Summer School Project Summary

Drill vibration reduction through active absorption – Part II

1. Abstract

In machining and other material removal processes surface finish is strongly correlated with vibrations and the dynamic interactions between the part and a rotary cutting tool. Parameters affecting these vibrations and dynamic interactions can vary in real time, and the overall response behavior of a system may not be sufficiently characterizable prior to use. It is suggested that a adaptive Positive Position Feedback (PPF) control technique be implemented to suppress unwanted vibrations. Such a system can effectively accomplish the desired dampening without the need for a priori models of the part since the system is designed to self-tune based upon the actual measured transfer function of the tool-part mechanical system.

This effort will focus on fabrication and testing of a simple, actively-damped, high speed drilling application. This builds upon previous work in 2013 for modeling and characterization of a drill press system. Actuator/sensor selection and location will be the primary focus of this work for building a simple prototype. Comparisons will be made to a one-dimensional model high-speed drilling operations for drilling through simple geometries with known resonances.

This will serve as the ground work necessary to obtain future financial backing from specific customers that would lead to final design for fabrication and detailed performance evaluation on prototypes**.** This technology has applications in several areas where it is important to minimize vibration and energy input into the part or other objects requiring drilling.

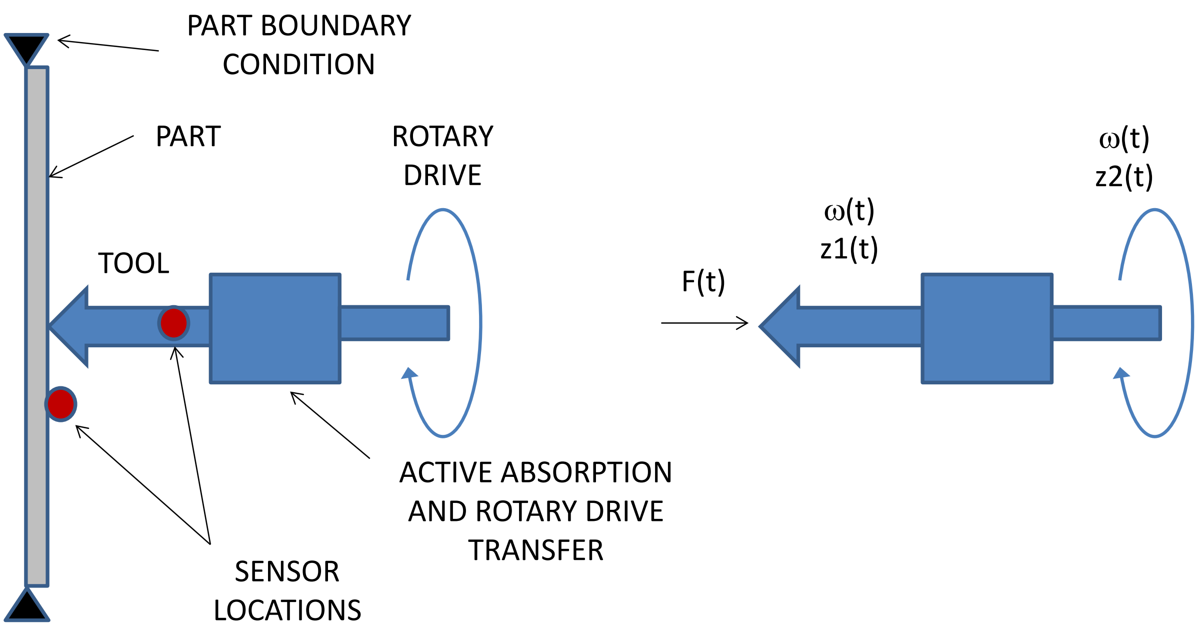
2. Project Outline

a. **Goal -**
The goal will be to utilize a one-dimensional numerical model for the sensor/actuator/tool interaction of a simple Part with known (or easily obtained) fundamental resonances. The model includes the actuator, the tool/part interaction, and part forcing functions. The model will be used to assess two sensor location options:
    i. A collocated sensor-actuator arrangement in which the stress imparted upon the high speed drill is used as the feedback signal (see figure below).
    ii. A non-collocated configuration in which a sensor is mounted to the ’part’, thus providing a direct measurement of the ‘part’ vibration as feedback for the control algorithm.

In addition, the model will be used to assess two types of actuator design to provide the necessary feedback signal for the material removal operation:

i. Piezoelectric-based: provides a high frequency response capability.
ii. Electromagnetic-based actuator: provides greater stroke in control implementation if large vibrations are expected.

Ultimately we are interested in what the reduction in amplitude or other meaningful metric results from the use of this versus conventional technology.



Simple schematic of the tool and part interaction. Sensors may be placed on Part or on the Tool. Rotary drive motion is modified by the active portion of the tool to reduce vibration amplitude.

b. **Motivation –**This work will serve as the ground work for a later final design, prototype fabrication, and detailed performance evaluation. These additional effort would be part of future proposals for a demonstration prototype**.** This technology has applications in several areas where it is important to minimize energy input into the part or other objects requiring drilling:
   - Applications in precision machining applications or CNC milling operations where sub 0.0005-in precision (or below the current limits of conventional technology) is necessary.
   - It also has potential application in a miniaturized version for the medical community in the form of a dental drill or implant/bone surgery applications where patient discomfort is of concern and necessary material removal may be reduced by more precise drilling.

- In situations where specialized bomb technicians must enter an enclosure for investigating or in the process of disarming explosives or ordinance this has potential application. In these cases, there may be tamper devices or unstable situations where simply disturbing the device is unwanted.

c. **Procedure –**

i. Review literature and previously-developed 1-D model for each piece of the system in a uncoupled situation.
ii. Study sensor location options and the tradeoffs using model and conceptual design of tool; consider response time, measurement accuracy, ability to fabricate.
iii. Study actuator options and the tradeoffs using model and conceptual design of tool; consider response time, measurement accuracy, ability to fabricate.
iv. Design Report including numerical results for test case of “simple plate”

3. Background Literature

a. Fanson, J.L, and Caughey, T.K., 1990, “Positive Position Feedback Control for Large Space Structures,” AIAA J., 28, pp. 717-724.
b. Creasy, Leo, Farinholt, 2008, “Adaptive positive position feedback for actively absorbing energy in acoustic cavities,” JSV, 311, 461-472.
c. Creasy, Leo, Farinholt, 2008, “Adaptive Collocated Feedback for Noise Absorption in Payload Fairings,” AIAA JSR, 45/3, 592-599.
d. Radecki, PP. Farinholt, KM., Park, G., Bement, MT., 2010, “Vibration suppression in cutting tools using collocated piezoelectric sensor/actuator with an adaptive control algorithm,” JVA, 132, 051002-1-8.

4. Week by Week Plan

Week	Task
1	Review literature
2	Review 1D modeling
3	Compare model to data
4	Study sensor location
5	Study actuator type
6	Fabricate test setup
7	Acquire data
8	Update model
9	Report, Final presentation

5. Real World Design Issues as a Project Consideration.

a. How would you scale this down to a dental drill? What are limitations
b. What are the limits on geometry? For example, plate thickness or stiffness.

6. Equipment Requirements.

a. Hand drill (perhaps need access to drill press)
b. Accelerometers and data acquisition
c. Simple test plate; perhaps a few of variable thickness
d. Piezostack

7. Software Requirements.

a. Any multi-equation solver, integration software (Matlab?) or
b. Any programming language with custom solver routines