Diagnostics of burning tungsten particles by two-color imaging pyrometry

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It is necessary to measure moving particles temperature for diagnostics of high temperature processes: plasma spraying (Fauchais, 2004), metal and coal particles combustion and so on.

The most appropriate non-contact diagnostics method of moving objects is spectral ratio pyrometry (Avila, 2012). So we use imaging pyrometry to define temperature histories of burning tungsten particles in-flight. The metal sparks are formed by tungsten rod pressing against a corundum grindstone. They are registered by digital camera through rotating stroboscope type disk. The image of the particle trajectory looks like set of streaks (Figure 1a).

Optical diagnostics of such sparks is not simple because tungsten glows rather dimly at temperatures below 1500 K. So to obtain sufficiently high signal to noise ratio we have to use relatively wide spectral bands. The built-in filters of Canon 350d have appropriate characteristics with half-width about 100 nm.

So we use the ratio of red (R) and green (G) channels signals S_R/S_G to determine burning particles temperature. The well known expression derived from Wien's formula isn't applicable for temperature calculation in this case. So we have to modify the traditional method of spectral ratio pyrometry to define color temperature of glowing particles.

We calibrate relative response of Canon 350d color channels by radiation of a platinum filament (20 cm length, 300 mcm diameter), heated electrically. The glowing platinum filament is imaged in raw format, and simultaneously its brightness temperature T_b is measured in the central zone by disappearing filament pyrometer. Then we calculate a true temperature value T_r according the well-known equation:

$$\frac{1}{T_r} = \frac{1}{T_b} + \frac{\lambda}{C_2} \ln \varepsilon(\lambda, T)$$

here: C_2 = 1.4388 m·K, λ=0.65 mcm, ε (0.65,T)≈ 0.3.

The raw files are converted into tiff format and are processed by use Image Processing Toolbox MatLab 7.0. Firstly a rectangular region is cropped in the central zone. The signals in R and G channels are filtrated, averaged over selected area and then their ratio is calculated. This procedure is fulfilled for various values of heating current. In so way the empirical dependence $S_R/S_G=f(T)$ is obtained. After that the images of tungsten sparks streaks are processed in the same way to determine temperature histories of hot moving particles. It is found that tungsten particles temperatures not exceed 1370÷1420 K and drop quickly. A formula for calculating a particle burning time is very simple: $t_b=n/v$, here n – a number of streaks along its trajectory; v – a stroboscope rotation frequency, c^{-1}. The particles burning times in cold air vary in range 0.04÷0.07 c. There are presented successive steps of temperature definition in Figure 1.

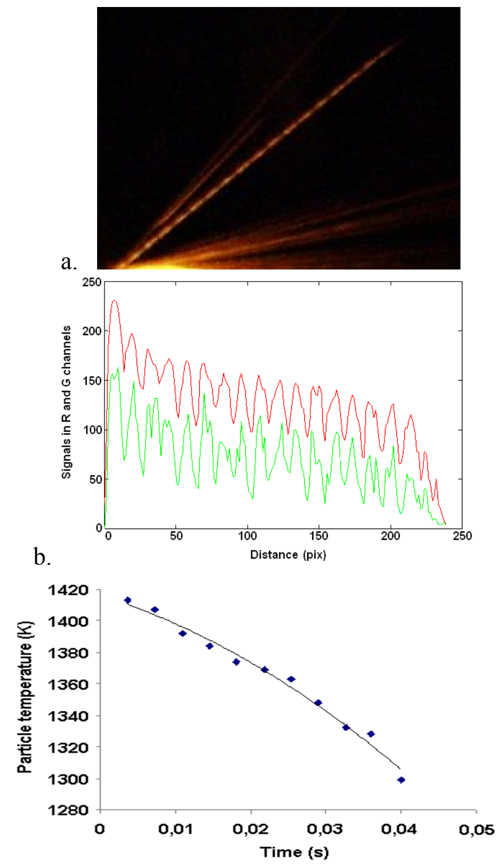

Figure 1. The particle streaks (a); the profiles of R and G values (b); temperature history of tungsten particle (c).

Thus the elaborated technique of two-color imaging pyrometry is applicable for diagnostics of hot moving particles.

Fauchais, P. (2004) *J. Phys. D: Appl. Phys.* **37,** R86–R108.
Avila M., and oth. (2012) *Industrial Combustion,* Article Number 201201.