

USE OF IMAGE-PROCESSING TOOLBOX FOR POWDER PARTICLE DIAGNOSTICS IN PLASMA SPRAY PROCESS

O. Chumak, V. Kopecky

Institute of Plasma Physics AS CR, Za Slovankou 3, 18221 Praha 8

Abstract

For measurements of distribution of powder particles and their velocities in plasma spraying, imaging by CCD camera is used. It is difficult to identify the particles injected into plasma jet on photos, because of high brightness of background light source, noises of CCD camera and low contrast of particle images. Filtering of the photos by a function of two-dimensional convolution enables seeing almost all particles, which are in a region of sharpness. Functions of image processing toolbox are used for recognition of particles and determination of velocity as well as direction of movement of particle of powder in plasma jet.

Introduction

Investigation of particle behavior in a jet of hot ionized gas is important in improvement of plasma sprayed coatings. Imaging by camera is prevalent way of powder particle diagnostic in plasma spraying. Experimental arrangement makes possible to observe particle in a region of its injection into plasma jet. One of the problems is low contrast of the images of powder particles. It is difficult to see particles on the photos without filtering and intensity adjustment. Matlab enables not only filtering and intensity adjustment of the photos but also identification of particles and calculation of velocity values as well as directions from exposure time and a track of particle.

Experimental arrangement

For measurements of particle velocity in a region of its penetration into plasma jet fast shutter CCD camera Sensicam (PCO Computer Optics) and flashbulb Solo1600 (Visatec) are used. Experiments are performed on WSP-H500 plasma torch (IPP AS CR). Experimental arrangement is shown in Fig. 1. Particles with diameter 50 μm are injected into jet of hot ionized gas that radiates light. Flashbulb tube is used for illumination of jet with particles. As intensity of flashbulb light is higher than intensity of plasma jet radiation, particles shadow glowing tube and can be seen. The camera is equipped with a filter with central wavelength 530 nm and width 10 nm. All the photos are made with two exposures and certain delay between them. In this case two tracks of each particle can be seen and distance between them is proportional to particle velocity.

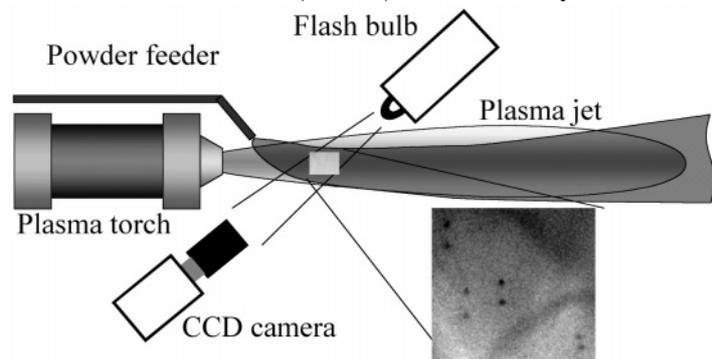


Fig. 1. Experimental arrangement. Axis of the CCD camera and the flashbulb is perpendicular to sheet

Treating of data

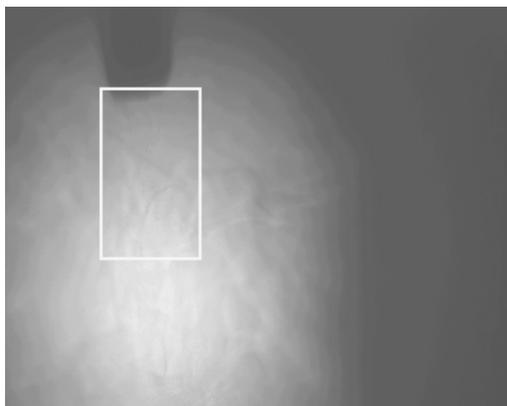


Fig. 2. Example of the shadow photo

An example photo of the region near powder feeder is shown in Fig. 2. Outlined part is used in the paper for demonstration of image treatment. In Fig. 3a you can see part of example shadow photo. First step after reading the photo from memory is filtering from background noises of CCD camera and from fluctuations of the brightness caused by gradients of refraction coefficient of plasma jet. Photos are filtered by 2-D convolution with 2-D filter (convolution kernel). The function `conv2` is used for this purpose. Function `filter2` give the same result and can be used as well. In [1] fast 2-D convolution function `convolve2` based on paper [2] is proposed, but in our case acceleration of calculation was not observed. Filtering by using a Fourier transformation gives the same result but is slower on 25% in our case. It works faster than `conv2` for larger filter image. Suitable convolution kernel was found empirically by means function `fspecial`. Its size is

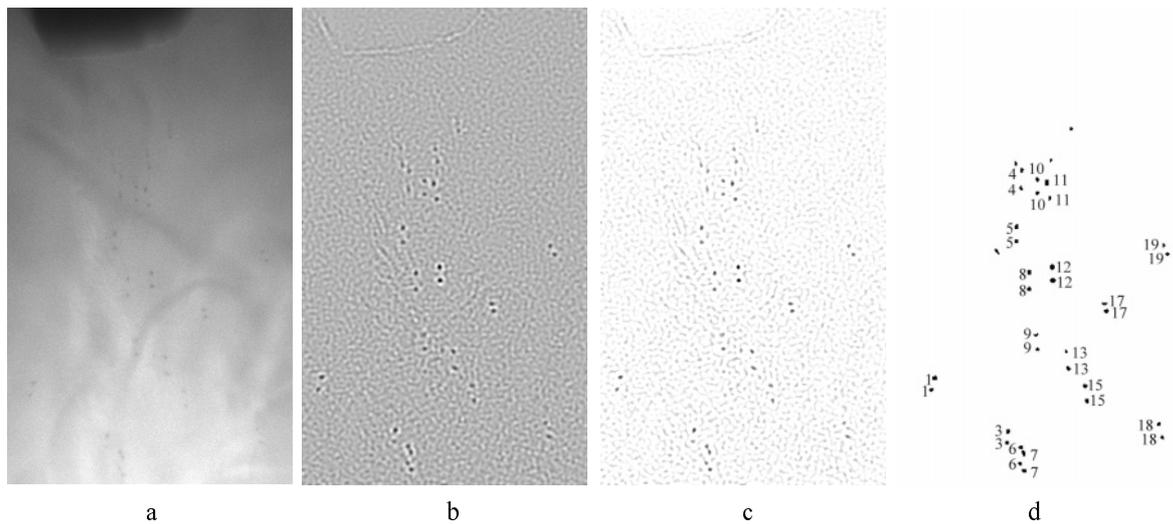


Fig. 3 Part of example photo before filtering (a), after (b,c) filtering, and with marked particles(d)

13x13 pixels (Fig. 4) and depends on the mean size of particle image in photo which diameter is about 4 pixels.

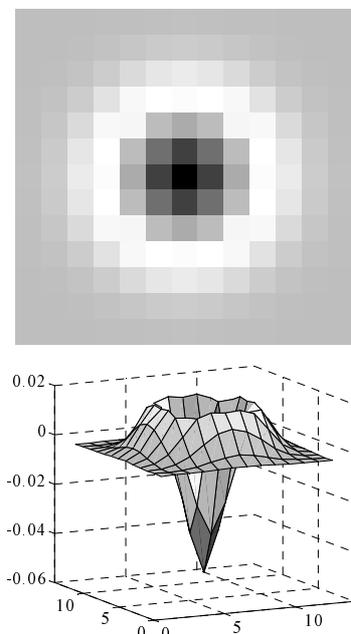


Fig. 4 Image and graph of convolution kernel

In Fig. 3b example photo after filtering is shown. In the filtered image background has the shape of ripples. Particles are better seen when negative values of filtered image are padding by zero as it can be seen in Fig. 3c. Both images in Fig. 3b and 3c are negatives of real data and was converted for printing into grayscale image with color depth 8 bit.

For further treatment it is better to convert data into logic format (black and white image). Threshold is calculated as multiplied by coefficient 1.5 mean value of local maxims in vicinity with the brightest particle. After conversion all black objects that has area less then certain value are deleted. Received black and white image is analyzed by functions **bwlabel** and **regionprops**.

Function **regionprops** returns position of the center and area of all objects. For each object coefficients with respect to all neighbors are calculated. Coefficient depends on deviation of distance and direction of line between examined and neighbor object from the mean values in this point and on difference of theirs areas. Mean velocity and direction in position of examined object is calculated by fitting of velocities and directions of particle movement determined from previous photos. Pair of objects with minimum coefficient assumes to present particle track, if the distance and direction of motion is in acceptable range. At the start, when the first photos is treated and mean values unknown, predefined data that substitute mean values. Fig. 3d demonstrates identified particles. Distance between them multiplied on scale factor gives velocity of the particle. After treatment of photos position and velocity of each distinguished particle as well as mean values of velocity and direction are written into file.

Conclusion

Program made for one purpose and it needs to be adjusted for each change of measure parameters. But it can be fitted to solve similar problems. Up to now program was tested on a small number of photos. On a computer with processor Celeron 266 and 128 Mb Ram treatment of one photo takes 23 s. 40 % of the time takes function **conv2** and 35 % functions of image analyze. Reading and writing data takes only 1.5 s. Since most of the time was spent by calculations, use of more powerful computer would lead to speed up of treatment.

References

- [1] D. Young, Fast 2-D convolution (convolve2), <http://www.mathworks.com/matlabcentral/fileexchange>
- [2] R.M. Haralick, L.G. Shapiro, Computer and Robot Vision, I, 1992, 298-299.
- [3] Matlab User's Guide, MathWorks, Inc., 2000.
- [4] Image Processing Toolbox User's Guide, MathWorks, Inc., 2001.