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FORTH: FORce-controlled Tool Holder for vibration-less, accurate and chip jamming-free internal turning

OBJECTIVES

The FORTH project aims at developing a mechatronic tool holder to provide a solution to the three problems that currently limit machining quality and/or productivity in turning operations :

- Active damping vibration suppression,
- Tool deformation,
- Chip jamming.

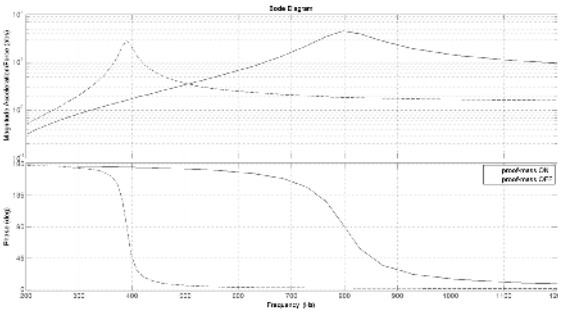

Fig. 1: Modeling of the impact of a proof-mass system on the boring bar response – Bode diagram of the acceleration at the tip of the boring bar versus the cutting force with a proof-mass active damper on or off

APPLICATIONS

Internal turning includes boring, bottle boring and trepanning operations performed in lathes to accurately create or enlarge a hole in a part. Internal turning is used in the manufacturing of a huge range of different parts in sectors such as aerospace, oil and gas, energy generation, automotive, naval, paper, and construction machinery.

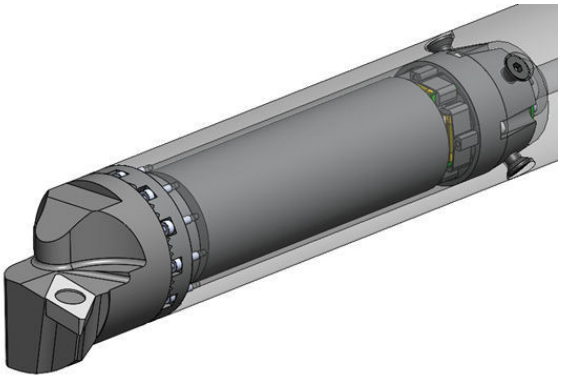

Fig. 2: Boring bar Ø32mm equipped with a PM35XS proof mass piezo actuator

FRAMEWORK

Within the framework of the FORTH project, CEDRAT TECHNOLOGIES is involved in several key tasks :

- Determination of the specifications of the actuators and sensors by test results analyses performed on a Ø32mm and Ø50mm boring bars in terms of :
  - » Dynamic force,
  - » Accelerations,
  - » Current and voltage,
  - » Bandwidth.
- Modeling of the system dynamics (boring bar and proof-mass actuator) and optimization of the closed loop response,
- Development and trade-off of several solutions for active damping,
- Design of two types of piezo actuators for active damping in boring bars Ø32mm,

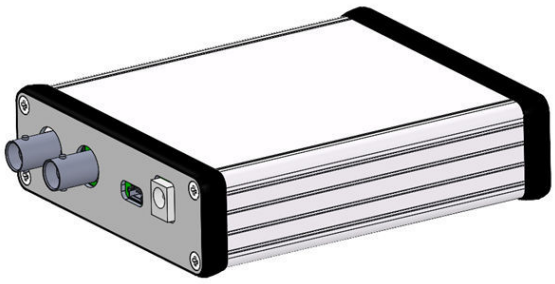

Fig. 3: Electronic box for signal conditioning

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- Design of a dedicated PCB (Printed Circuit Board) for acceleration measurements at the level of the actuator,
- Design of dedicated PCBs for signal conditioning,
- Manufacturing of a dedicated electronic rack with integrated controller and driver,
- Mounting and factory verification of the piezo actuators,
- Tests of the active boring bar (equipped with the piezo actuators) in real conditions (machining operations) and performances analyses.

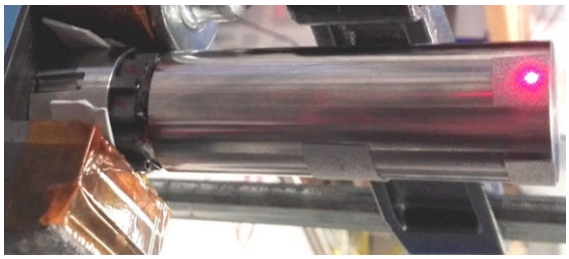

Fig. 4: Piezo actuators factory verification using laser instrument

MAIN RESULTS:

Two actively damped boring bars were achieved relying on Cedrat Technologies piezo actuators customized for the project:

- 4 x PPA20M,
- 1 x PM35XS (based on XY35XS stage).

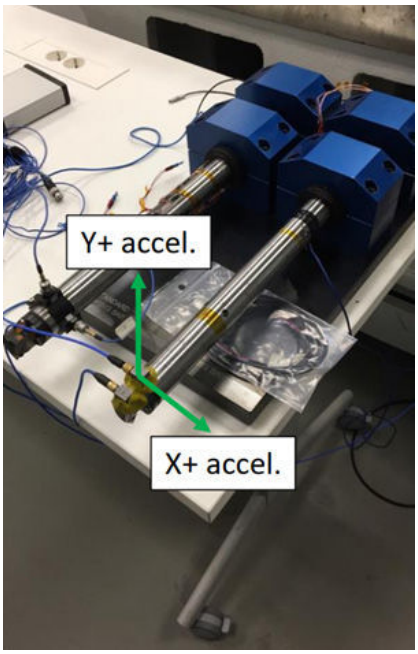

Fig. 5: Boring bars designs (left: PPA20M design, right: PM35XS design)

The controller applied during the tests uses the velocity as a feedback signal to close the loop (Fig. 6) with additional filters to isolate the parasitic modes.

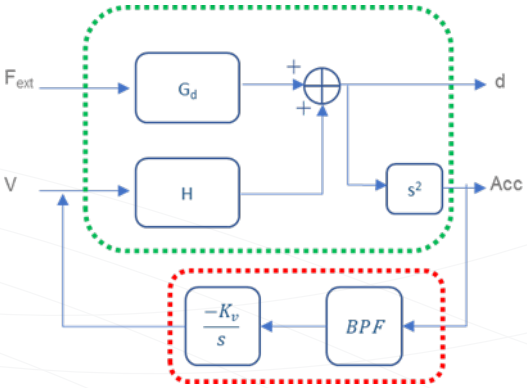

Fig. 6: Closed loop control structure

It was possible to reach more than 80% damping reduction on the first mode of each boring bar (hammer shock test).

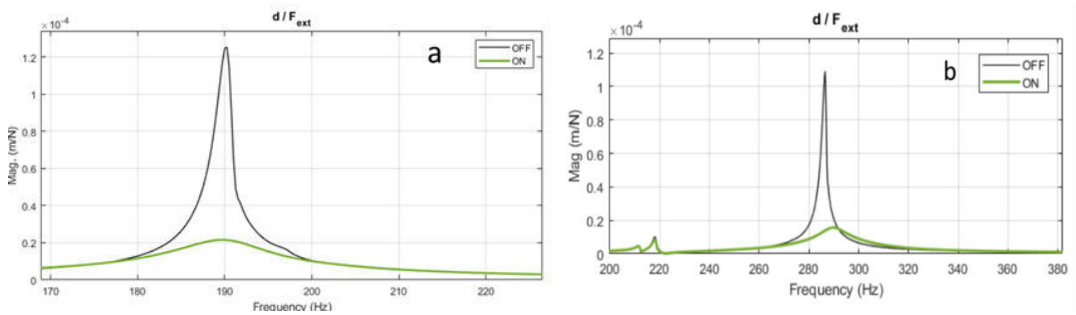

Fig. 7: FRF amplitude for both open loop and closed loop results in the case of **a**) PPA20M boring bar: **b**) PM35XS boring bar

Final performances of the mechatronic tool holders are given in Table 1.

BORING BAR Ø32X10D EQUIPPED WITH:	4 X PPA20M	1 X PM35XS
Boring bar resonance frequency [Hz]	190	285
Damping ratio @ Boring bar resonance on both axis	>80%	>80%
Actuator voltage range [V]	[-20, 150]	[-20, 150]
Actuator envelope [mm^3]	Ø32x53	Ø26x100
Estimation of the actuator dynamic force at the boring bar tip [N] @ Boring bar resonance	± 11.7	± 4
Actuator bandwidth [Hz]	Up to 1kHz	[100, 600]
Stiffness reduction vs plain boring bar	20%	negligible

Table 1: Mechatronic tool holders final performances

PARTNERS INVOLVED :

- SIKULAN (Spain)
- DANOBAT (Spain)
- DARPAMOTION (Hungary)
- Budapest University of Technology and Economics (BME) (Hungary)

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