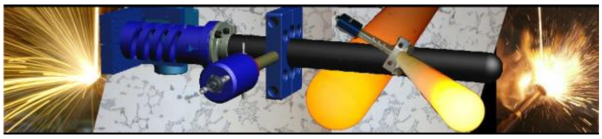

If we really understand the problem, the answer will come out of it, because the answer is not separated from the problem.

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MMM Technology applied to Static, DC and CC casting process

Proposal for applications of MMM technology

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1. Introduction

MMM Technology was developed by MP Interconsulting. Based in Switzerland MPI has 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. Currently MP Interconsulting is working with some important companies of CC and DC casting around the world. Recent developments have been shown the increase of interests in ultrasonic technology for liquid metals processing. MMM sonic and ultrasonic technology is a reliable technique for melt treatment that has been developed and applied in processing different non-ferrous alloys.

Ultrasonic MMM technology, when operating above the cavitation threshold, is promoting creation of numerous low pressure (almost vacuum) bubbles in a liquid metal. Mentioned cavitation bubbles start growing, pulsing in a continuous expansion/compression regime and finally collapse producing wideband ultrasonic spectrum, 5000°C local (spot) temperature, and very high explosion pressure (100 bar or more). Ultrasonic **MMM processing** applied to non-ferrous alloys' melt treatment can result in metals purification, microstructure refinement, structure modification, (better and faster melt homogenization, optimized alloying and micro alloying, wetting of non-metallic inclusions, and significant alloy density increase) and degassing. All of that is possible based on the specifically created acoustic field spatially and uniformly well distributed, creating wideband multi- frequency cavitation in a liquid metal.

When a liquid metal is exposed to high intensity ultrasonic vibrations, the alternating pressure above the cavitation threshold creates numerous cavities, promoting two effects:

(1) Degassing effect: Cavitation produced by ultrasonic MMM technology intensifies mass (and heat) transfer processes and accelerates the diffusion of hydrogen from the melt by developing low pressure cavitating bubbles that are collecting hydrogen. As acoustic cavitation progresses with a time, adjacent bubbles mutually touch and coalesce, growing to a size sufficient to allow them to rise up through the liquid, against gravity, until reaching surface. Degassing is easier and faster if melt temperature is higher than optimal temperature for grain refinement, but on such high temperatures microstructure refinement is not effective.

(2) **Microstructure refinement and grains modification effect**: the alternating pressure achieved by MMM ultrasonic processing of liquid metal is creating cavitation bubbles able to absorb kinetic (thermal motion) energy in a melt, undercooling the liquid metal at the bubble-

liquid interface, resulting in nucleation on bubble surfaces. When bubbles collapse acoustic micro streaming develops in the melt, distributing initially created nuclei into surrounding liquid producing significant number of new nuclei in the molten alloy, thus promoting heterogeneous nucleation. Microstructure grain refinement for every alloy has its optimal temperature, which is significantly lower compared to optimal degassing temperature (and should be found before starting real production and technological testing). Operating as closer as possible near liquidus temperature curve will produce finer and denser grain structure, but we also need to satisfy real casting conditions and keep liquid metal temperature sufficiently high, meaning that optimal and compromising temperature should be experimentally found (before applying ultrasonic processing in a production line).

Based on the results achieved with different alloys and according to results obtained in a laboratory and industrial scale, the main conclusions that can be drawn are:

(1) Ultrasonic degassing can be an efficient process to degas molten non-ferrous alloys. For melting charges in static conditions (industrial scale) acceptable degassing is achieved after 2 minutes ultrasonic treatment, although after 1 min the alloy density is already up to 90% of the maximal value.

(2) When compared with the traditional fixed-frequency ultrasonic sources MMM ultrasonic technique seems to improve significantly ultrasonic degassing process by increasing the final alloy density and degassing rate.

(3) Ultrasonic processing by MMM technology is an external supply of acoustic energy – presenting physical process - environmentally clean and efficient that can promote refinement of primary grains and intermetallic phases, modification of eutectic Si, and decrease of porosity in non-ferrous alloys.

(4) Ultrasonic treatment clearly improves mechanical properties and the fluidity of treated alloys.

2. Research and Development

In order to efficiently apply ultrasonic processing, the preexistence of highly professional knowledges in areas as metallurgy, mechanics, automation and electro-mechanics is mandatory. Why? Because, this technology is based on an integration of two type of parameters: (1) Parameters related to number of metallurgical aspects (i.e, temperatures, chemical composition of alloy, acoustic impedance etc.); and (2) Operational parameters which concern everything that is related to applied ultrasonic technology. So, the limits of metallurgical and mechanical parameters should be understood, matched and adjusted with the objective to improve the process performances. The ultrasonic technology will not be only as a simple as add-on to the process, but it should rather be an integral part of the process. There isn't a ready-made, universal DEMO equipment that can be applied in every casting house. Every casting house should first analyze and understand the problem, perform some preliminary tests, and build customized ultrasonic equipment for a targeted processing.

When speaking about ultrasonically assisted degassing it is important to understand that such degassing is very significant taking into account other useful effects of ultrasonic processing, what also means to clean and increase density of molten metal. This is much more than only to remove a hydrogen dissolved in liquid metal; in the same process we remove or neutralize impurities and nonmetallic inclusions, and improve the homogeneity and density of melt. Moreover, supplied acoustic energy acoustically activates the liquid metal (on longer distances from the place where we create ultrasonic agitation), what is extremely important and beneficial for mold casting concerning metal fluidity. Here is also very important to satisfy resident-processing time-duration of ultrasonic processing in order to maximize desired effects of degassing.

Can ultrasonic technology help to improve characteristics of casted components? Yes, it can. How? This is a challenging, multi-parameters dependent and important question to answer and understand?

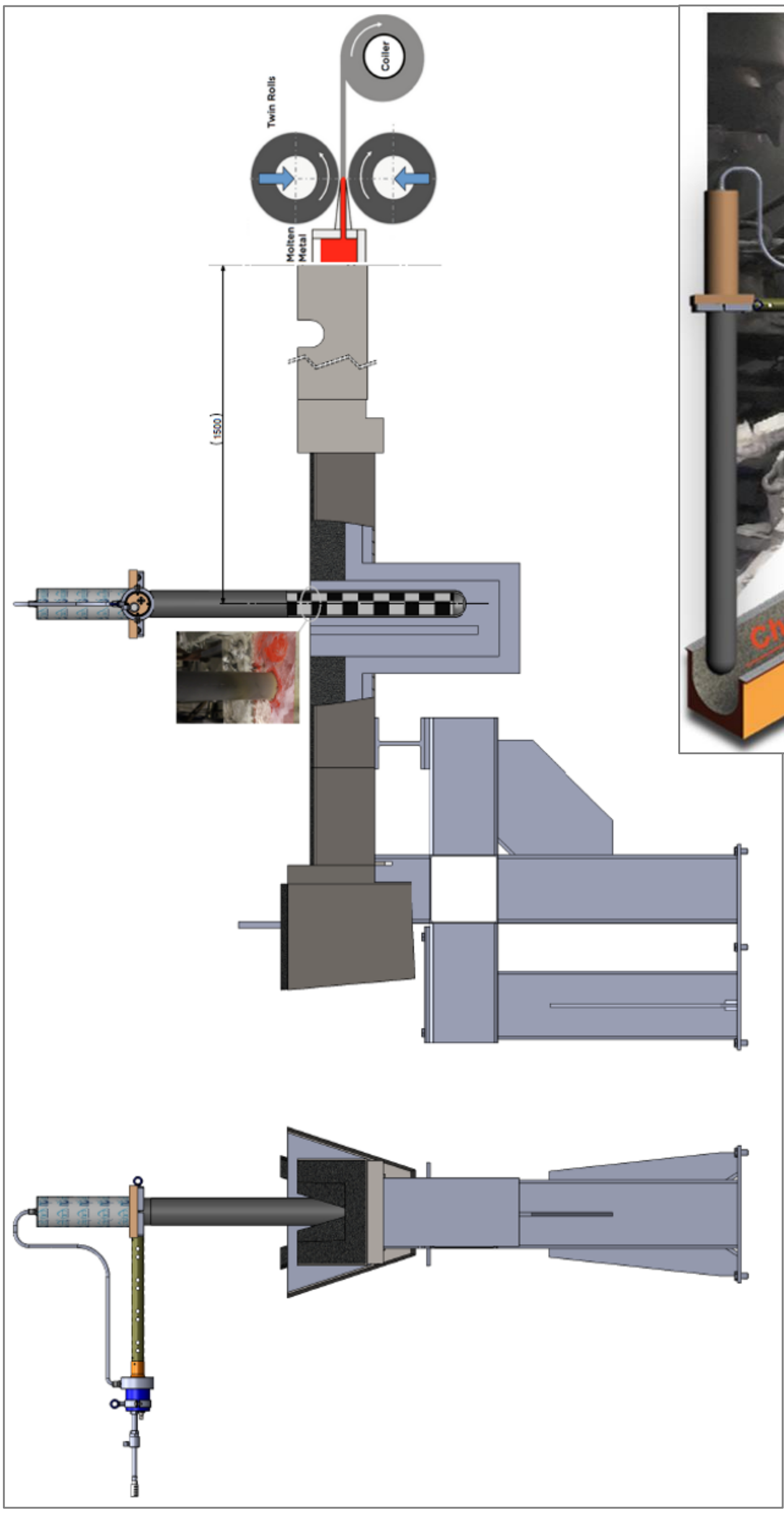
In real practice the answer what to do isn't easy. However a good starting step is to control the temperature of melt. We could approximately say that to refine the grain size it is necessary to work in temperatures range between 630° and 650ºC, but exact temperature range depends on alloy, on melt volume, and on a geometric relations between sonotrode and crucible, as well as on resident-processing time-duration of ultrasonic processing. If the liquid metal flow is high, we need to apply (proportionally) more than on one of ultrasonic processor units.

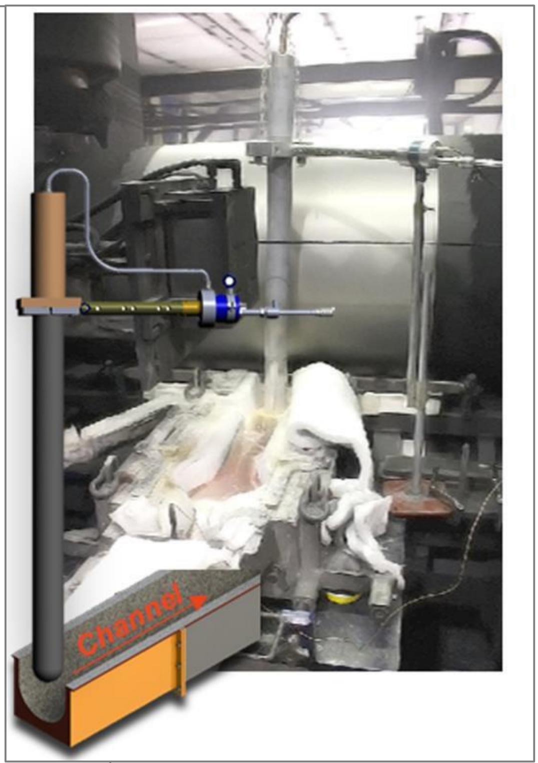
Other and important situation is the way how acoustic energy will be supplied to a liquid metal, i.e. during metal cooling, or isothermally, during certain time period. These two ways of ultrasonic processing are producing different results due to the operating temperature and the conditions related to physicochemical reactions between metal elements.

The optimal technological choice should be selected based on client's objectives, alloy in question and taking into account actual (existing) technology and casting equipment in the production facility.

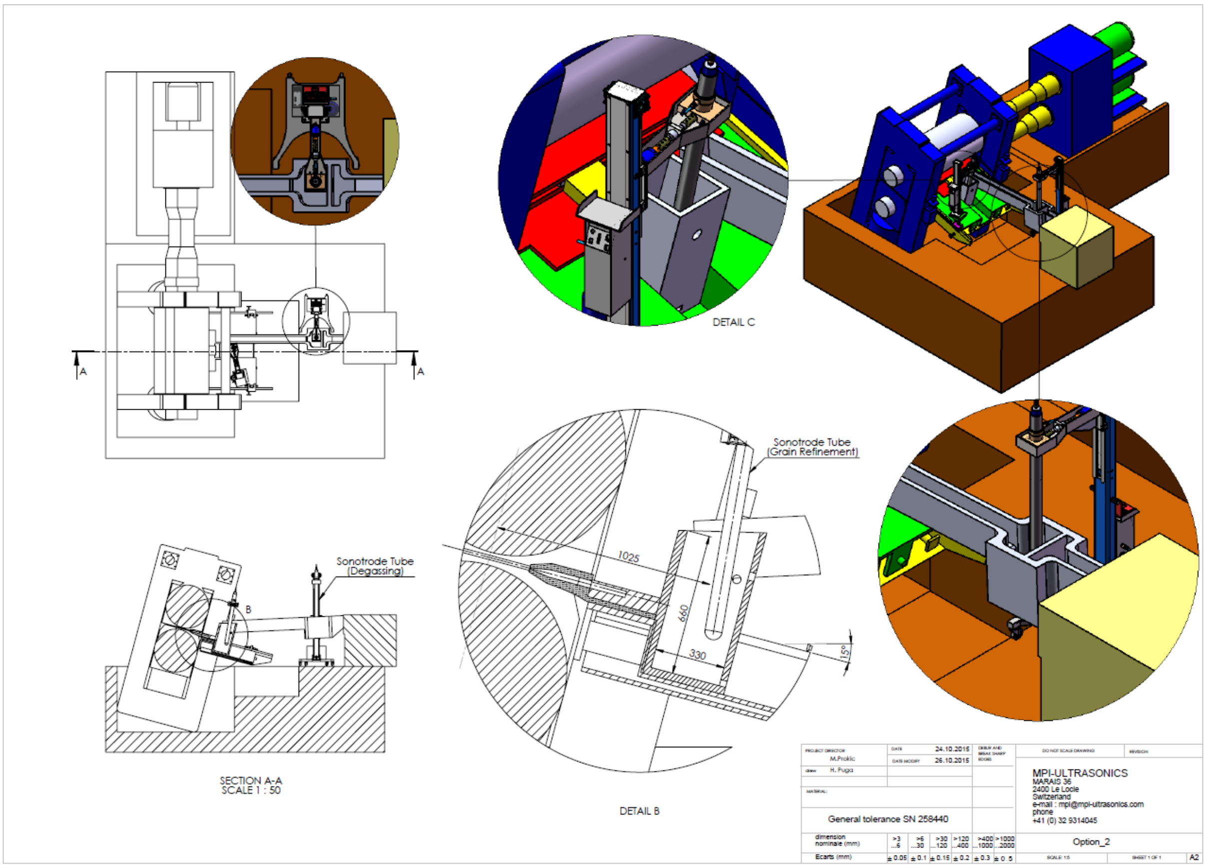
The ultrasonic liquid metals processing based on MMM technology may have several applications. The implementation of ultrasonic vibrations in casting process will dramatically increase the integrity and mechanical properties of casted alloys. Furthermore, current results are showing that when the process is controlled, it is possible to optimize production in scaling up, what leads to cost reduction, energy savings, and other metal quality benefits.

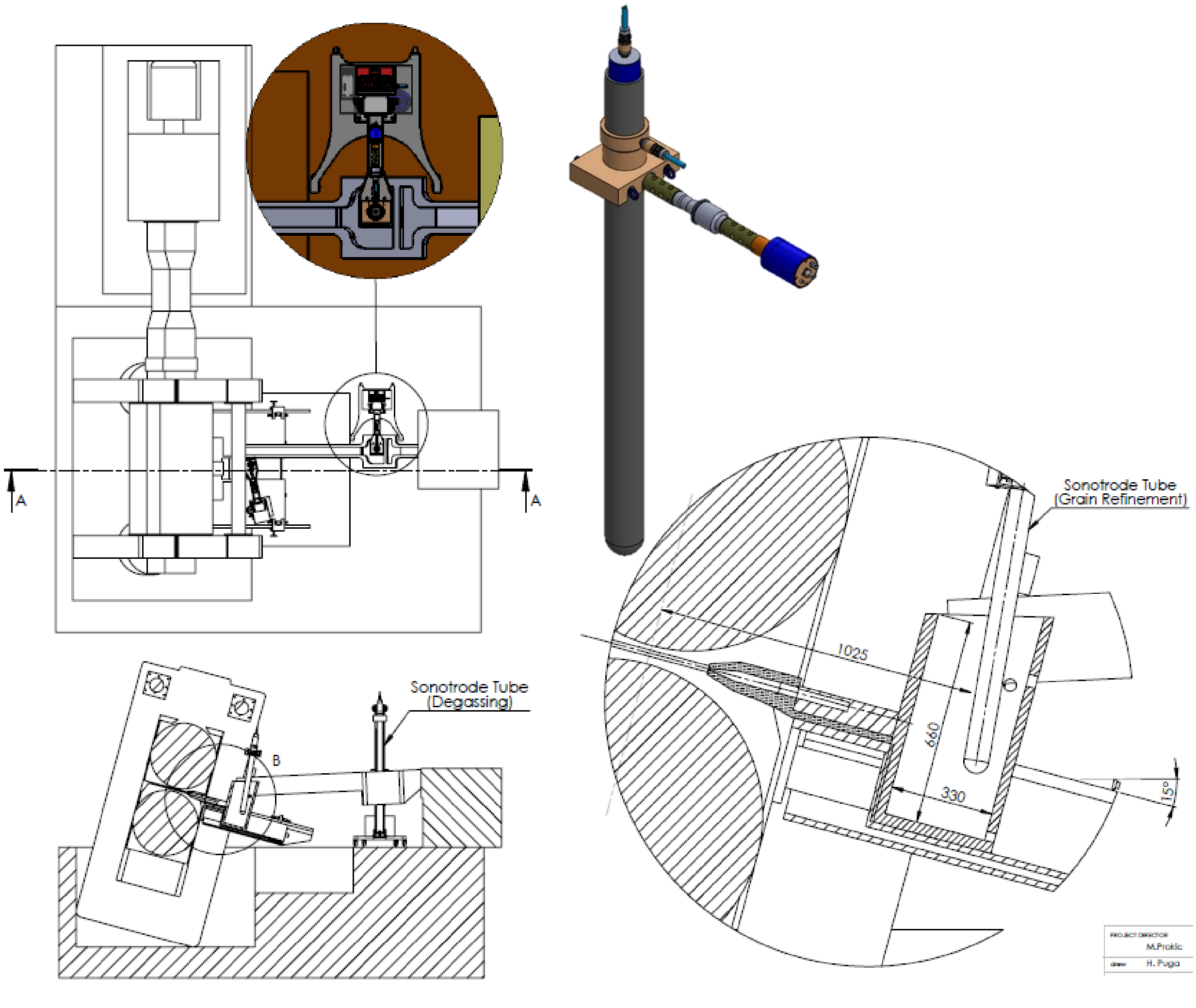
3. Design options available for CC Casting





Proposed layout should be adjusted to real dimensions of relevant casting equipment. Also there are situations convenient to introduce 2 or more of such US systems for degassing and refinement.


DETAIL C
Sonotrode Tube
(Grain Refinement)
1025
660
330
15°
Sonotrode Tube
(Degassing)
B
A
SECTION A-A
SCALE 1 : 50
DETAIL B
PROJECT DIRECTOR M.Prokic
DATE 24.10.2015
DATE MODIFY 26.10.2015
DEBUR AND BREAK SHARP EDGES
DO NOT SCALE DRAWING
REVISION
draw H. Puga
MATERIAL:
General tolerance SN 258440
MPI-ULTRASONICS
MARAIS 36
2400 Le Locle
Switzerland
e-mail : mpi@mpi-ultrasonics.com
phone
+41 (0) 32 9314045
dimension nominale (mm) >3 ...6 >6 ...30 >30 ...120 >120 ...400 >400 ...1000 >1000 ...2000
Ecarts (mm) ± 0.05 ± 0.1 ± 0.15 ± 0.2 ± 0.3 ± 0.5
Option_2
SCALE: 1:5
SHEET 1 OF 1
A2


A
A
Sonotrode Tube
(Degassing)
B
SECTION A-A
SCALE 1 : 50
Sonotrode Tube
(Grain Refinement)
1025
660
330
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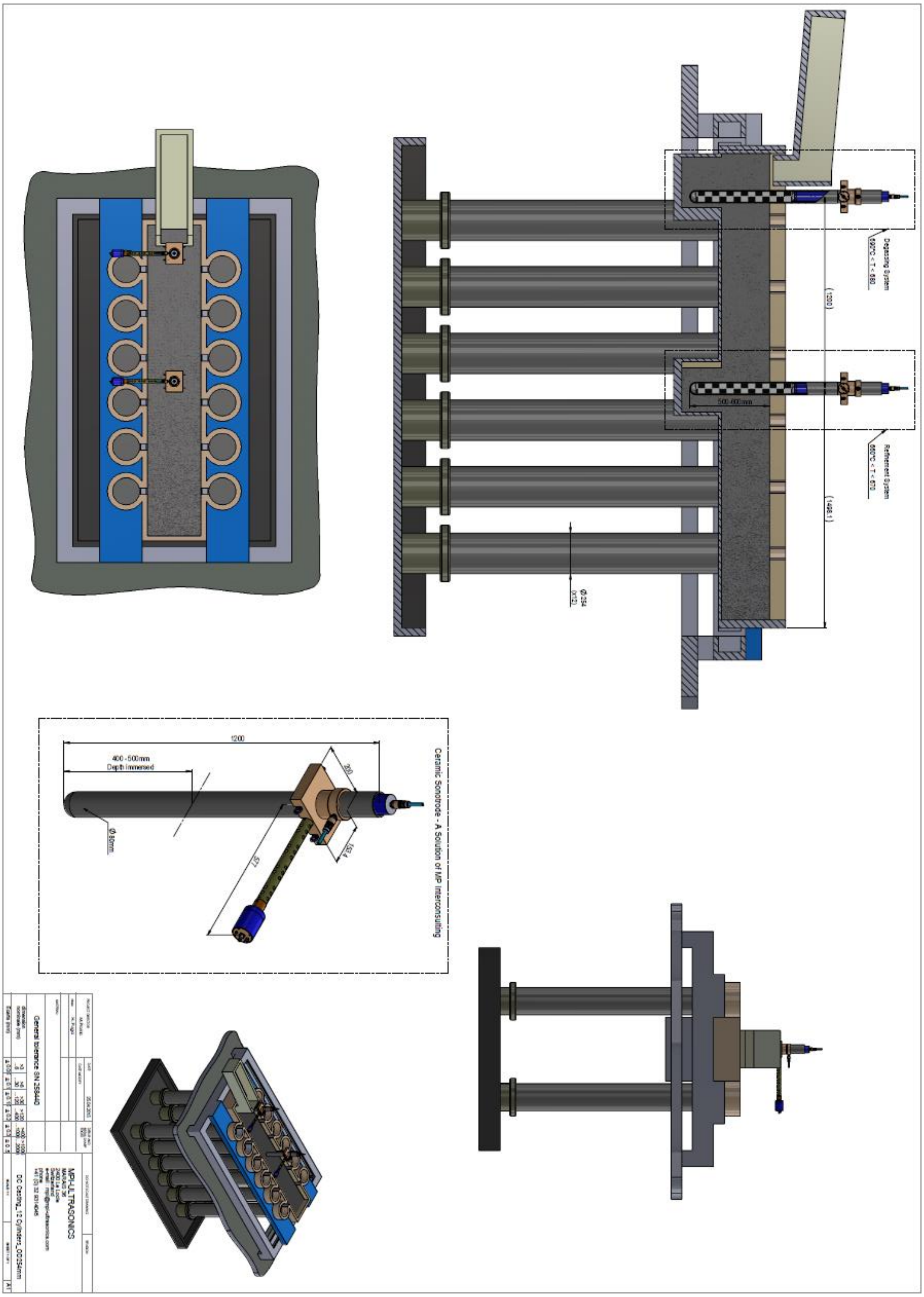
PROJECT DIRECTOR
M.Prokic
draw H. Puga

4. Design options available for DC Casting

For billets...



For ingots…

The figure below shows MPI ultrasonic device suitable to perform treatment of aluminum alloys in a sump of DC-cast ingot. The use of ultrasonic device based on MMM technology will allow formation of non-dendritic structure during DC casting, making the ingot structure more homogeneous and decreasing the macro segregation. The proposed layout should be adjusted to real dimensions of DC casting equipment.