Efficiency Improvement For Power Ultrasonic Transducer Systems

Case studies by using a simplified loading model

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CHENG-CHENG ULTRASONICS

Company Profile

- **Established in 1999**

  Beijing Cheng-cheng Weiye Ultrasonic Science and Technology Co., Ltd

  (CHENG-CHENG ULTRASONICS)

- **Professional manufacturer**

  Ultrasonic transducers, ultrasonic apparatus and piezoelectric ceramics.

- **Locations**

  Headquarter - Beijing, China

  Factory - Baoding, capital of Hebei province

  Departments - R&D, production, domestic sales, international and after-sales service

  Domestic - two branches: Zhangjiagang and Shenzhen

  International – representatives: Japan and USA

- **Partnership**

  Institute of Acoustics, Chinese Academy of Science

  Tsinghua University

  Consultants – renown ultrasonic experts within China

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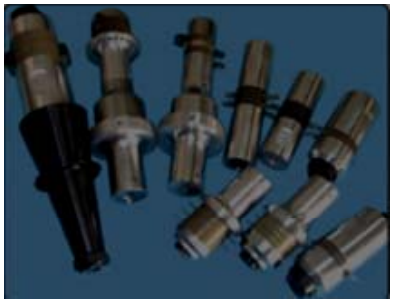
Power Ultrasonic Applications– Major Categories



- Cleaning, liquid processing, sono-chemistry, cell disruptor
- Plastic joining, metal welding, machining
- Wire bonding, therapy, surgical

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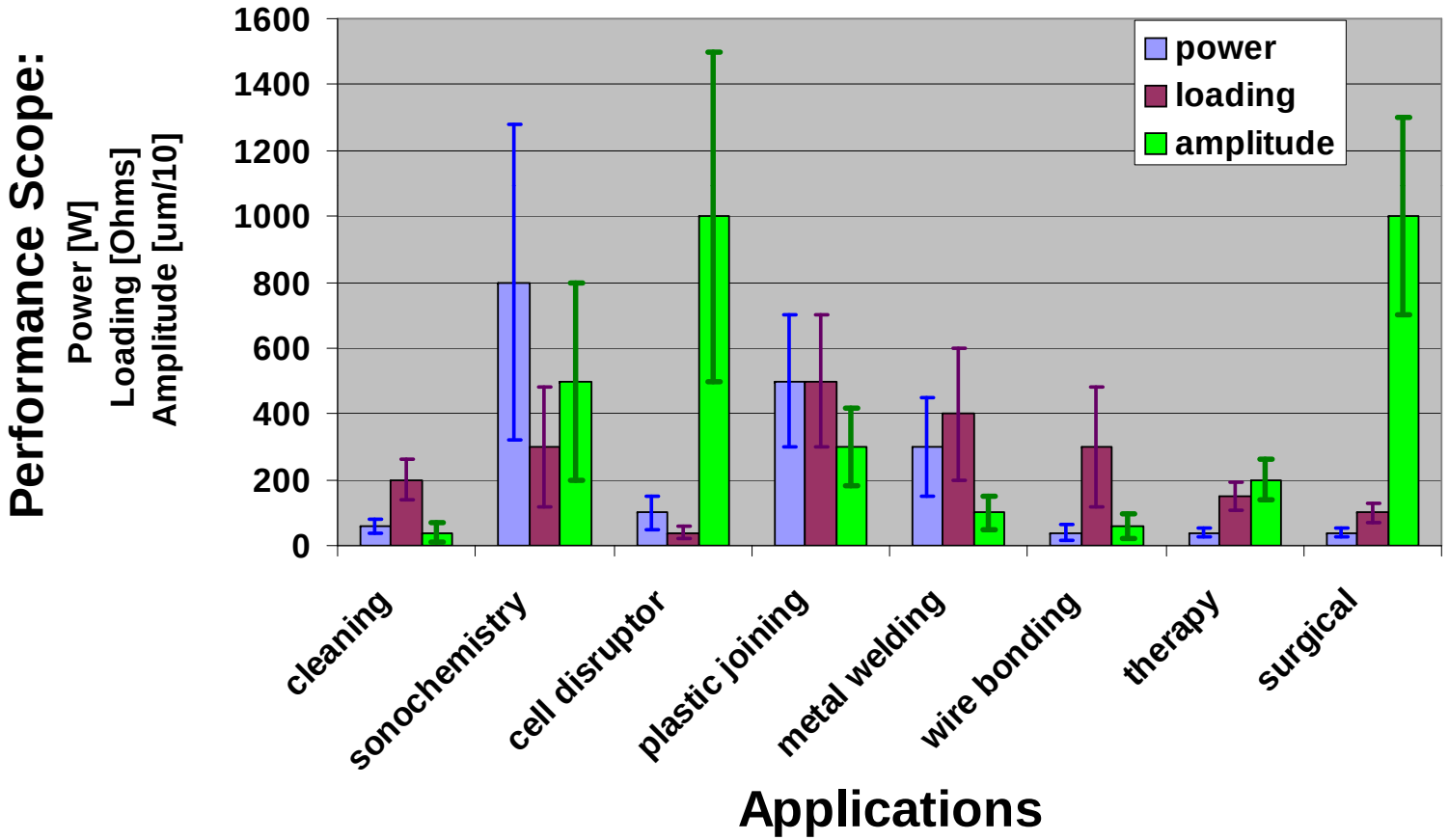
Performance – General Scope

- Rough illustration of power, amplitude and loading scopes for different applications in general



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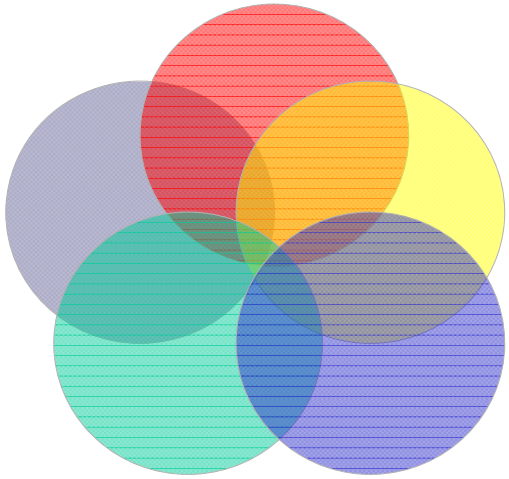
Limitation of the Transducers

Thermal –

Temperature at the source area, affected by mechanical loss, dielectric loss, coupling loss, duty cycle, cooling

Mechanical –

Nonlinear stress, preload screw, stress concentration



Size –

Space, automation, movement

Electrical –

Voltage, generator

Loading –

Output under load, sensitivity

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Design Balance

General rule

Based on the vibration output requirement (amplitude, frequency, area), use the drive source to its full extent (heating, mechanical, electrical)

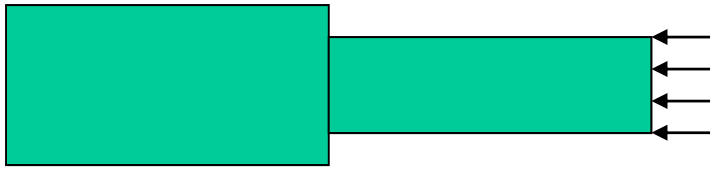
Ideal

Small vibration at drive source area
Large vibration at large radiation surface
i.e. high efficiency,
Balance –
gain, bandwidth, loading capability, size

Prior Works

- Shoh A., U.S.Patent 3524085, Aug.11, 1970 – Optimum PZT location to minimize losses
- Lemaster R.A. and Graff K.F., IEEE Ultrasonic Symposium Proceedings 1978, 296-299 – Experiment PZT location on mechanical factor Q and the vibration amplitude
- Yan Z. and Lin Z. ACTA ACUSTICA (in Chinese) Vol.20, No.1, 1995, 18-25 – Theoretical analysis of material, PZT location and volume on efficiency

Simple Model for Efficiency Estimation

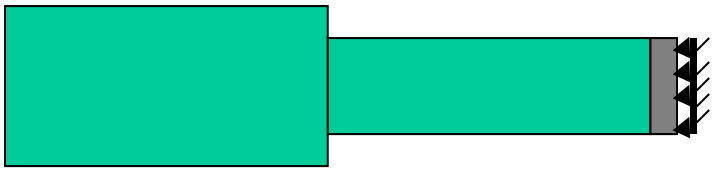


Variable: ***F/S*** *(N/mm^2)*

Efficiency = $1-V_{load}/V_0$

F: force, *V* – velocity, *S* - area

Resistance component: simulate by opposite force, monitor by the amplitude drop



Reactance component: simulate by constrained mass, monitor by the frequency shift

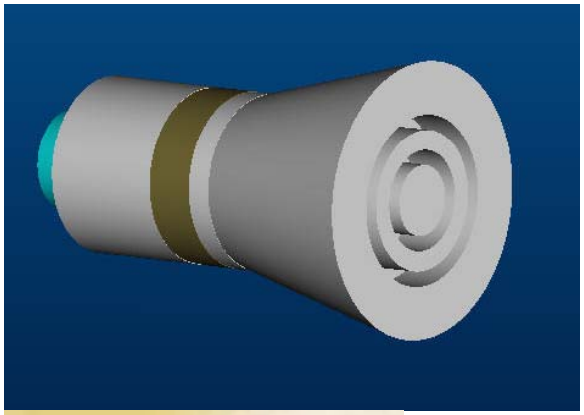
Variable: ***E*** *(Gpa) in the constrained mass*

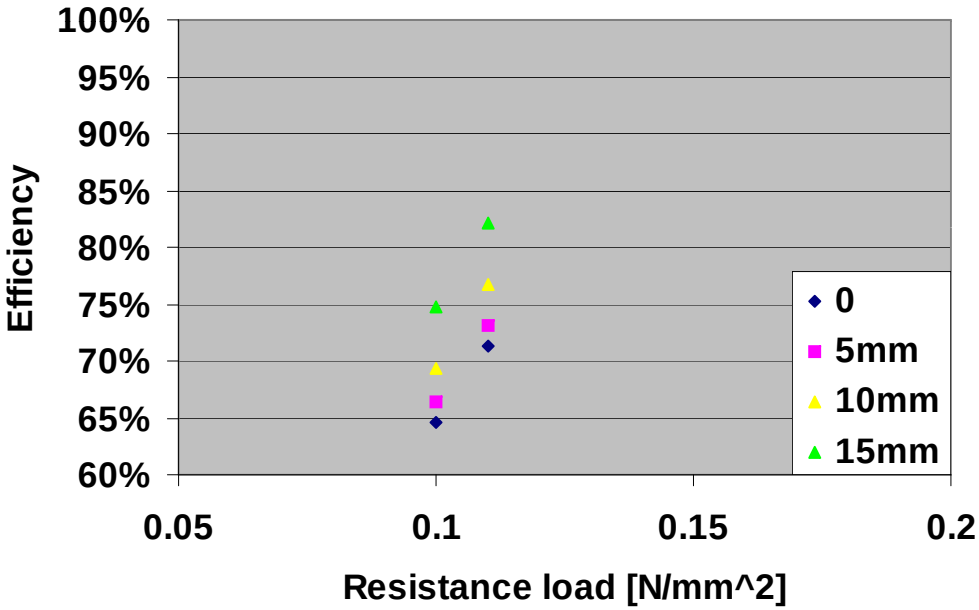
Efficiency = $V_{load} * V_0^{PZT}/(V_0 * V_{load}^{PZT})$

E: Elastic Modulus, *V* – velocity

Efficiency Improvement (EI) for Ultrasonic Cleaning

- Less critical areas: Thermal, mechanical, electrical, size
- Area to improve: efficiency, bandwidth
- Areas to look: Increase loading, optimize structure, large radiation surface, position of drive source.





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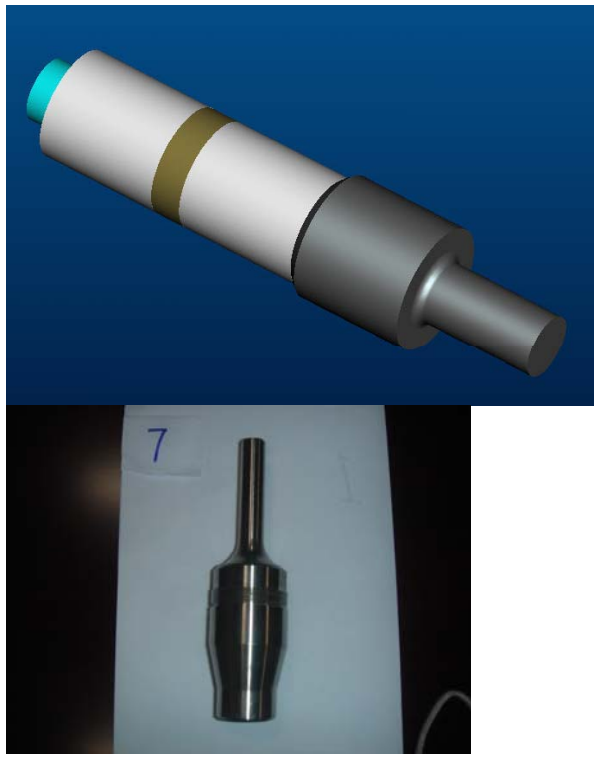
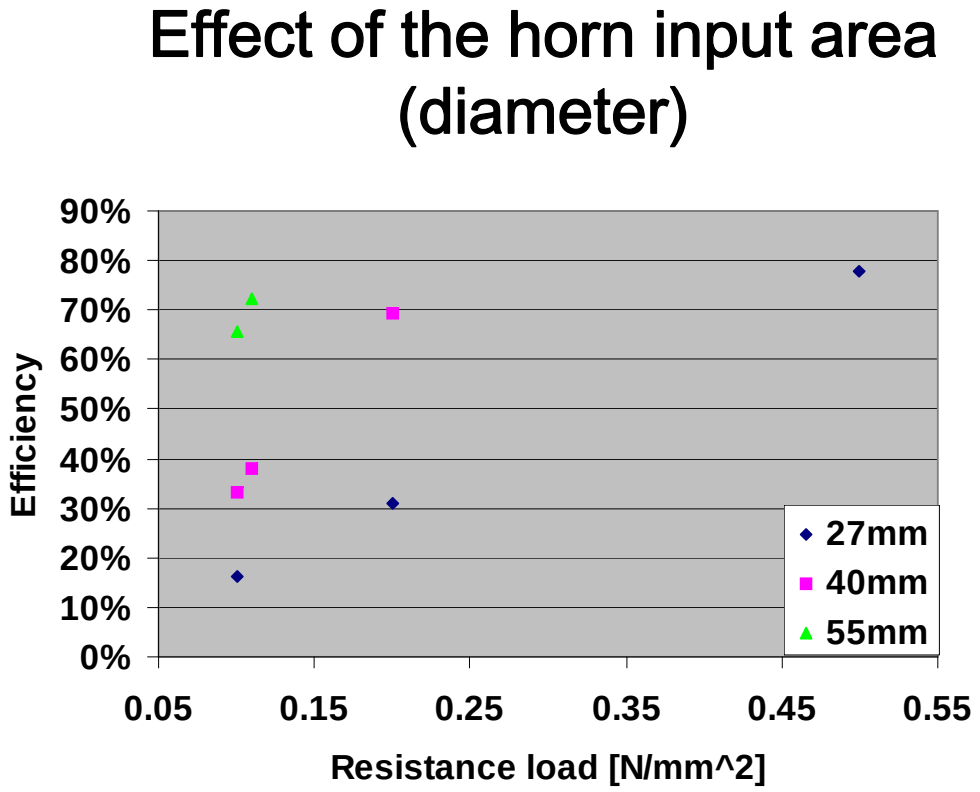
EI for Lab Scale Liquid Processing

- High amplitude
- Light load (heavy load for ultrasonic machining, drilling)
- Increase the gain, increase the booster input area, position of drive source





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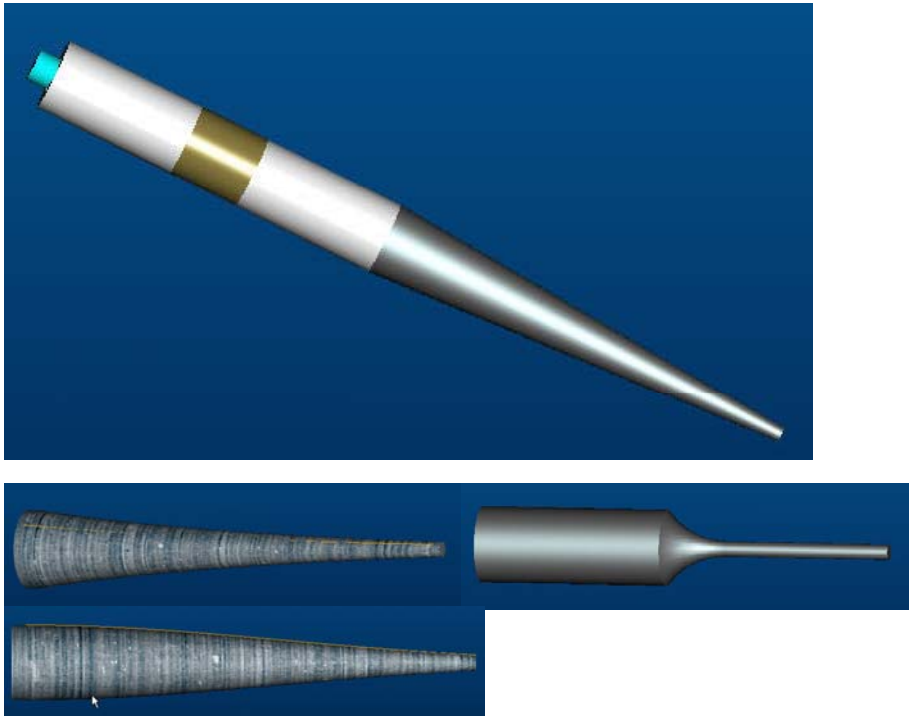
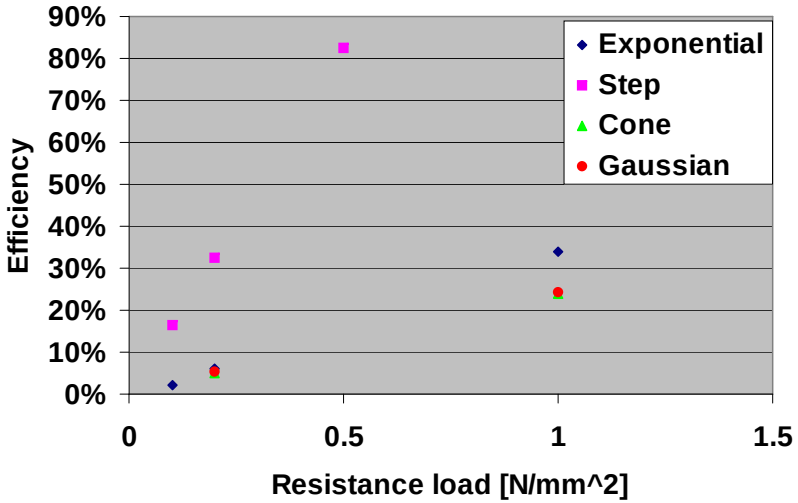
EI for Surgical System

- High amplitude, high velocity, varying load
- Material selection, size, stability, loading capability
- Large driving source, shape of the horn



Effect of the horn shape



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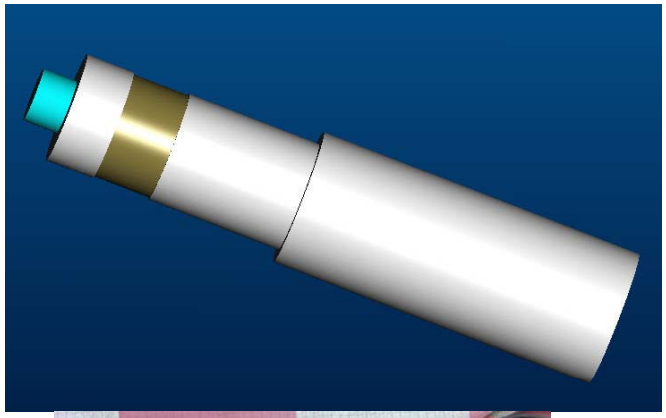
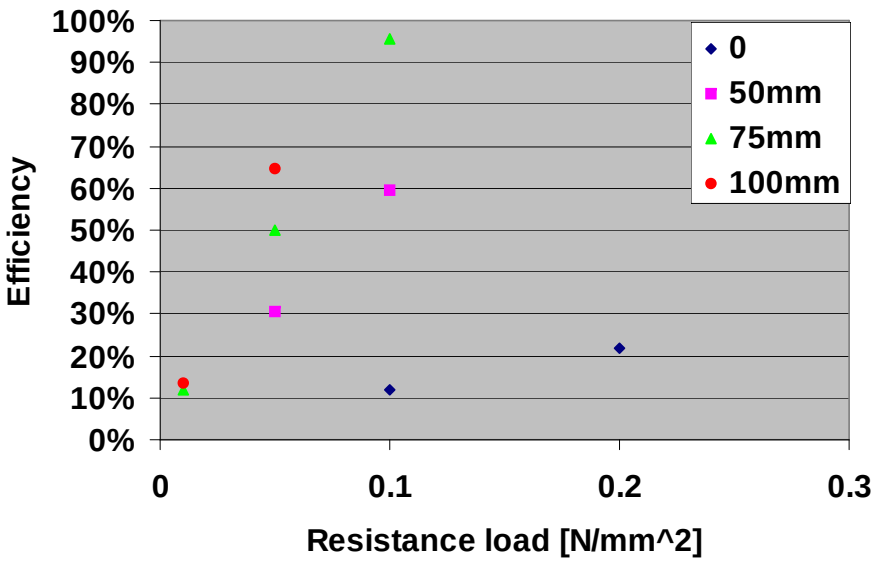
EI for Sonochemistry Large Scale

- High amplitude, large radiation surface, heavy load, high power
- High gain, increase the radiation surface, large driving source, multi-stack drive elements, mode conversion – longitudinal to radial, to strip transverse





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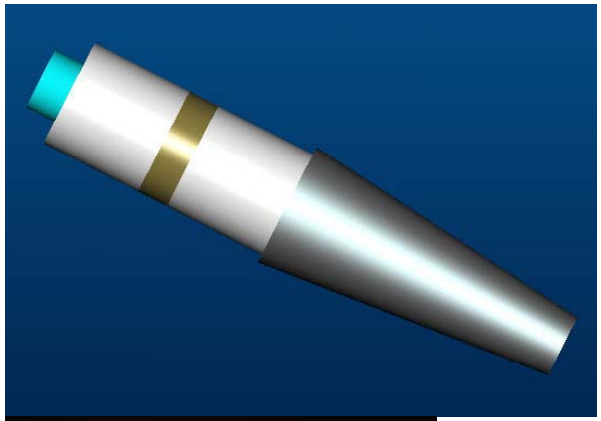
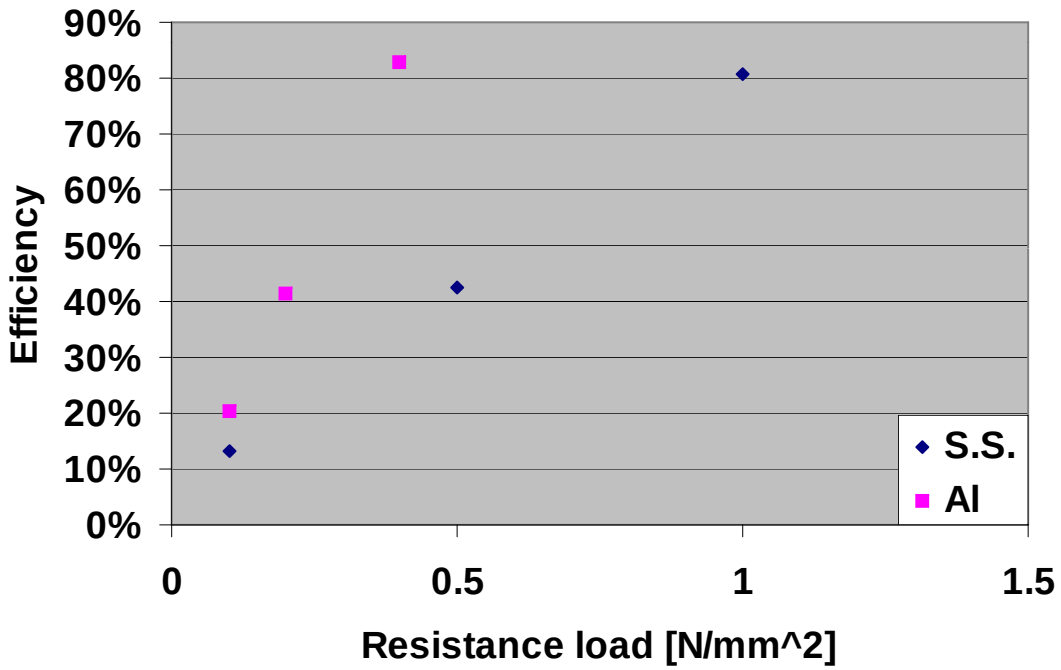
EI for Metal Welding

- High power, heavy load, moderate gain
- Parasite modes, cartridge (driver) material, drive element location and volume, less frequency shift





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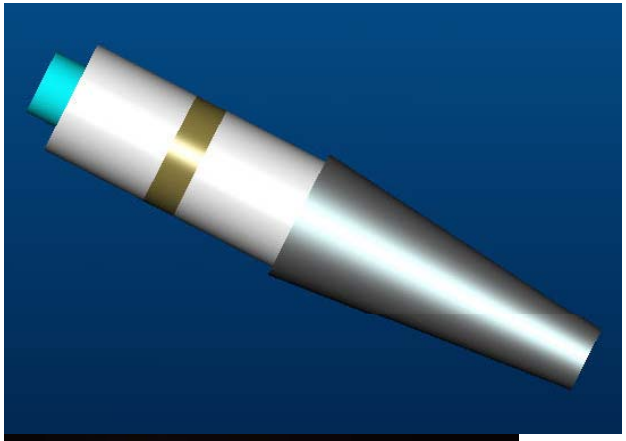
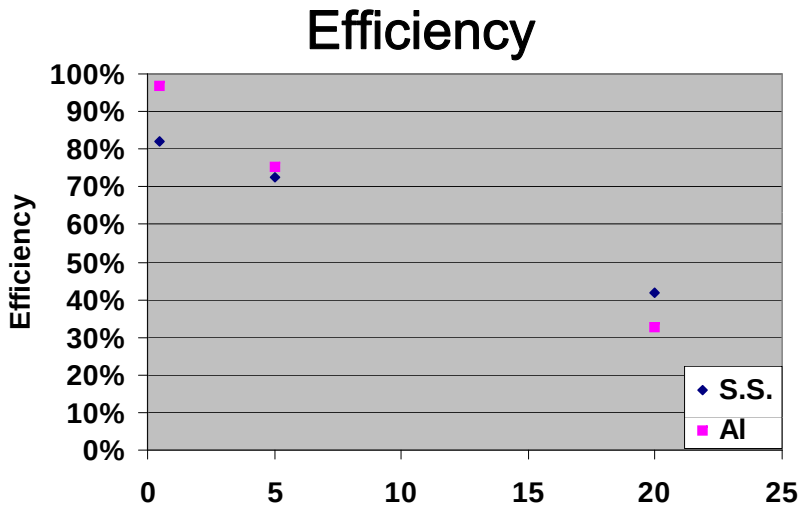
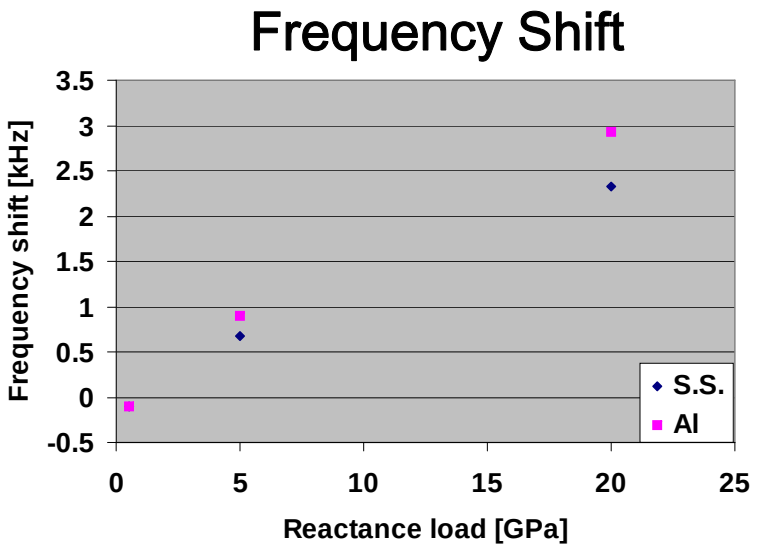
Metal Welding VS. Reactance Load







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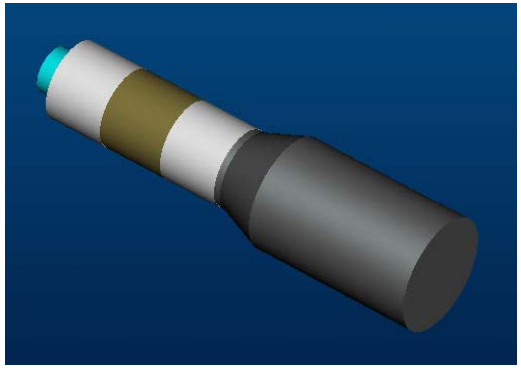
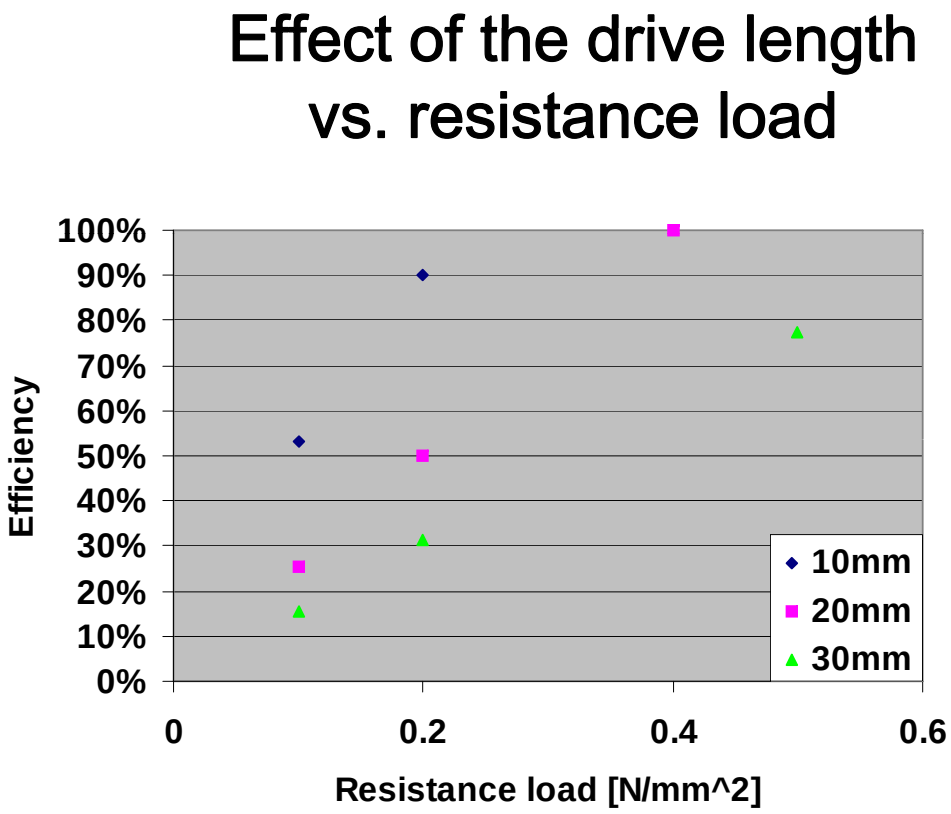
EI for Plastic Joining

- High power, large radiation area, heavy loading
- Cartridge (driver) material, drive element location and volume, less frequency shift





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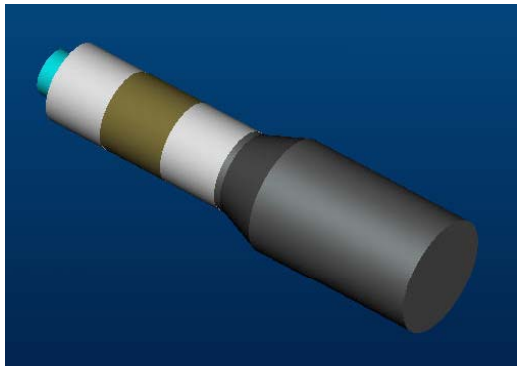
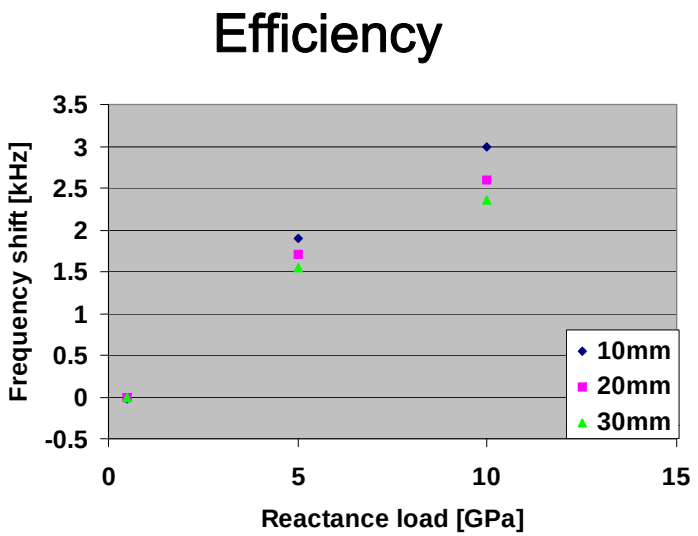
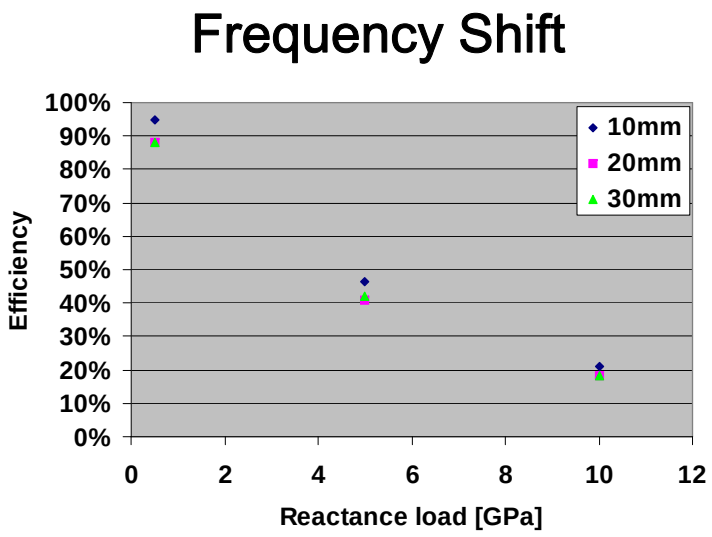
Plastic Joining VS. Reactance Load







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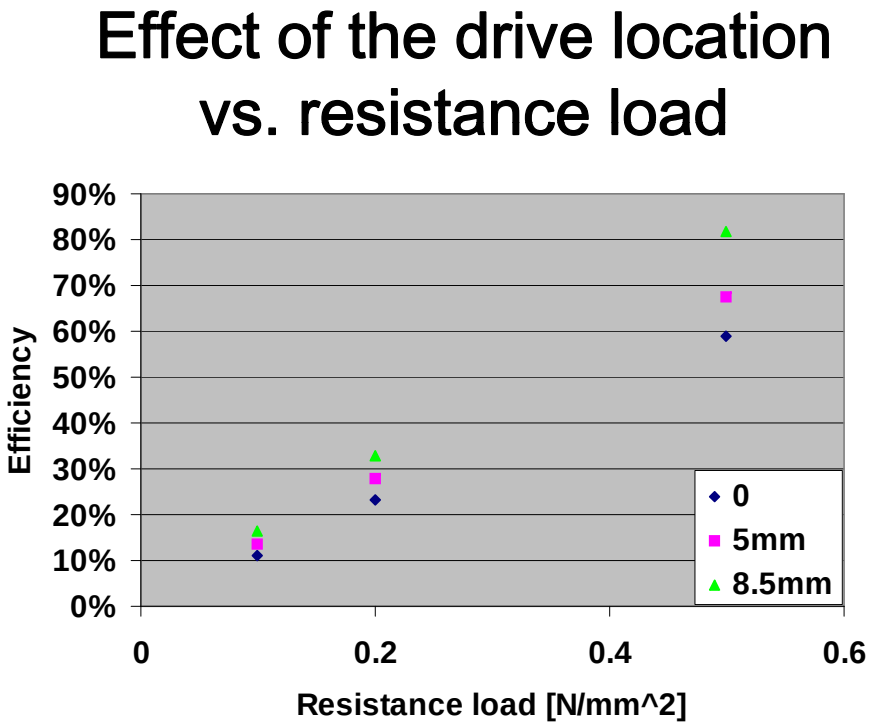
EI for Wire Bonding

- Certain gain, certain loading capability, mounting location, size, generator input
- Drive source volume and location, cartridge material, parasite modes



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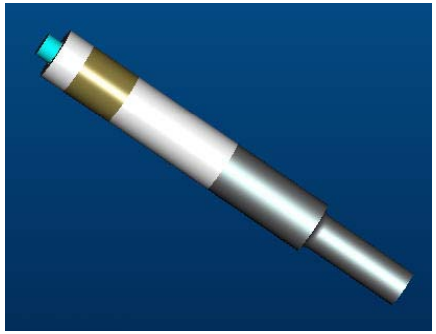
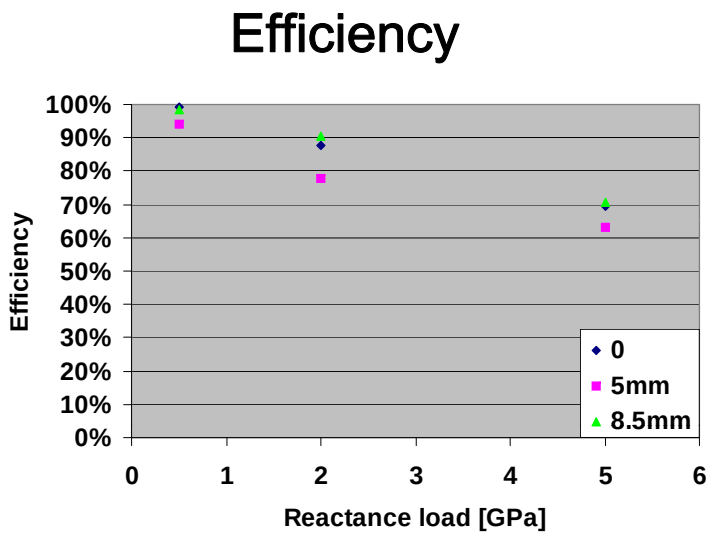
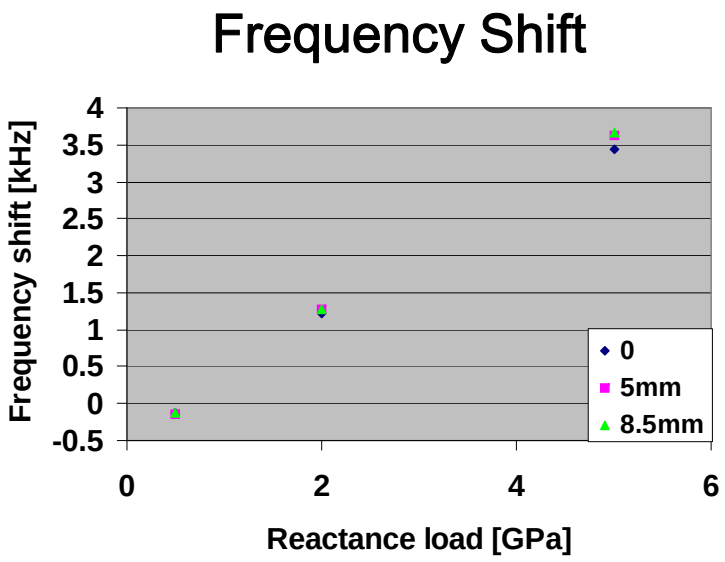
Wire Bonding VS. Reactance Load







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Summary

- ✓ Variety of power ultrasonic applications
- ✓ Simplified Design by using mechanical FEA
- ✓ Improved analysis by using the load model
- ✓ Analysis of the old designs and optimization of the new power ultrasonic transducers are made easy!
- ✓ Mass production and lowered cost are available by Cheng-Cheng Ultrasonics

Thanks!

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