Abstract—This project discusses vibration suppression of milling machines by suspensions employing the inerter. We establish the mathematical model of a milling machine and apply springs, dampers, and inerters to suppress system vibrations. Then we consider mechanical networks employing these elements and design the optimal layouts. The results are verified by simulations and experiments in terms of the cutting acceleration, air pressure, roughness.

Introduction

Inerter is a two-terminal passive element, as shown in Fig. 1, with the corresponding force proportional to the relative acceleration across the terminals:

\[ F' = b \cdot a = b \cdot \frac{d^2 x}{dt^2} \]

where \( F \) represents the reacting force, while \( x \) is the relative displacement across two terminals, and \( b \) is the inerterance with a unit of kg.

Experimental results of adding inerter

Fig. 4 shows the experimental acceleration, air pressure, and frequency response by adding the inerter. Note that Inerter 2 has bigger inerterance and results in smaller acceleration, air pressure, and resonance peak than inerter 1.

Optimal mechanical networks

We test the individual effects of the spring, damper, and inerter. Then we design and implement an optimal mechanical network that consists of these three elements, as shown in Fig. 5. The results show that the optimal mechanical network can greatly suppress system acceleration (the green line) compared to other sub-optimal designs.

Conclusion

This project has demonstrated the vibration suppression of milling machines by the inerter. First, we obtained the dynamic model of the system. Second, we discussed the individual effects of the spring, damper and inerter on repressing system vibrations. Third, we design an optimal mechanical network that comprised these three elements. Last, we verified the results by simulation and experiments. Based on the results, the inerter is deemed effective in suppressing vibration of the milling machine. In the future, we can apply the inerter to other machine tools.