MP Interconsulting

ULTRASONICS - SONOCHEMISTRY - INNOVATION

MMM Technology in Ultrasonic Extruding, Tubes and Wires Drawing, Metal Forming & Machining

Plastic Extruder Head & Ultrasonic Transducer

Plastic Extruder Head, Ultrasonic Transducer and MMM Generator

Clamp-On transducer can be fixed to an extruder head

Plastic Extruder in a Production

Tubes Drawing Die and Ultrasonic Transducers

Tubes Drawing Die, MMM Generator and Transducers

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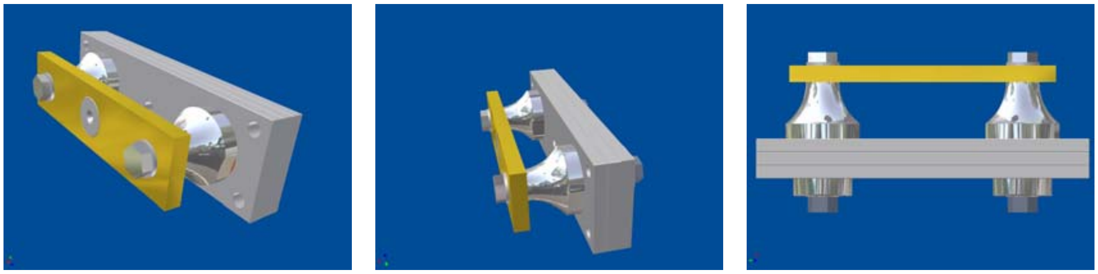
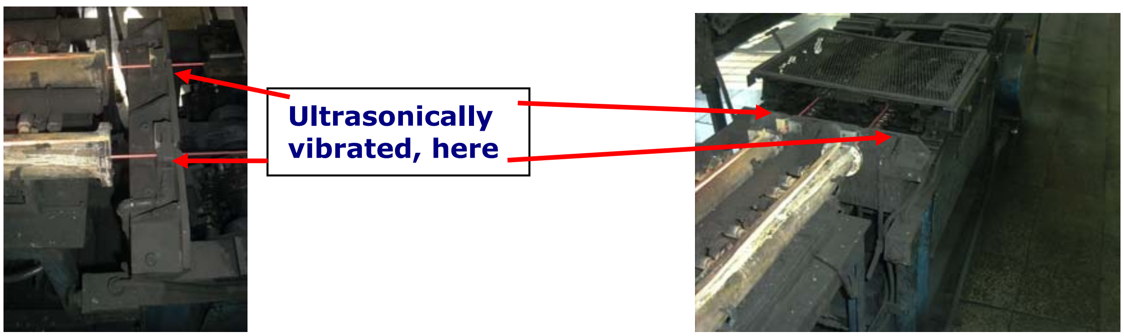
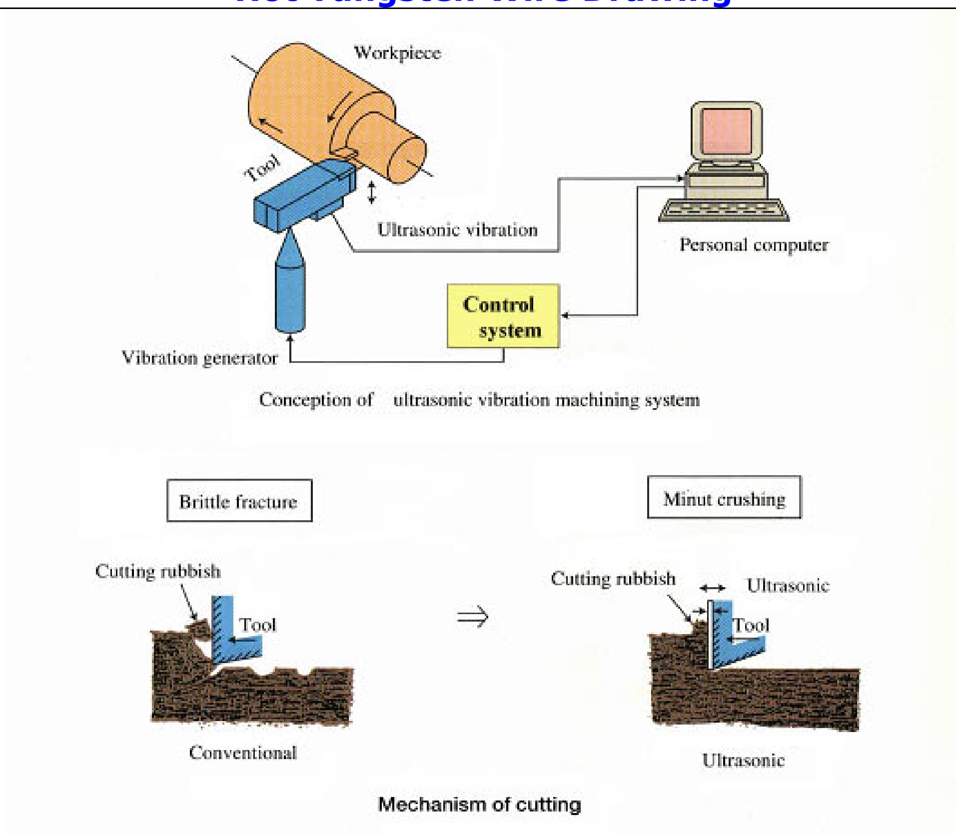


Thin Wires Drawing



Hot Tungsten Wire Drawing



Ultrasonic Machining

Ultrasonic Extrusion and Drawing

- Ultrasonic **Plastic Extrusion**
- Ultrasonic **Metal Extrusion**
- Ultrasonic **Glass Extrusion**
- Ultrasonic **Food Product Extrusion**
- Ultrasonic **Tube Extrusion**
- Ultrasonic **Profile Extrusion**
- Ultrasonic **Wire Drawing**
- Ultrasonic **Glass Drawing**
- Ultrasonic **Fiber Optic Drawing**

MPI offers the industry's one and only effective solution for ultrasonically assisted extrusion and drawing applications. Our patented MMM ultrasonic generators have the unique ability to apply high power ultrasonic energy to large mechanical systems like extruder heads and drawing dies.

In these applications the key benefits to ultrasonic vibrations are:

- Friction reduction between the tool and the extruded or drawn material
  - Improved Material Flow
  - Reduced Pressure
  - Faster Extrusion or Drawing
  - Less breakage in a drawing process improves production yield.
  - Improved surface quality of extruded or drawn material.
- In some processes the material structural characteristics may improve.

The ability to implement such systems in production environments has been restricted due to limitations of conventional ultrasonic technology. Our MMM solution is a breakthrough in this regard and allows us to greatly expand and create new applications.

Key benefits to the MMM ultrasonic technology are:

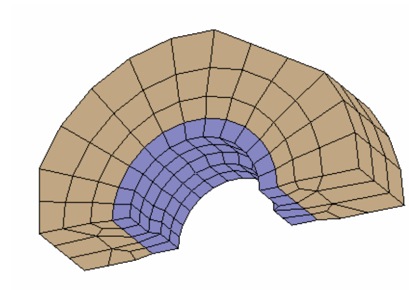
- Can stimulate wideband (sonic to megahertz) acoustic activity throughout the extruder head or die greatly improves the process.
- MMM eliminates standing waves, the areas of low and high acoustic energy, as seen in fixed frequency systems.
- MMM technology will effectively drive most any size tool or mechanical systems.
- Wave-guides connecting the transducer to the tool can be extended up to 3 meters for very high heat environments or unusual applications requiring the transducer to be located away from the working tool.

Example: Plastic Extruder Head

Tube Extruder Die shown with dual driving transducers

About powerultrasonics.com

History



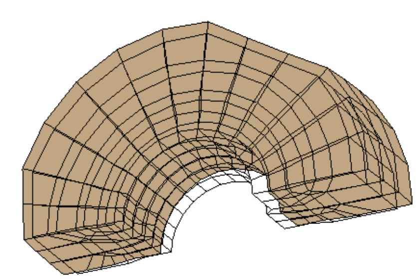
Power Ultrasonics (www.powerultrasonics.com) is a web site set up by Chris Cheers to promote high power industrial ultrasonics and provide information on current technology, equipment suppliers and new applications.

Chris's experience in this field began with his PhD, the subject of which was the development of ultrasonic dies for metal forming. The research work, carried out in the late 1980s, led to the development of a new process for manufacturing steel aerosol cans which is still in production in the UK.

Other projects Chris developed while working for the Metal Box (subsequently Crown Cork and Seal) research establishment at Wantage, UK included new machines, processes and tooling for can wall ironing, can shaping (by blow-forming and other methods) and food processing.

Chris left Crown Cork & Seal at the end of 1998 to become an independent consultant, and now lives near Sydney, Australia. In addition to ultrasonics he offers consultancy in metal packaging and sheet-metal forming, as well as software programming, particularly for Internet applications.

Ultrasonics in metal forming



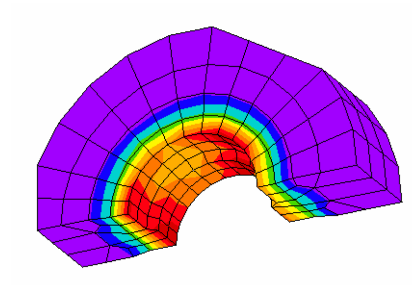
Since the 1970s ultrasonics have been applied to many metal forming processes, particularly tube drawing, wire drawing and deep drawing. Research results were generally promising - remarkable reductions in draw force and / or increases in draw ratios were often reported. The most popular theories put forward to explain this were:

1. the ultrasonics were working the metal, like a high speed forging process.
2. friction was reduced, eliminated or in some cases even reversed.
3. yield stress / work-hardening was reduced (ultrasonic softening).

Despite encouraging research results, the process was not widely accepted in production. This is believed to be a result of the equipment then available for generating ultrasonics (expensive and inefficient) plus a lack of understanding of the die vibrations – successful die designs were largely a matter of chance.

Generating equipment has since improved greatly with extensive use of ultrasonics for plastic welding. Modern systems are now relatively cheap and extremely efficient - ideal for metal forming applications. Understanding and controlling the die vibrations was the purpose of Chris's PhD research – with the release of his thesis in 1998 (after a 3-year moratorium) that knowledge is now available to all.

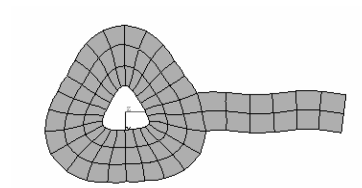
Ultrasonic dies



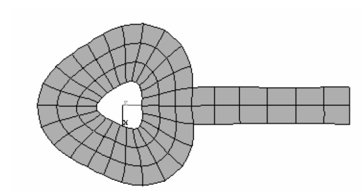
When applying ultrasonics to an axi-symmetric forming process (such as tube drawing), the most effective and practical approach is to use radial vibrations, ie. the die expands and contacts as a ring. At typical ultrasonic frequency and amplitude the die surface may achieve accelerations around 15 000 g (fifteen thousand times gravity).

To make this possible the die must be resonant - effectively ringing like a bell. The transducer is necessary only to start up and maintain the vibrations, it does not provide all the force required to move the die. This is why one transducer can cause the whole die to expand and contract uniformly, but it can only work if the resonant frequency of the die matches the operating frequency of the ultrasonic system.

To achieve this a special construction is required - the die is assembled from a hard inner part (generally similar to the standard die) and an outer part which fixes the resonant frequency of the assembly. Successful die design requires that the material properties and dimensions of the two parts combine to produce a complete die that is resonant at the correct frequency.



There is a further problem, however, which was not generally recognized in earlier research. There is a multitude of other possible modes of vibration, some of which appear at very similar frequencies. These "harmonic modes" have little effect on the metal forming but conversely are easy to excite, so that in use the die can switch from the required radial mode to one of the unwanted modes, making it completely ineffective. The die design must prevent this.



Finite element analysis (FEA) is essential to ultrasonic die design - for any proposed die it predicts the resonant frequencies of both the radial and the unwanted modes and allows design optimization without building multiple prototypes.

Process limitations

Dimensions - The use of ultrasonic frequencies (above the human audible range) dictates a maximum internal die diameter and a maximum die length - both about 2.5 to 3 inches. High stresses would require operating at reduced amplitude for internal diameter less than about 1 inch.

Materials - The die outer is subjected to high cyclic stresses. It should be made from titanium alloy for production tools, although high-strength aluminum can be used for experimental prototypes. Ceramics and tool steels are ideal for the die inner. Some materials, notably tungsten carbide, are NOT suitable for use in ultrasonic dies because of their extremely high modulus and density.

Workpiece - To avoid de-tuning the die the workpiece (or that part of it in the die) should be relatively low mass and low stiffness, compared to the die.

Temperature - The transducer must be kept below about 70°C (160°F). In use at ambient temperature dry cooling air circulated around the transducer should be sufficient, but for high temperature applications more effective cooling systems would need to be developed.

Intellectual Property

Crown Cork and Seal has two patents on this process applied to metal cans and packaging (see below). The use of ultrasonic dies in tube drawing and other metal-forming applications pre-dates these patents and is not known to be restricted by any current patent.

Publications

"Reducing the diameter of tubular bodies" US patent 4854149 (1989). Inventors Paul Porucznik and Chris Cheers.

"Maintaining a preferred vibration mode in an annular article" US patents 5165309 and 5095733 (1992). Inventors Paul Porucznik and Chris Cheers.

"Design and optimization of an ultrasonic die system for forming metal cans" PhD thesis, 1995. Chris Cheers

Applications and benefits of ultrasonic metal forming, tubes and wires drawing, and machining are already known. Most of the difficulties are coming when applying constant frequency ultrasonic technology, such as:

- **A) Need for precise resonant tuning of all vibrating elements. Often it is not possible or practical to design all elements of drawing systems to resonate on certain frequency.**
- **B) Resonant frequency tracking-problems in connection with dynamic and heavy loading are so big, that in many cases traditional technology can not be applied.**

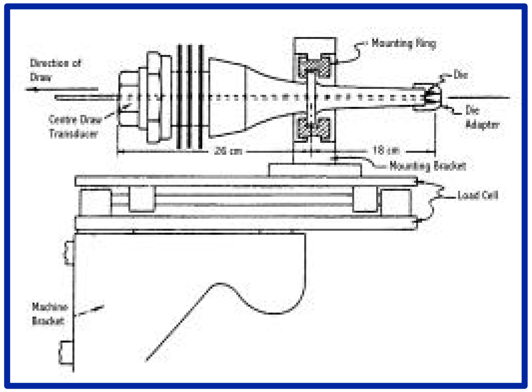
AND HERE IS THE PLACE FOR MMM TECHNOLOGY: no dependence of loading, no need to make resonant tuning, dynamical and very much variable loading is not making tracking problems, almost any mass can be efficiently vibrated... Only our imagination is creating the limits.

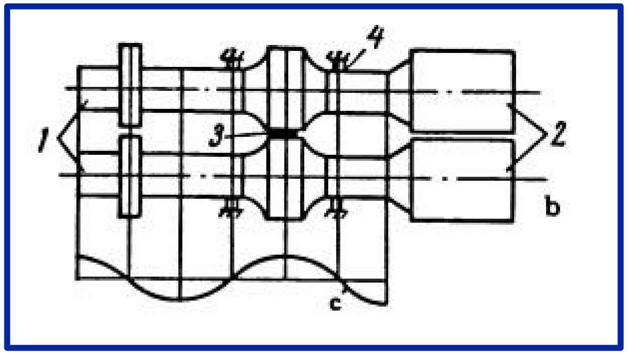
Ultrasonic Drawing of Composite Superconducting Wire

Karl Graff, EWI/Global

Mike Tomsic, Global

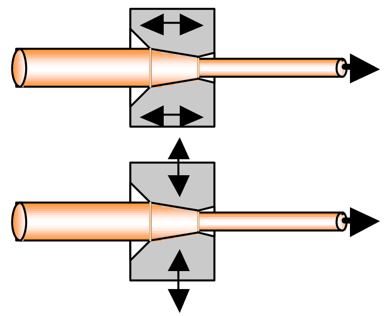
Edward Collings, OSU

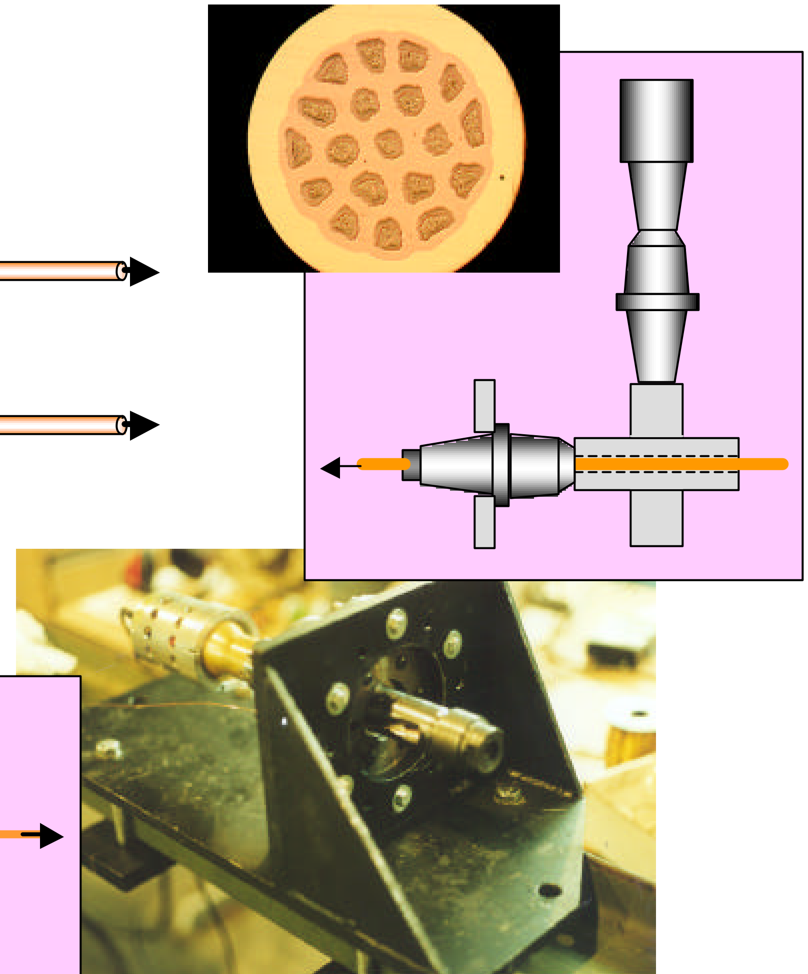


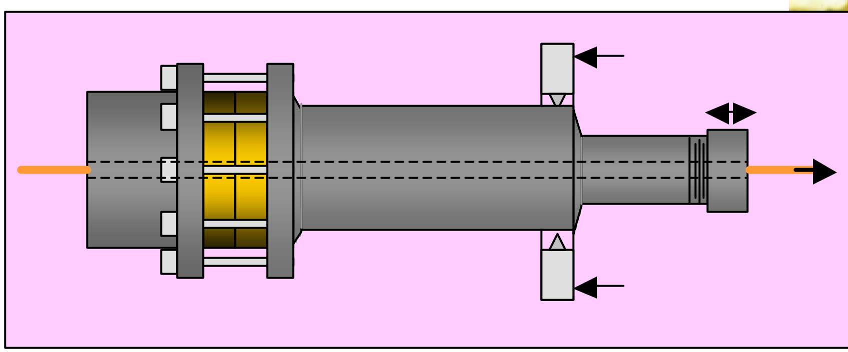


Outline

- Objective
- Approach
- Results
- Phase 2

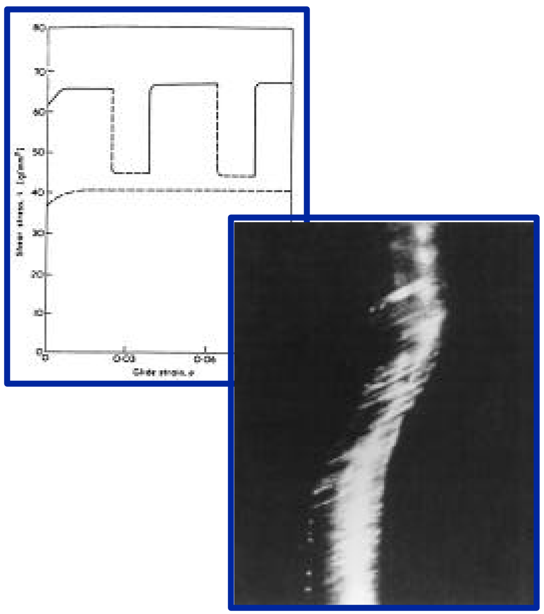


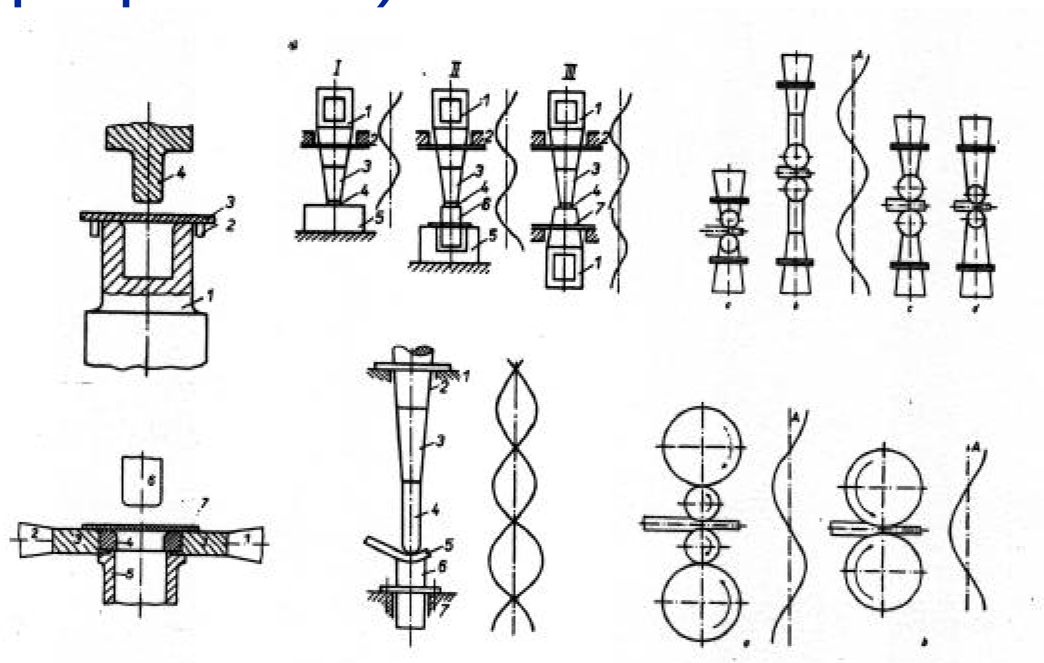




USWD - Background

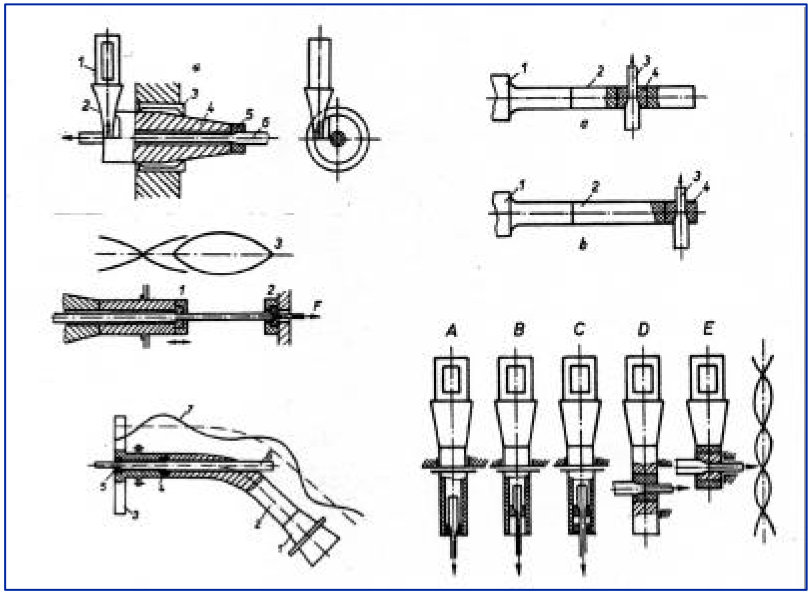
- "Acoustic softening" report led to much work in metal forming
- Deformation mechanism still unclear (acoustic softening or superposition)

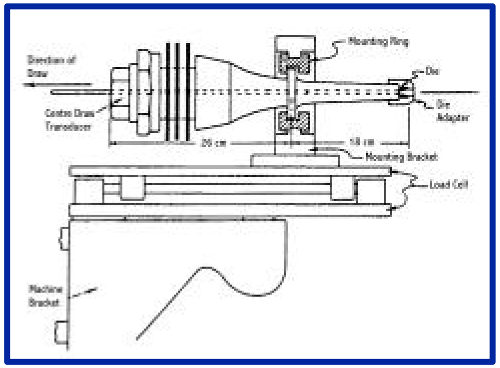




USWD - Background

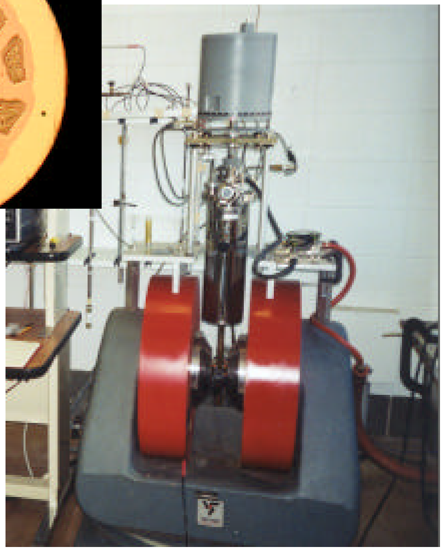
- Extensive work in WD/TD continues
- Advantages sought (reduce force, area reduction, finish, die life, speed)
- Specialty applications

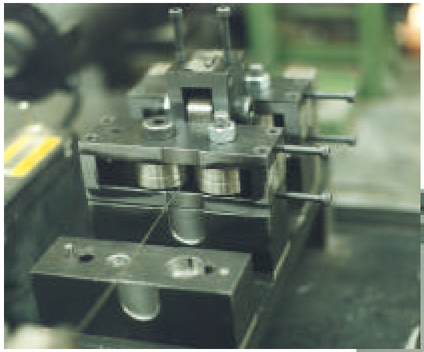


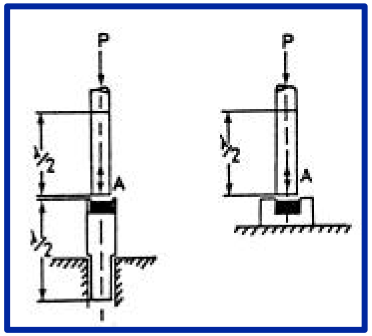


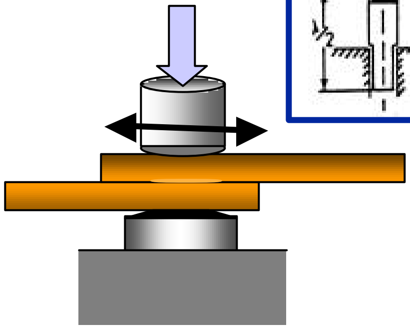
Current Application

- Superconducting wire
- Key issue – breakage
- Bonding/consolidation
- Global/OSU background



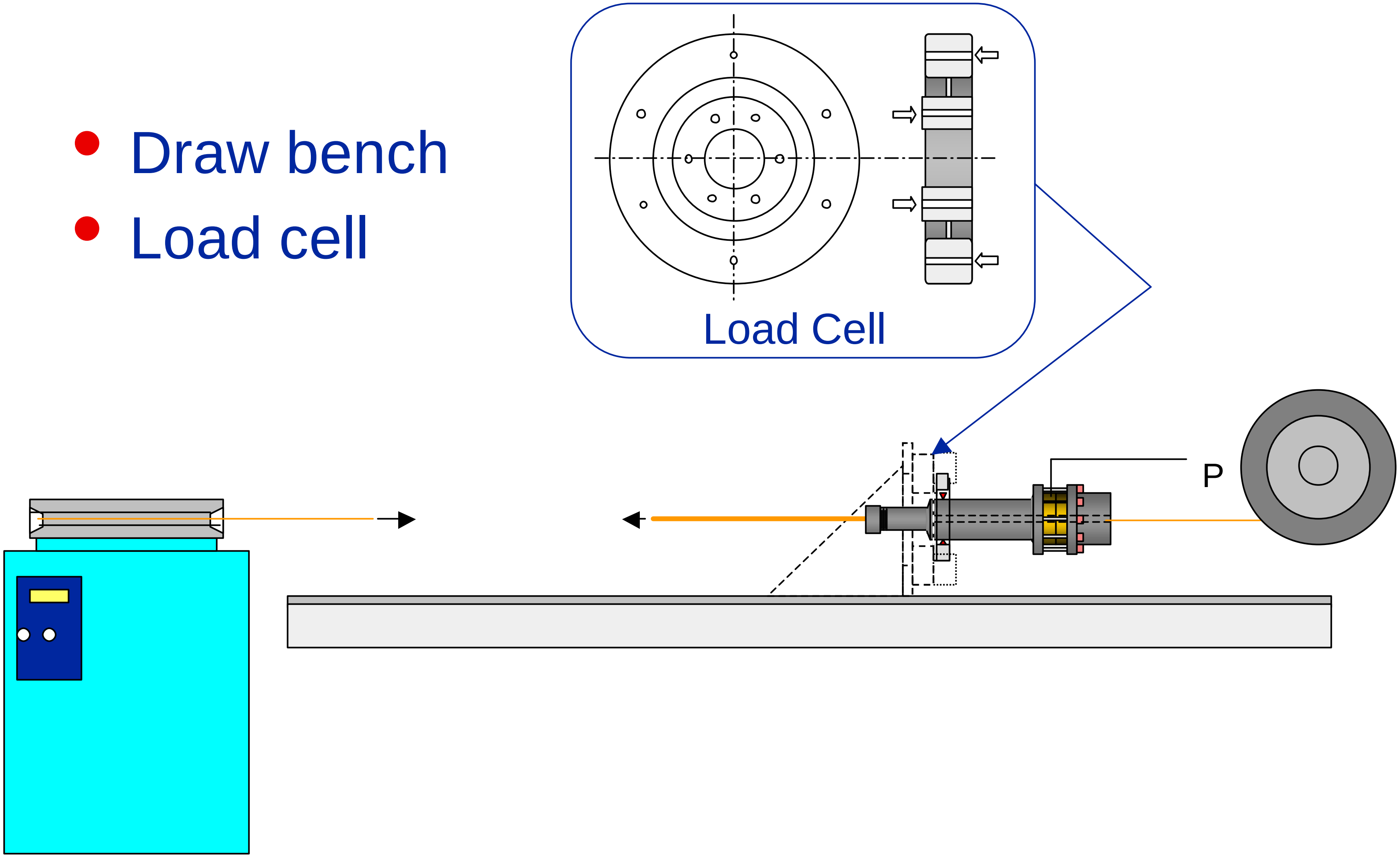






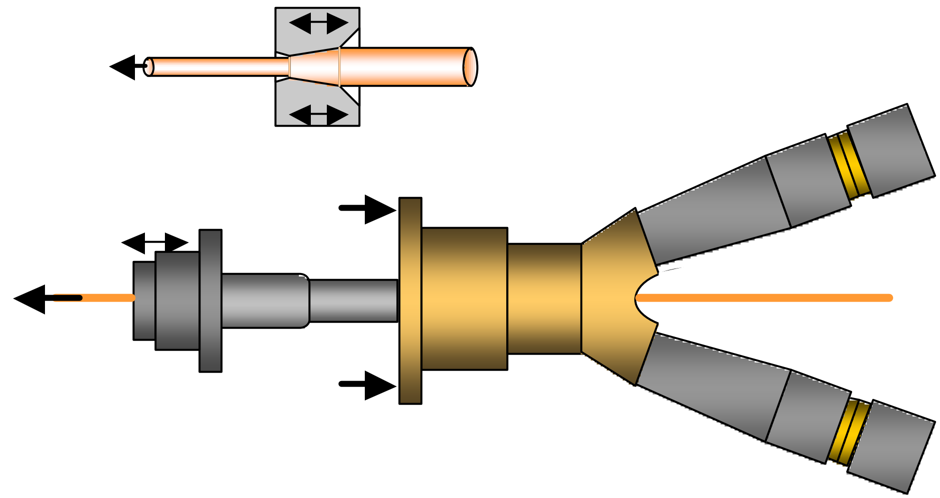
Wire Drawing System

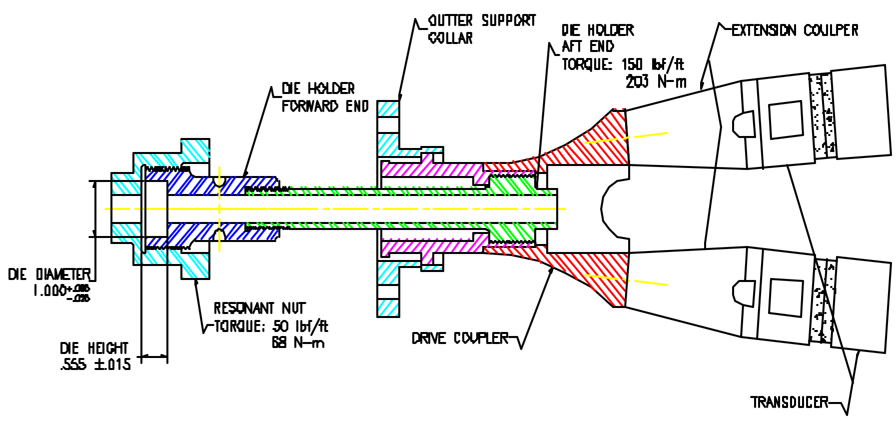
- Draw bench
- Load cell

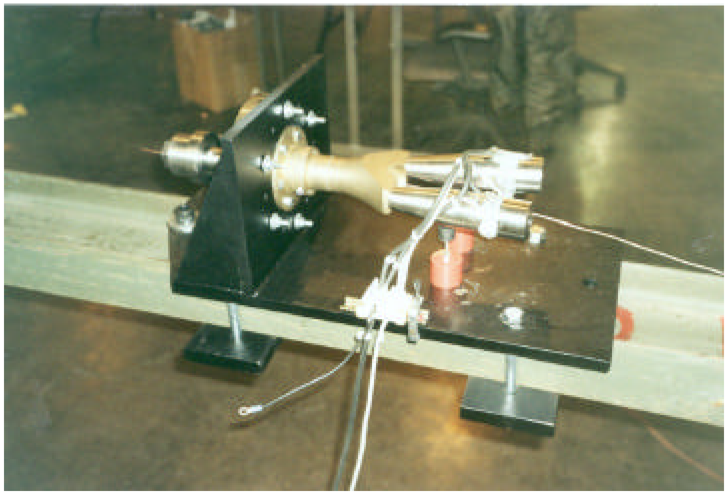


Y-Coupler System

- LM system
- 28 kHz, rigid mount
- Results, Plan B

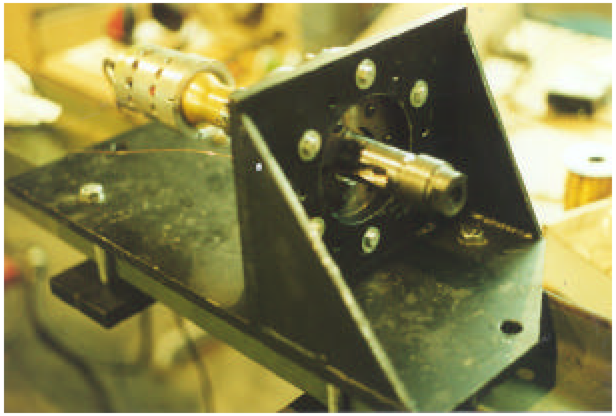


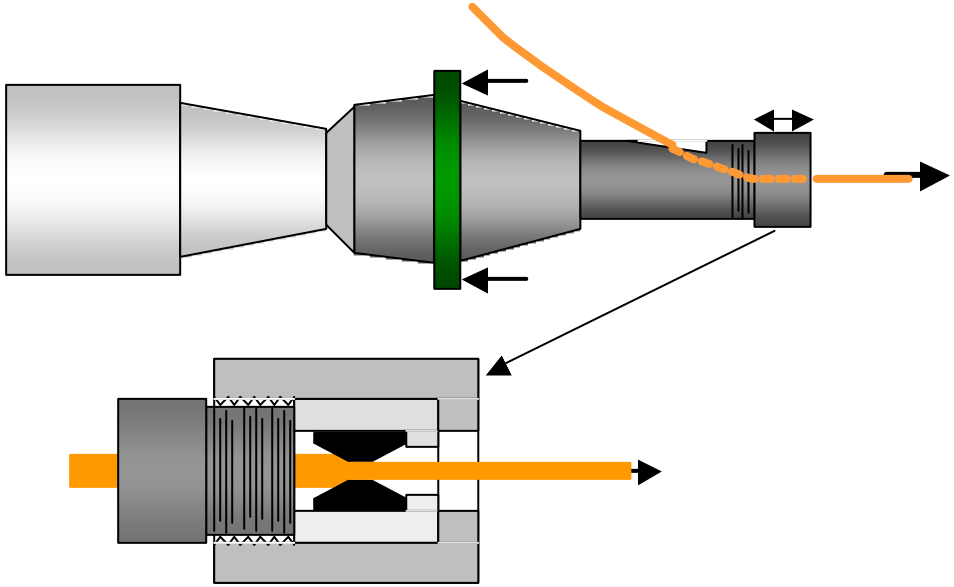


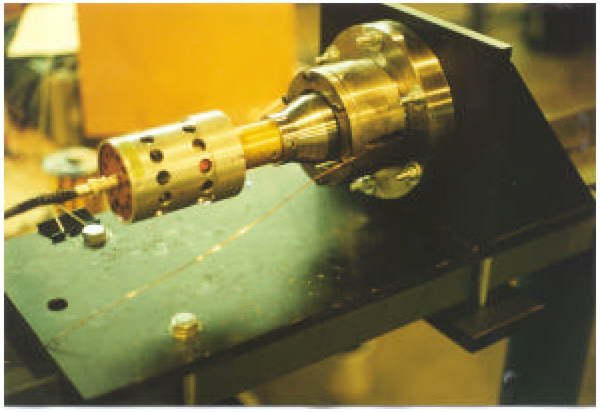


Side Draw System

- Standard Xducer, booster
- Special sonotrode
- Results

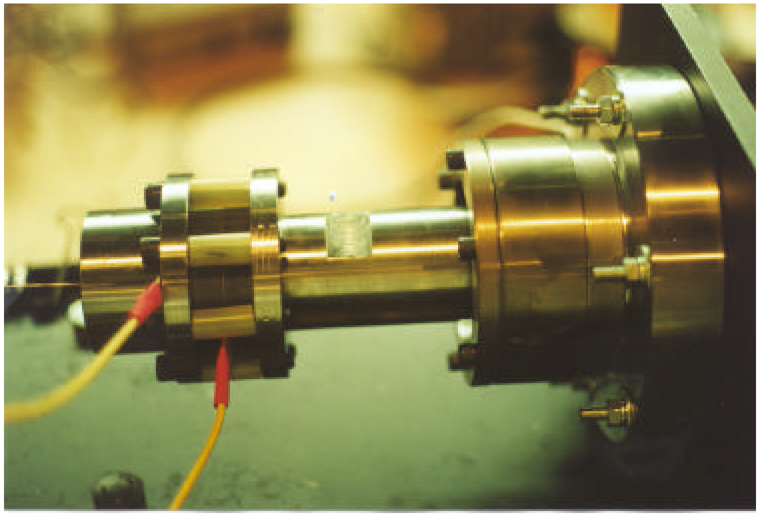


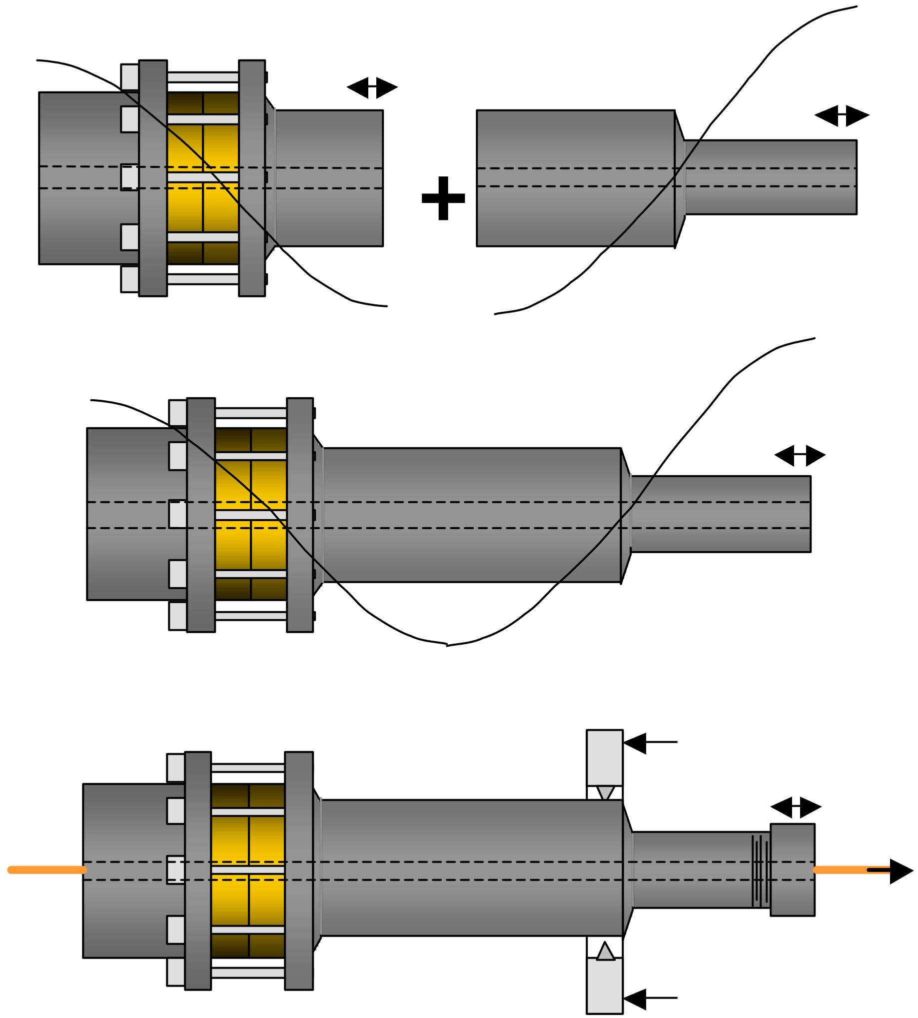




Center Draw System

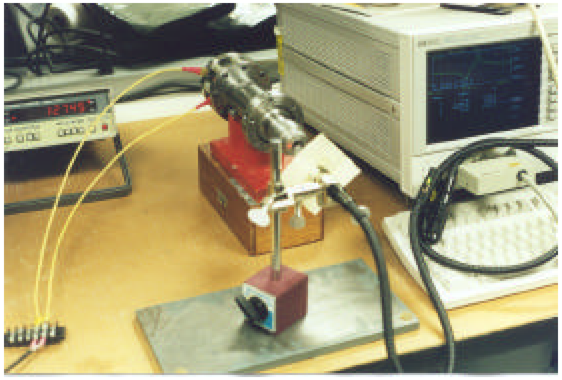
- 3-step design
- Results



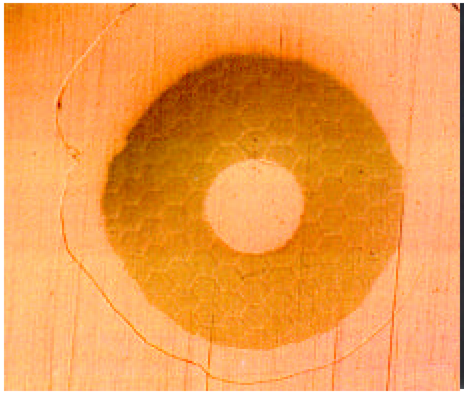


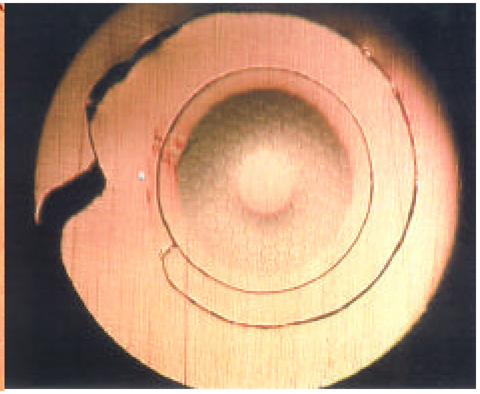
Results – Phase 1

- Plan B1, B2 systems developed
- Draw force reductions
- Evidence of bonding



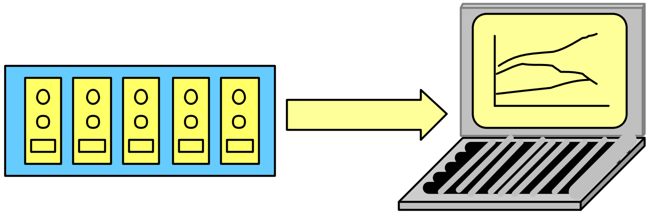
System	% Force Reduction
Side Draw	29
Center Draw	26

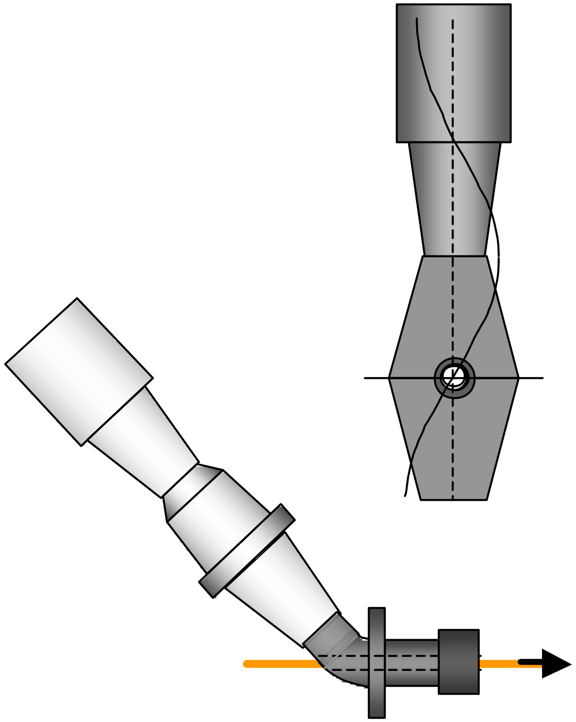


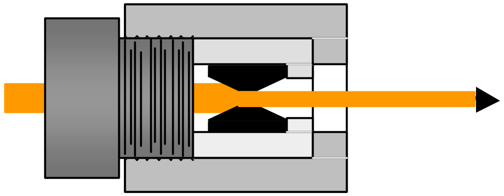


Phase 2 – Objective/Approach

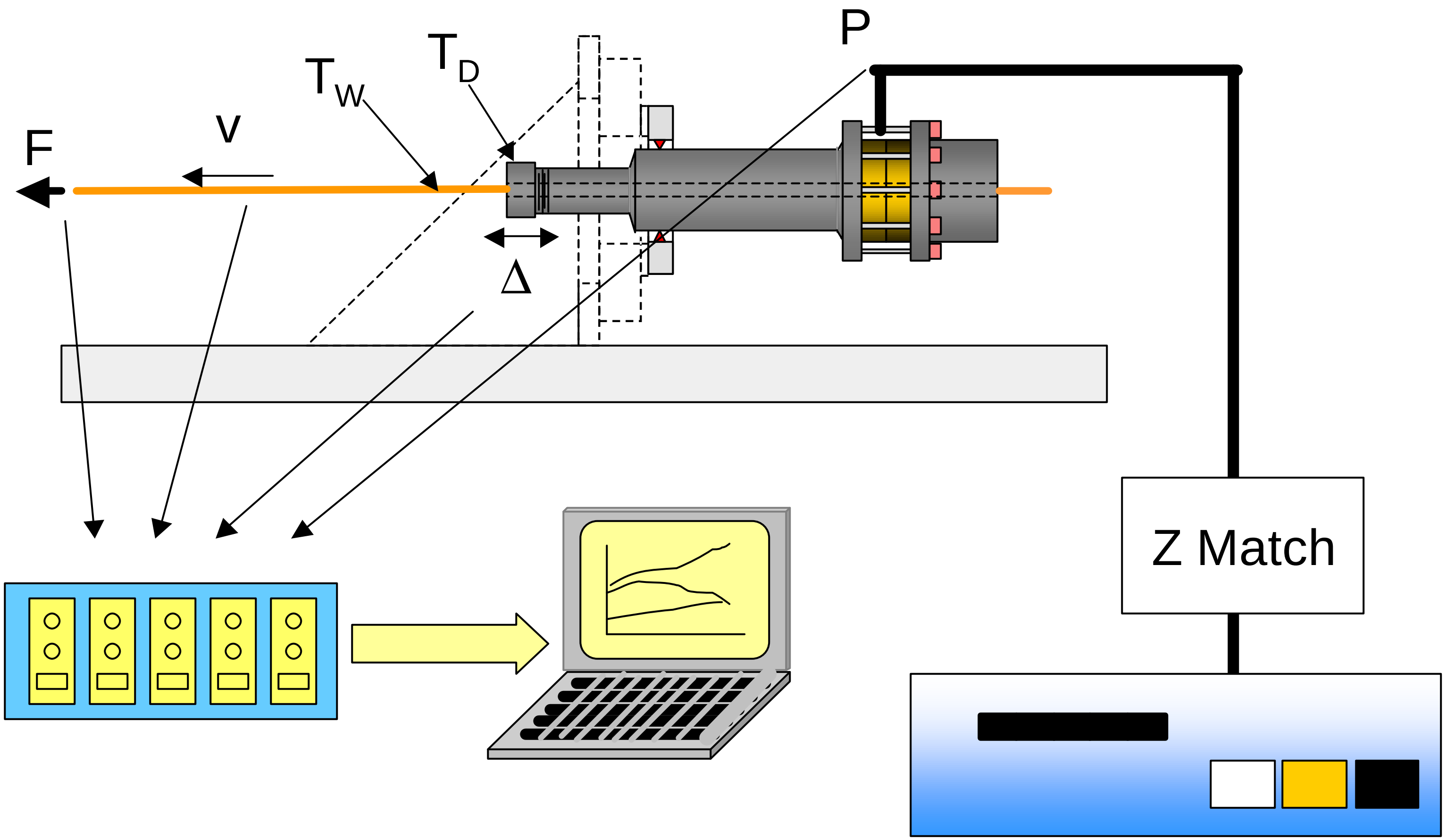
- Can US yield long draws, other benefits?
- Optimize LM system
- Develop radial mode
- Die design
- Instrumentation







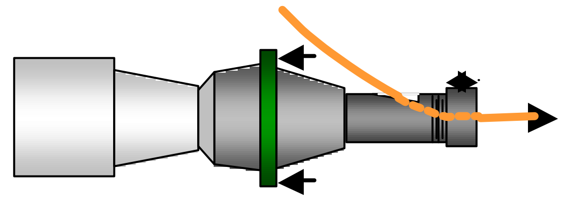
Instrumentation



Longitudinal Mode Options

1) Side draw
2) Center draw
3) Y-coupler
4) Cross die
5) Curved line

1)



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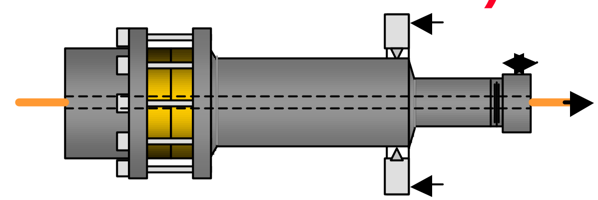
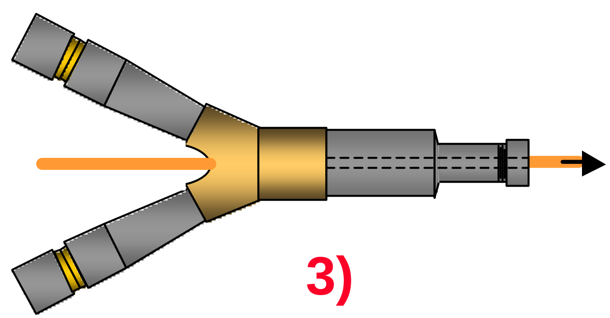
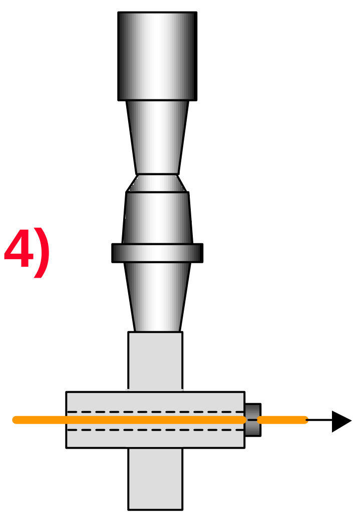




3)

4)



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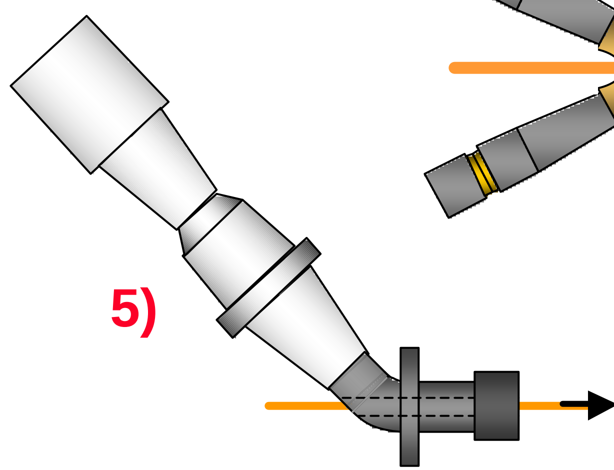
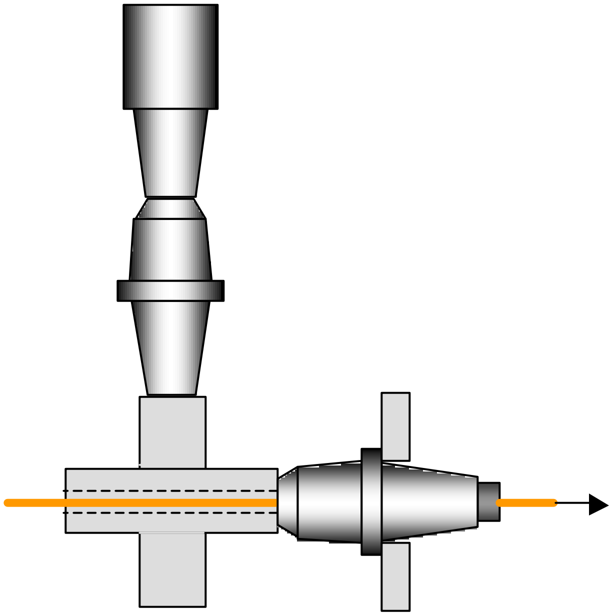
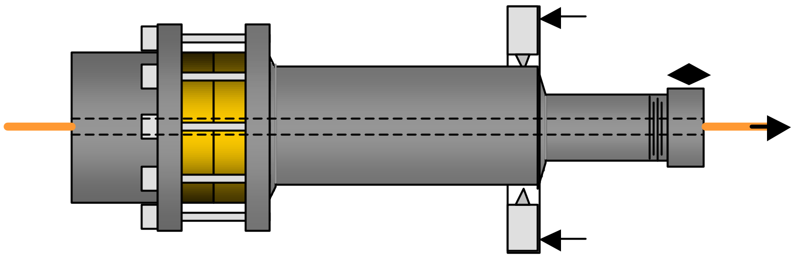


LM Systems

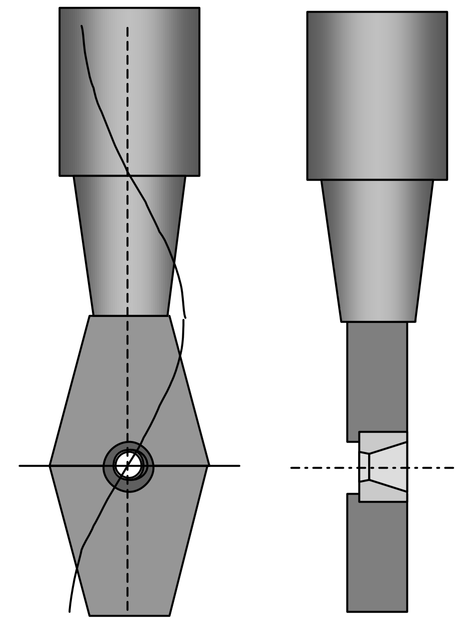
- Cross die design – load cell
- New CD system – match to standard PS
- Die design

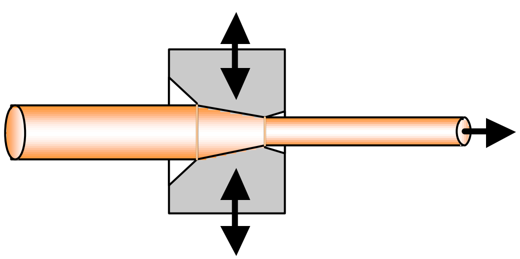


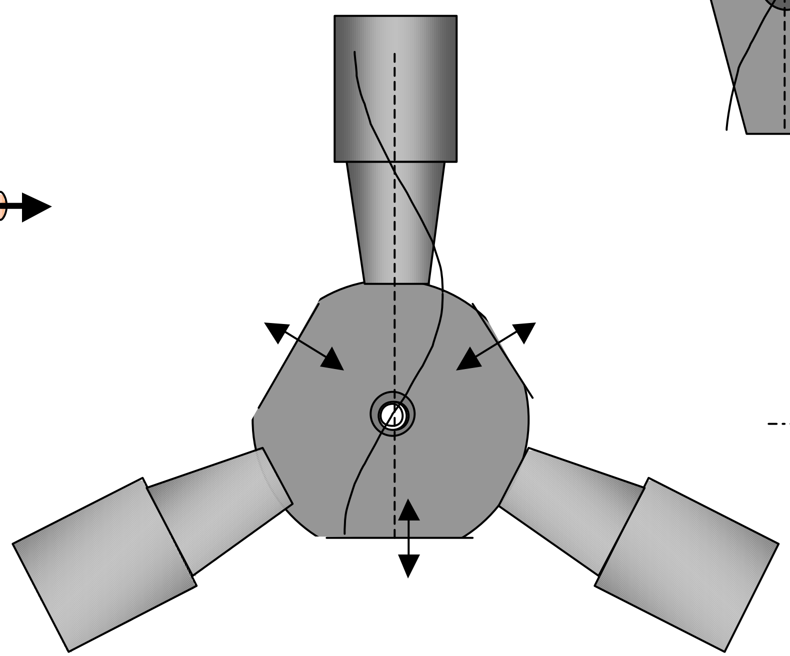


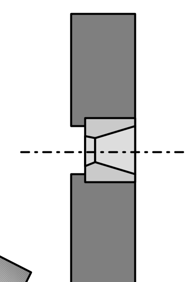
Radial Mode Systems

- Enhance compaction
- Small diameter – less US action
- Complex modes

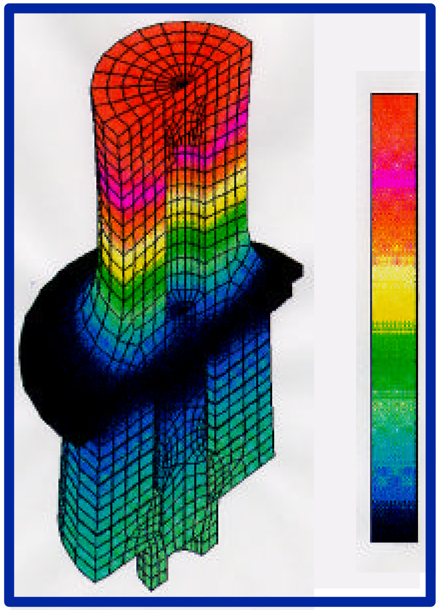




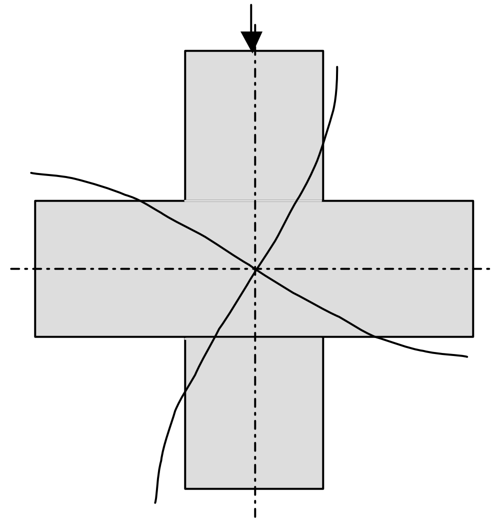


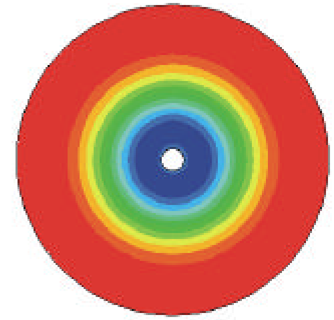


FEA of US Components

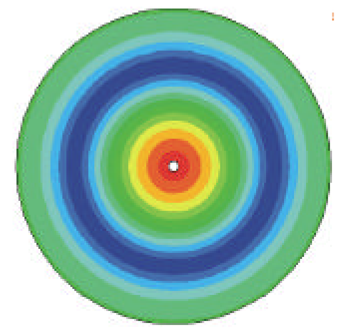


Krell Engineering

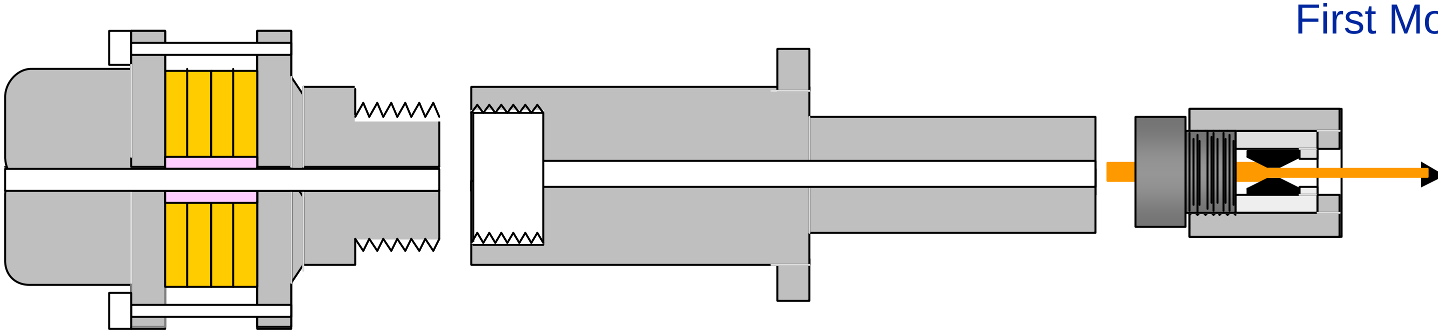




Breathing Mode

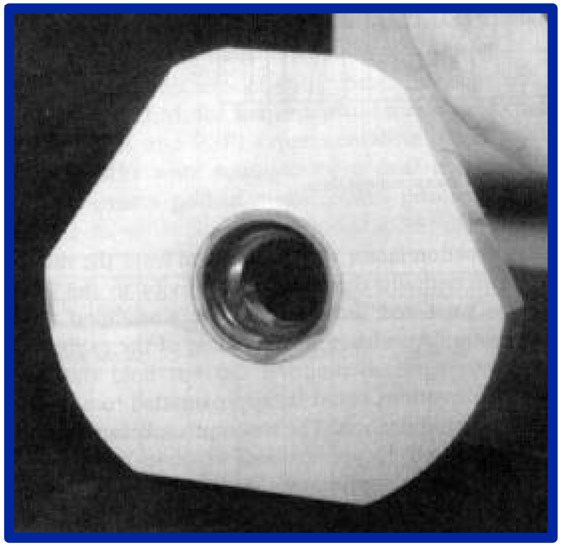


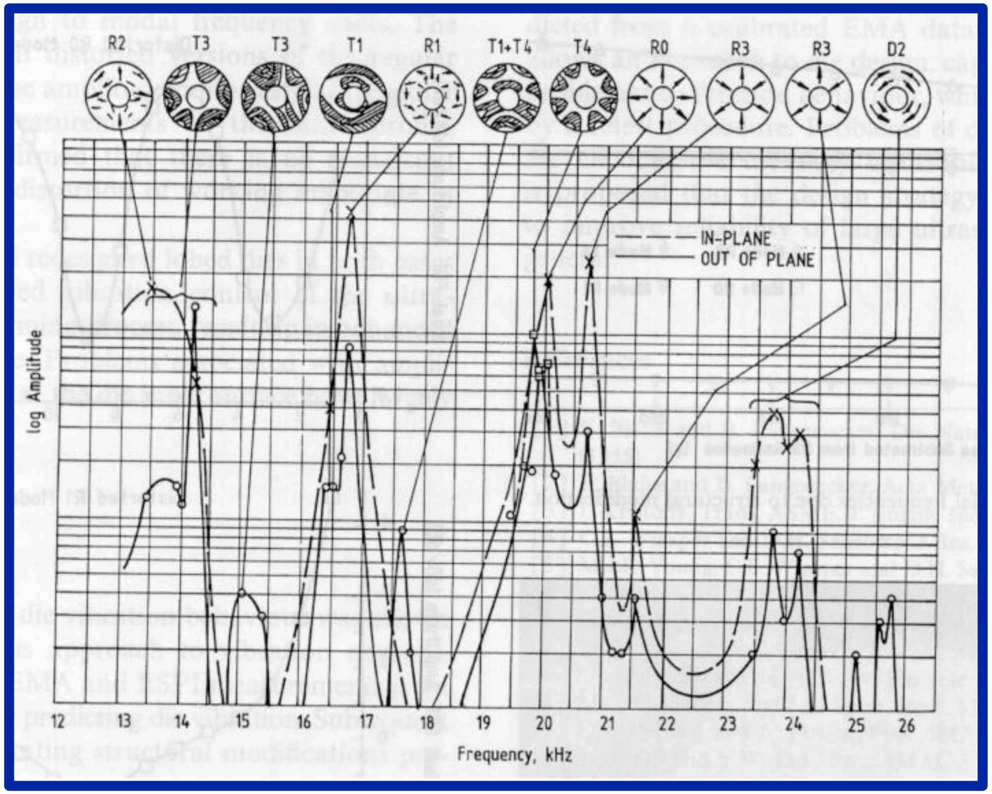
First Mode



Prior Work

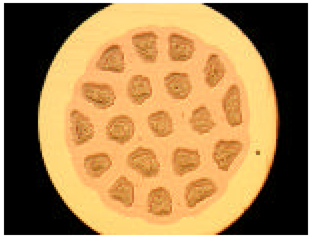
- Lucas ('96)

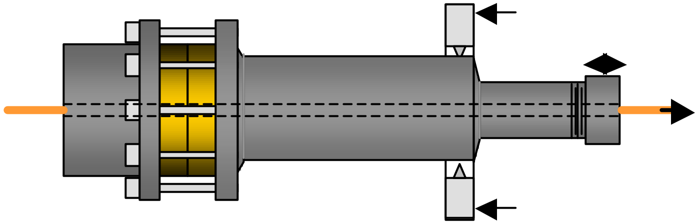


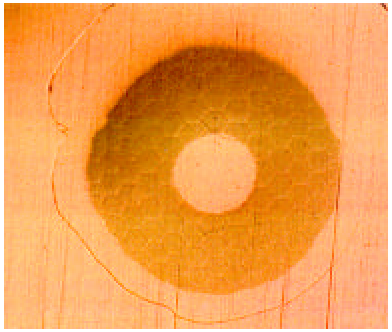


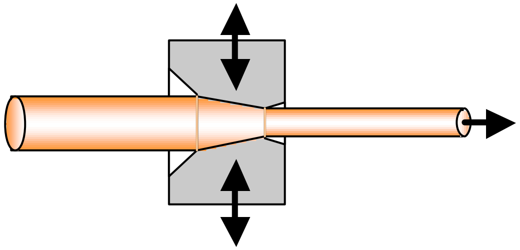
Summary

- “B1, B2” WD systems developed
- Draw forces reduced
- Bonding achieved
- Phase 2 – in-depth development of LM and RM systems









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We have literature from a company called Technoform Sonic Ltd. West Midland UK. In 1985 Technoform started manufacturing ultrasonic tube draw units and related products after research work done at University of Aston, Birmingham UK.