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## IMPROVEMENT METHOD FOR MEASURING KINEMATIC FIELD BY DIGITAL IMAGE CORRELATION FOR 2D TENSILE TEST AT HIGH TEMPERATURE

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### 1. Introduction

In aerospace industry, the shapes of some complex parts, e.g. pylons or engine air inlet made by Ti-6Al-4V (TA6V) titanium alloy sheet are manufactured by hot forming processes. To control the final geometry after forming operation at high temperature and/or to improve the accuracy of the Finite Element Method (FEM) model during the cooling phase, an access to continuous full-field kinematic measurements would be appreciated. One solution is to use Digital Images Correlation (DIC) method. Although this method is relatively mastered at room temperature, it is more complex to implement at high temperatures (from 500°C to 800°C). This is due to two main factors, including the mirage effect (Mirage effect induces images deformed and blurred due to gradient of refractive index of air between a recorder (camera or human eyes) and a hot object [1]), the loss of image contrast decreasing DIC accuracy and precision. This communication develops a numerical spatial filter in DIC applied for planar tensile tests to eliminate errors due to temperature effects for the identification of Young's modulus.

### 2. Materials and methodology

Material studied is a TA6V alloy sheet of 1.6 mm thickness. The elastic behavior of TA6V at different temperatures (between 500°C and 700°C) is identified by uniaxial tensile tests (MTS with the measuring range of 0-15kN) and DIC system for full-field kinematic measurements. Tensile specimens (width 8 mm x height 25 mm) are heated by the electrical resistance oven AET. Images during tensile tests are captured by a fronto visible camera system (macro Tamron and sensor CCD 5M pixels AlliedVision) with a frame rate of 5fps. The Zone Of Interest (ZOI) dimensions are 8 mm x 15 mm equivalent to 757 x 242 pixels<sup>2</sup>.

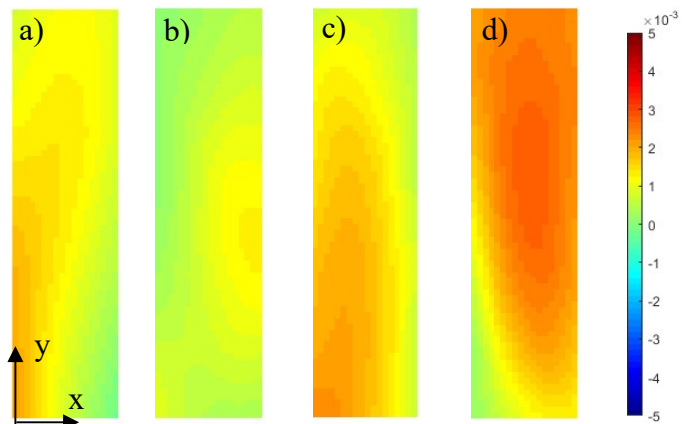


Figure 1: Transversal strain map at four different time measured by DIC at 600°C at static condition

Captured images are used to calculate strain maps by local DIC algorithm (VIC-2D, Correlated Solution®). Kinematic measurements are performed at three stages: i) room temperature served as reference images, ii) static stage (without load) and iii) during mechanical load at three temperatures: 500°C, 600°C and 700°C in nearly isothermal conditions (The thermal gradient is 1°C in ZOI of specimen). In static stage, since no load is applied on TA6V sample (Figure 1), the Background Oriented Schlieren (BOS) technique [2] is employed to characterize temperature dependence of DIC errors. To eliminate mirage effect, an algorithm based on a Gaussian low-pass

filter [2] whose radius  $r$  and standard deviation  $\sigma$  depend on temperature is developed. This filter is optimized thanks to the temperature – dependence of displacement/ strain errors measured in static stage. Gaussian filter allows to separate mechanical strain appeared at low frequency and error due to mirage effect mainly caused by convection flow in the oven appeared at high frequency.

### 3. Results and discussions

Firstly, by comparing mechanical strain in elastic domain obtained by the analytical solution and DIC measurements, we observed that mirage effect induces an error in DIC measurements at high temperature. The temporal and spatial DIC errors at a given time  $t$  are demonstrated in Figure 1.

Secondly, Figure 2a and 2b present longitudinal  $\epsilon_{yy}$  strains at time  $t$  measured by DIC before and after eliminating temperature effects at  $600^{\circ}\text{C}$ . Before correction, the strain values (in absolute) are from 0 to  $2.5 \times 10^{-3}$ . After correction, the heterogeneous strain map is significantly reduced. Its range is from 0 to  $1.0 \times 10^{-3}$ . However, small part of DIC errors is still present probably due to the high dispersion of strain errors from the turbulent convection. Figure 3 presents stress –  $\epsilon_{yy}$  strain curves of local subsets in Figure 2 before and after correction by Gaussian filter. Young’s moduli are calculated from stress – strain curves in the elastic domain. After correction, Young’s modulus of TA6V material at  $600^{\circ}\text{C}$  is 67 GPa, 12% lower than its value in literature at same conditions [3].

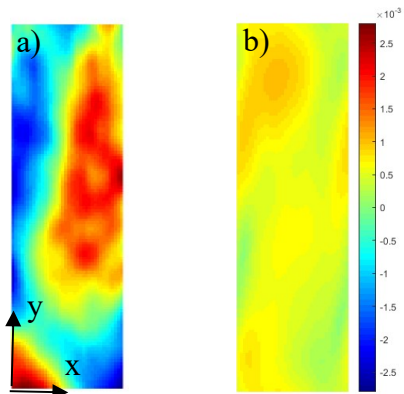


Figure 2: a) Initial  $\epsilon_{yy}$  strain map at time  $t$ ,  
 b)  $\epsilon_{yy}$  strain map at time  $t$  after correction.  
 Dashed rectangles represent local subsets

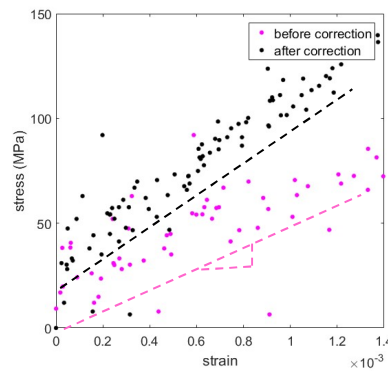


Figure 3: Stress –  $\epsilon_{yy}$  strain curves of tensile test measured on local subsets by DIC before correction (in rose) and after correction (in black) at  $600^{\circ}\text{C}$

### 4. Conclusion and perspectives

The study aims to suggest a spatial filter adapted to temperatures to eliminate errors in kinematic measurement at high temperature. Preliminary result showed that at  $600^{\circ}\text{C}$ , Young’s modulus after correction is 67 GPa, only 12% lower than the value in literature [3]. Future studies should be investigated to measure Young’s moduli of others materials or others temperatures. Furthermore, studies would develop this method for any conditions. Finally, the spatial filter could be extended to temporal spatial filter to remove maximum errors due to temperature effects.

### 5. References

- [1] A. Delmas. Y.L. Le Maout. J.M. Buchlin. T. Sentenac and J.J. Orteu (2013). Shape distortions induced by convective effect on hot object in visible, near infrared and infrared bands, *Exp. Fluids*, 54(4), 1-26.
- [2] E.M.C. Jones and P.L. Reu (2018). Distortion of Digital Image Correlation (DIC) displacement and strain from heat waves, *Exp. Mech*, 58(7), 1133-1156.
- [3] M. Vanderhasten, Ti-6Al-4V: Deformation map and modelisation of tensile behavior, PhD thesis report, Katholike Universiteit Leuven, 2007.