Model Validation of Loose Bolted Joints in Damaged Structural Systems

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Abstract

The bolted or riveted lap joint is a common fastening technology for structural members. Figure 1 depicts a typical scenario. When a joint becomes worn the joined members can move in a nonlinear fashion relative to each other as well as impact each other and the lap joint plates. For low frequency bending modes the system can experience sticking or frictional sliding motion at the contact points indicated in the figure. Proposed in this project is the experimental validation of a theoretical frictional contact impact model of the typical loose bolted joint.

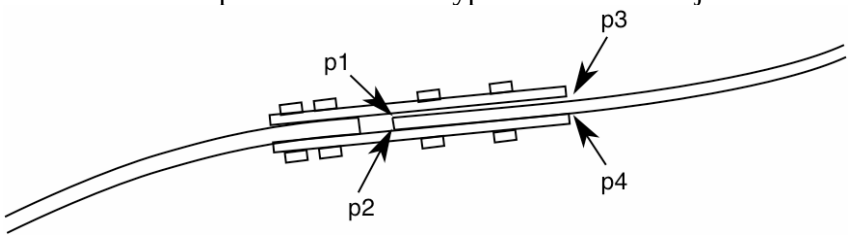
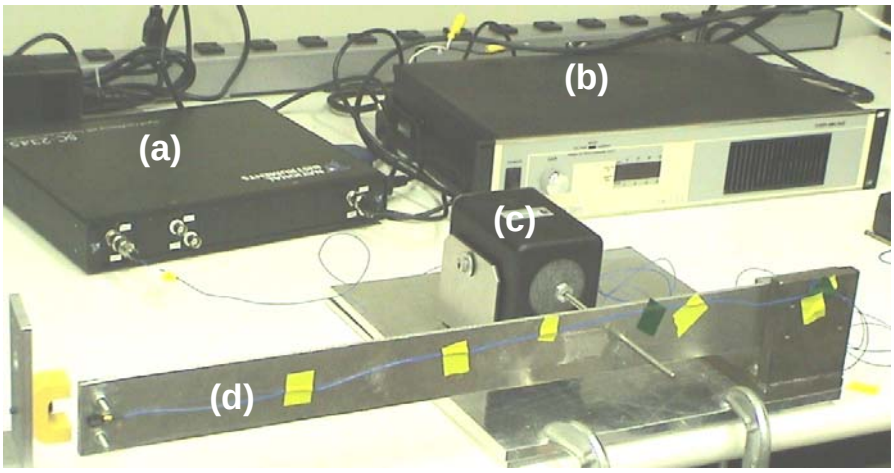


Figure 1. Typical Loose Lap Joint

Project Description and Approach

This project will focus on the experimental validation of a theoretical model of the frictional contact and impact of a loose bolted joint. A cantilever beam will be used as the test structure and is shown in Figure 2. A joint, similar to the joint shown in Figure 1, as well as a tip mass on the outboard beam will be added to the system.



(e)

f. National Instruments signal conditioner SC2345
g. Labworks PA-138 amplifier
h. Labworks ET-132-2 electromechanical shaker
i. Test Structure – 6061 Aluminum beam with steel plate at free end

j. Permanent, stationary U-magnet (NOT APPLICABLE FOR THIS PROJECT)

Figure 2. Experimental setup

The cantilever beam sections will be instrumented with one or more accelerometers and one or more strain gages to provide measurement data. The lap joint will be instrumented with accelerometers and contact sensors as well. Actuation will be provided by a small electro-dynamic shaker attached to the stinger near the base of the inboard beam as indicated in Figure 2. The data acquisition will be implemented in LabView software with National Instruments hardware.

The general procedure for the project will be as outlined here. First the basic parameters of the system will be measured or identified by experimental means. Mass, stiffness, inertia, damping and friction coefficients will be determined. Damage will be introduced in the form of changing the gap width of the joint. The experiment will be run and data acquired. The experimental results will then be compared to simulation results. Simulation input will be adjusted (i.e. the parameters fine-tuned) until a reasonable match of simulation and experimental data is obtained. The experiment will be run with low medium and high excitation frequencies, as well as with various joint gap widths.

Timeline

- Week 1: LANL training and orientation, introduction to vibration and control.
- Week 2: Hardware and LabView software orientation. Parameter determination.
- Week 3: Theoretical model and simulation model overview.
- Week 4: Develop data processing tools in Matlab or LabView, time and frequency domain tools. Automate the data comparison.
- Week 5: Run experiment and simulations under varying input and gap width conditions.
- Week 6: Continued experiment and simulation comparison.
- Week 7: Repeat necessary tests, begin write-up.
- Week 8: Prepare presentation, complete write-up.

References

[1] "Modeling and Experimental Verification of Frictional Contact-Impact in Loose Bolted Joint Elastic Structures", Foster, J, Barhorst A., Wong, C. N., and Bement, M. *In proceeding of the ASME Design Engineering Technical Conference*, September 24-28, 2005, Paper No. DETC2005-85465, pre-print at: http://www.lanl.gov/projects/dss/Projects/2005/Alan/contact.pdf
[2] Franklin; Powell; Emami-Naeini; *Feedback Control of Dynamic Systems, Third Edition;* Addison-Wesley; 1994 (general reference for control theory)
[3] Thomson; *Theory of Vibration with Applications, Fourth Edition;* Prentice-Hall; 1993 (see the section on vibration of continuous systems)