Ultrasonic Metallurgy

and MMM Technology

www.UltrasonicMetallurgy.com

Multifrequency ultrasonic applications for the non-ferrous alloys industry

In modern metallurgy and production of metal parts it is increasingly clear that parts quality performances are directly related to implemented metals processing.

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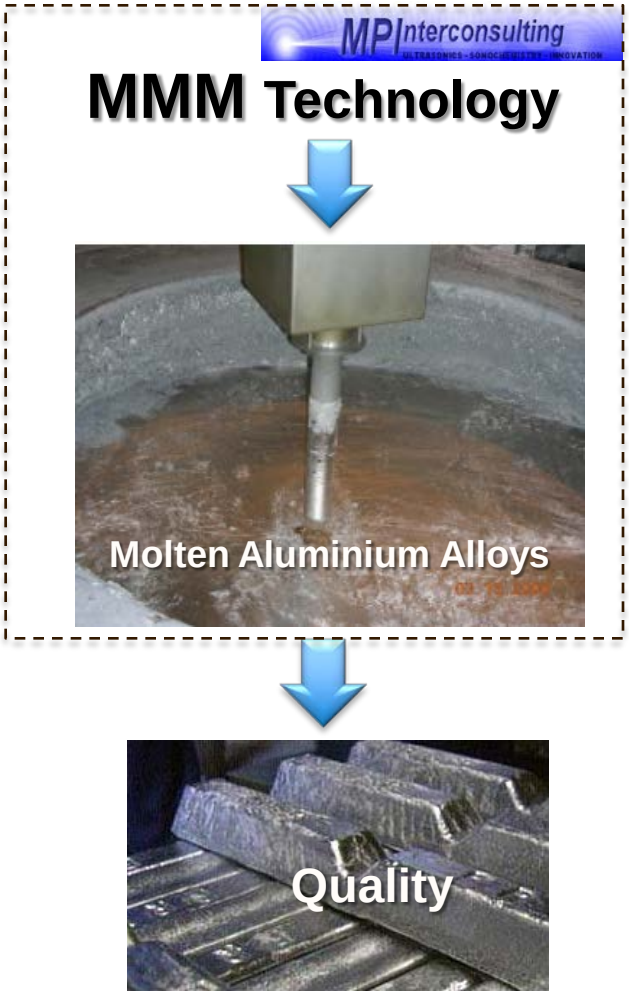
MPI Interconsulting
ULTRASONICS - SONOCHEMISTRY - INNOVATION

If we really understand the problem,
the answer will come out of it,
because the answer is not separate
from the problem.

Agenda

1. Multifrequency ultrasonic processing: MMM Technology
2. Advantages and applications
3. Shaping the foundry of the future
4. Experimental RESULTS
5. Conclusions

✓ MPI Proposal



Multifrequency Ultrasonic Processing

Fixed frequency sound waves

1 Standing waves consequently break Ceramic sonotrodes, while creating zones of very high and very low acoustic activity.

MMM (=) Multifrequency, Multi Mode, Modulated sound waves.

2 **Multi-frequency, pulse repetitive, frequency, phase and amplitude modulated, bulk-wave excitation.**

Elimination of ultrasonic standing waves gives spatially uniform processing of liquid metals.

Capability to drive ultrasonically any arbitrary solid body shape, or large mechanical system at high energy, if needed.

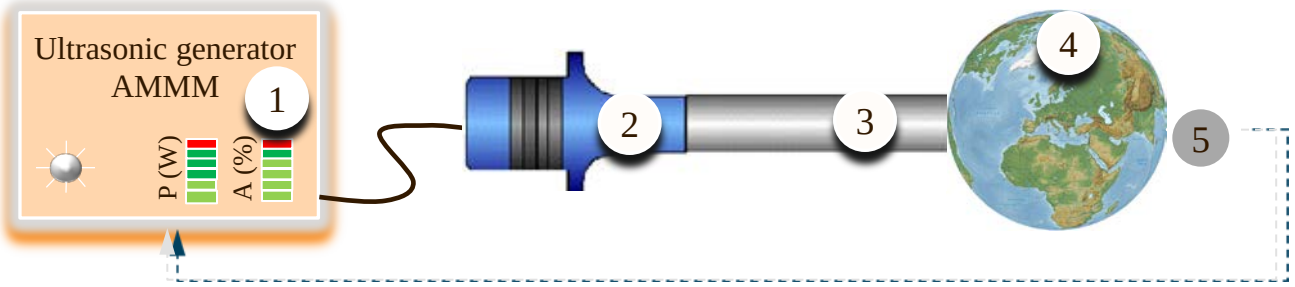
1 High frequency Ultrasonic generator

2 Ultrasonic Transducer

3 Waveguide

4 Load (medium…)

5 Sensor



Applications

Based in MMM Technology

Liquid Atomizers

1 Large quantity spray/mist units, humidifiers, coating systems.

Ultrasonic Coating

2 Surface coating with very fine layers realized by high capacity spray units.

Others…

3 **Wastewaters processing; MMM Induction Heating; Metal Welding; Recuperation, Recovery, Recycling**

Based in Switzerland with clients around the world, MPI offers products, R&D services and consultancy in high power ultrasonics, a range of top quality ultrasonic cleaning and sonochemistry equipment and special equipment development for new applications

Application of acoustic waves in treating of melt aluminum alloys.

A promising future

What is the role of casting / foundrymen in improving the properties of aluminium alloys?

- Control of melting process.
- Melt treatment: degassing, microstructure refinement and modification.

and...

- Assessment of variables which could contribute to improved castings. quality

Application of acoustic waves in treating of melt aluminum alloys.

A promising future

Ultrasound above the threshold of acoustic cavitation can be introduced into a molten metal (e.g. during the continuous casting process), this way promoting:

Degassing of liquid metals using high intensity ultrasonic activity.

Ultrasonic grain modification technology (improving micro crystallization).

Ultrasonic filtering and refining of molten metal.

Ultrasonic mixing and homogenizing of liquids is exceptionally efficient.

Liquids and liquid metals that do not mix in normal conditions can also be mixed, homogenized and/or alloyed in high intensity ultrasonic reactors or in any casting process.

Continuous and Static Casting with Ultrasound

Ultrasonic solidification

Degassing

Principle:
Supplying acoustic energy to the melt, in order to induce cavitation:

(i) A great number of small cavities developed inside the liquid.

(ii) Diffusion of hydrogen from the melt to the developed bubbles

(iii) The large bubbles coagulate and float to the surface of liquid pool

Refinement of α-Al

Besides degassing, the development of cavitation promotes significant undercooling and the formation of numerous solidification nuclei.

Si and Intermetallic modification

Grain refinement exerts a positive influence on several properties of cast aluminium, namely: porosity, shrinkage distribution, intermetallics distribution and mechanical properties.

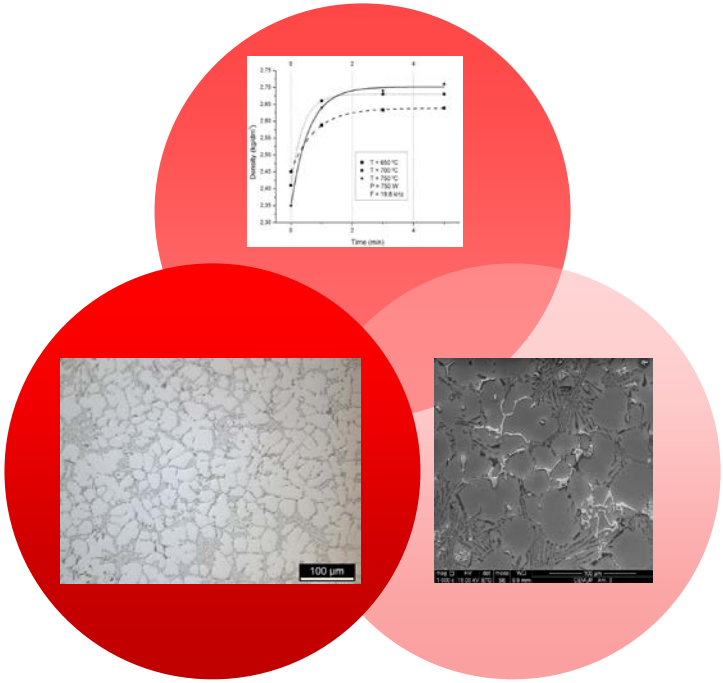
Acoustic Intensity - Advantages

$$I = \frac{P}{A}\left(\frac{W}{cm^2}\right)$$

- Grain refinement, with significantly improved and 3D uniformly distributed micro-crystallization.
- Disintegration, elimination, wetting and dissolving of non-metallic and metallic inclusions, making smooth intermetallic transitional areas.
- Alloys mixing with nano-particles, increasing density of alloys, varying percentages of alloys ingredients.
- Improving chemical, mechanical and physical properties and corrosion resistance, e.g. in Al-Li alloys and other aerospace alloys.
- Alloys' density increase until theoretical limits.

The main goal of MPI is to develop and promote the use of an alternative Ultrasonic processing technique in traditional treatment of molten aluminium alloys.

Experimental **Results**



1. Ultrasonic degassing

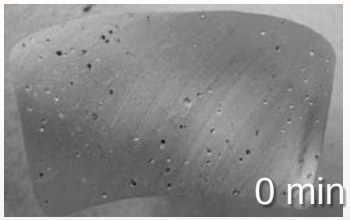
(i) Effects of operating temperature
(ii) Effects of applied power

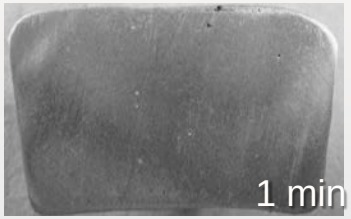
2. Ultrasonic Refinement

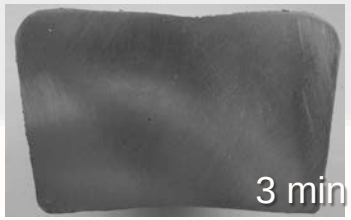
(i) Isothermal vibrations
(ii) Continual vibrations

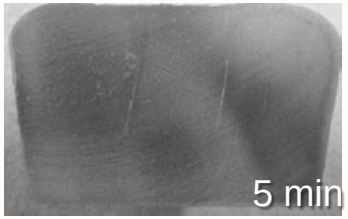
Static Casting, Ultrasonically Assisted

Some of our experimental results



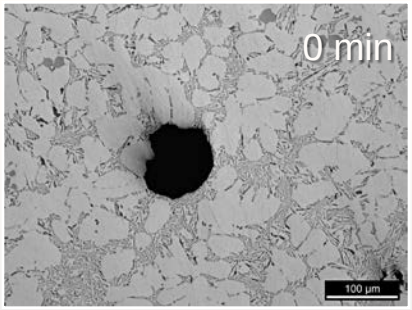


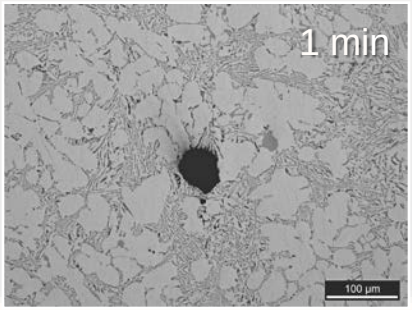


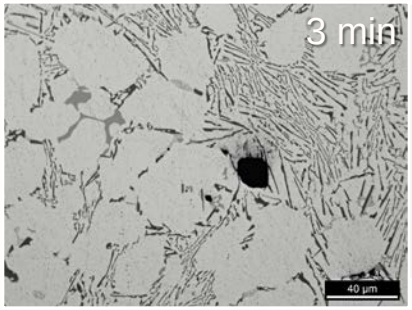


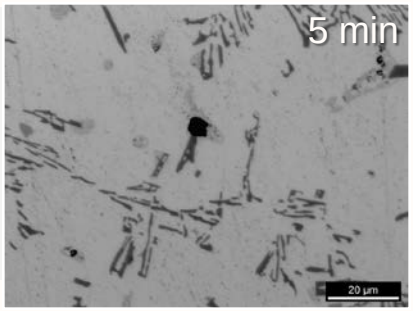
Samples

RPT tests







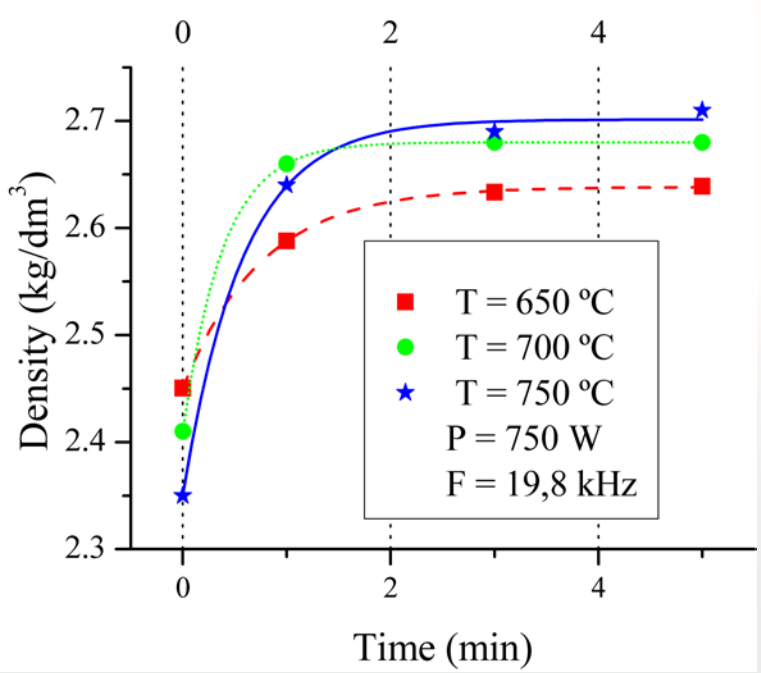


Samples

Porosity

Static Casting, Ultrasonically Assisted

Experimental results

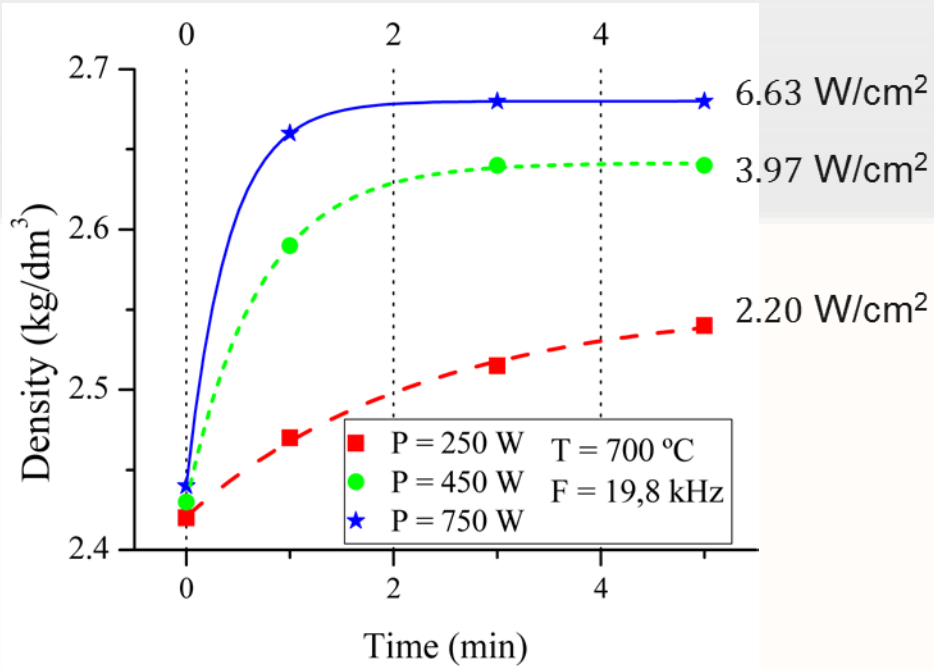


Samples

Density

Effect of power

$$I = \frac{P}{S}\ (\mathrm{W/cm^2}) \quad I_{min} = 2\ \mathrm{W/cm^2}$$



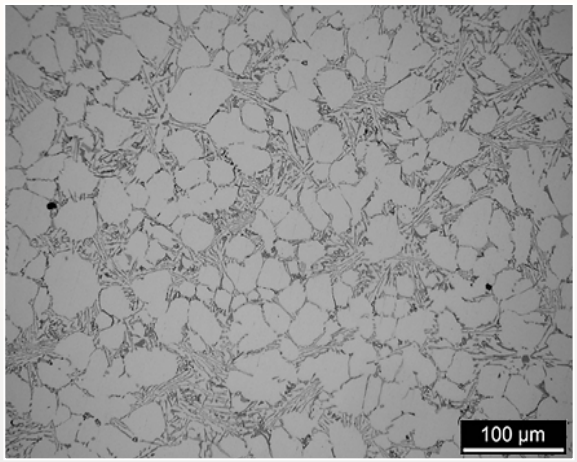
T ↓ → viscosity ↑ → rate of diffusion ↓

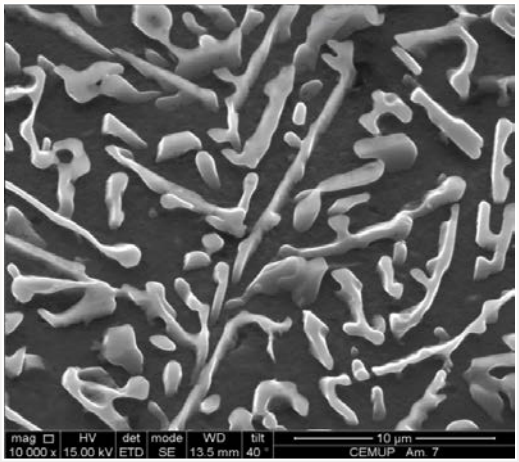
Static Casting, Ultrasonically Assisted

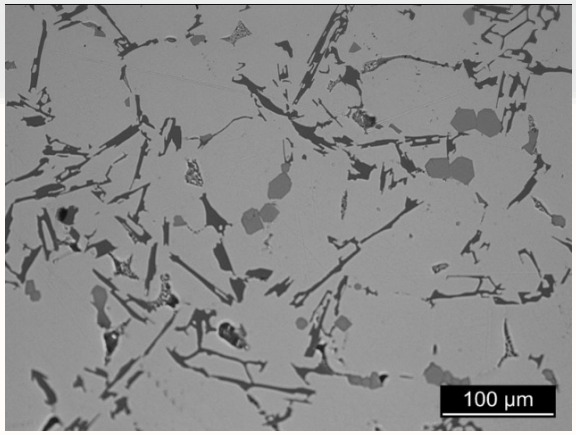
Experimental results

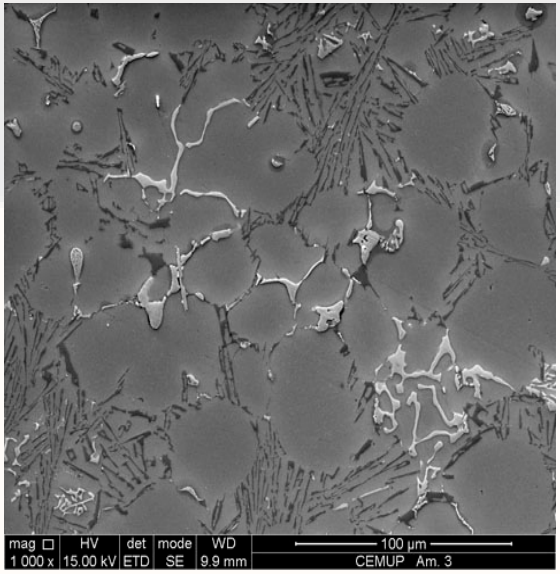
Samples

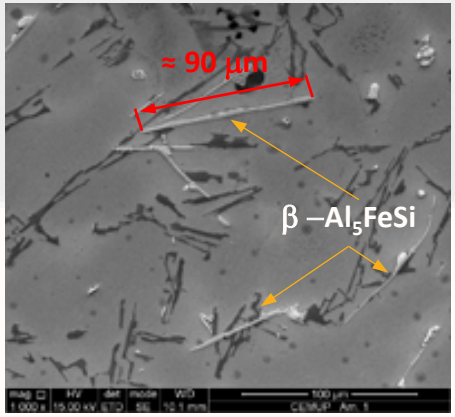
Refinement
Modification











The β-Al5FeSi phase is the most harmful amoung the intermetallic phase in Al-Si-Cu

Conclusions

1	Use of Sialon sonotrode directly into the degassing box
2	3-5 times faster than conventional systems
3	Removal of hydrogen close to theoretical equilibrium
4	Uniform agitation of the mold during solidification
5	Non-dendritic structure of solidified aluminium
6	No, or little dross
7	More than 50% increase of production speed

Solutions…

What do you need?

-Improve the quality of products

-Save processing energy

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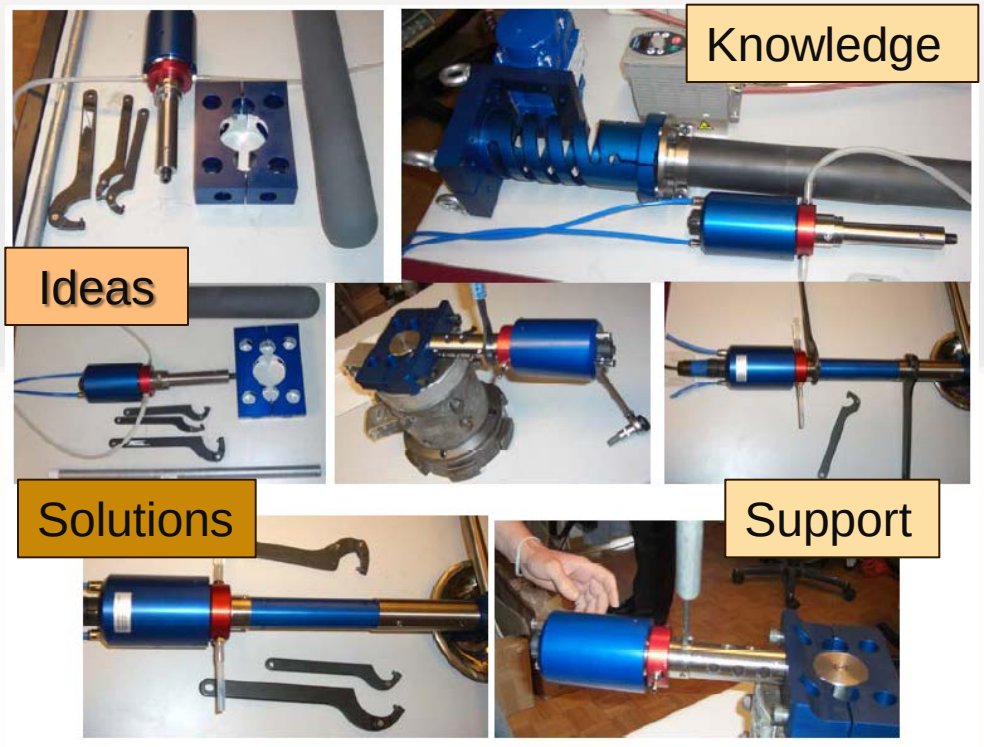

Thanks to MMM technology

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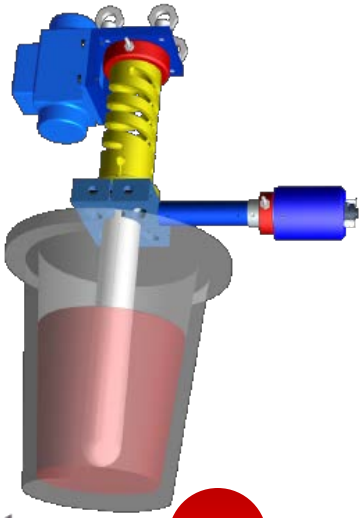
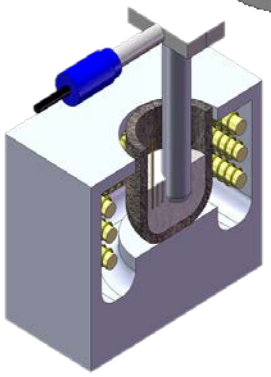
Solutions…

High Intensity Ultrasound in Metalurgy



1 2 3 4 5 6



US + Mechanical stirring

Remarks

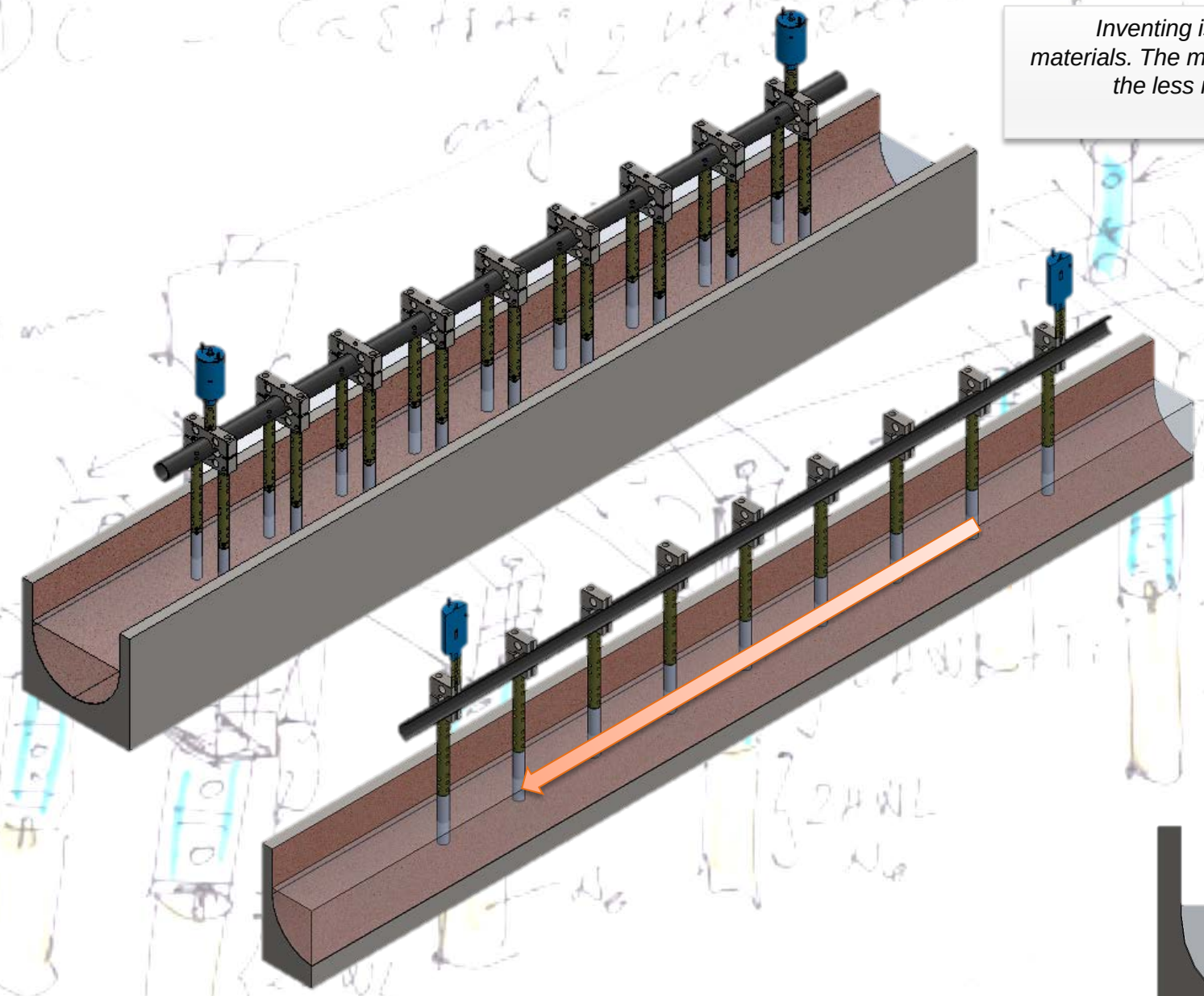
Traditionally available ultrasonic equipment for liquid metals treatment is still not compatible with high-volume in-line metal processing (single frequency is creating standing waves and dead zones).

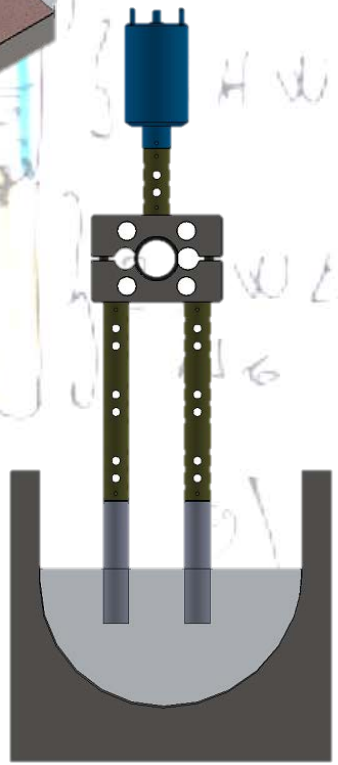
High temperature of liquid metals presents an enormous problem to continuous operation of ultrasonic transducers.

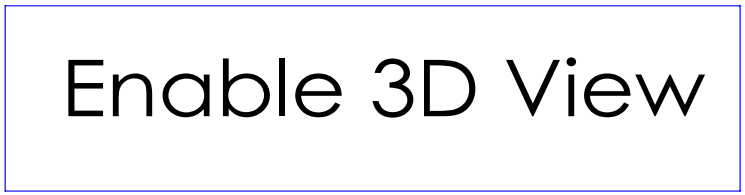
We can now separate the ultrasonic transducers from the liquid metal using long metal waveguide rods, yet still introduce high ultrasonic power into liquid metals.

MPI proposal for your factory

Inventing is mixing brains and materials. The more brains you use, the less materials you need.






Enable 3D View

How it works…

Cavitation

Degassing (movie file)

Crystallization (movie file)

Publications

Influence of indirect ultrasonic vibration on the microstructure and mechanical behavior of Al-Si-Cu alloy
H. Puga, J. Barbosa, S.Costa, A.M.P.Pinto, S. Ribeiro, M. Prokic

Influence of ultrasonic melt treatment on microstructure and properties of AlSi9Cu3 alloy
H. Puga, S.Costa, J. Barbosa, S. Ribeiro, M. Prokic
Journal of Materials Processing Technology 211 (2011) 1729-1735

The combined effect of melt stirring and ultrasonic agitation on the degassing efficiency of AlSi9Cu3 alloy
H. Puga, J. C. Teixeira, J. Barbosa,E. Seabra, S. Ribeiro, M. Prokic
Materials Letters 63 (2009) 2089-2092

The influence of processing parameters on the ultrasonic degassing of molten AlSi9Cu3 aluminium alloy
H. Puga, J. Barbosa, E. Seabra, S. Ribeiro, M. Prokic
Materials Letters 63 (2009) 806-808

Books

Piezoelectric Transducers Modeling and Characterization
Miodrag Prokic, 240 pages, January 2004
MPI, Le Locle, Switzerland,
www.mpi-ultrasonics.com

Patents

European Patent Application (related to MMM technology): EP 1 238 715 A1
Multifrequency ultrasonic structural actuator
Applicant: Prokic Miodrag, MP Interconsulting, 5.03.2001 – 11.09.2002

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Thank You

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