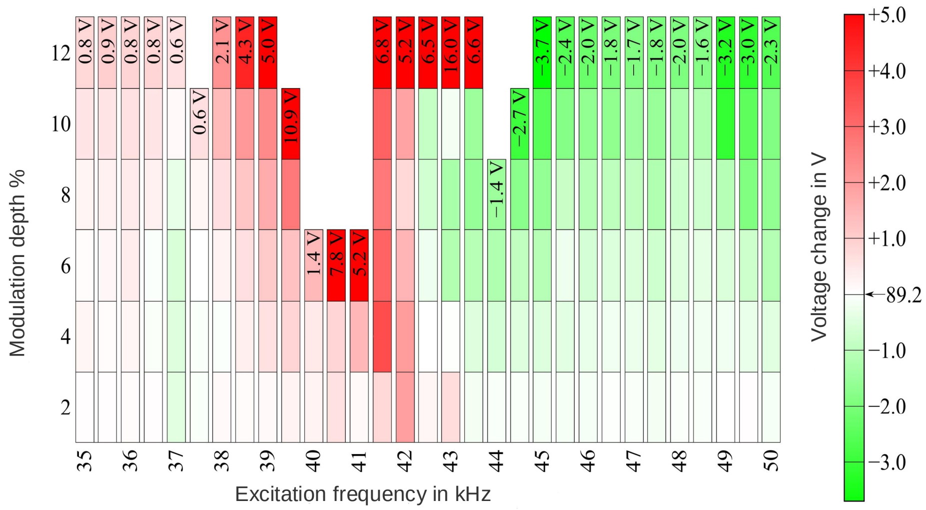

Fig.4 Flicker as function of excitation frequency and modulation depth for HID lamp 50W.

The experimental results are illustrated in Fig.4. The green box indicates that no flicker has been observed during the measurement, the Magenta color marks operating parameters at which periodic flicker, and the red boxes highlight operating parameters at which a stochastic behaviour of the flicker has been detected. In the case of periodic flicker, the initial frequency increases with increasing excitation frequency.

The absolute value of arc deflection increases with the modulation depth because the higher excitation power increases the force that arises from the acoustic streaming effect. We have concluded that at periodic flicker, the value of the arc deflection is positive significantly the discharge arc is directed upward.

4. CONCLUSION

After characterization of the discharge arc in HID lamps at different excitation frequencies near the first acoustic eigenfrequency, we conclude that the flicker frequencies of light intensity measurements with photodiode and motion frequencies of arc deflection measurements with camera are in good accordance. Therefore, we deduce that the frequency periodic flicker increases with increasing excitation frequency.

At frequencies near the eigenfrequency, the flicker frequency is significantly lower and stochastic motion occurs above a precise value of the modulation depth characterized of each type of lamps. The changes of the temperature distribution in the arc tube introduce a movement of the plasma arc; the altered temperature field leads to a different acoustic streaming field and affects the flicker frequencies. For this reason, we will focus our next work on the effect of the distribution arc temperature on the increase of the flicker frequency.

Appendix A

Fig. A1

Fig. A2

Figure A1 represents the manipulation done in Hamburg University, laboratory of mechanical engineering and production. However, Figure A2 shows the type of the HID lamp CDM-T Elite 50W/930 used for the experience.

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