

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

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.

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Introduction

Ultrasonic MMM technology, when operating above the cavitation threshold is creating numerous low pressure (almost vacuum) bubbles in a liquid metal, which start growing, pulsing in a continuous expansion/compression regime, and finally collapse. 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, based on the specifically created acoustic field introduced in a molten metal in order to create spatially and uniformly well distributed and wideband multi- frequency cavitation.

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

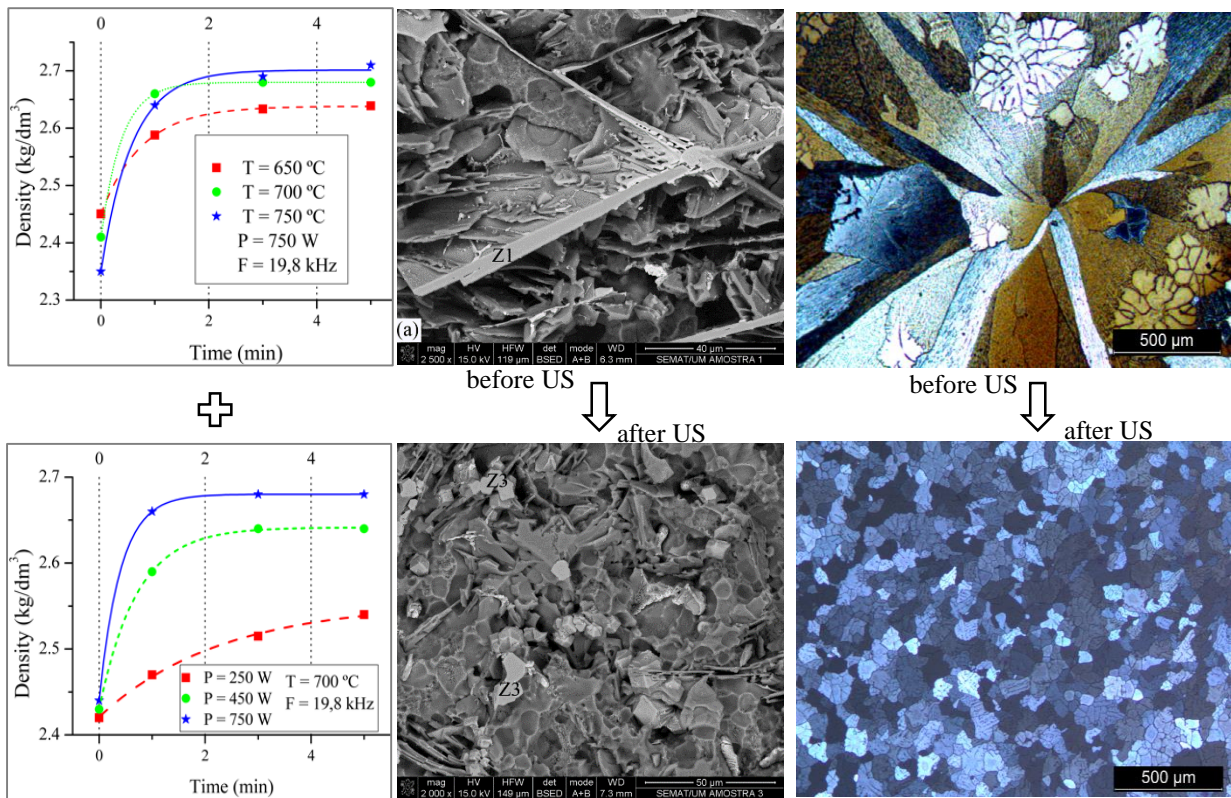
(1) Degassing effect: Cavitation produced by ultrasonic MMM technology intensifies mass (and heat) transfer processes and accelerates the diffusion of hydrogen from the melt by developing low pressure cavitating bubbles that are collecting hydrogen. As acoustic cavitation progresses with a time, adjacent 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).

MMM sonic and ultrasonic technology is a reliable technique for melt treatment that has been developed and applied in different non-ferrous alloys. Based on the results achieved from

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 of 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 using MMM technology presents an external supply of acoustic energy – meaning physical process - environmentally clean and efficient, also promoting 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 fluidity of treated alloys.



Examples of US processing results: degassing, intermetallic refinement and grain refinement.

Research and Development

This document is created to facilitate fundamental understanding of ultrasonic energy effects on liquid metals processing – based on MMM technology, specifically on degassing and refinement of liquid nonferrous metals, including practical advices based on our recent studies.

Presence of hydrogen eventually manifests as porosity during the solidification of aluminum alloys and it is detrimental to mechanical properties of aluminum alloy castings. Reducing porosity during casting is still a challenging problem in aluminum industry. Traditional techniques based in rotary degassing (that uses finely dispersed argon), or based in chlorine waffles are used for degassing. However, mentioned techniques are characterized by modest efficiency and could create environmental problems. Apart from problems arising from the presence of hydrogen, the non-ferrous alloys are prone to achieve heterogeneous structures (usually dendritic), requiring suitable melt treatment to reduce and control the grain size, homogenize the alloys, modify the intermetallic content etc. Therefore, controlling the microstructure of non-ferrous alloys is of primary importance to achieve highest mechanical performances, thus requiring suitable degassing, grain refinement and structure modification.

Our results are making possible to achieve high efficiency of degassing and grain refinement in aluminum and magnesium alloys.

Currently, thanks to our continuous research and equipment development, for each kind of casting process (i.e.: static casting in crucible, CC casting or DC casting), we can always offer different customized approach, thanks to accumulated relevant and multidisciplinary knowledge in relation to Ultrasonically Assisted Metallurgy, Mechanics and Electronics. The combination of such knowledges allows to build and readapt MMM technology to different casting practices.

For efficient ultrasonic processing, considering variety of casting options, it is necessary to know:

What is user's casting process where ultrasonic processing will be installed?

What are your raw-materials?

What are existing operating conditions, i.e. temperature, volume of melt, flow rate...

What are expected objectives and limits? ...Of course, should be realistic.

Thus, (for every user), taking into account existing factory casting conditions, the ultrasonic processing project should satisfy and respect the following steps:

- (1) Perform preliminary laboratory tests to demonstrate the applicability of MMM technology in actual alloys, and establish operating limits that are fundamental for successful ultrasonic processing (meaning: going directly to a production, casting line, without preliminary laboratory testing is highly not-recommendable).
- (2) Within laboratory established operating limits, apply the ultrasonic device on degassing of non-ferrous alloys in real process conditions. Of course, ultrasonic equipment should be conveniently modified and adjusted to fit existing casting line, and certain modifications should often be implemented on a casting line in order to facilitate ultrasonic processing. This is highly professional design process (not just simple implementation).
- (3) Experiment certain time directly with a production line in order to find the best operating conditions regarding ultrasonic controls, casting line and used alloy, this way formulating the working guidelines for maximizing results of degassing process.

For ultrasonic grain refinement, considering variety of casting options it is necessary to know:

What is your casting process where ultrasonic grain refinement will be installed?

What are your raw-materials?

What are presently applied operating conditions, i.e. temperature, volume of melt...

What are expected objectives and limits? Should be realistic.

Thus, for each client and according to existing factory conditions of a casting process, the project should respect the following steps:

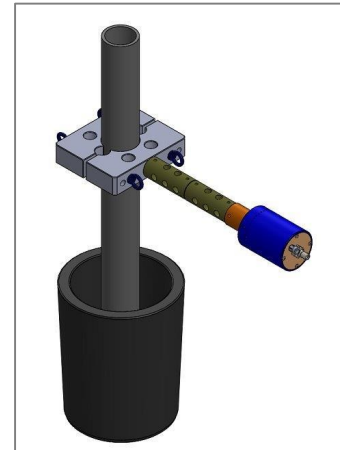
- (1) Perform preliminary tests in a laboratory to demonstrate the applicability of MMM technology in used melt alloys, and establish operating limits that are fundamental for following steps (meaning, going directly to a production casting line without preliminary laboratory testing is highly not recommendable).
- (2) Within laboratory-established operating limits, apply the ultrasonic device on processing of non-ferrous alloys in real technology conditions. Of course, ultrasonic equipment should be conveniently modified and adjusted to fit existing casting line, and often certain modifications should be implemented on a casting line in order to facilitate ultrasonic processing. This is highly professional design process (not just simple implementation).
- (3) Experiment certain time directly with a production line in order to find the best operating conditions regarding ultrasonic controls and used alloy, this way formulating the working guidelines for maximizing results.

Although results obtained through an application of MMM ultrasonic technology in different process conditions confirm the potential of degassing and grain refinement of aluminum and magnesium alloys, it is recommendable that developed technology should be preliminarily evaluated on alloys and technological conditions in your company before making a commitment to it. There is no magic, immediate and miraculous ultrasonic processing that will produce optimal results without mentioned preparatory and optimization steps.

Laboratory testing in crucibles (static conditions)

In order to perform laboratory testing and evaluate the capability of ultrasonic degassing and grain refinement of non-ferrous alloys by MMM technology, several considerations should be taken into account:

The introduction of ultrasonic energy in a melt requires an ultrasonic transducer and an ultrasonic power supply (or generator). On the webpage: <http://www.UltrasonicMetallurgy.com/>, it is possible to see relevant information and set of relevant available products.



Experimental setups to test ultrasonic processing on non-ferrous alloys can be built according to your needs and objectives. Thus, it is necessary to have:

- (1) Ultrasonic Generator based on MMM Technology
- (1) Piezoelectric transducer tolerant to fast signal modulations (usually 20 kHz)
- (1) Set of clamp-on sonicator parts for melt processing
- (1) Composite ceramic or metal tube resonator for melt processing
- (1) Solid metal sonotrode for grain refinement (homogenization, alloying...).

Experiments should be carried out in two independent groups or setups: (1) degassing and (2) grain refinement (because for degassing we need significantly higher melt temperature than for grain refinement).

(1) Degassing

In order to investigate ultrasonic degassing, different batches of Al alloy should be sequentially degassed. (1) An electro-resistive heating furnace (between 2 to 10 kg), equipped with a SiC-graphite-clay crucible, can be used to melt the alloy. (2) After stabilizing operating temperature, molten melt must be ultrasonically degassed, as a parametric function of melt temperature of batches, and based on different degassing time intervals. In addition, a positioning device that supports the US unit and controls its relative position to the surface of the molten alloy should be used.

(3) After each degassing test pre-established in test protocol (for instance, like presented in the table 1, below), the treated sample should be poured in a thin-walled iron cup and allowed to solidify under a reduced pressure of 60 mm Hg.

Table 1

Use the RPT test to evaluate the hydrogen content of sample, it is assumed that every porosity in the sample is due to hydrogen.

<i>Alloy</i>	<i>Temperature</i> [°C]	<i>Time</i> [min]	<i>Frequency</i> [kHz]	<i>N° of Samples</i> [-]	<i>Observations</i>
...

Each density result is the average of (N°) number of samples. RPT samples should be taken for each processing time interval. Degassing efficiency η will be calculated using the following equation, where D is the theoretical alloy density, and D_i and D_f are the initial and final alloy densities, respectively

$$\eta = \frac{D_f - D_i}{D - D_i} \times 100$$

(2) Refinement

An experimental laboratory set-up used to perform grain refinement of aluminum alloys consists of ultrasonic equipment as mentioned above for ultrasonic degassing. Only refinement sonotrode could be different.

(4) The alloy must be melted and held inside the crucible at different temperatures established during 15 - 30 minutes in order to rich homogenization. (5) Molten alloy should then be slowly cooled until the pre-established US processing temperature. (6) For every set of experimental conditions, US vibrations must be applied isothermally during 30-60 seconds. Then, the US unit should be removed, the melting crucible taken out of the furnace and the molten alloy poured in a steel die pre-heated at 250 °C, or in a sand mold. (7) For the sake of comparison experiments (with control samples) must also be carried out without ultrasonic treatment.

(8) Samples for microstructure characterization must be taken from each cast sample, and then cut, grinded and polished up to 1 μm (using 1200 SiC paper). Such samples for optical microscopy characterization should be etched using specific reagent (according to alloy) to reveal the resulting microstructure.

(9) Phase identification and chemical composition must be evaluated by quantitative EDS analysis using a high resolution a Scanning Electron Microscope. (10) For tensile testing, the specimens should be machined from the cast samples respecting standardized shapes and conditions.

Ultrasonically assisted melt degassing and refinement should be understood as the main objectives, i.e., during each of them, the associated and arising phenomenology is very complex, where, for instance, a small shift in temperature could present a high impact on the final process efficiency. Thus, the foundrymen interested to use this technology must be prepared and feel comfortable to proceed with necessary adjustments in the process within the operating limits allowed by different equipment and products.

Here, in order to efficiently apply ultrasonic processing, the preexistence of highly professional knowledges in areas as metallurgy, mechanics and electro-mechanics is mandatory. Why? Because, this technology is based on the integration of two type of parameters: (1) parameters related to number of metallurgical aspects (i.e., temperatures, chemical composition of alloy, and so on.); 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 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, because this also means to clean the molten metal. This is more than only to remove a hydrogen dissolved in liquid metal; in the same process we remove or neutralize and integrate impurities and nonmetallic inclusions, and improve the homogeneity and density of melt. Moreover supplied acoustic energy activates the liquid metal, what is extremely important and beneficial for mold casting concerning metal fluidity.

Ultrasonic degassing is based on the cavitation, i.e., the production of cavitation bubbles in melt is the root of success. But, how we can create dense, uniformly distributed and efficient cavitation should be mastered? Theoretically we can offer simple answers, but practical application-related answers to such questions is the key of success of ultrasonic treatment.

To reach high performances in ultrasonic degassing it is necessary to study, experiment and create a correct protocol of testing. Then, technology user will be ready to apply ultrasonic degassing based on MMM technology.

In what concern to effect of refinement of light alloys assisted by ultrasonic technology is important to say and understand that the phenomena that arise from treatment are several and complex, as well as each of them represent a different effect on the performance of casting components. It is know that performance of casting component is affected by the soundness, sanity and structure of matrix, i.e. treatment as grain refinement, refinement and/or modification of intermetallic compound, modification of silicon eutectic and chemical homogeneity... should be achieved.

Can ultrasonic technology help to improve characteristics of the casted components? Yes, it can, but we should select optimal strategy and equipment design.

In real practice the answer isn't easy. However, a good principle to understand and start to have success is to control the temperature of melt. We can say that for refine the grain it is necessary to work in range of temperatures between 630 – 650°C, but is this statement correct? Depends of alloy, depends of volume of melt, flow conditions and on geometric relation sonotrode/crucible.

Other and important aspect is the way how the acoustic energy will be supplied to the liquid, i.e. during cooling or during certain time period at isothermal temperature conditions. These two ways of work will produce different results due to operating temperature since each temperature range is relevant for certain reaction of chemical elements. The choice of ultrasonic processing strategy should be "selected" by the needs of client, by the type of processing, and to be applicable within existing operating conditions.

Regardless of the actual treatment (such as degassing or grain refinement), it is good practice to perform a chemical characterization of the alloy, for instance a DSC analysis (Differential scanning calorimetry). With such analysis is possible to control and quantify different chemical

reactions as well as temperatures when they occur. These temperatures will be very good indication how to organize ultrasonic treatment.

The effects and efficiency of ultrasonic treatment can be measured and qualified based on involved physics, since we transform electric energy (from ultrasonic generator) to mechanical energy (sent to ultrasonic transducer and sonotrode) and eventually transformed to acoustic cavitation (in a liquid metal).

Thus, the high efficiency process will mean to transform almost all of input electrical energy into acoustic energy (without losses in resonant operating conditions of ultrasonic system), while operating liquid metal temperature is kept technologically correct.

Ultrasonic treatment based on MMM technology may have several applications. The integration of ultrasonic vibrations in casting process will dramatically increase the integrity and mechanical properties of alloys' castings. Furthermore, obtained results are showing that when the process is well-controlled, it is possible to scale-up ultrasonic equipment and increase production, leading to a total cost reduction, energy savings, and other benefits.

General Considerations for CC and DC casting process

For ultrasonic grain refinement process, flow rate (m^3/h or l/min) and casting speed should be evaluated in order to establish the best operating conditions. Another very important aspect for the same process is the melt cooling rate. For instance, in DC casting is normal to have values between $0.5 - 2 \text{ K/s}$, contrary to what happens in CC casting where cooling rate can be $200-1000 \text{ K/s}$. These values show that in case of DC casting it will be possible to have degassing and refinement in a sump, but such treatment will depend on the product shape: (i) billet or (ii) ingot.

Normally billets have around 250mm of diameter (meaning that here is not possible to apply US directly in a sump). In cases of sufficiently big ingots, presenting a rectangular geometry, it is possible to apply US directly to sump.

In both cases: DC and CC casting, the most important is to reduce the hydrogen level by degassing. Regarding grain refinement, when we compare both processes, the situation is different, i.e., in case of CC casting the effect of high cooling rate and squeezing of twin

rolls will destroy or promote longer grains. In DC casting can be easier to get good grains refinement. However in this process the grain refinement will dependent on final product (remelting, rolling, etc.).

Check List / Reminder – CC Casting

- 1 – CC casting is a process where is possible to achieve a low level of hydrogen, however grain refinement will present always the problem due to mechanical distortion promoted by the squeezing of twin rolls.
- 2 – The ultrasonically resonating tube (degassing sonotrode) should be submersed **400 to 450 mm** in a liquid metal inside a launder.
- 3 – The distance between ultrasonic ceramic tube and the twin rolls should not be more than **1m**.
- 4 – We need to know which Al alloys processed in CC casting are.
- 5 – Which is the temperature near twin rolls?
- 6 – Is there a possibility to change or adjust operating melt temperature?
- 7 – What kind of mechanical structure can be used to support ultrasonic device? Presently, ultrasonic device is conveniently designed for holding using steel cables.
- 8 – It is important to have a supply of pressurized air for cooling ultrasonic device.
- 9 – We need single phase main supply, electric source 230 Vac.
- 10 – The Trial tests should collect different parameters, such as: Temperatures in different positions, velocity of rolls, etc....
- 11 – After tests the samples should be characterized on microstructure and mechanical properties. Is there a possibility to make such analyses in client's labs?
- 12 – In CC casting applications we need to know what is more important for a client: Low porosity? Reduced grain size? Elimination of a central line of segregation?

Check List / Reminder – DC Casting

- 1 – We need to know which Al alloys processed in DC casting are.
- 2 – What is the shape of castings? Billet or ingot?
- 3 – Processing temperatures?

4 – What Client wants in DC Casting? For instance: Degassing and grain refinement?

5 - “Macro segregation is one of major and irreversible defects in direct chill (DC) casting of aluminum alloys. Usually, the variation of the concentration of alloying elements all over the cross section of the billet results in thermal and mechanical properties variations, what can weaken the quality of final products. The cause of macro segregation is a relative movement of segregated liquid and solid elements during solidification. Due to such driving forces, the extent of segregation in a real DC casting depends not only on thermo-physical properties of an alloy but also on the actual casting parameters influencing the solidification process (e.g. casting speed, cooling rate and melt feeding).”

Has Client such questions or problems? Is Client interested to solve such problems?

MPI ultrasonic equipment can significantly improve segregation related problems. With correct operating parameters we can eliminate effects of segregation producing more homogeneous microstructure.

Main Framework

For realizing ultrasonic degassing and grain refinement it is recommendable to have two ultrasonic processors:

- (1) One operating in the casting line where liquid aluminum has relatively high temperature (good for degassing);
- (2) One that will be placed closer to the final casting place or mold, where liquid metal naturally has lower temperature (good for initializing and stimulating fine grains crystallization).

In order to be sure about optimal (technological) liquid metal temperatures for degassing and grain refinement, MPI needs to get from you samples of aluminum alloys you intend to use for ultrasonic processing, and we will make parametric testing in our laboratory. Later, we need to discuss with your experts how to satisfy optimal technological conditions. **Technical parameters such as operating temperatures should be absolutely respected if we like to get desired results.**

Next joint activity (between your company and MPI) is to prepare conditions within existing casting line, where we will be able to place and fix ultrasonic processors. MPI is producing some kind of mechanical (controllable) lifting device (as presented on the Figure), as a holder for ultrasonic resonator.

Practically, we will need to organize joint design work, make realistic 3D modeling (to present what we will produce and place in your technological conditions), slightly modify your flow channel and customize our lifting device to fit to your casting line (since this is kind of mechanical frame, or holder, and we need to respect available space you have).

MPI designers will initially make necessary 3D drawings, and client's designers will give necessary information, and later interactively participate in modifying drawings, until we conclude that we have what we need and what can be produced. For getting better feelings or impression about what we will install on/in your casting lines it is recommendable that somebody of your R&D members place a visit to MPI laboratory in Switzerland.

As you can see, for realizing such projects, it is not enough to sell you only a piece of ultrasonic equipment. We need to organize how to apply ultrasonic equipment in your real production conditions, we need to be sure to have (i) good cooling conditions, (ii) proper electric energy supply, (iii) basic thermal protections etc. Consequently, your related investments will be for: MPI ultrasonic equipment, for consulting and design activities regarding 3D modeling and redesign of proper mounting frame and holders, and for parametric testing of your alloys' samples in our laboratory (including our know-how and consulting). We also need to prepare drawings for you to explain how and where you need to modify certain casting-line channel (meaning that



highly professional designers should work on both sides)... and there are always number of other smaller (not counted) activities in such process. This is also kind of learning and technology transfer process, since you will learn from us what is possible, what is not possible, how and where to apply ultrasonic processing, what to do and what to avoid, and all of that has its industrial, intellectual and technological property value. Of course, we are still not discussing technology transfer or selling technology rights and similar industrial and business property items.

Usually, regarding similar projects and collaboration MPI is asking clients to accept the obligation not to patent something what is directly and closely related to our project (meaning to sign an Agreement or Contract). Of course, other arrangements are imaginable in case if we make such Contract (what will have different price).

Below you can see a brief summary about how we could organize works on such projects:

(i) Your production line for continuous aluminum casting should be conveniently prepared (modified or adjusted), that we can install our ultrasonic processors there. This is the process that could take several months of joint work (our and your experts).

(ii) You need to have your team of experts and engineers, dedicated only to this project (to ultrasonic aluminum processing). We will have a lot of joint work and your engineering team should participate and collaborate.

(iii) Your experts should be able to create drawings in Solid Works (or another high level CAD software), and should be well informed to describe your technological, and production lines in all details. We will ask lot of questions and ask you to send us photos and drawings from your production to analyze where and how we need to place ultrasonic processors. Often our ultrasonic equipment should also be slightly modified to fit specific production lines.

(iv) This is the capital investment in new technology, and should be considered as very significant, strategic project for your company. It is not just to buy something from us, and you will continue working alone. You need to involve your top management and to create proper working and R&D environment in your company. All of that is from our experiences collected during long time, when we worked with others. This is also relatively expensive technology (you will need to dedicate significant funds for such projects, since different experts, equipment and preparatory works should be properly organized and financed. You need to include young and motivated, energetic and well educated engineers (***from the fields as: metallurgy, modern mechanics and automation***). Without such structure on your side we will not have good results). Your visit to MPI in Switzerland will be very useful, since you could get much more of very important information.

(v) Our design of ultrasonic equipment is unique and original, and we do not have competitors (you can find number of information about other sources of ultrasonic equipment for metallurgy, but this is not comparable to our design solutions and presents mostly publicity and marketing activities without real industrial and technological potential, or some of authors just need to publish something for keeping their positions). What we have is not a standard ultrasonic equipment you can find on any other place.

The most important items for our discussions and technical collaboration are:

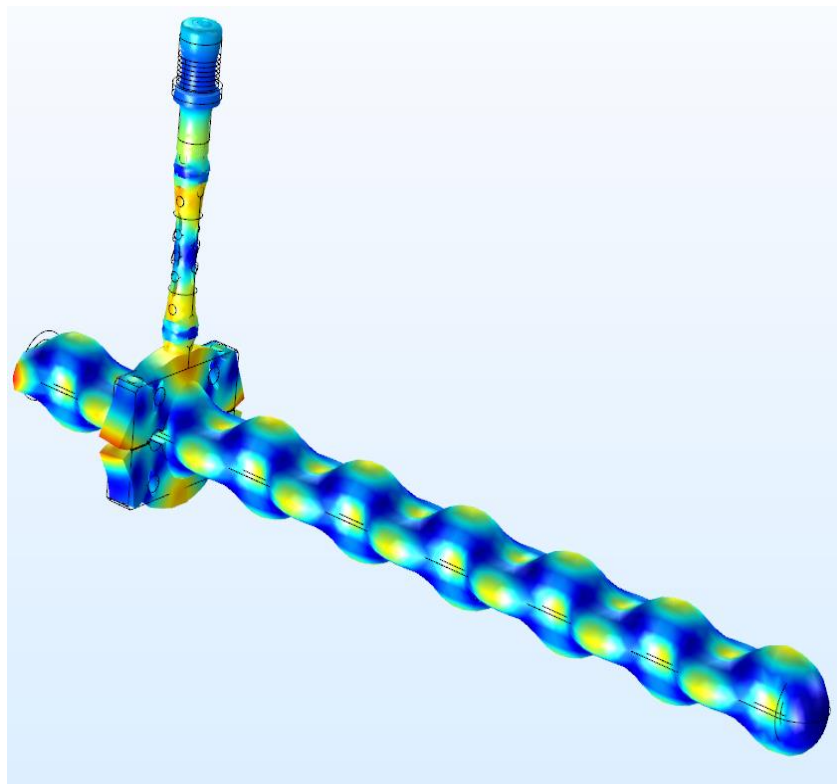
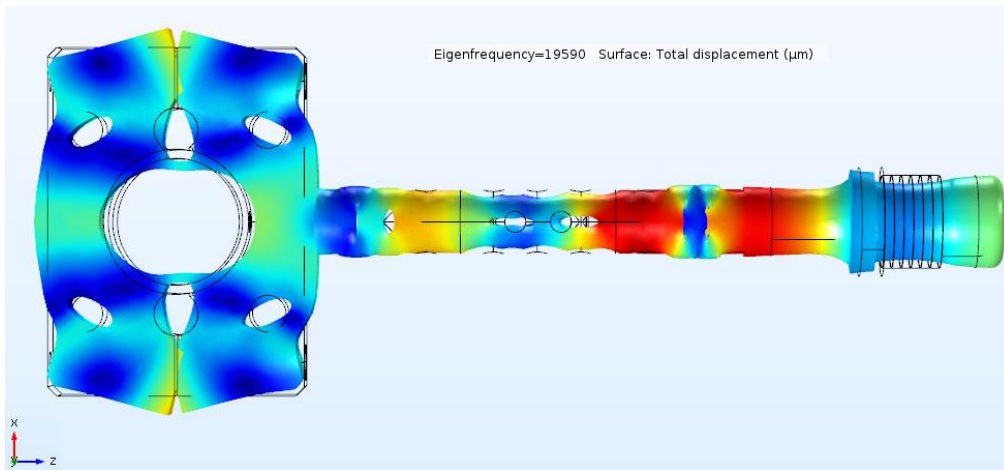
1. Where and how to apply ultrasonic processors taking into account your existing casting lines. We need to see and analyze what should be modified in your factory. We need to find practical ways how we will apply our ultrasonic processors. We also need to apply very good cooling on certain parts of ultrasonic processors. This kind of work is also related to creating realistic 3D models in Solid Works... since we need to produce necessary holders and mounting parts, lifting device etc. All of that is a kind of interactive collaboration between client's and our experts.

2. For metal degassing it is more convenient to have higher liquid metal temperature, and for grain refinement it is necessary to make ultrasonic processing on a lower melt temperatures, meaning that we need to apply minimum 2 ultrasonic processors. We need to make preliminary, parametric testing and to establish optimal degassing and optimal grain refinement temperature ranges (this we can make in our labs). Consequently, we need to apply ultrasonic degassing close to the filter box where liquid metal has higher temperature, and second ultrasonic processing unit should be closer to the casting place (exit) where metal has lower temperature. If you do not have strict control of mentioned technological temperatures, we need to discuss and establish how to control and stabilize liquid metal temperatures in your casting lines, to be within necessary limits for degassing and for grain refinement. Of course, we will also discuss other options regarding minimizing master alloy etc. This is the wide and demanding field, and you will need our collaboration during few years.

3. For ultrasonic degassing, (as well as grain refinement, micro-alloying, homogenizing, inclusions wetting...) it is necessary to satisfy optimal resident and processing time since ultrasonically produced metal transformations are not immediate. In cases of higher flow rates, it will be important to make proper scaling and apply optimal number of ultrasonic processing units.

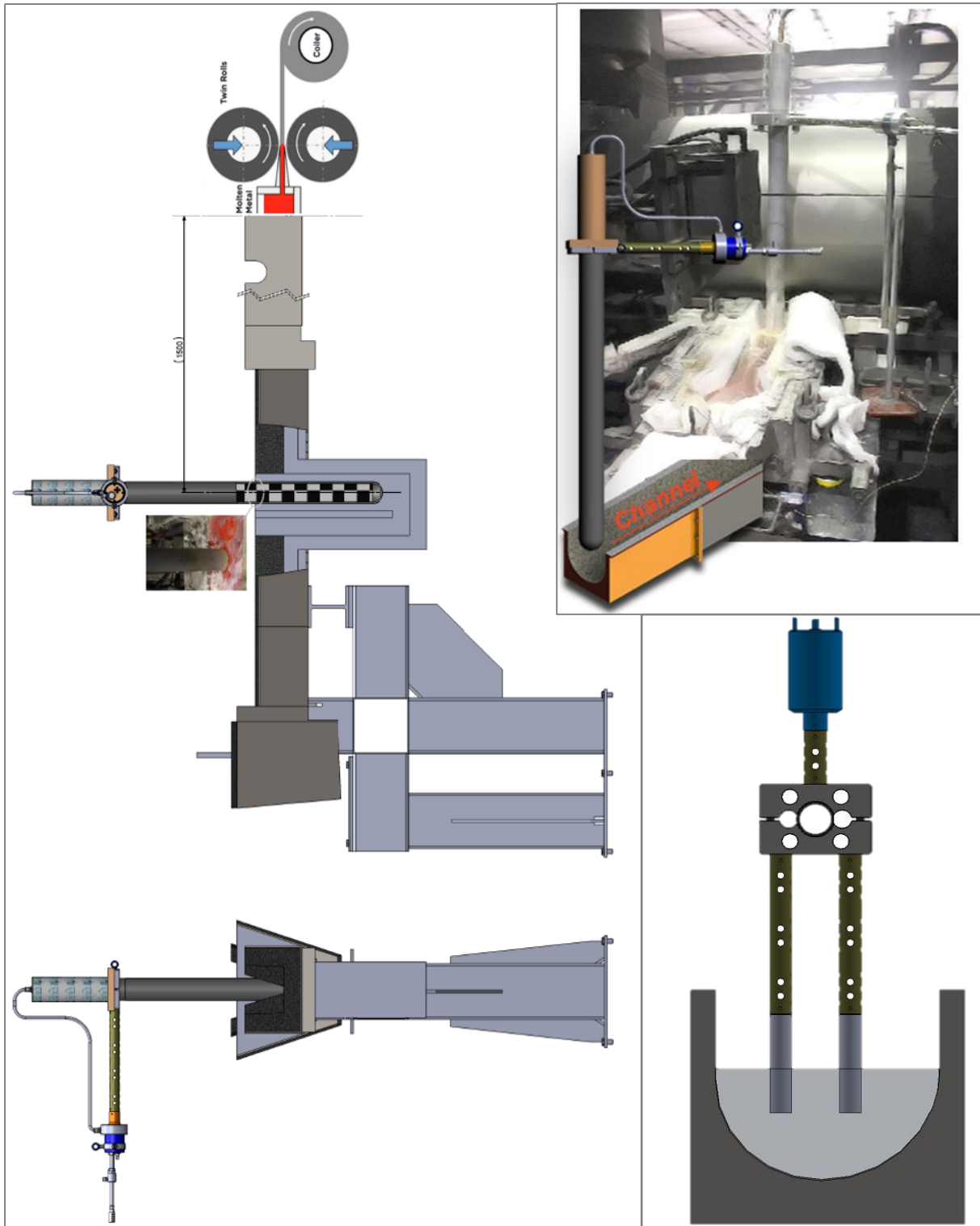
4. Other important items are related to business arrangements, as for example: How we will collaborate, how project will be financed, what kind of support you need. For instance if you only like to buy ultrasonic equipment and get minimal support, or in addition to get know-how and technology transfer that later you can produce ultrasonic equipment...

CAD/CAE Optimization



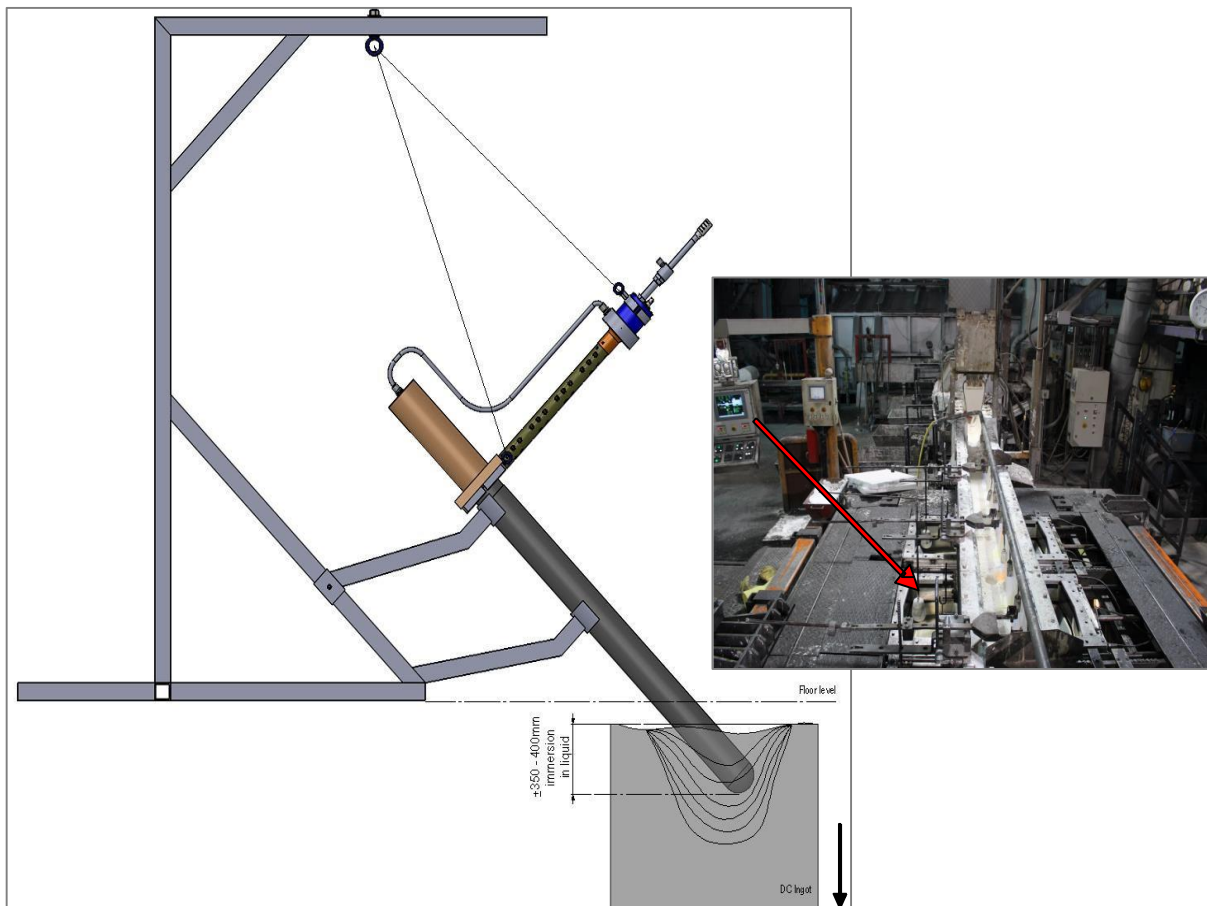
Design options available for CC Casting

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

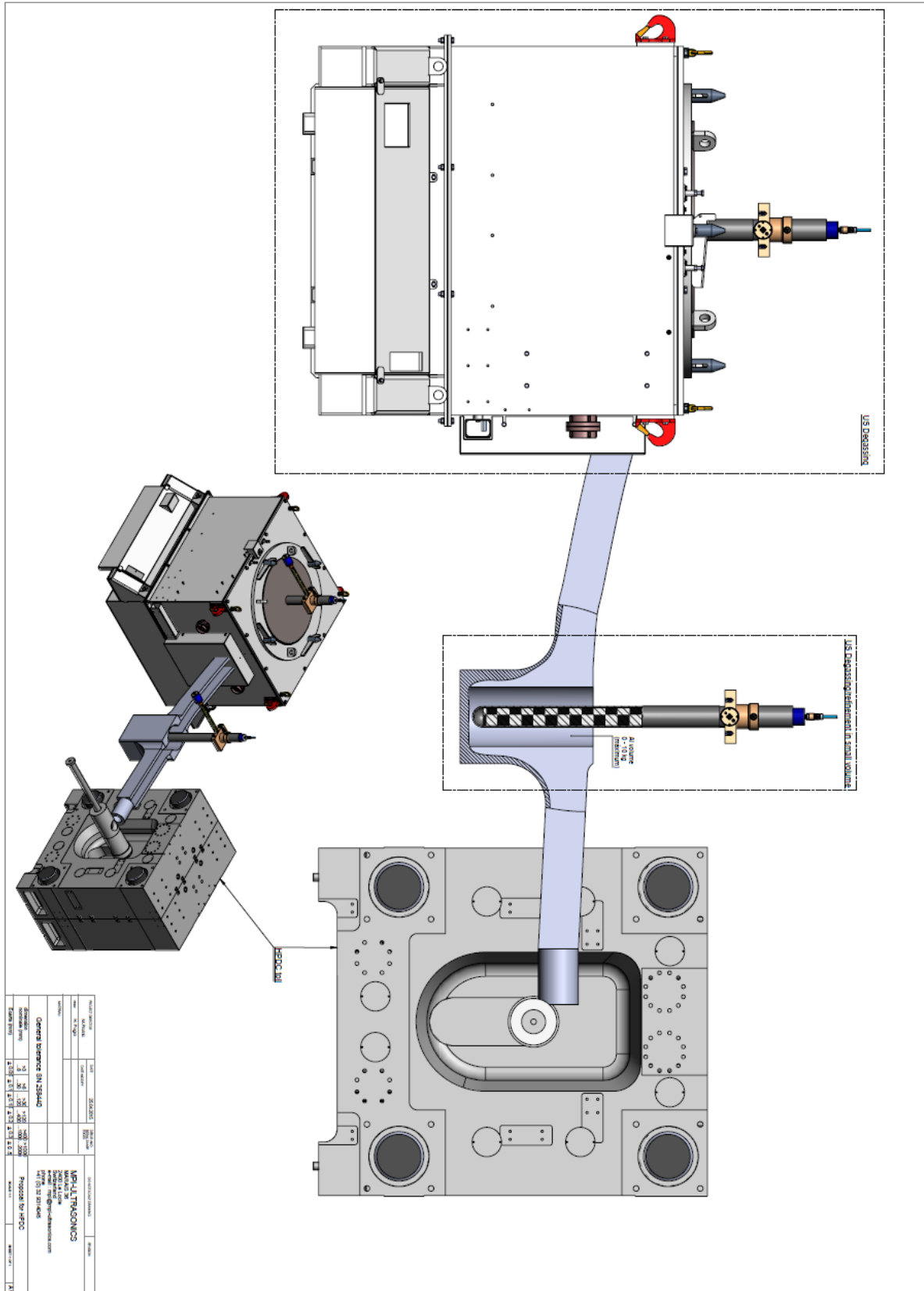


For ingots...

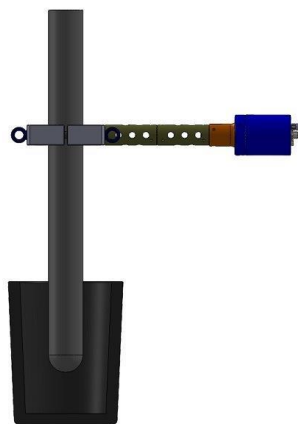
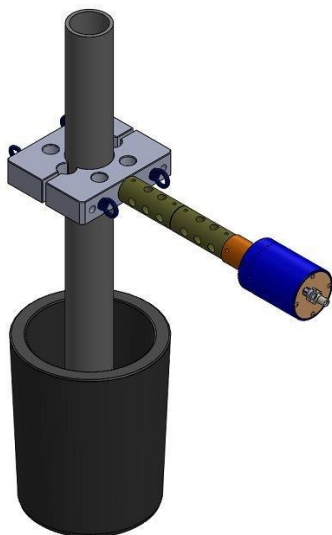
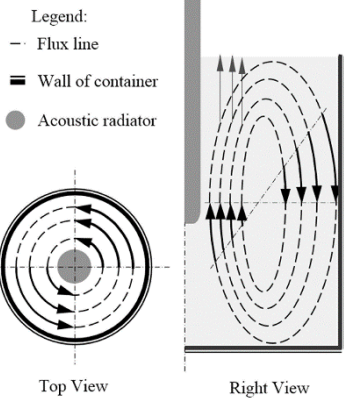
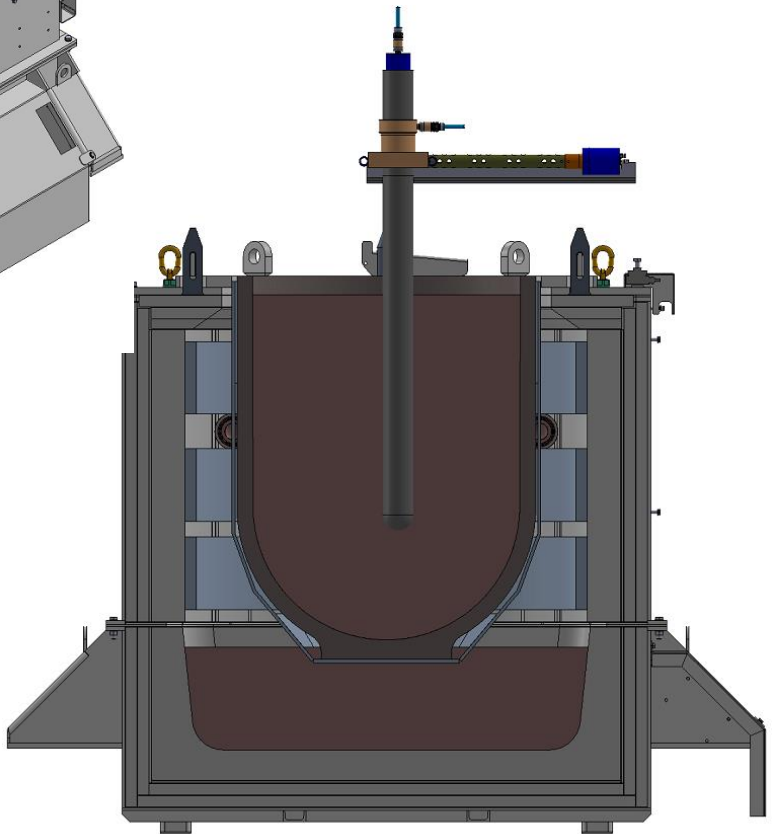
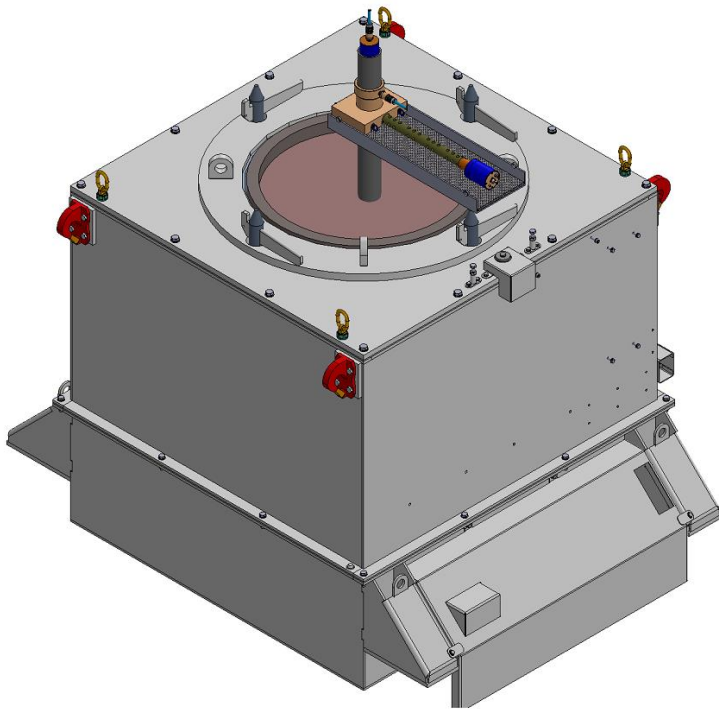
The figure below shows the ultrasonic device suitable to perform treatment of aluminum alloys in a sump of DC-cast ingot. The use of ultrasonic device based on the MMM technology will allow the formation of non-dendritic structure during DC casting making the ingot structure more homogeneous and decreasing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



Design options available for HPDC



Design options available for degassing of aluminum alloys in crucibles



Proposal for Small Ladle