This research thesis aims to achieve the structural analysis and active vibration damping of the Tetraform machining structure. The Tetraform is a space frame made up of four equilateral triangles with spherical masses at the four vertices. This frame was originally developed for grinding of optical lenses and is now being adapted for use in micro-precision milling. The Tetraform is beneficial to the milling process due to its exceptionally high dynamic stiffness characteristics, which increases the machining stability and allows for higher material removal rates and accuracy. However, there are still some modes of vibration that are critical to the milling process and need to be dampened out.

Under operating conditions of many structures, resonant modes of vibration can easily be excited which often lead to structural failure or significant reduction in operating performance. For the milling application, resonant frequencies of the machining structure can severely limit the milling process. The goal of the presented research is to increase surface and subsurface integrity with optimal material removal rate and least possible machining vibration, while maintaining accurate precision and surface finish. The vibrations from the machine tool not only affect the quality of the machined part but also the machine tool itself, since the cutting tool is susceptible to break or wear quickly when operating at high vibration modes, thus inevitably decreasing tool life.

Vibration control has gained considerable attention in many areas including aerospace, automotive, structural, and manufacturing. Positive Position Feedback (PPF) is a vibration control scheme that is commonly used for its robust stability properties. A PPF controller works as a low pass filter, eliminating instability from unmodeled higher-frequency modes. The PPF controller concept is used in developing an active vibration control scheme to target the critical frequencies of the Tetraform. The controller is implemented with use of piezoelectric actuators and sensors, where the sensors are bonded to the opposing sides of the beams as the actuators, allowing for the assumption of collocation. The sensor/actuator pairs are placed at an optimal location on the Tetraform with high modal displacements for all the critical frequencies.

Multiple finite element models are developed in order to analyze the structural dynamics and allow for controller design. A model is developed in the finite element software ANSYS and is used to obtain the Tetraform’s dynamic characteristics, which include natural frequencies and mode shapes. This model is also used to visualize the changes in mode shapes due to structural modifications or different material selections. Other models are also developed in Matlab and Simulink. This consists of the creation of a finite element model which is then converted to state space. The piezoelectric transducers are included in this model for the input and output of the state-space model. This model can be used for controller design where the goal is to create maximum decibel reduction at critical frequencies while attempting to minimize controller effort.

Major: Mechanical Engineering

Educational Career:
Bachelor's of Mechanical Engineering, BS, 2007, Ohio State University

Committee in Charge:
Dr. Chengying Xu, Chair, MMAE
Dr. David Nicholson, MMAE
Dr. Ali Gordon, MMAE

Approved for distribution by Dr. Chengying Xu, Committee Chair, on October 2, 2009.

The public is welcome to attend.