Optical Measuring Techniques
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Application Example: 3D Motion Analysis

Development: High Speed Deformation Analysis of a Cooling Fan

Measuring Systems: PONTOS
Keywords: Rotation, blade deflection

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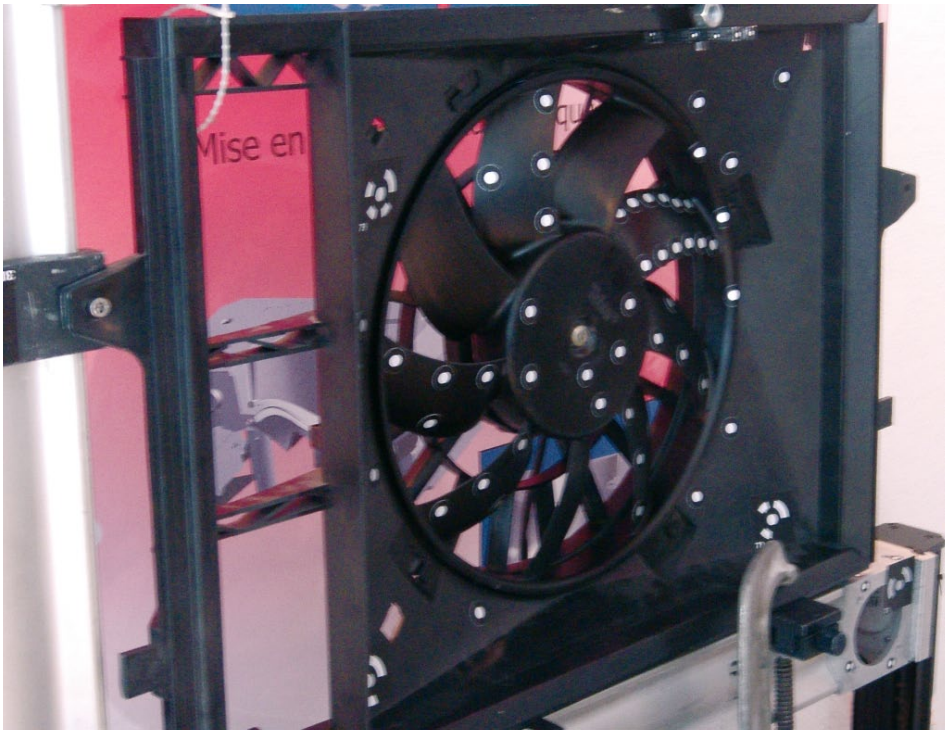

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3D Motion Analysis / Development

High Speed Deformation Analysis of a Cooling Fan

Noise reduction is a major requirement designing modern cars. Computer simulations are widely used to optimize acoustic behaviours of parts. However, the verification of these models, especially in case of aerodynamic parts, still remains an issue. Cooling fans are lightweight and cost efficiently produced, but their deformation behaviour under aerodynamical load is quite complex. Therefore, their design in terms of aerodynamic and acoustic optimizing is difficult. Fast and non-contact 3D measuring techniques are needed to explore the mechanical behaviour of a fan for engine cooling in operation.

Task:
The global and local 3D displacement and 3D deformation of a cooling fan at 2400 rpm is required. Due to its fast speed and the lightweight structure, only a non-contact measurement method is applicable. Furthermore, to determine the local 3D deformation of each blade, a high number of simultaneously acquired measurement points and a result representation using a compensation of rotation is essential.

Setup:
PONTOS, an optical system to measure 3D displacements and 3D deformations was used to determine the behaviour of the cooling fan at 2400 rpm. This system with its calibrated stereo-camera setup was positioned in front of the fan (Fig.1).
The fan was mounted on a simple fixture. Optical markers were used to label specific measurement points (Fig.2).

Fig. 1: PONTOS setup

Fig. 2: Fan with optical markers applied

These retroreflective markers are thin, lightweight, and can easily be applied to the surface of the blades, without influencing the blades' aerodynamical performance.

First, one measurement of the static fan was taken and the 3D coordinates of each optical marker were calculated automatically. The fan was then operated at 2400 rpm, which correlates to a speed at the tip of the blade of above 200 km/h. 200 high speed measurements were taken with 480 fps and a shutter time of 25µs. Here, the simultaneous acquisition of all measurement points is important. As all measuring points in the 2D images are recorded simultaneously, the number of markers used is not restricted. The 3D coordinates of each measurement are calculated and automatically transformed into the coordinate system as defined at the static stage. Thus, the 3D displacement and therefore the blade deformation was determined.

Results:
Below, the displacements and deformations of the fan are displayed. First, the axial displacement is shown superimposed to a series of 2D images (Fig.3). In addition to the highest deformation at the tip of the blade, two maxima per revolution can be determined. In Fig.4 the axial and tangential displacement is visualized on a static image, to analyze the local deformation of one blade.

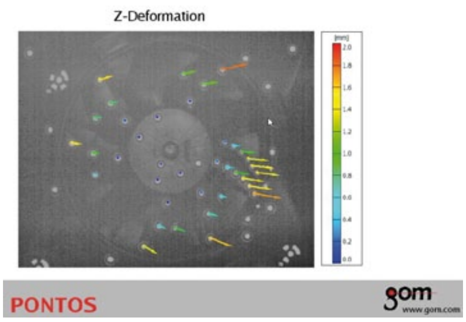

Fig. 3: Axial deformation of fan

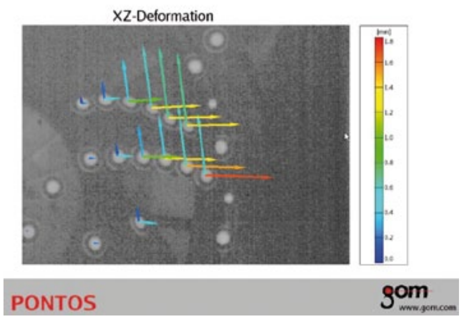

Fig. 4: Axial and tangential deformation of blade

It is obvious that the blade is bending axially with amplitudes of up to 1.8 mm and translating tangentially up to 0.8 mm. The simultaneous data acquisition of all markers allows a measurement between the leading edge and the trailing edge, which shows an oscillating torsional motion, induced by a trailing edge vibration with amplitudes of up to 0.8 mm (Fig. 5).

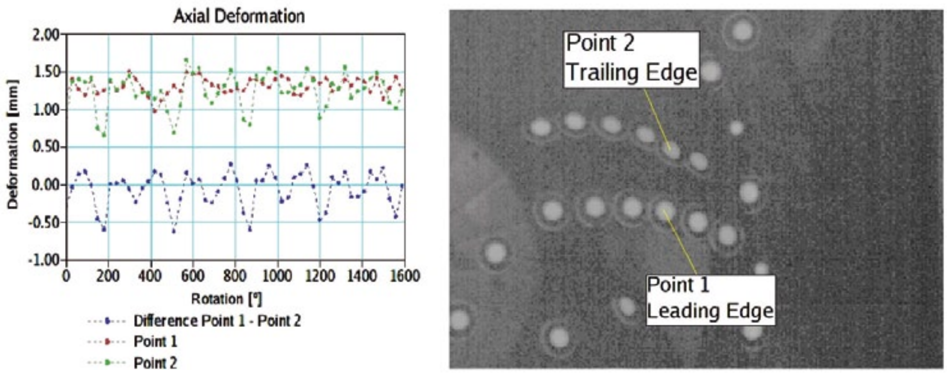

Fig. 5: Axial deformation: Comparison leading edge – trailing edge

Conclusion:
The optical measurement using PONTOS allows an easily applicable measurement and precise analysis of 3D displacement and 3D deformation without influencing the aerodynamic loading mechanism. The intuitive representation of the results on 2D images makes this technique an efficient tool to analyze the mechanical behaviour of fans in operation.