**MatchID**
Metrology beyond colors

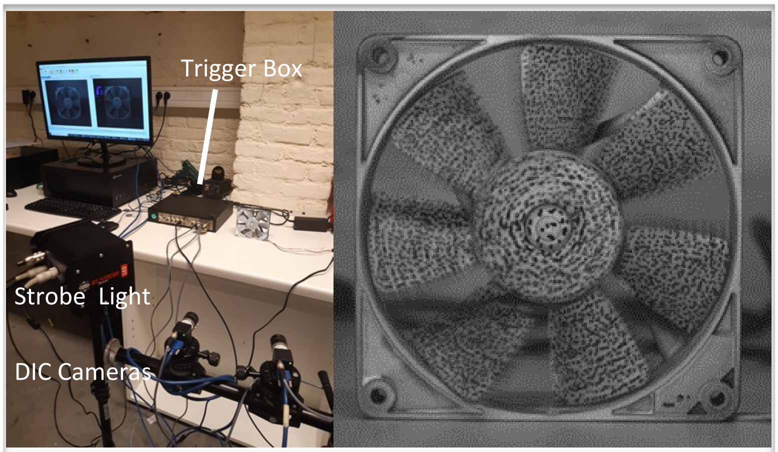
Application Note

# Turbomachinery: Usage of basic DIC hardware for imaging and analyzing rotating structures

## Case Description

**This application introduces a method to track fast rotating structures using basic DIC hardware involving moderate imaging speeds and temporal sampling.**

**To this purpose, we speckled and imaged a computer fan that has one defective blade. During its rotation, two cases are considered. First, the blade is slightly damaged creating small imbalances and causing inherent vibration. In the second case the blade is completely removed and the rigid motion of the whole frame is extracted.**




## Experimental Setup

- ✓ **Cameras:** 2 x Flir Pointgrey Blackfly S USB3 5MPx 75Hz cameras
- ✓ **Acquisition Speed:** Precalculated to guarantee 1 degree rotation of the fan per image: Variable with fan speed

## Analysis

- ✓ **Type:** Incremental Stereo DIC with optimized settings
- ✓ **Vibration:** Natural frequencies determination with operational deflection shapes module

## Results

- ✓ **Stereo DIC:** Time resolved displacements and strain results
- ✓ **Natural frequencies:** Time and frequency response of the structure
- ✓ **Motion Trajectory**

## Why MatchID

- ✓ **Intelligent incremental DIC** enabling large translation and rotation tracking.
- ✓ **Higher-order stereo shape functions** generating a lower geometry reconstruction error.
- ✓ Phase based sub-sampling adopting high spatial resolution **basic DIC hardware** for **time-resolved capturing.**

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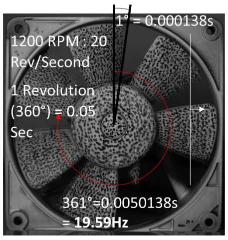
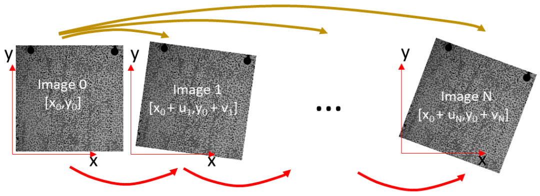
## Image Acquisition by Sub-sampling and incremental DIC

The image acquisition is performed on a rotating fan using quasi-static cameras. The speed of the camera is predetermined in order to achieve a rotation angle between 2 consecutive images of approximately 1 degree. This angle can be reduced even further by considering the fan speed and capturing the rotation angle positions in different revolution cycles.



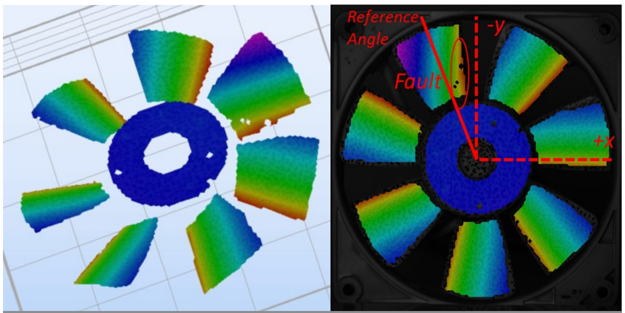

| | | |
|---|---|---|
| Standard Correlation Algorithm | $[u_1,v_1]$ = correlate(Image1, Image 0) | $[u_N,v_N]$ = correlate(ImageN, Image 0) |
| Reference Updating Correlation Algorithm | $[u_1,v_1]$ = correlate(Image1, Image 0) | $[u_N,v_N]$ = correlate(ImageN, Image N-1) + $[u_{N-1},v_{N-1}]$ |

A standard DIC algorithm will perform well up to rotations of around 40 degrees. To comply to larger rotations, a reference updating scheme can be adopted. As such, correlation is not performed w.r.t. the initial reference state, but to the preceding image in the rotation cycle. The total displacement is then achieved by incrementally adding these small-step rotational displacements . Noise might be accumulated as well, but giving the large signal involved this is of minor importance.

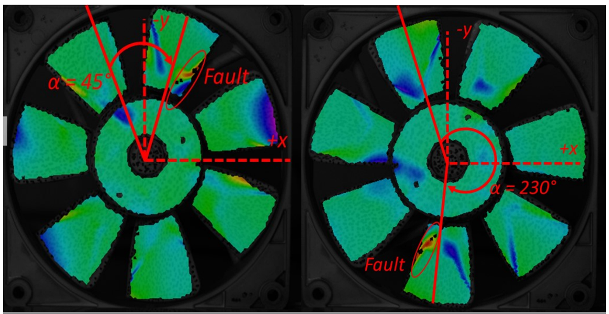
Incremental Correlation Strategy

## Mode Shape Frequency Detection

DIC initially delivers the 3D shape of the fan including the blades. A quick look at the shape reconstruction of the fan, reveals the damaged blade. The incremental correlation algorithm makes it possible to correlate all images during a full rotational cycle. This allows to study the strain at different rotation angles, helping to understand the behavior of the structure when operating in rotational conditions.




Shape of the fan in the reference state

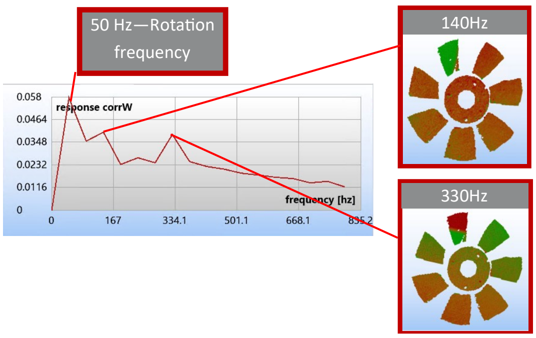


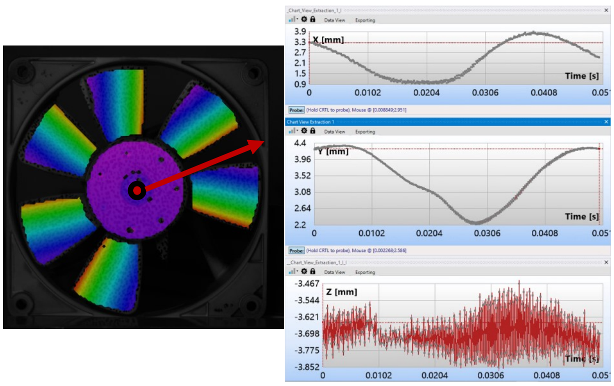

Maximum principal strain at 45° and 230° rotation angles

## Imbalance Detection

A vibration analysis is made using FFT and the ODS module of MatchID. An FFT analysis on the out-of-plane motion of the defective blade reveals the actual vibration frequency of the blade. This frequency can be used to reconstruct the operational deflection shape of the faulty fan assembly.

The case with a fully removed blade is a clear example of rotation induced rigid body motion. The nature of this motion is easily tracked by following the mid-point of the center of the fan using MatchID.

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