Dynamics Characterisation and Vibration Control in Robotic Machine System

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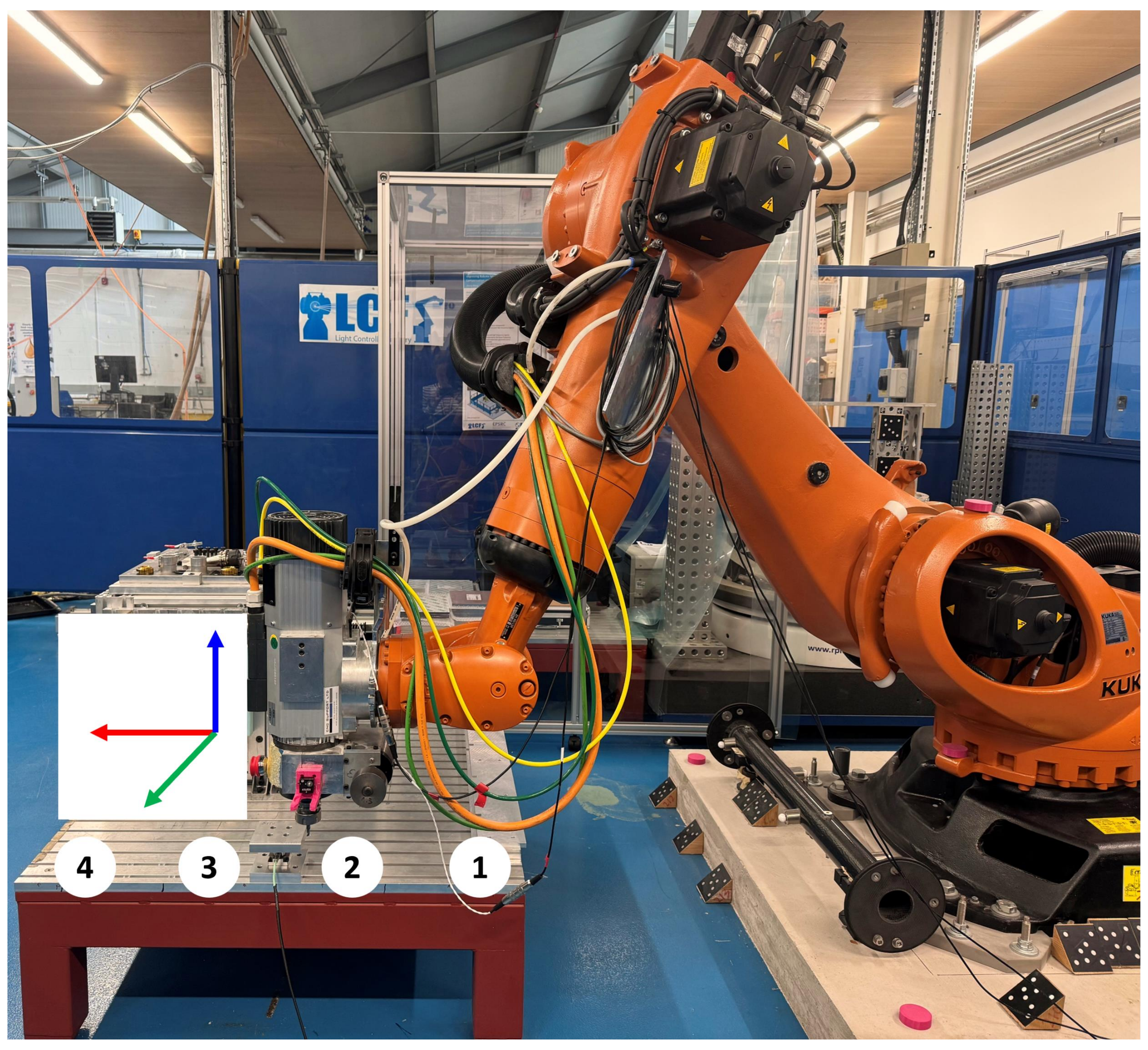
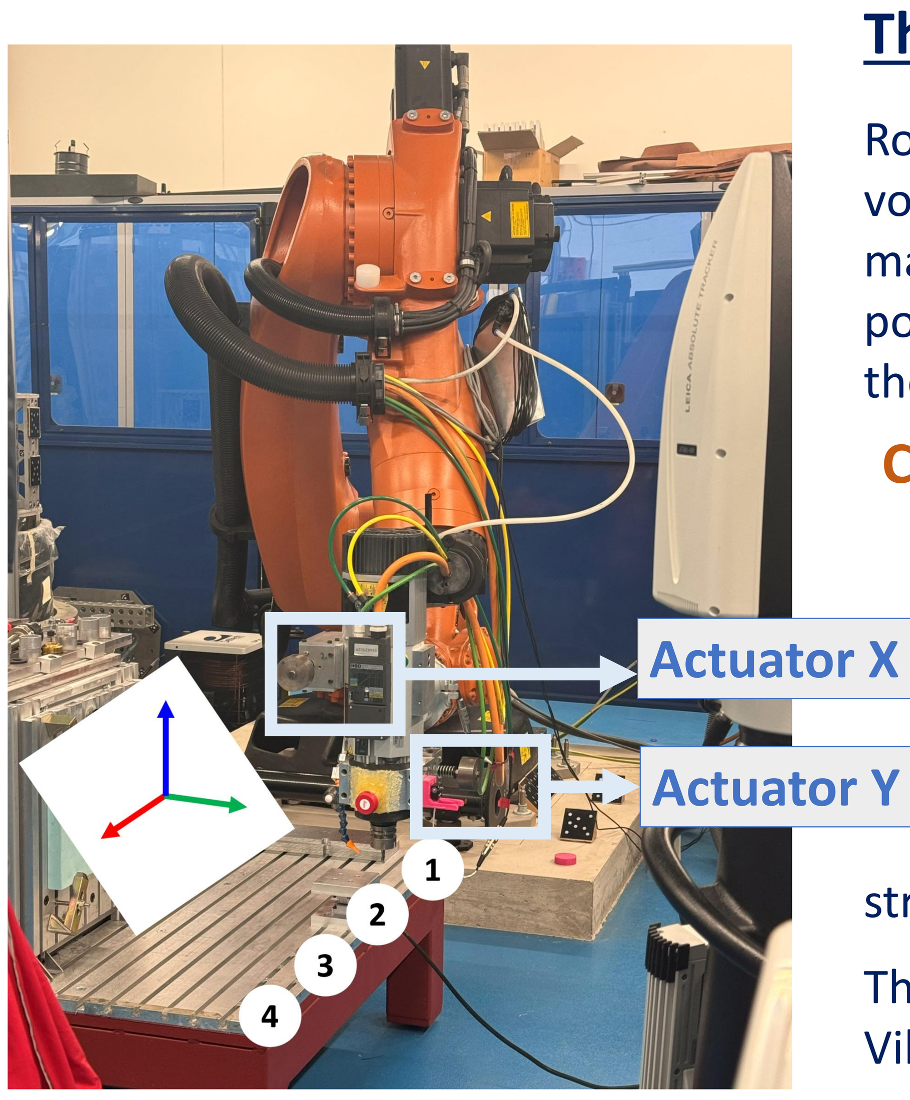




The problem: dynamics are pose-dependent

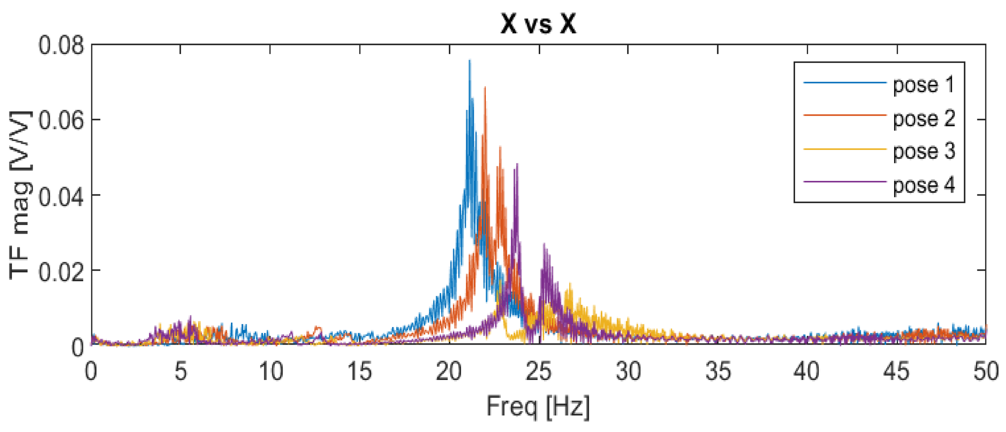
Robotic machining systems are favoured for their lower costs and larger work volumes than traditional machining systems. However, their lower stiffness makes them susceptible to induced vibration and tool chatter. This causes poor surface finish and dimensional tolerances. The dynamic properties of these robots are **pose-dependent**.

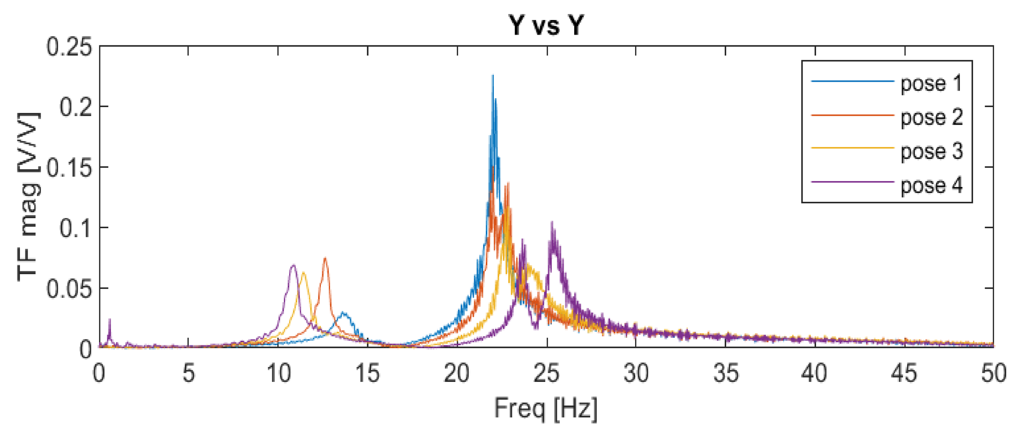
Can we control these vibrations to improve machining quality?

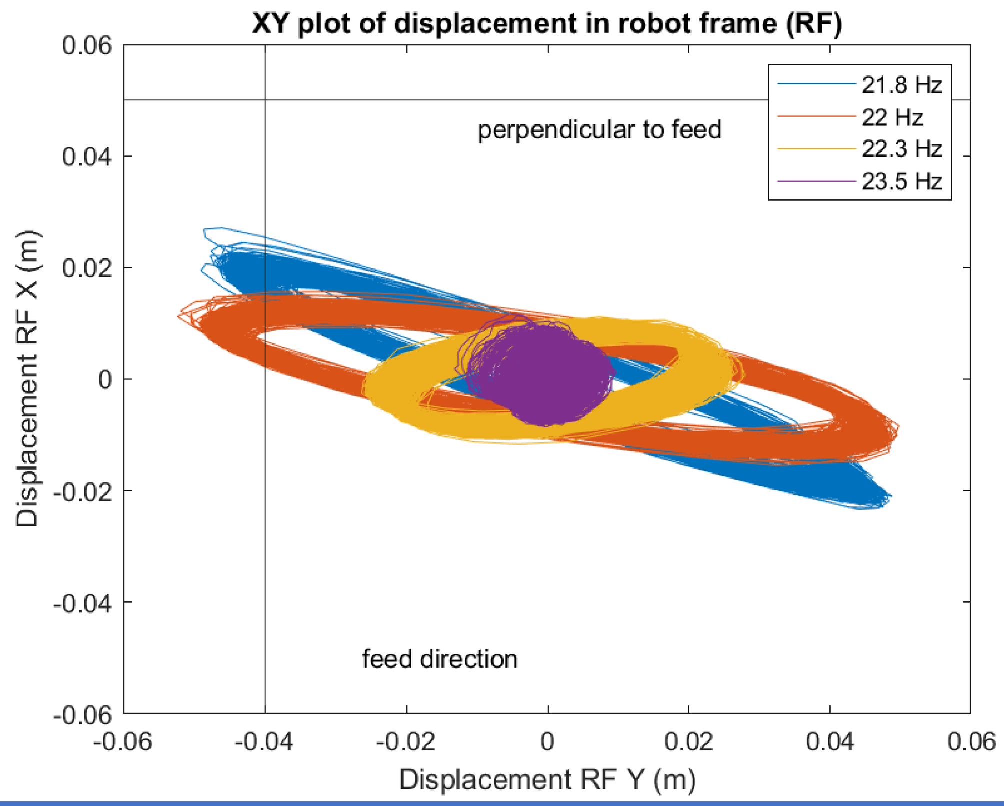
Method

Using a KUKA KR120 R2500 pro robot with custom spindle attached to the end-effector, four poses along the edge of the machining table were defined. At each of these poses, two orthogonally mounted voice coil actuators with attached masses were used to excite the robot structural modes.

The excitation signal was a chirp wave from 1 - 100 Hz over 40 seconds. Vibration data was collected using a DJB Instruments tri-axial accelerometer and a Leica AT960 laser tracker at 500 Hz.







System models

The collected acceleration and displacement vibration data was used to evaluate the frequency response of the system and identify the dominant structural models of the robot. The frequency response plots were used to determine the system models describing the robot. These system models were implemented into a simulation of the system including dynamics and excitation signals. This simulation was used to design and test various control strategies.

Eccentric mass tests

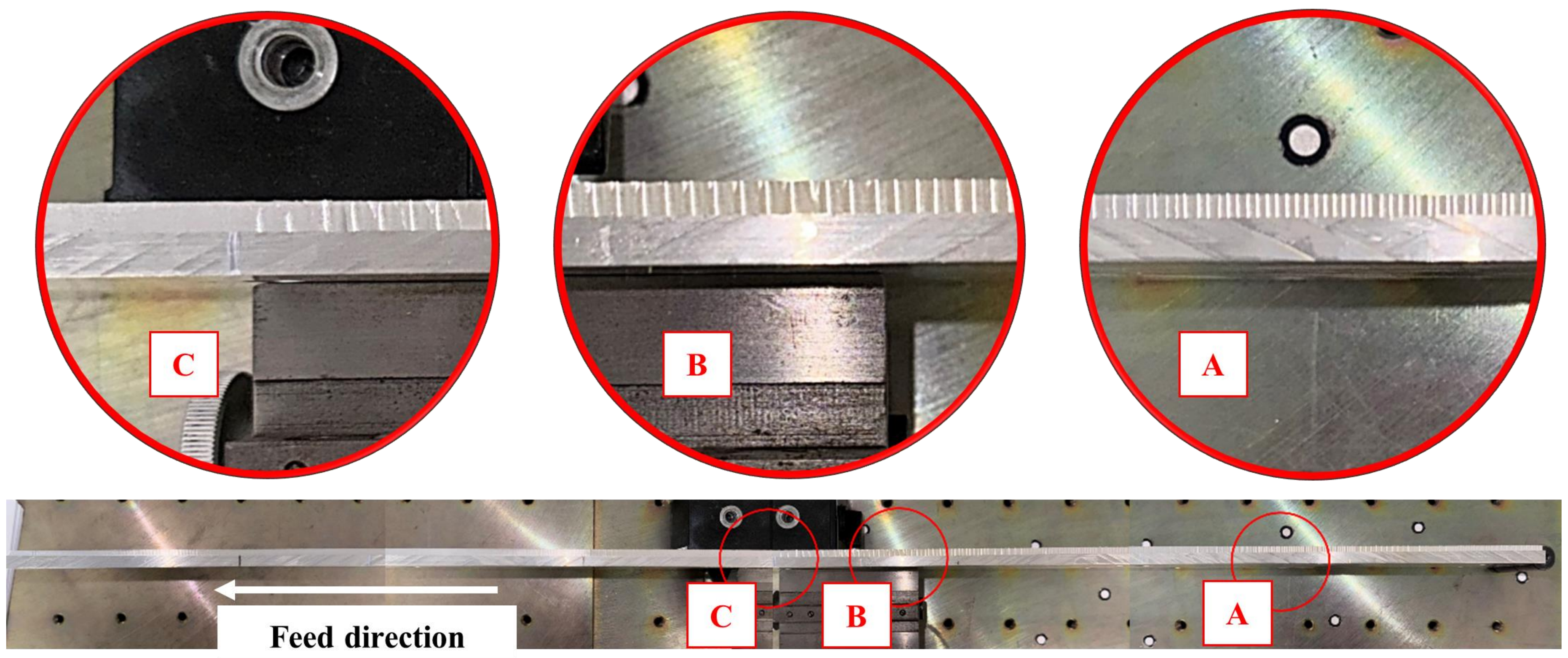
An eccentric mass was attached to the tool tip and the spindle was spun at frequencies coinciding with the identified structural modes. The displacement amplitudes in the orthogonal axes exposed the **Y-axis as the critical axis of vibration.** Therefore, the X-axis was chosen as the feed axis for machining trials.

Pose dependence

The figure to the right shows how the surface finish of this 90 cm aluminium workpiece changes along its length as the robot moves through different poses.

The **chatter marks** are clearly visible here in regions A and B which span poses 1 and 2.

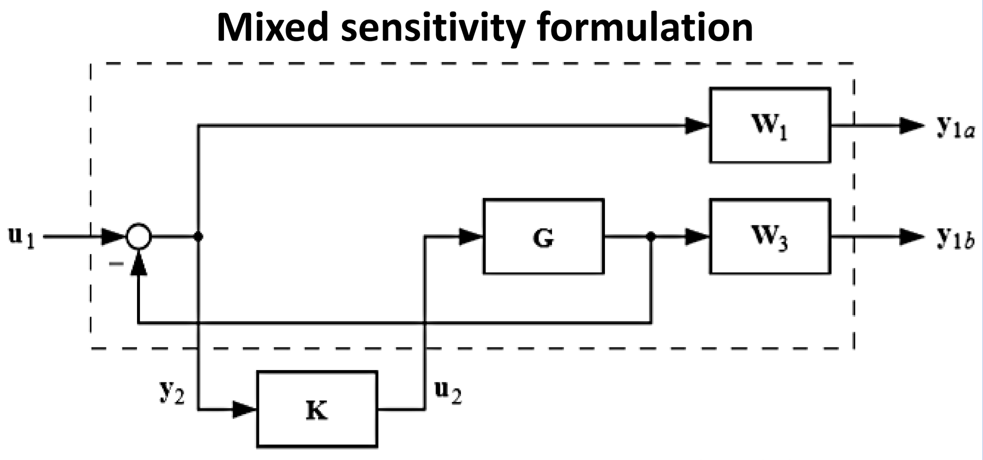
The width of these marks increases from A to C until the chatter decreases significantly.



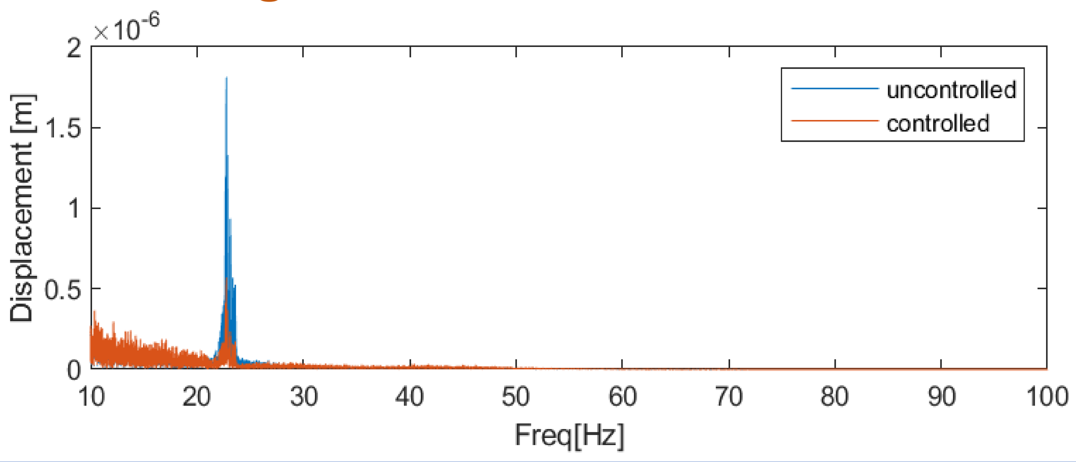
H-infinity control

H-infinity control is robust and can be constrained to maintain stability.

A mixed-sensitivity formulation was used to design the controller action. It was assumed that coupling between the two orthogonal axes was negligible. All system uncertainties were assumed additive.



Application of the designed controller in the system simulation indicated an **improvement in machining vibration of 70%.**



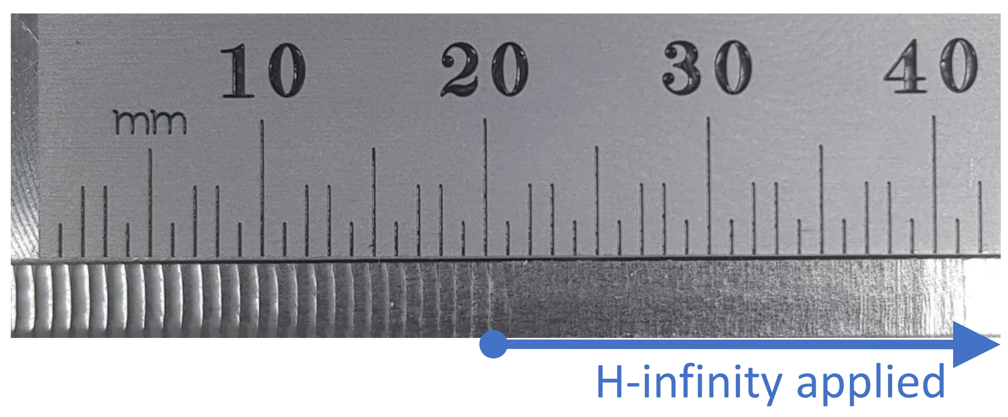
Single pose machining trials

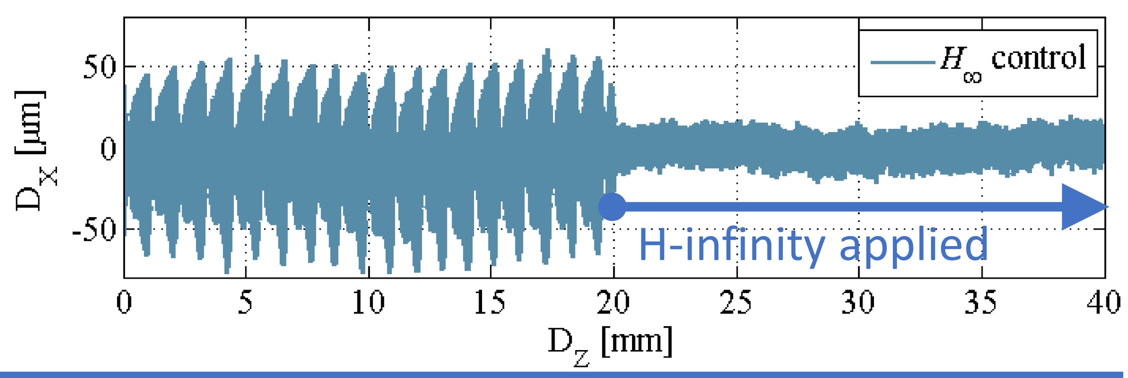
Edge-trimming along the X-axis using a 6mm 3-flute mill bit, a spindle speed of 1720 rpm, 1mm/s federate, 3mm cutting depth and 0.5mm step progression.

Aluminium workpiece of 100 x 100 x 20mm, spanning a region defined as a single pose wherein the robot dynamics are unlikely to change significantly.

Shown here (right), before the application of control, there is visible chatter on the workpiece.

The application of the H-infinity control reduces this, improving the surface finish by **reducing machining vibrations by 80% in the critical direction.**





Conclusions

This work has shown the potential for using inertial actuators in the generation of forces for active vibration control by counteracting vibration and chatter during robotic machining.

This enables improved surface finish and dimensional accuracy achievable using robotic machining systems.

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