

DIC measurements for friction interface motion monitoring

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Abstract. Monitoring the local behaviour of friction interfaces during vibration can provide valuable information for the nonlinear dynamic modelling of an assembled structure. For this purpose, a measurement system, based on a high speed camera setup, Digital Image Correlation, and specialised post processing tools, has been developed. The application to two test cases demonstrated the capability of the technique to monitor stick, slip and separation during a vibration cycle allowing the identification of the underlying nonlinear mechanism.

Introduction

One of the most common source of uncertainty for the accurate prediction of the dynamic response of an assembled structure is the presence of joints [1], where the contact interfaces can lead to an amplitude dependent frequency response behaviour. Gaining insights into the underlying mechanism of the friction joint during a vibration cycle, can help with the fundamental understanding of the joint and provides valuable validation data for detailed nonlinear dynamic models. Experimental observation of the localised phenomena at the interface can be quite challenging due to their low amplitude and high frequency nature [2]. For this purpose, a high-speed camera set-up in combination with digital image correlation and specialised post-processing tools will be presented, together with its application to two test cases.

Measurement technology

The developed experimental approach to monitor the local dynamic motion at a frictional interface was based on a high speed camera (Photron Mini UX100), capable of 4000 fps at the full HD resolution (1280x1024 pixels). The high frame rate thereby allowed capturing operational frequencies, while the use of a microscope or macro lens enabled capturing the local motion in great detail. Digital image correlation (DIC), based on the MATLAB open source code Ncorr [3], was used to extract the displacements in the area of interest. A large sensitivity of the extracted displacement field, ranging from μm to mm depending on the application, towards the selected subset size in Ncorr was observed, requiring a convergence study for each application. A calibration of the different lens sets highlighted strong distortion fields, which had to be taken into account due to the small motion and the use of the entire sensor area during measurements.

An additional set of specialised post processing tools was developed in Matlab to track different single points or lines at the interface, in order to compute absolute and relative displacements in the orthogonal and sliding directions at the interface for the identification of stick, slip, and separation.

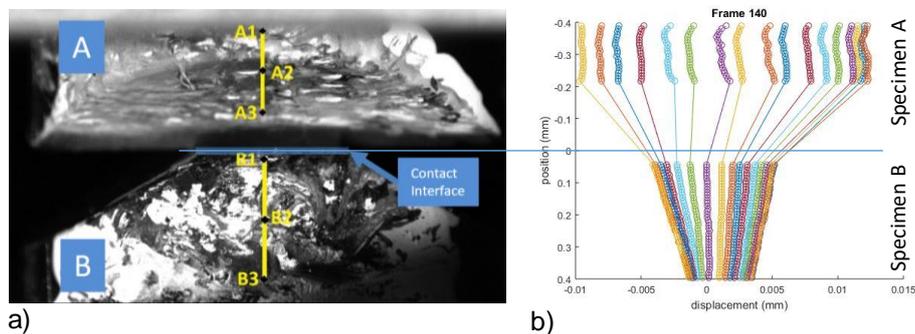


Fig.1, a) friction specimens (A and B) with contact interface, b) displacement plot

Application to the 1D Friction Rig

The first application of the developed experimental technique was to the 1D friction rig, developed to measure friction hysteresis loops [3]. In the rig two specimens (A and B) with flat interfaces (see blue line in Fig.1a) are loaded with a constant normal load. Specimen A is then excited sinusoidally between 20-200Hz via an electrodynamic shaker, whereas specimen B is considered rigid, leading to a macro slip motion between the two specimens.

A microscopic lens was used to capture a high resolution image at the contact interface, with very strong LED lights providing the required illumination. Fig.1b) shows the obtained displacements at the centre line of the

two specimen (see yellow lines in Fig.1a) for consecutive frames. The DIC was able to resolve displacements in the μm range, highlighting an in plane sliding of the upper specimen and a rotation of the lower one, indicating a rather complicated macroslip motion.

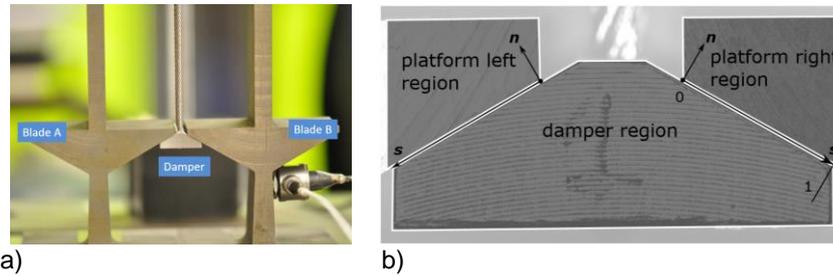


Fig.2, a) underplatform damper test rig, b) damper close-up with local coordinate system

Application to an Underplatform Damper Test Rig

The high-speed camera and DIC post-processing technique was also used for the underplatform damper (UPD) test rig [4] in Fig. 2a). The UPD rig consists of two pseudo-blades, excited by a shaker, with a friction damper in between, which is loaded in the radial direction of the blades.

Applying the developed technique to the damper-blade interface (see Fig. 2b) allowed to capture their relative motion during a vibration cycle. In Fig.3a) the separation of the normal motion (left plot) of the platform and the damper indicates the appearance of a gap, while the overlying tangential displacement lines (right plot) highlighted no sliding at the interface. Fig. 3b) on the other hand shows full contact in the normal direction (matching lines), but the difference in the tangential direction indicates macro sliding at the interface. Once more the resolution is in the μm range, allowing accurate measurements at high frequencies.

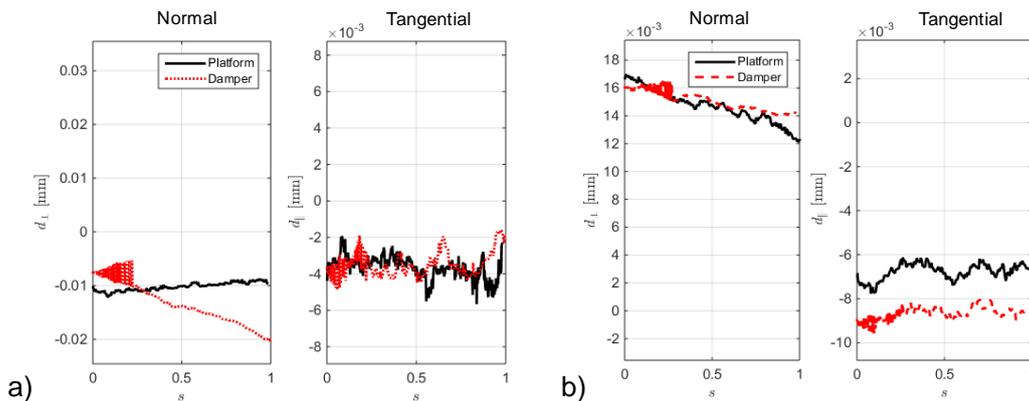


Fig.3, Normal and tangential displacement plot, a) large separation, b) sliding

Conclusion

An experimental technique based on a high-speed camera set-up, and DIC post-processing was presented to monitor local contact motion at a friction interface during a vibration cycle. Two test cases were presented demonstrating the capability of the system to monitor stick, slip and separation at the interface for small scale vibration amplitudes (μm) and relatively high frequencies.

References

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