Nonlinear Modes of Jointed Structures with As-built Surface Topography

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Abstract. Structures with bolted joints produce large variability in nonlinear dynamic behavior, making it challenging to accurately capture even with high-fidelity models. Several parameters contribute to the observed variation, including preload, alignment, and material properties, among others. This study explores the influence of surface topography on the nonlinear phase resonant modes of a mechanical system. Small variations in as-built surface geometry can influence the contact stress distributions within the preloaded bolted joint. Contact stress distribution and gaps provide the initial conditions for time-varying contact conditions during its dynamic response and influence how the surfaces separate and slip over time. This work develops a parameterized model of a bolted structure to investigate the sensitivity of the nonlinear phase resonant modes as a function of surface profile variation to better characterize the dominant sources of variability observed in bolted assemblies.

Introduction

Surface topography plays an important role in science and engineering and is known to influence wear, friction, and contact stress within bolted joints [1]. Surface texture is influenced by the manufacturing and machining process, so it is important to characterize and define the surfaces for the intended application. It has been hypothesized that the largest wavelengths in the surface geometry within a bolted joint interface most strongly influence the global time-varying contact stress distribution within the mechanical interface of the bolted joint. The purpose of this study is to parametrically model the surface topography and predict the preloaded equilibrium state and the nonlinear phase resonant modes [2] of the preloaded assembly.

Results and discussion

An example of a milled surface is shown in Figure 1, where the cumulative topography is plotted in the top row. The spatial wavelengths can be filtered into different components, namely form, waviness, and roughness, going from largest to smallest wavelength (or feature size). These surface profiles are mapped onto the discretized surface of a finite element model to predict their sensitivity to quantities of interest such as contact stress distribution, nonlinear energy dissipation, and nonlinear natural frequencies. This study will help understand the surface profile length scales that cause the structure's nonlinear behavior to deviate from those with a nominally flat surface topography.

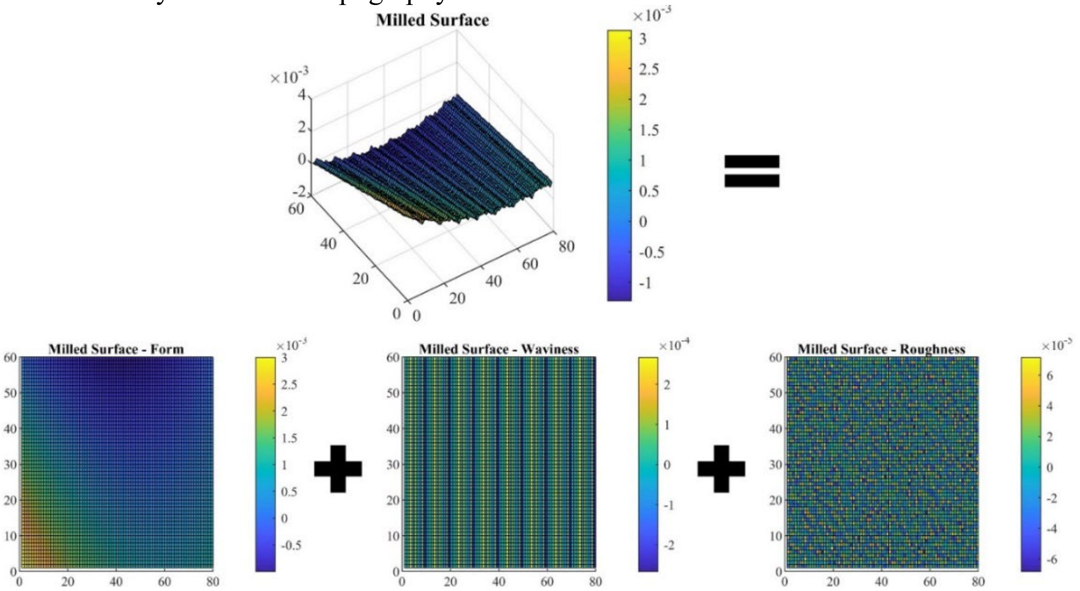

Figure 1: Machined surface filtered into separate form, waviness, and roughness wavelengths.

References

[1] Wall M., Allen M.S., Kuether R.J. (2022) Observations of modal coupling due to bolted joints in an experimental benchmark structure. *Mechanical Systems and Signal Processing* 162:107968.

[2] Volvert M., Kerschen G. Phase resonance nonlinear modes of mechanical systems. *Journal of Sound and Vibration* 511:116355.

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