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# AN INTEGRATED APPROACH TO DIGITAL IMAGE CORRELATION APPLIED TO A NOVEL THREE ACTUATORS FRETTING FATIGUE RIG

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**Abstract**
This poster showcases a novel three-actuator fretting fatigue rig that features a horizontal contact orientation. The machine is equipped to conduct tests under lubrication and enables independent control of all loads in terms of intensity and angle phase. To validate this new rig, we performed fretting fatigue tests on a Ti-6Al-4V alloy couple in a cylinder-plane configuration, instrumented with an integrated approach to digital image correlation.

## 1. Introduction

The attachment zones of blades and disks in aeronautics are susceptible to damage caused by thermomechanical and vibratory loads, resulting in low-amplitude displacements and creating a discontinuity in the contact interface. As a consequence, high stress concentrations occur, leading to the formation of microcracks that propagate via fatigue and ultimately causing fretting fatigue [1]. It is crucial to comprehend the phenomena controlling engine performance to optimize and design components of turbofan engines. Safran Aircraft Engines has recently invested in a novel test bench to improve the understanding of fretting fatigue. The test bench is equipped with three hydraulic servo-actuators, each with a load cell and an LVDT sensor to monitor force and displacement during testing. The fatigue actuator can sustain a load up to 25kN, the fretting actuator up to 10kN, and the normal actuator up to 5kN. A unique feature of this rig is the orientation of the tangential load, which is horizontal rather than vertical as in most existing fretting fatigue machines. This allows for studying the influence of the third body in contact and conducting tests with fluid lubrication.

## 2. Results

The objective of this study is to establish a correlation between experimental results and the model proposed by [2], which employs the Linear Elastic Fracture Mechanics (LEFM) analogy [3] to analyze fretting fatigue. The displacement field in the contact area was obtained using DIC, and nonlocal Stress Intensity Factors (SIFs) were calculated in the vicinity of the contact edge. The model partitions the velocity field $v$ around the contact edge into several terms, each expressed as the product of a nonlocal intensity factor ($I_I$, $I_{II}$, $I_{III}$) and a spatial reference field ($\phi_I$, $\phi_{II}$, $\phi_{III}$), considering the effect of the gradient as described in Equation 1.

$$\underline{v}(\underline{x},t)_{R'} \simeq \dot{I}_I(t)\underline{\phi}_I(\underline{x}) + \dot{I}_{II}(t)\underline{\phi}_{II}(\underline{x}) + \dot{I}_{II}{}^c(t)\underline{\phi}_{II}{}^c(\underline{x}) \quad (1)$$

Instead of utilizing the conventional nodal displacements approach as typically done in classical DIC (Equation 2), we can opt for an integrated approach that yields closed-form expressions for the DIC-obtained field. For the purpose of LEFM, William's series [4] can be employed as shown in Equation 3.

$$u(x) = \sum_i v_i \Psi_i(x) \quad (2)$$

$$u(z) = \sum_{j=I}^{II} \sum_{n=p_i}^{p_f} \omega_n^j \psi_n^j(z) \quad (3)$$

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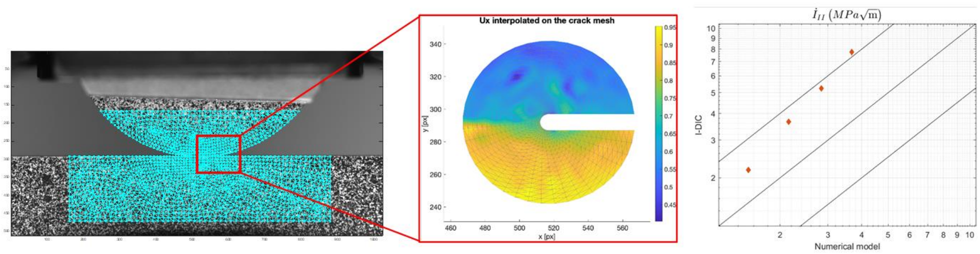
In this case, the amplitudes amplitudes $\omega_n^j$ are treated as the unknown kinematic degrees of freedom of DIC. Multiplying these amplitudes by the sensitivity fields $\psi_n^j$ allows for obtaining the total displacement fields [5]. The SIFs for mode I ($K_I$) and mode II ($K_{II}$), can be calculated by the amplitudes $\omega_1^I$ and $\omega_1^{II}$, respectively. The DIC outcomes shown in Figure 1 were processed with the Correli 3.0 framework, which was created at LMPS [6].




a) b)

Fig.1 – a) Mesh used in the IDIC with intensity factor extraction region attached to the contact front in detail. b) $I_{II}$ values obtained via experimental IDIC and numerical calculation method.

There is an evident divergence between the results obtained from the IDIC and numerical calculation methods, with IDIC showing higher values for $I_{II}$. This discrepancy may be due to the scope of the numerical model, which only accounts for horizontal displacement movements, while experimental setups may involve additional movements such as vertical or rotational motions of the pad. Moreover, it seems that the IDIC is sensitive to the position of the crack tip, and the positioning technique needs to be improved. Subsequent to the image acquisitions, the specimens were tested until failure to compare their lifetimes. Additionally, we assessed the regularity of the crack front propagation to assess the specimens' alignment accuracy during the tests.

## 3. Conclusions

A new three actuators fretting fatigue rig is presented, capable of conducting fretting fatigue tests under complex loads with good repeatability in terms of lifetime and regularity of crack front propagation. An integrated approach to digital image correlation is used to extract ISF and establish correlation between numerical and experimental results in fretting fatigue tests. Despite observing a divergence between IDIC and numerical calculation for $I_{II}$, the initial study yielded satisfactory results with potential for further improvement.

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