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Uncertainties of stereo-DIC measurements within the range of thermoforming temperatures

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Uncertainties of stereo-DIC measurements within the range of thermoforming temperatures

1.CONTEXT

- Stereo-DIC is an optical-numerical technique which can be used for « in-situ » monitoring of materials during the thermoforming processes.
- Within laboratory confines (i.e. under controlled environment), kinematic and deformation full-fields can be measured.

Table.1: Cases that were studied by our research-team:

Experimental studies	Numerical studies
<ul style="list-style-type: none"> ▪ Measurement of out-of-plane curvatures and monitoring thinning of thermoplastic sheets [1]. 	<ul style="list-style-type: none"> ▪ Implementation of FEMU based inverse identification procedures for material properties [2].

[1] Ayadi. A, Lacrampe MF, P. krawczak. *Int. J. Mat. Forming*; 13 (2020), 59–76.

[2] Dastidar A.G., Ayadi A. , Lacrampe MF. *Procedia Manufacturing*, 47 (2020): 933-939.

2.OBJECTIVE

- The current study, sheds light on the accuracy of displacement measurements with the presence of heat waves which affect refractive index homogeneity during thermoforming processes.

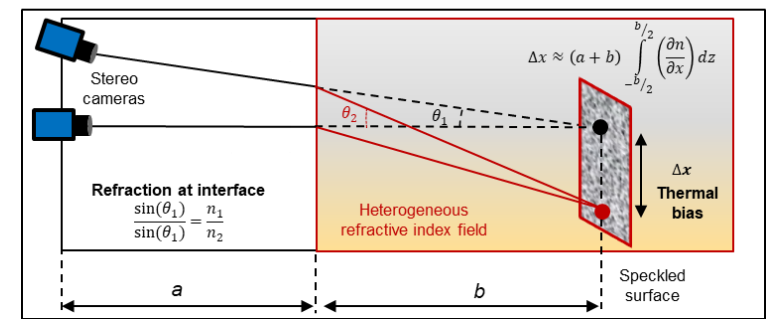


Fig.1: Schematic illustration of the studied problem.

- **The main objective** is to evaluate the sensitivity of random and bias errors within the range of thermoforming window of thermoplastics (such as HIPS).

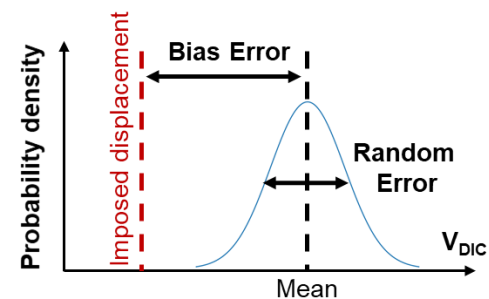


Fig.2: Statistical representation of bias and random errors in the case of a Gaussian distribution.

3.EXPERIMENTAL SETUP

Table.2: Experimental setup details

Setereo-cameras	Camera 1	Camera 2
Positions (mm)	(-14.2, -195.2, 645.8)	(-22.3, -192.4, 653.9)
Rotations (°)	(37.0, -2.9, -2.1)	(36.0, 6.4, -0.8)
Focal length (mm)	43.16	43.34
Pixel size (µm)	5.5	
Heating chamber		
Tested temp.	{25,105, 110, 115, 120}°C	
DIC settings		
Software	DaVis (LaVision)	Software
Subset	19*19	Subset
Stepsize	9*9	Stepsize
Shape function	6 th order spline	Shape function

- **Step1:** Re-generation of heat waves in a convective environment within the thermoforming window.

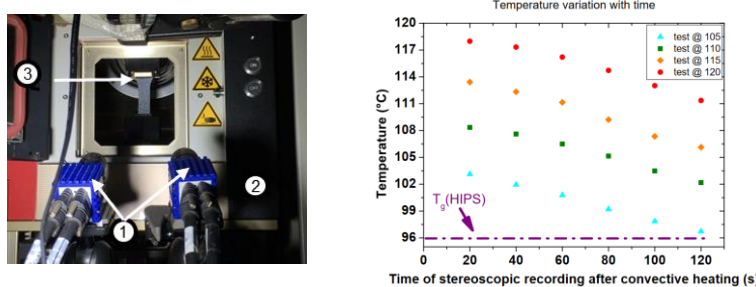


Fig.3: Equipment (left), temperature while recording (right).

4.RIGID BODY TESTS

- **Step2.** Identification of the reference state ($u_y = 0$)

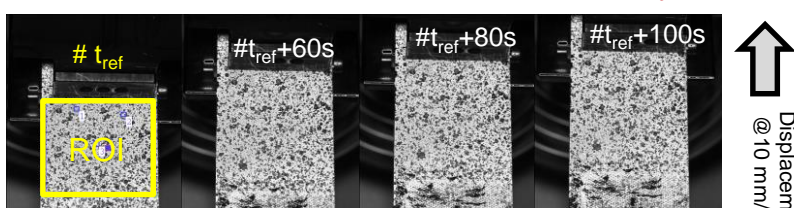


Fig.4: Recorded images during a rigid body test (left camera).

PERSPECTIVES

- More focus will be attributed to initial few seconds of stereoscopic recordings.
- The procedure will be textended to quasi-static stretching tests in the thermoforming range of temperatures.

5.RESULTS

- **Step 3:** DIC computation of disp. vectors (u_y, T)

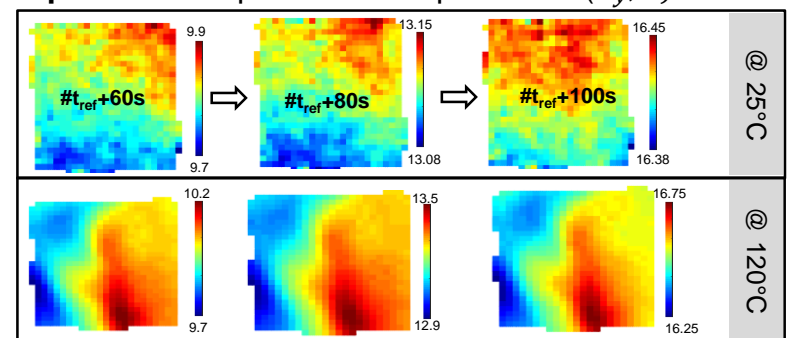


Fig.5: u_y component of stereo-DIC displacement vectors in mm.

- **Step 4:** Evaluation of Random and bias errors

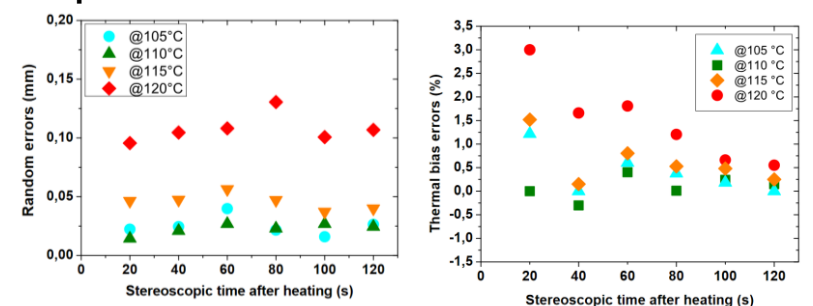


Fig.6: Errors evolution during stereoscopic recording time following convective heating

- Random errors only depend of the identified reference state of the speckled surface after heating.
- Bias errors are sensitive to the heat wave attenuation during stereoscopic recording. Thus, stereo-DIC measurements require temporal filtering of errors.