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Compensation and Lamp Life Model of HID Lamp

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Abstract–This paper is to find out the alternative method to compensate a Xenon lamp near the end of its life time. In the past, the lamp will be disposed if an effective intensity cannot be obtained. The proposed study is to provide a compensation method that, based on the measured characteristics of general Xenon lamps, and to calculate the required compensation power and to extend the constant illumination time. The method call the constant illumination of the light output even under the aging of the lamp. The method can effectively extend the effective life time of an Xenon lamp.

Keywords–Lamp life model, HID ageing lamp, Flux

I. INTRODUCTION

High intensity discharge lamp (HID) is now an alternative lighting for vehicle front lighting system. HID lamp offers a number of advantages as compared with the conventional incandescent lamp. HID lamps offers better illumination, high rendering factors, higher efficacy and longer life time[1-3]. The circuit design of HID lamps is much more complicated than the magnetic version because of the high excitation voltage is needed. The voltage is needed to deliver 33kV in order to provide warm restrike.

In the control method of the HID, the development work on power control has been reported. The HID lamp [4,5] ballast is under the operation of constant power control to examine the ageing of the lamp. Under such condition, the equivalent lamp resistance will be increased at the same time and the excitation voltage of the lamp in the steady state is increased from 85V to 104V, even to 140V. In addition, the distance between the electrodes will be enlarged, that is, the voltage drop of the electrodes is increased. With the lamp ageing, the output of lumen flux decreases continuously. When the output has declined to a point where an effective intensity cannot be obtained and the lamp still lights, but it is called to reach the end of its 'usable life'[6]. In the past, the lamp will be disposed if an effective intensity cannot be obtained. Car headlights are the important devices which offer the lighting for the car driver and offer the caution and help signal for driver especially under the condition of night and low visibility. Car headlights must have enough luminous. Because car vibrated in driving will change the lamp position and the lamp will ageing with the burning time, the luminous of headlight will be decreased. If the light is low, the driver would make difficult to identify the road and accident would be happened. So, if the lamp aged and the output light decreased the compensation method to increase the output light is needed. In order to ensure the safety of the car driver, compensation of the lumen flux is needed. The HID lamp has a negative-resistance characteristic so that constant power control is needed in steady state.

The proposed study is to provide a compensation method that, based on the measured characteristics of general Xenon lamps, and to calculate the required compensation power and to extend the constant illumination time.

II. EQUIVALENT RESISTANCE OF AGEING LAMP

Lamp lifetime is a measure of ageing and the lamp life model means the ageing model of the lamp. The ageing level of the lamp is affected by the following factors [7]: 1) The burning cycles. The shorter the burning cycle is, the shorter the lamp life. 2) The type of ballast used to operate the lamps. 3) The surroundings, such as, the temperature, the sunlight and the lamp locations. The lifetime calculation of a pulse lamp is [8]:

$$Lifetime = \left(\frac{E_0}{E_x}\right)^{-8.5} \tag{1}$$

where E_0 is the pulse energy and E_x is the corresponding explosion energy at a specific pulse duration.

An approximate lamp life model used to estimate total cost of light with different incandescent and compact fluorescent lamps was developed by Sullivan [9]. In order to apply easily, the equivalent lamp resistance model is used to do as the lamp life model for the compensation. The study is firstly to conduct the life time measurement of a number of lamps [6]. Two test groups, whose burning cycles are 100 hours and 25 hours, have been conducted under the continuous lighting condition. The generalized characteristic of lamp resistance is obtained. The required power for maintaining constant lumen output is made and to compensate for the correct lamp output. The burning cycle is 100 hours and the data used here are given in group 2 [6]. The resistances of 5 different brands lamps (whose names are A, B, C, D, E) are shown in Fig. 1. If the lamp ages, the lamp equivalent resistance and the lamp voltage increase; however, the lamp current decreases. In Fig. 1, the lamp resistance is zero when the lamp burns out.

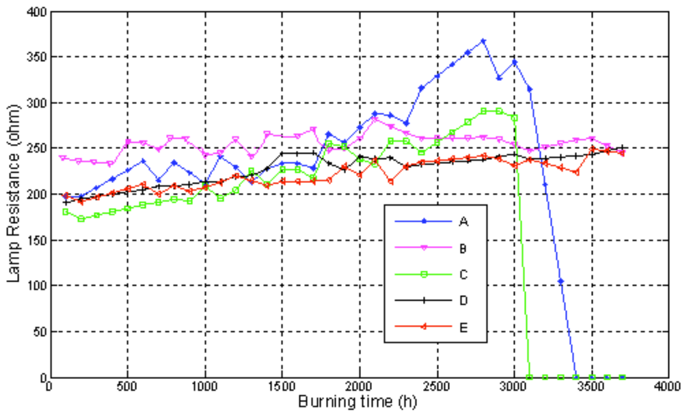

Fig. 1: Lamp resistance vs burning time

The equivalent lamp resistance R_{ageing} could be seen as a function of burning time t_o:

$$R_{ageing} = C_1 t_o + C_2 \quad (2)$$

where C_1 and C_2 are the constants obtained from the experimental data. The fitting values of C_1 and C_2 in different brand lamps are shown in Table 1.

Table 1 Fitting Values of the lamp resistance

Brand	C_1	C_2
A	0.0501	175.9469
B	0.0019	165.4634
C	0.0407	162.8149
D	0.0141	201.9560
E	0.0134	195.5795

The average resistance value of the five lamps could be obtained from:

$$R_{ageing\_av} = C_{1\_av} t_o + C_{2\_av} \quad (3)$$

According to Table 1, the rated average life of HID lamp in standard is 2000 hours. The lumen flux maintenance $R_{\Phi m}$_a is around 60% when the lamps burn at 3000 hour (from the data of the lamps in group 2) where the compensation method could be used.

III. COMPENSATION METHOD

The cost would be high if a calculagraph is used in the ballast. In order to know the time for the compensation, the parameters of lamp voltage, current and resistance are needed. According to (3), the average resistance is 272Ω at 3000 hours. In the normal operation, the lamp works at 35W constant power control in steady state. Hence, the lamp voltage is 97V and lamp current is 0.359A. The lamp voltage is measured in the control process and it is used as a signal for the compensation. If the power loss is accounted for, and the lamp voltage is over 95V three times, the compensation is used in the HID lamp. When the lamp comes to the compensation state, the lamp voltage needs not to be measured again to avoid the error operation.

The light output is affected by the lamp current. In compensation process, the lamp current is fixed as 0.4A (as the nominal current in the requirement in Standard) and the compensation power is calculated by

$$P_{com} = i_{lamp}^{\;2} * R_{ageing\_tr} \quad (4)$$

where *Rageing_tr* is the lamp resistance at the time of compensation. Pcom is the lamp power in compensation process. If the lamp resistance in equation (4) is known, the power for compensation could be obtained. The values of *Rageing_tr* could be calculated by the lamp voltages measured as compensation signal. Because the constant power is 35W if the compensation is not used, then:

$$R_{ageing\_tr} = \frac{|v_{lamp}|^2}{P_{rate}} \quad (5)$$

where v_{lamp} is the lamp voltage measured at the time of compensation and P_{rate} is the rated power of the lamp. In this case, it is 35W. The relationship between the lamp voltage and compensation power is shown in Fig. 2.

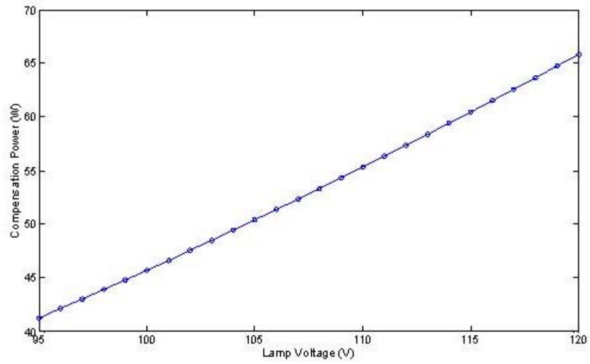

Fig. 2: Compensation power and lamp voltage

In order to conduct the test, a manual switch is used. Fig. 3 shows that a switch (SW1) and an RC combination is integrated with the usual ballast. The software monitors the status of the switch. The compensation request is initiated when the switch is ON and cancelled when OFF. The software is designed to accept the compensation request only after the lamp has attained the steady state.

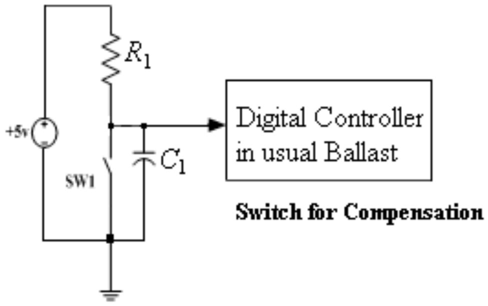

Fig. 3 Manual Switch for compensation

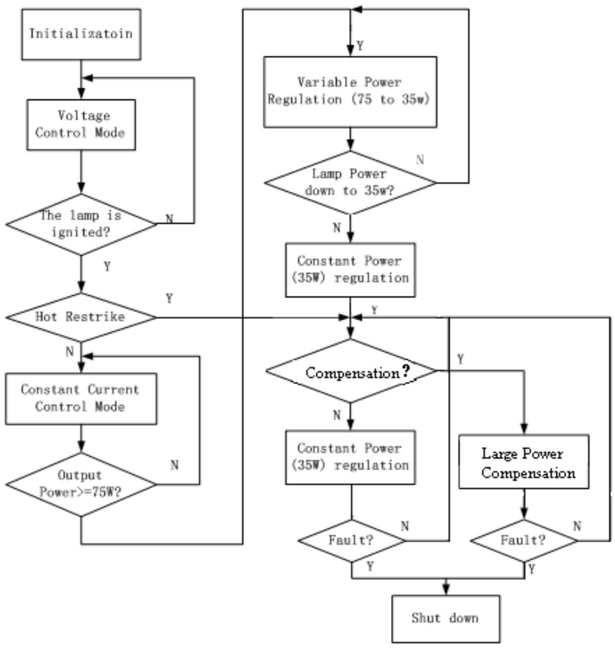

Fig. 4: Flow chart of compensation

The experimental results for new lamp, aged lamp and compensation installed aged lamp are as shown in figures 5, 6 and 7 respectively. The output luminous flux of aged lamp is 1823 lm. The ballast is able to compensate the lamp luminous flux from 1823 lm to 2208 lm. But the compensation method would increase the ageing speed of the HID lamp due to the large power used in the steady state. This method is controversial because if the lamp illumination output is not satisfactory, the lamp will not be used or replaced. This method of the compensation ensures that the lamp's illumination performance is unchanged with the drawback of the reduced lifetime, but the lifetime is not useful practically for uncompensated lamp as the illumination is below the required rating.

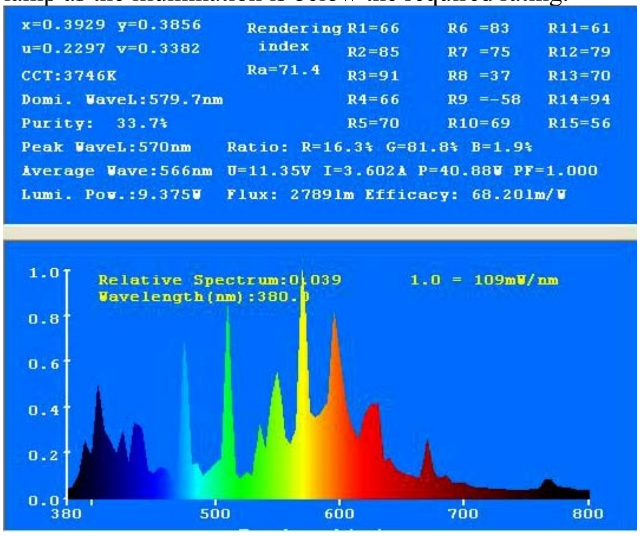

Fig. 5: Spectrum map of the new lamp (Flux: 2789lm)

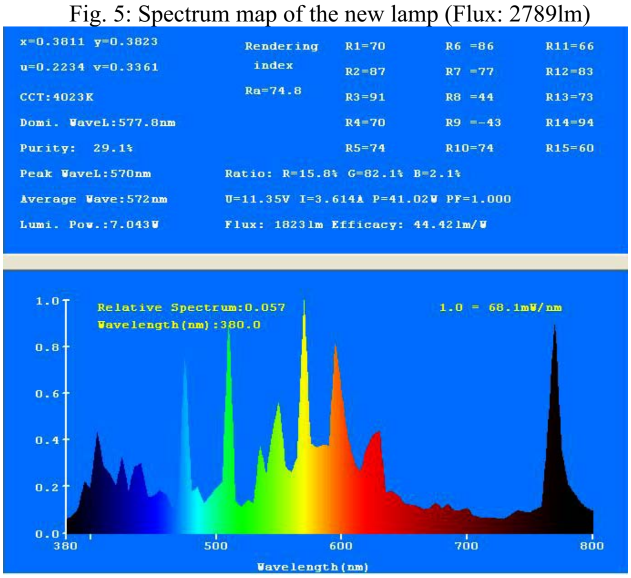

Fig. 6: Spectrum map of the aged lamp (Flux: 1823lm)

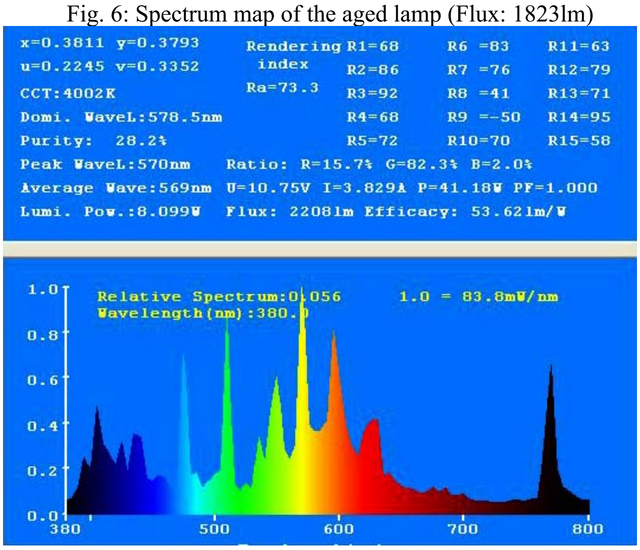

Fig. 7: Spectrum map of the aged lamp with compensation (Flux: 2208lm)

The proposed method is a simple way to provide the compensation. The method based on the pre-measured database to provide the compensation. The data base is proven and this allowed an relatively accurate , simple and quick method of compensation. The proposed method is not supposed to provide exact method of compensation and its intended to be sued for the commercial lamp that have a reasonable compensation for extend the life time of illumination.

IV. Conclusion

A number of experiments were carried out on two groups of HID lamps to monitor the change in the lamps' characteristics as they age. It is evident from the study that frequent switching makes the lamps age more quickly. From above analysis, the following conclusions can be drawn:

(1) The burning cycle will affect the lamp ageing, such as the lamp current and lamp voltage. The shorter the burning cycle is, the larger the effect.
(2) The mortality will be increased with the shorter burning cycles.

The auto-compensation method has been developed in this paper. According to the lamp life model of the HID lamp, the lumen maintenance is around 60% when the lamps burn at 3000 hour and the compensation signal is obtained as the lamp voltage is larger than 95V. The lamp resistance varies with the burning time. In order to supply enough lamp current to the lamp, the compensation power is calculated by the lamp resistance. Then the compensation power serves as the reference constant power in steady state. This compensation method can extend the constant illumination life time. The experimental results show that this compensation method is feasible and can be applied to automotive system effectively.

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