Modelling the vibration behavior in hands: influence of pushing / gripping forces

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Introduction

In France, almost 2.2m workers are exposed to hand-transmitted vibration. A sustained exposure to high level vibration may induce various health disorders named “Hand-Arm Vibration Syndrome” [1]. Symptoms onset could be linked to mechanical stress and strain caused by vibrating machines. Knowing these quantities could be the basis for future prevention strategies. Unfortunately, measuring this quantities remains still tough challenging.

Objectives

Thus, this study aims at estimating mechanical stress and strain fields inside the hand by developing a finite element model of a hand tightening a vibrating handle. Unlike previous works limited to a finger or a highly simplified hand, this thesis seeks to reproduce a complete hand including a detailed MRI-based geometry, realistic constitutive laws and muscle activation. The model should replicate pushing and gripping efforts and will be validate with several experimental measurements.

Figure 1. Example of using a chipping hammer

Methods

Model definition

- Kinematic joints for modelling movements between bones.
- Boundary conditions with rigid arm and trunk are specified.
- Visco-hyperelastic constitutive law for soft tissues [2].
- A specific law with muscle activation should be identified using indentation and elastography tests.

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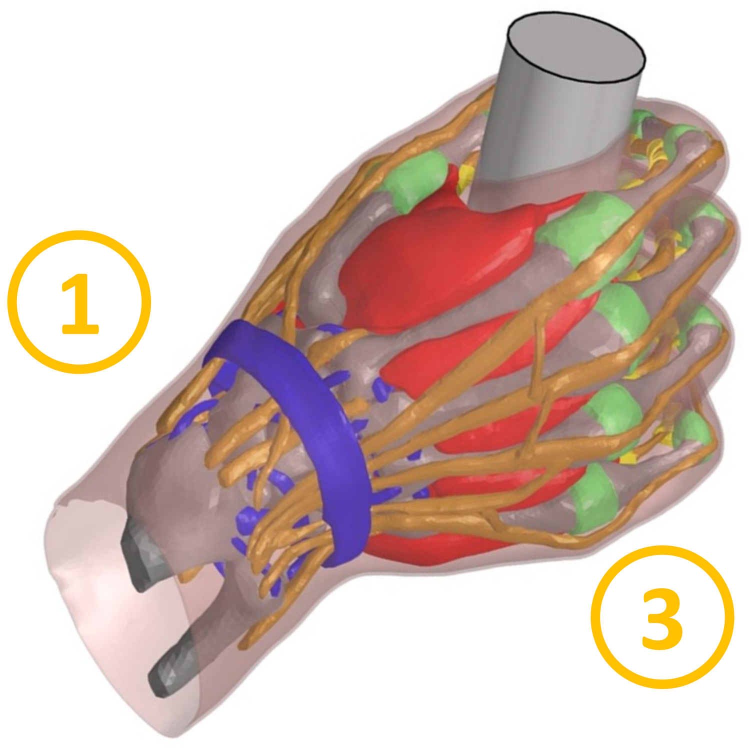

Figure 2. Finite element model of the hand

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Gripping simulation

- Nonlinear quasi-static simulation.
- Rotations and displacements are imposed to bones joints. Values to be applied would be identify comparing pressures on the handle obtained by calculation and experimental measurements.

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Vibration simulation

- Harmonic linear simulation with the former pre-stress conditions.
- Accelerations are imposed on the handle.
- A direct solution is computed (no modal projection) and simulated accelerations on the back of the hand are compared with accelerations measured by laser vibrometry.

Identification of revolute joints axes

Parameters of the kinematic joints were identified with a predictive method. For revolute joints used between phalanges, the axes are estimated using the "Bone-based curvature method“ [3].

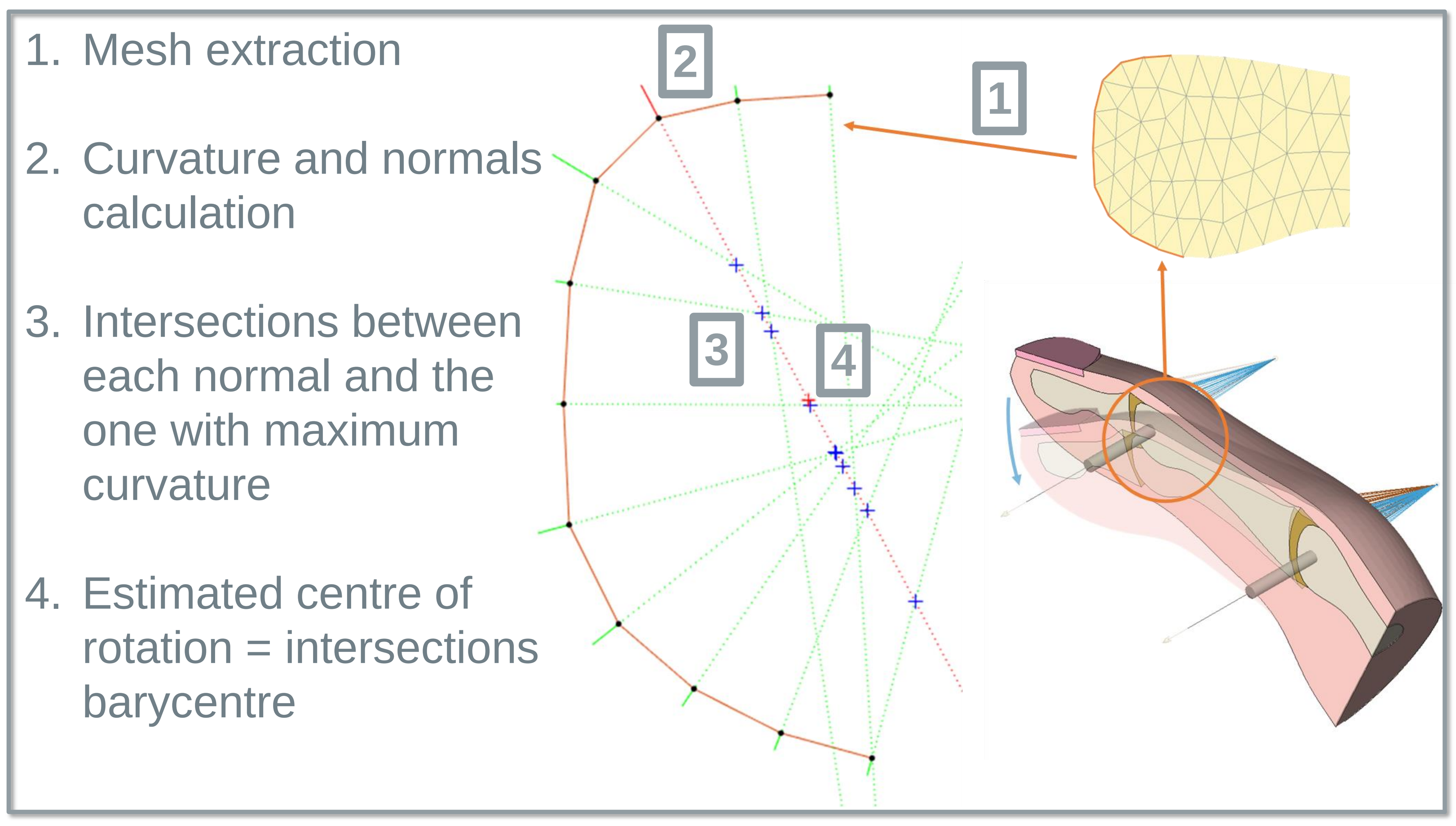

Figure 3. The bone-based curvature method applied on a phalanx

Conception of an instrumented handle

Acceleration measurements require designing a handful instrumented with force sensors. The device should be attached on a shaker with a range of use of [5 ; 2500] Hz. In this range, design criteria are : no resonance in the excitation direction and a flat and spatially homogeneous response in the grip area.

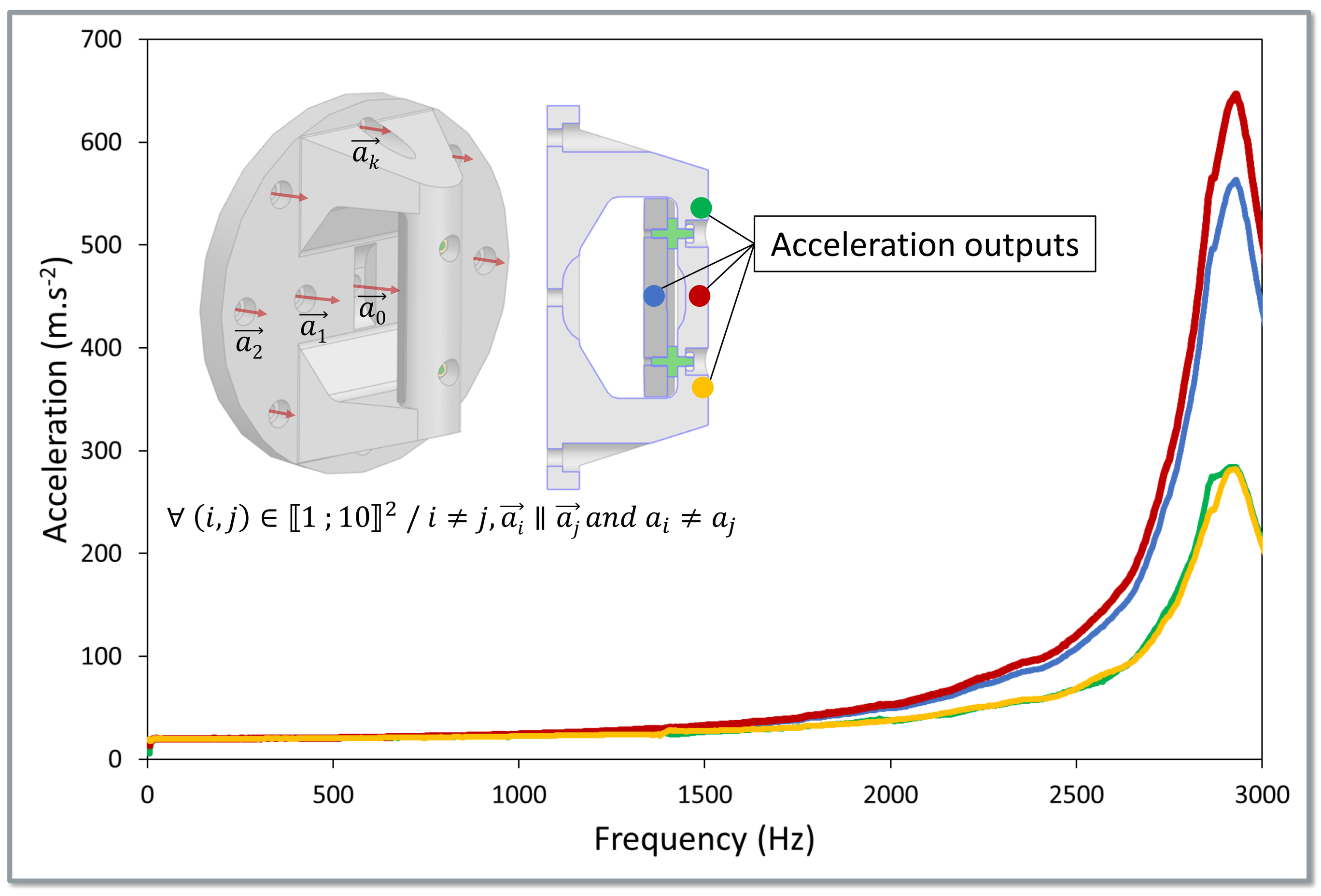

Figure 4. Simulated acceleration response in the grip area due to measured shaker excitation

Conclusions and prospects

Short term

Implementation of a working predictive method to estimate revolute joint centre. Conception of an instrumented handle to validate vibration simulations.

Long term

Improvement of the estimation of the maximum regulatory vibration dose. Design of handle minimizing vibration transfers.

References

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