Color contamination matrix property assessment for improvement of colored smoke PIV

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A single-camera color PIV system that can acquire PIV data of three separated layers has been re-designed, purposing improvement of wind tunnel applicability. We target smoke image that has particle-per-pixel values higher than unity. The system constitutes of a high-power color-coding illuminator and a digital color high-speed video camera. RGB values in recorded image involves severe color contaminations due to five optical and digital sequences (**Fig. 1**). To quantify this, a snapshot calibration is proposed to describe the contamination matrix equation (**Eq. (1)**). Taking the inverse matrix (**Eq. (2)**) allows in-plane PIV in each color layer to be accurately implemented. We also derive mathematical limits to operate the colored smoke PIV, which is explained by the matrix property (**Eq (3)**). Feasibility of the proposed method has been demonstrated by application to a turbulent wake behind a Delta wing (**Fig. 2**) and also to a boundary layer flow along heated chocolate.

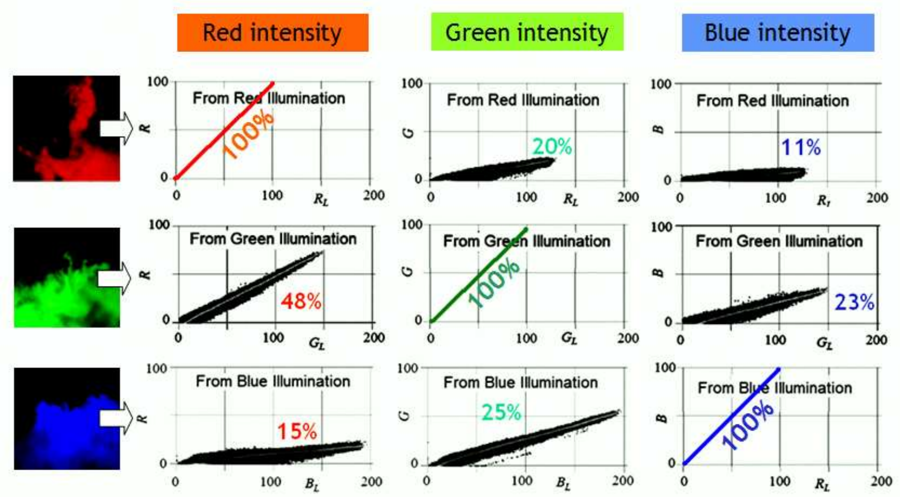

Fig. 1 Color contamination property for a water mist in air projected by a sheet of color light

Color contamination matrix equation:

$$\begin{bmatrix} R \\ G \\ B \end{bmatrix} = \begin{bmatrix} 1 & a_3 & a_5 \\ a_1 & 1 & a_6 \\ a_2 & a_4 & 1 \end{bmatrix} \begin{bmatrix} R_L \\ G_L \\ B_L \end{bmatrix} + \begin{bmatrix} b_1 \\ b_2 \\ b_3 \end{bmatrix}, \tag{1}$$

Inverse matrix equation for estimating smoke density in three colored layers

$$\begin{bmatrix} R_L \\ G_L \\ B_L \end{bmatrix} = \frac{1}{K} \begin{bmatrix} 1-a_3a_6 & a_3a_5-a_4 & a_4a_6-a_5 \\ a_2a_6-a_1 & 1-a_2a_5 & a_1a_5-a_6 \\ a_1a_3-a_2 & a_2a_4-a_3 & 1-a_1a_4 \end{bmatrix} \begin{bmatrix} R-b_1 \\ G-b_2 \\ B-b_3 \end{bmatrix}, \tag{2}$$

Determinant of the inverse matrix

$$K = 1 + a_1a_3a_5 + a_2a_4a_6 - (a_1a_4 + a_2a_5 + a_3a_6)\,. \tag{3}$$

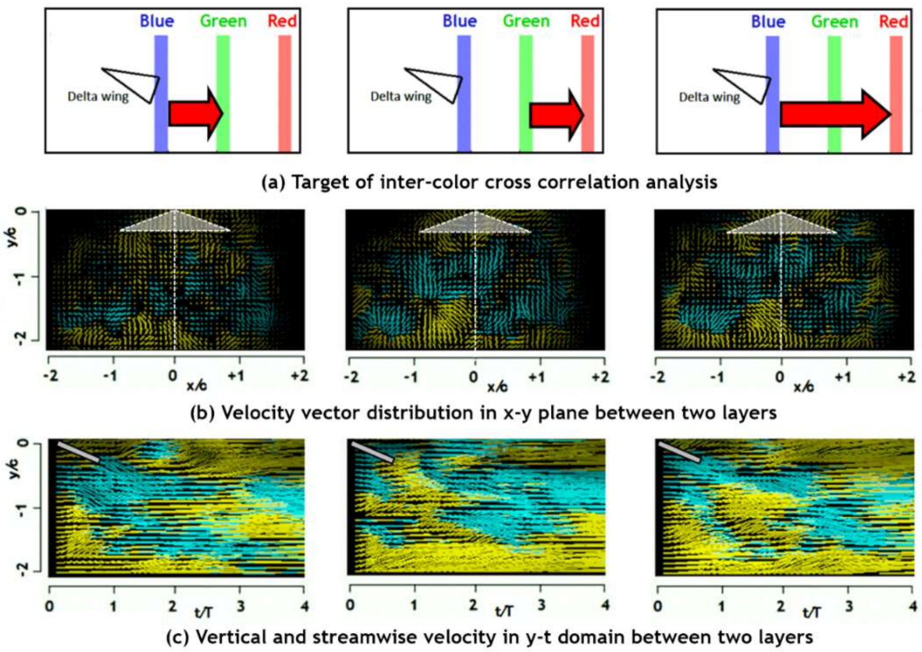

Fig. 2 Flow velocity vector distribution obtained by inter-color 3-D cross correlation for a wake behind a delta wing of 25 degree in angle of attack at which periodic stall occurred.

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