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Design of a mechanical resonant station to free jammed micro-mechanisms

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- Design
- FEM analysis (Comsol)
- feasibility study
- Quality Control

- Prototypes
- Industrialization
- Production
- Marketing
- Quality Control

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SPECIAL CLEANING APPLICATION

Some types of **mechanical devices**, such as molds, **include a large number** (many hundreds) o**f micromechanisms**, valves, channels, vents, or other devices subject to deterioration or malfunctioning, frequently caused by unwelcome phenomena such as incrustations, fillings, or reciprocal bonding and adhesion of parts following prolonged periods of intense use.

Standard cleaning techniques (wet washing with detergents, sandblasting, cleaning with high power lasers, ultrasonic cleaning with chemical solvents) can be highly automated and optimized in terms of time and costs, but they **can't solve the problem of blocked micro-mechanisms.**

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SPECIAL ULTRASOUND SYSTEM

We have conceived an **invention** of a **mechanically resonant station** that allows the **easy unlocking of all micromechanisms** at the same time.
The station consists of an electromechanical transducer and a closing clamp, which operate in such a way that at least one mechanical resonance mode of the system is excited.
For example, a frequency range of considerable practical interest for the purposes of the device is that between 20 kHz and 24 kHz, hence in the ultrasound spectrum.

COMSOL Multiphysics® FEM was **essential for the project**, in order to obtain the following results:
- design of the electromechanical (piezoelectric) transducer, with high power and efficiency
-design of the closing clamp
-optimization of the mechanical resonance of the assembly.

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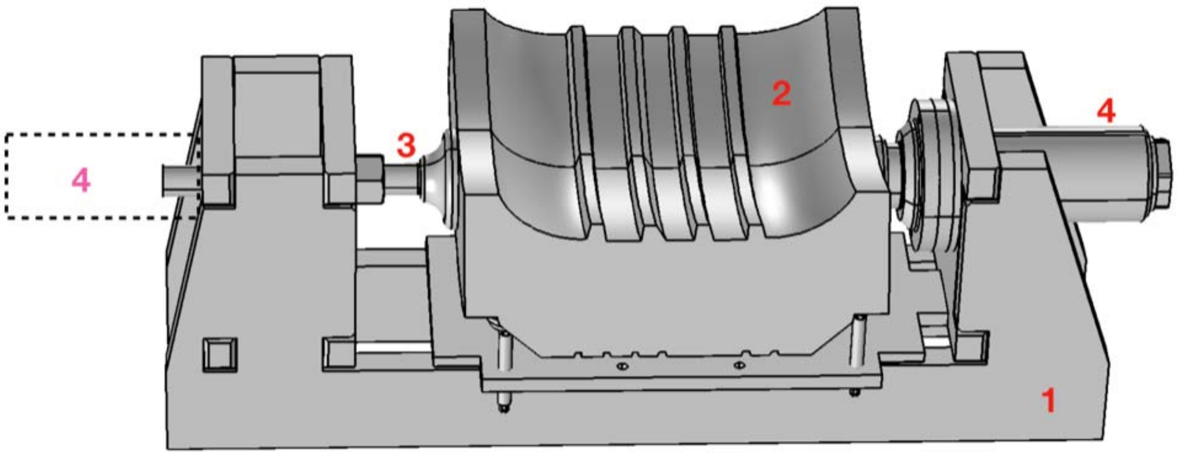
3D MODEL



ultrasound resonance station:
1: frame, 2: mold, 3: clamping device, 4: transducer

The most important devices in the mechanical resonant station are :

- **Voltage Generator**
- **High Power Ultrasound Transducers**
- **Clamping Device**

As regard the voltage generator that drives the electromechanical transducer, it is a high technology device, equipped with a smart electrical impedance analyzer that ensures in real time the **best operating conditions** when the load for the transducer varies.
One or two opposite transducers are pressed on the mold by a clamping device that keep the assembly vibrating efficiently.

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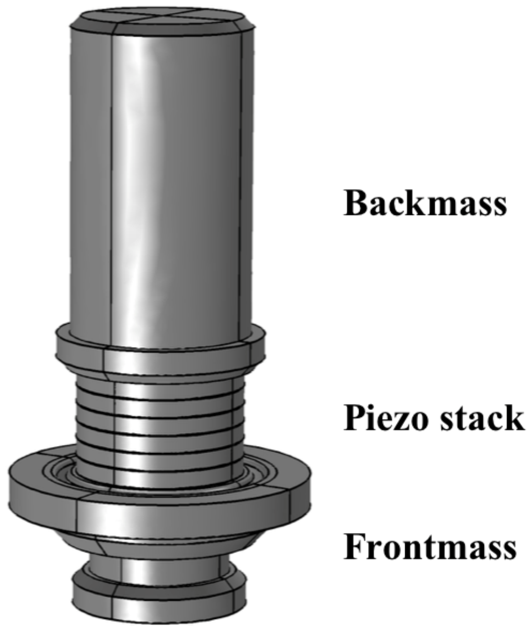
ULTRASOUND TRANSDUCER

The **electromechanical transducer** is based on a standard **Langevin** structure, but with many design details and innovations to get the maximum efficiency. It is based on a stack of Hard-PZT-8 piezoelectric rings, pre-stressed through a central bolt and operating electrically parallel, mechanically series. The stack is stressed between a 'Frontmass' and a 'Backmass' : the design and material choice for the two metallic masses is essential for the tuning and efficiency of the transducer.



Ultrasound Transducer

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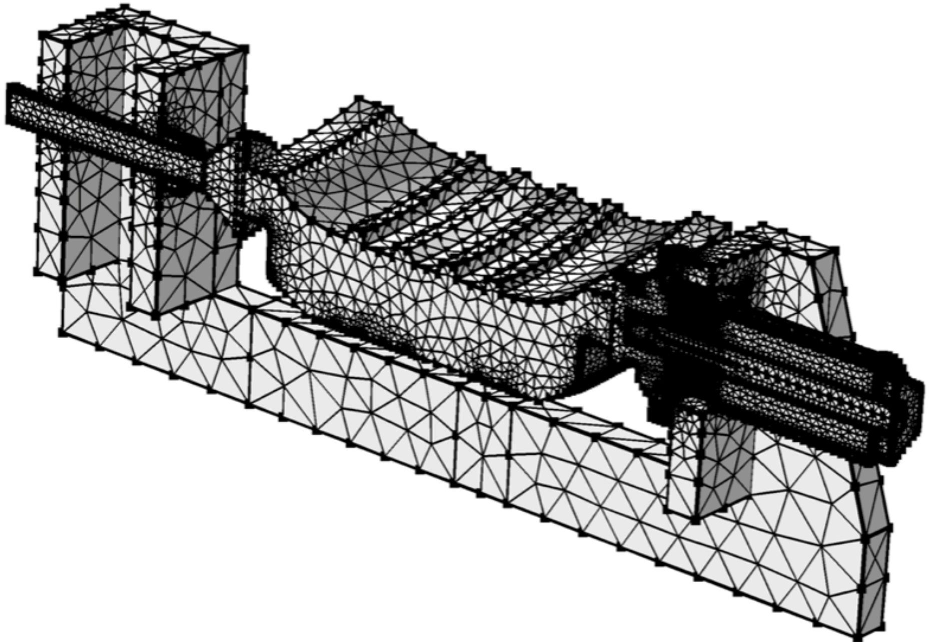
COMSOL 3D MODEL

A detailed FEM was developed for the transducer, making use of Comsol Solid Mechanics-Piezoelectric coupled modules and a frequency analysis was performed to achieve the **best design** in terms of high **efficiency** and clear resonance.



Mesh and symmetry

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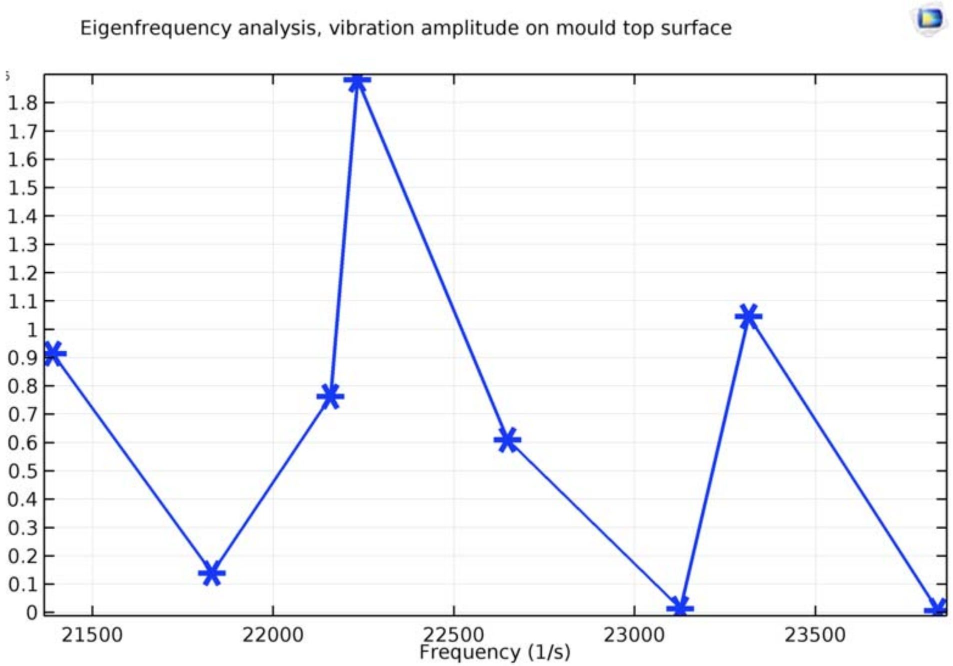
SIMULATION RESULTS - 1

First the **Eigenfrequency** analysis of the selected mold alone was performed, with the following result for the average vibration on the top surface of the mold :



Clearly a strong resonance can be excited at approx. **22.2kHz** and the ultrasound transducer was tuned accordingly.

Indeed these molds exist in various sizes and the resonance frequencies vary accordingly to their dimensions and mass, in a range from 21 to 24kHz. The results reported here refer only to an aluminum mold with medium size, for briefness.

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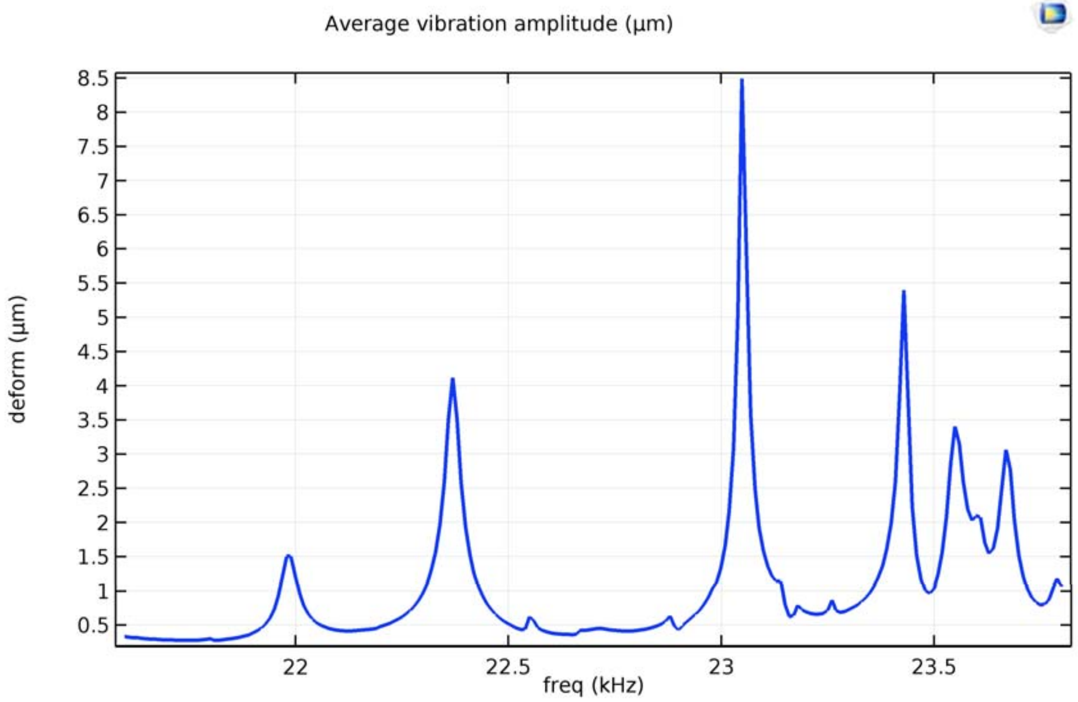
SIMULATION RESULTS - 2

Then a **frequency analysis** was performed for the complete assembly, with a frequency sweep from 21 to 24kHz for the ultrasound transducer driving voltage, in order to record the most important resonances.

The average vibration calculated on the top surface of the mould is reported, vs. frequency :



it's clear that a strong resonance is present at approx. **23kHz** , with an average vibration amplitude of the mold close to **9 microns**

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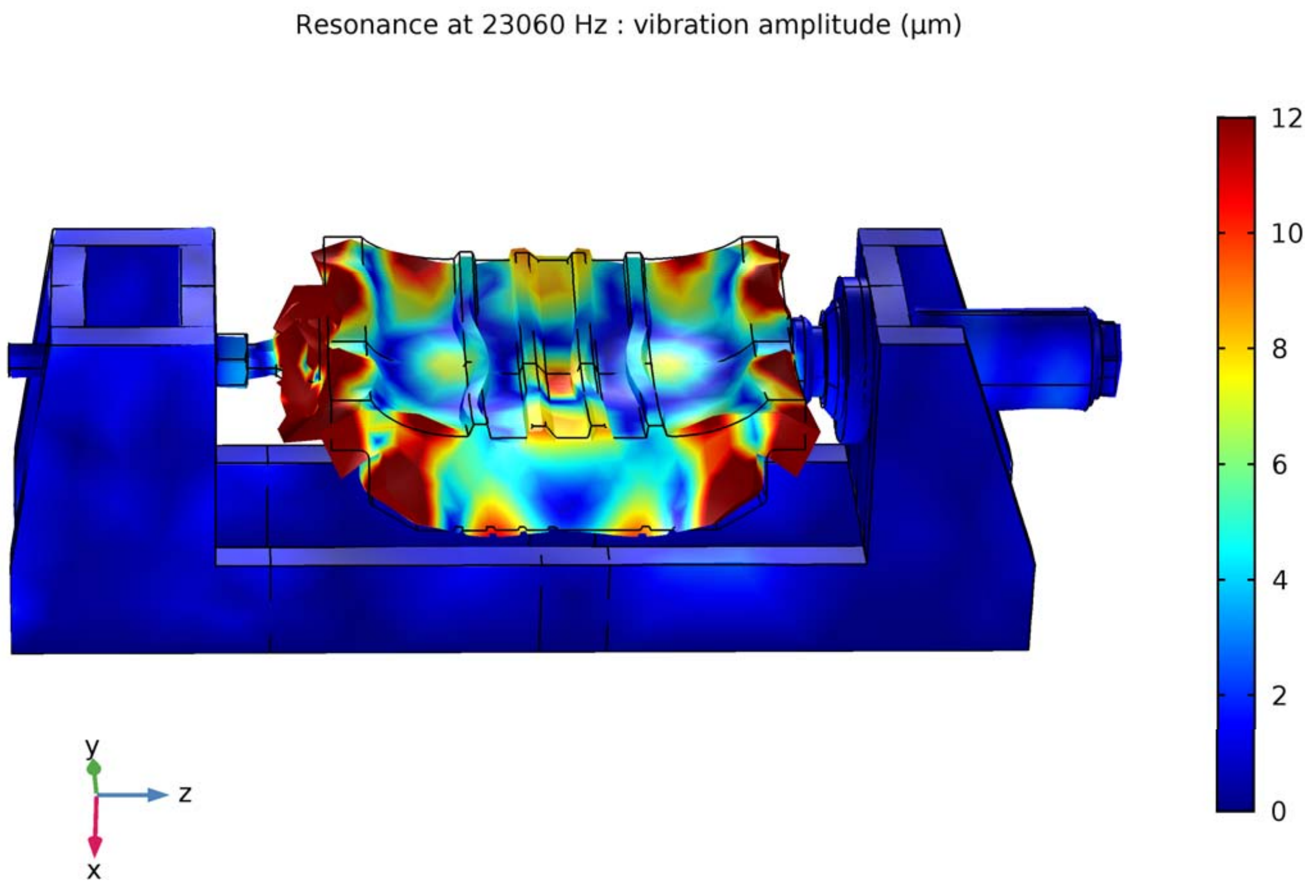
SIMULATION RESULTS - 3

And a deformation map of the structure at resonance (approx. 23kHz) follows :



the regions of maximum **vibration, at resonance, are inside the mold** and not on the external structure, as desirable.

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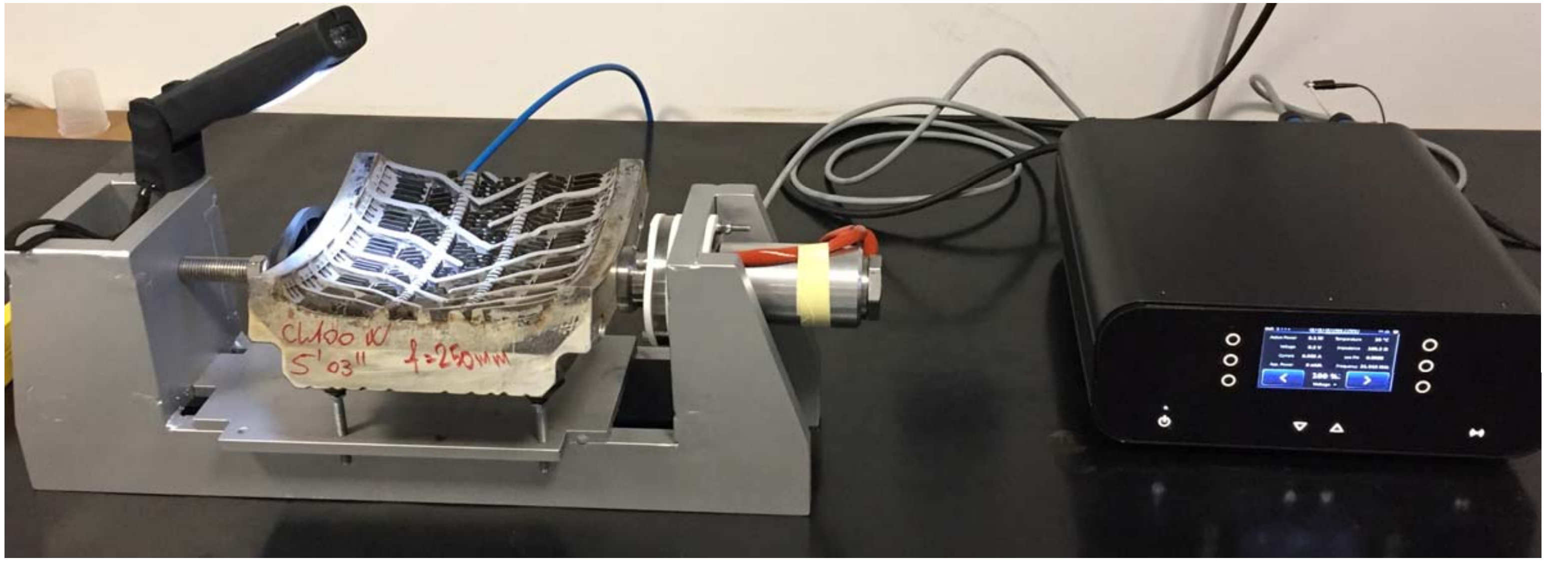
PROTOTYPE AND EXPERIMENTAL RESULTS

A **prototype was manufactured** according to the FEM design, in order to validate both the model and the invention.



The best operating condition was found to be pulsed (burst of vibration with short breaks), with very high clamping force (3000-5000N, depending on mold dimensions and weight) and a total time of vibration of 5min. The average driving power was approx. 300W.

Thanks to the accurate FEM design, at least **90% of all micro-mechanisms are always unlocked and clearly vibrate** (the remaining ones are often broken or excessively filled with dirt), allowing to say that **the invention leads to a qualitative leap in the unlocking process** with respect to current manual techniques, which are more laborious and time-consuming.

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CONCLUSIONS

A 3D FEM was developed for a mechanical resonant station that allows the easy unlocking of jammed micromechanisms inside a mold. The station consists of an electromechanical transducer and a closing clamp, which operate in such a way that at least one mechanical resonance mode of the system is excited. A frequency range of considerable practical interest for the purposes of the device was found between 21 and 24 kHz, hence in the ultrasound spectrum.

COMSOL Multiphysics® was essential for the design of the invention, in order to :
- **design** and tune the electromechanical **transducer**, with high power and efficiency
- **optimize the mechanical resonance** of the assembly

In the end it was possible to manufacture a **prototype** where at least **90% of jammed micromechanism were unlocked**, after 5min. of pulsed vibration.

[redacted]