MPI Ultrasonics - sonic and ultrasonic processing technology

mpi ultrasonics
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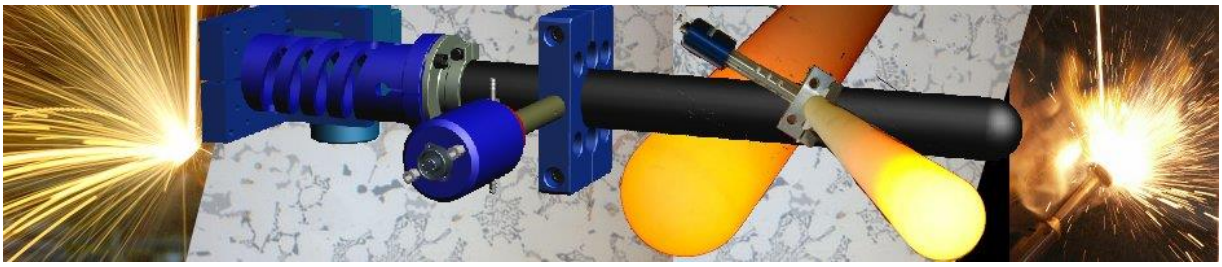
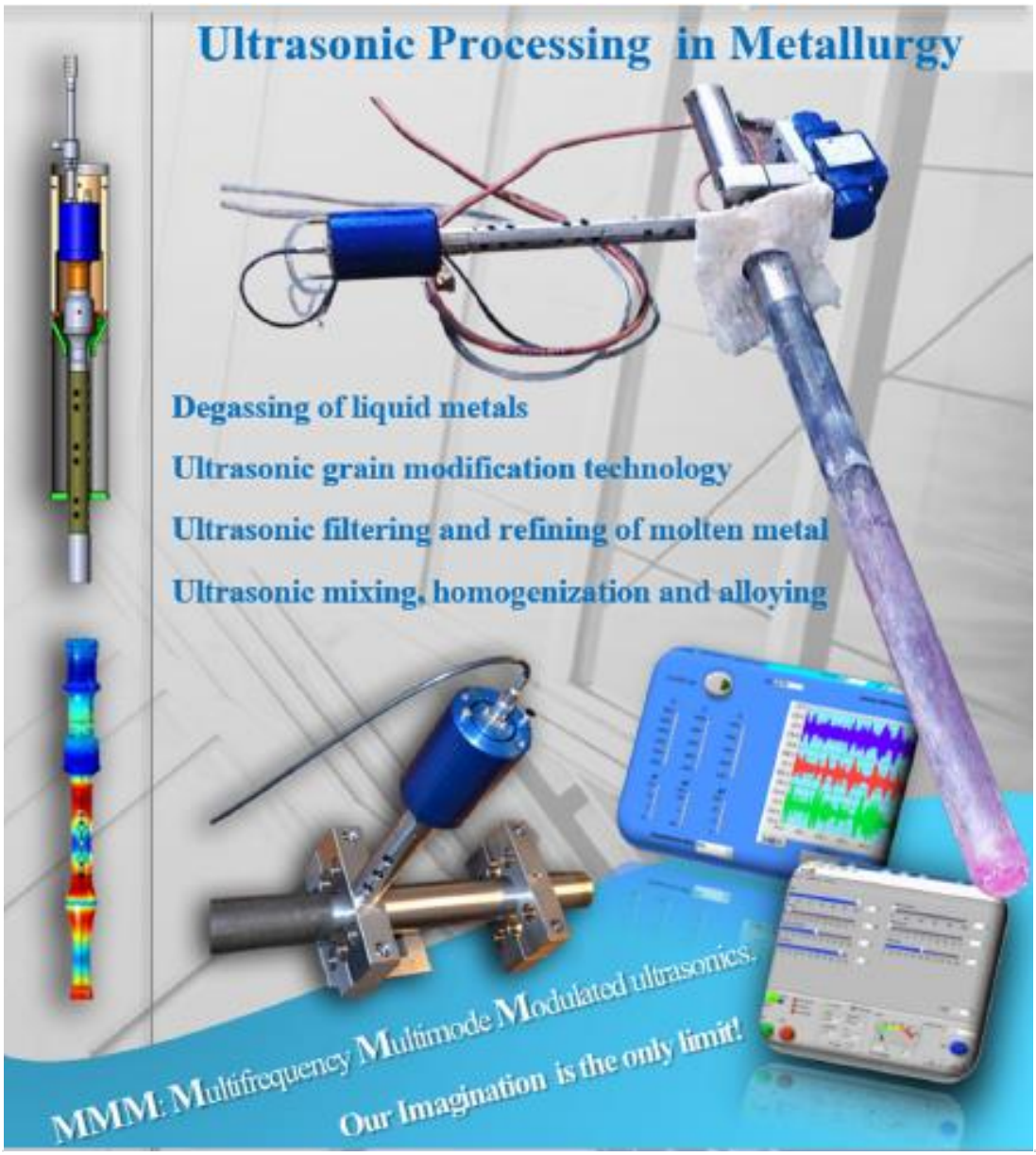


www.UltrasonicMetallurgy.com, www.MPI-Ultrasonics.com



With MMM ultrasonic processing we can realize very strong and long lasting memory effect and extended, residual vibrating life of ultrasonically excited, liquid metal mass. After stopping ultrasonic agitation metal atoms and molecules are still on some acoustic way excited by ultrasonic cavitation and MMM vibrations, and this kind of excitation or perturbation has very long residual life; -for instance 15 minutes.

Of course, mentioned memory effect (of prolonged acoustic activation) is strongly dependent on liquid metal temperature, type of metal alloy, ultrasonic field distribution and delivered ultrasonic energy or power. Effects of ultrasonic cavitation in a liquid metal are the most probable dominant sources or causes of prolonged memory effect.

Generally valid recommendation for ultrasonic processing is that on high liquid metal temperatures, degassing and homogenization effects are dominant, and on temperatures closer to solidification level, grain refinement effects are dominant. If we select certain middle (optimal) temperature, we can create optimal conditions, both for degassing and for grain refinement.

Based on mentioned memory effects (or prolonged vibrational excitation), we can separately make ultrasonic MMM liquid metal agitation and excitation (in a vessel, melting pot or crucible). Later, after we stop ultrasonic transducer, we still have very long time (15 minutes) with active internal vibrations of exited metal atoms to make any kind of casting in another place or mold. Practically, excited metal can be prepared in melting pots or crucibles and later used for casting (since 15 minutes is very long time)...

If we cannot realize good and compromising conditions regarding optimal temperature for simultaneous degassing and grain refinement, we need to analyze other options with two sonicator units: one to place where melt temperature is very high (for degassing), and the second where the temperature is closer to solidification temperature (for good grain refinement).

MMM Ultrasonic excitation is not disappearing fast, having long operating life, and long residual activity. In addition, it is useful to know that MMM ultrasonic vibration sources (sonotube transducers) are creating progressive, omnidirectional Push-Push ultrasonic waves, propagating easily along flow channels, and in cases of casting, metal flow speed (or total casting time) could be accelerated 3 to 4 times (meaning that fluidic resistance and viscosity will decrease during ultrasonic activity). Also progressive MMM ultrasonic waves are propagating over long distances along liquid metal channels and conduits (several meters, for instance), meaning that in static casting and molding we do not need to agitate liquid metal directly inside molds.

We need to control the level (oscillating amplitude or power) of ultrasonic MMM excitation. If sonication is too strong, casting effects regarding crystalline structure are negative (we will get chaotic crystalline structure). If ultrasonic activity is too weak, grain refinement and degassing is also not good. We can control the level of MMM ultrasonic activity by selecting proper combination of ON and OFF time of ultrasonic pulse train on ultrasonic generator (what is in the same time realizing good metal degassing), and by selecting sufficient oscillating amplitude or ultrasonic power.

<u>Different sonicator options</u>, depending on metal processing objectives are:

1. **Ceramic sonotube (or sonotrode) is universally applicable and good for aluminum and magnesium alloys (meaning stable, and no erosion based on cavitation and on chemical activity of liquid metal). Only, pay attention, since ceramic sonotrodes (or tubes) could be broken (not easily because this is silicon nitride, but ceramic is not like metal).**

2. **There is also metal sonotube, made from very special high temperature steel alloy, which is good only for magnesium alloys. Advantage is that metal tube cannot be broken by mechanical shock.**

Both, ceramic and metal sonotubes, operate using the same ultrasonic generator. Metal tube has 50mm external diameter, and ceramic tubes have 60 and 80 mm of external diameter (we can design tubes with different diameters). Ultrasonic Clamps for different tubes are different.

Sonotube sonicators are producing strong and uniform cavitation in a liquid metal, what is good for degassing, homogenization, grain refinement... (and also beneficial for nano-powders mixing with liquid metal, but initial, raw powders mixing should be realized mechanically by steering, and by thermal and diffusion effects in a melting pot). Cavitation could be considered as producing clouds of vacuum micro-bubbles in a liquid metal. When such bubbles are collapsing, about 5000°C is produced locally (microscopically), around submersed solid particles mixed with liquid metal. Also very high, pulsing pressure is being produced (being like micro explosions of cavitation bubbles) in the pressure range of thousand bar or higher. Cavitation is realizing good powders wetting, mixing, homogenization and alloying, including degassing and grain refinement (particles are getting integrated in a liquid metal, also thanks to ultrasonic capillary effect).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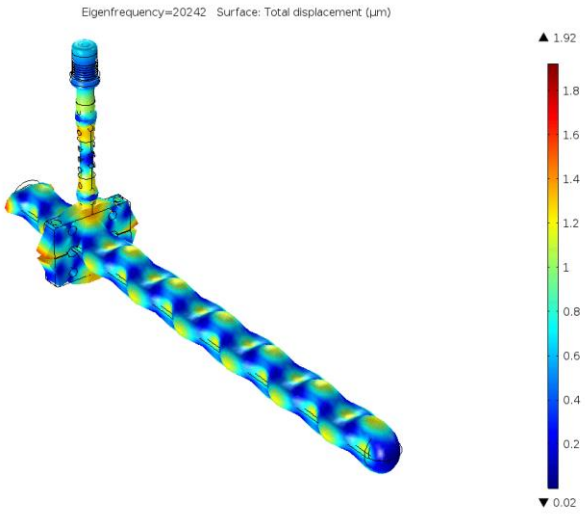
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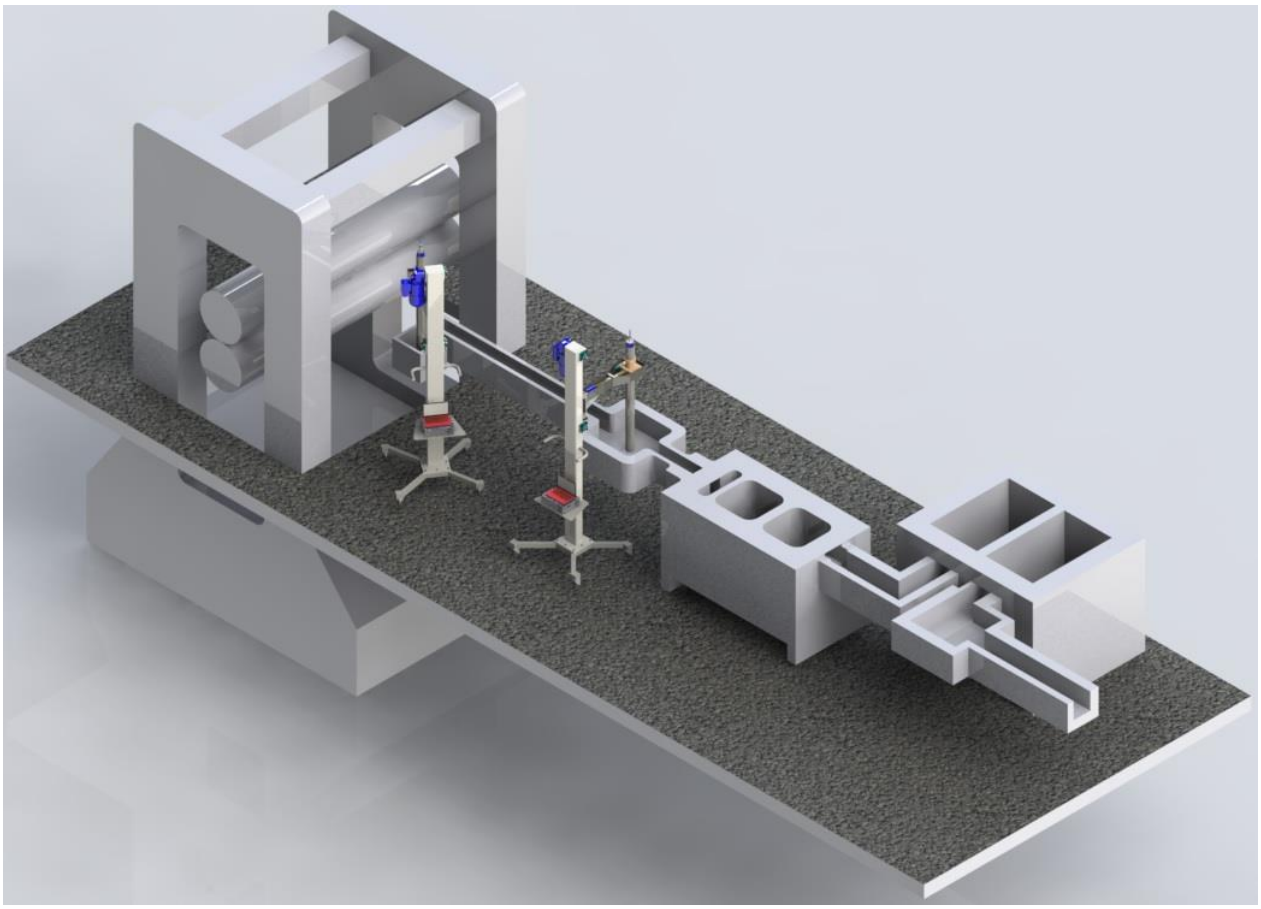
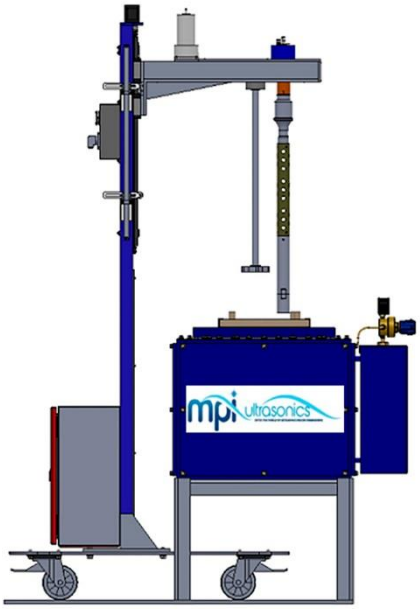
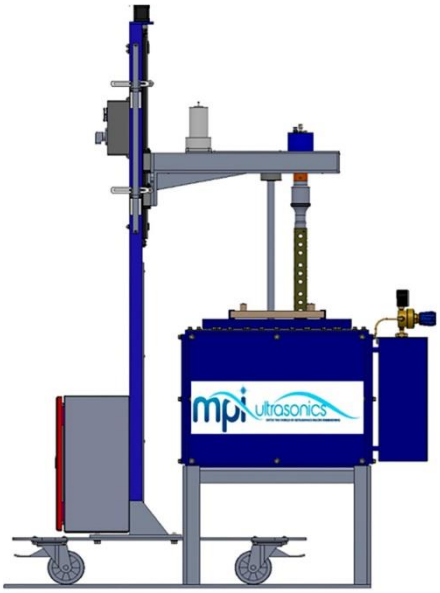


3. **There is, in addition, metal probe mixer (probe sonicator) for very high intensity, laboratory mixing (usually good for small crucibles and ceramic pots). Such metal sonotrodes (or probes) are slowly wearing and disappearing (or dissolving) when operating in a liquid metal, but mixing and homogenization effects of such sonotrodes are very strong. Metal sonotrode tips should be replaced after certain time. Such probe sonicators are smaller compared to sonotubes. Probe sonicators are producing strong liquid metal jet (like an acoustic torch) and strong fluid streaming, but not producing significant cavitation (compared to sonotubes).**





This is anyway multidisciplinary technology and very complex and demanding field of applications, where metallurgical processing is always kind of multi-parameter dependent system. Not all answers, best conditions and solutions are known or present when starting new, challenging projects. Preliminary, qualification and R&D testing will be always necessary (for every new alloy) to determine parametric, optimal operating conditions.

The following text is originally created for specific clients (clients names are removed), but it is generally good and instructive for everybody in aluminum and magnesium alloys industry.

Here, you will get short comments for fast recognition of different situations, technologies and users operating conditions, and for making fast and good recommendations and decisions. Such situations should be clearly presented to potential clients, users and collaborators, as follows:

1. **Easiest applications** (for us and for ultrasonic liquid metals processing) are static casting lines and static crucibles... If we go step by step, starting with simpler and smaller R&D projects and smaller casting lines, where it is easier to control everything, it will be easier for everybody to create proper conclusions and later to create optimal industrial processing.

2. **Worst case scenario** is if our client will immediately ask us to install ultrasonic equipment into certain big, old-fashion, mass production factory, where they have very big casting line with high flow rate of liquid metal, with not well controllable melt temperature, with metal alloy from recycled and dirty or polluted alloys... Such clients should first learn about what is possible and how to realize it... For instance, what are preferable technical and physics related conditions for realistic and good ultrasonic processing. We should be very careful with clients or users who belong to such worst-case scenario situations. Users often show a tendency to react such as: they ask only how much ultrasonic equipment will cost, to make it fast, and obtain the best results in mass-production in existing technological conditions. Existing casting lines should be conveniently modified to accept ultrasonic processing equipment if we like to have good results. Operating temperatures and flow channels should be properly controlled.

3. **Best and always preferable case scenario** (for us and for our clients) is to go step by step, from smaller R&D projects towards more demanding and more complex projects, starting from well-defined and well controllable laboratory, university or scientific research conditions. For instance, starting with static and small casting crucibles. Later we can create bigger casting lines. It is preferable to have all necessary laboratory and analytic conditions around for taking samples and making different measurements, testing and qualifications, almost in real time... To have collaboration with scientific and university experts.... And to learn about ultrasonic liquid metals processing from available sources and references. Later, we can extend and apply ultrasonic processing equipment to gradually bigger casting lines and equipment. Of course, existing casting lines should be conveniently modified for being optimal for ultrasonic processing. We need to learn how many of ultrasonic processors should be installed in certain casting line, since important parameters for getting good

ultrasonic processing results are: **liquid metal temperatures, ultrasonic power and delivered ultrasonic energy, and resident-processing-time of ultrasonic activity necessary to perform certain operation like degassing and grain refinement...**

4. There is **generally present misunderstanding, incorrect opinion or missing knowledge** about the state of the art of worldwide ultrasonic technology and ultrasonic equipment. Badly informed, potential users of ultrasonic equipment for liquid metal processing often think that this is easily available equipment and technology on many places and this is completely incorrect.

Here we will briefly give you the following information (like very short and oversimplified overview and conclusions):

a) Ultrasonic aluminum processing, benefits and good results are known since more than 40 years (Prof. Eskin started such research). Unfortunately, equipment developed in Russia (and everywhere else) is not good for mass industrial production (it was mostly good for getting small scale, laboratory and scientific conclusions).

b) Until present, we can find many publications, publicity materials, books and patents regarding ultrasonic equipment for liquid aluminum processing. Unfortunately, all of that has so many weak sides and it is not applicable for continuous mass production. But many of our big competitors are trying to develop such equipment (and we know most of them, and most of them visited MPI). Problems they have are related to ultrasonic generators (electronic equipment), transducers and materials that should be directly submersed in a liquid metal and perform ultrasonic processing. This is too wide field to be elaborated here. MPI has answers and solutions for all of known difficult problems regarding ultrasonic equipment.

c) Practically, there is nobody (worldwide) who can satisfy all users' demands and expectations... Many clients are often asking questions with certain background or presumptions that they can find such ultrasonic equipment easily, ready-made, on number of places (worldwide), and this is too far from being correct.

d) Presently, what we are doing, and what we have (what you can see on our web sites: www.UltrasonicMetallurgy.com) is too different, too far and too much advanced compared to what others are offering. This is just a beginning of new insight, strategy and projects for applying ultrasonic processing in mass production of aluminum and magnesium (for degassing, grain refinement, creating new alloys, micro-alloying, creating new master alloys, making metal-ceramic composites etc.). To explain all of that in details would also take a lot of time.

e) We will propose different ultrasonic processing units that will be directly applicable in production, but I suggest that you go systematically and start with smaller capacity production, or laboratory casting lines. Learning and adjusting process parameters and practical optimizations are taking a time.

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

g) User/Client needs to have a team of experts and engineers, dedicated only to such projects (meaning to ultrasonic aluminum processing). We will have a lot of joint work and your engineering team should participate and collaborate.

h) User's experts should be able to create drawings in Solid Works (or another high level CAD software), and should be well informed to describe their technological, and production lines in all details. We will ask lot of questions; -ask you to send us photos and drawings from your production, to see where and how we need to place ultrasonic processors. Our ultrasonic equipment should also be slightly modified to fit your production lines.

i) This is the capital investment in new technology, and should be considered as very significant, strategic project. 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. I am telling you all of that from our experiences collected during long time, when we worked with others. This is also relatively expensive technology (you will need to dedicate significant financing funds for such projects, since different experts, equipment and preparatory works should be properly 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 user's side we will not have good results. ***Client's visit to MPI in Switzerland will be very useful, since it will be possible to get much more of very important information.***

j) Our design of ultrasonic equipment is 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 academic positions. What we have is not a standard ultrasonic equipment you can find in any other place.

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

-One operating in the casting line where liquid aluminum has relatively high temperature (good for degassing),

-And 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).

l) In order to be sure about optimal (technological) liquid metal temperatures for degassing and grain refinement, MPI needs to get from User's 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 User's experts how to satisfy optimal technological conditions. Technical parameters such as operating temperatures should be absolutely respected if we like to get desired results.

m) Next joint activity (between User 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 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 there), 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 User'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 User's casting lines it is recommendable that somebody of User's R&D members place a visit to MPI laboratory in Switzerland.

n) As we can see, for realizing such projects, it is not enough to buy only a piece of ultrasonic equipment. We need to organize how to apply ultrasonic equipment in User's real production conditions. We need to be sure to have good air-cooling, electric energy supply, basic thermal protections etc. Consequently, one part of the price is for MPI ultrasonic equipment, then additional price is for consulting and design activities regarding 3D modeling and redesign of proper mounting frame and holders, then our parametric testing of your alloys in our laboratory (including our expertise and consulting) has certain price. We also need to prepare drawings for you to explain how and where you need to modify certain casting line channel (meaning 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 client 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 and

technological property value. Of course, this time we are not discussing technology transfer or selling technology rights and similar industrial and business property items.

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

Important Comments

1. **MPI's principal R&D and business activity is related to design of high power, ultrasonic industrial equipment, meaning transducers and ultrasonic generators. In addition we are often creating customized ultrasonic processing equipment**
2. **MPI laboratory is typical high power electronics and mechanics lab for ultrasonic transducers and generators assembling and testing.**
3. **MPI in Switzerland does not have professional metallurgical laboratory. We simulate operating regime of liquid aluminum and magnesium sonicators using water loading (since properties of liquid aluminum and magnesium on 700 to 750°C are similar to water regarding viscosity, acoustic impedance and acoustic loading). Others, involved in similar R&D, are also using water loading for standard laboratory and R&D testing, when developing sonicators for liquid aluminum and magnesium processing.**
4. **After we are sure that we have well operating sonicator (regarding every particular project), we test ultrasonic aluminum processing in professional metallurgical factories and laboratories of our partners, friends and clients.**
5. **MPI also has very close collaborators, partners and friends, where we have access to metallurgical, R&D or university labs. Sporadically, we carry mentioned small-scale testing before we go to bigger metallurgical facilities (since it will be too expensive for MPI in Switzerland to have a big metallurgical facility).**
6. **Anyway, MPI has lot of accumulated results, publications, pictures, movie files, documentation and drawings related to our metallurgical projects and results. To have more of that in MPI will be too expensive. We are perfectly able to make customized equipment design regarding new applications. Of course, universally applicable, ready-made, and immediately available sonicators for all metallurgical conditions in different factories do not exist. We also do not give to our potential clients mentioned ultrasonic processing equipment, just for preliminary trials, and free of charges, for testing, or to satisfy their curiosity... This will also be too expensive for MPI, and anyway all sonicators are getting affected by different testing... We will first try to give, maximum as possible, free-of charges information, to our clients, and to answer many questions they could ask. Later, there will be a clear threshold zone when a client should decide to open the project and to start investing.**

Here is the RESUME with arguments regarding foundations of new projects with different clients.

1. ***Our opinion is that we will every time apply ultrasonic degassing after the filter box (because metal temperature there is high enough for degassing, and metal is already filtered and ready for degassing). If there is not enough space in a degassing box and around, we need to make small modification of a flow channel and create place for our sonicator tube (just after the degassing box). This is the reason why we need pictures and drawings of degassing box (and space around), and in this case we need to collaborate with a client to create necessary documentation and design proposals, how and where to modify casting line or flow channel.***

2. ***For DC casting we need to design very specific, customized mounting and holding frame, or lifting device in order to be able to apply ultrasound directly in a sump. For this design process we need to have real dimensions of the casting place (close to the sump), including pictures, drawings, and if possible some movie showing the casting of ingot... Based on such data we need to create necessary mounting frame and lifting device for ultrasonic processor unit (for our sonicator).***

3. ***Ultrasonic optimization and modification of master alloy is very good idea and project... this could be beneficial in all kind of castings. We will continue working on this project. You know our discussions about ultrasonically created master alloys...***

4. ***If we need to mix different metal components, and if this is making problems in Client's place, your idea to create an independent mixer (specific crucible) with mechanical mixing and ultrasonic processing inside is very good. This way, if Client is using recycling grade, old and dirty scrap metals, we will first create good, homogenized alloy (meaning produce clean ingots), and later we can use such ingots for standard casting lines.***

5. ***Liquid metal temperatures are decisive (very critical and very important) parameters for good degassing and grain refinement. Other important factors are resident processing time (duration of ultrasonic radiation to realize desired effects), and geometry or shape of casting lines and places where we will install sonicators... In some cases maybe we will need to apply several***

sonicators in different positions... This is also part of R&D, consulting and belongs to a learning process (technology optimization).

6. ***Client needs to have kind of professional designer's team (engineers), and we need to make lot of preparatory design work in order to be able to apply ultrasonic processor units. This introductory work is a kind of consulting and design work and should have its price (it will take several months to make proper 3D and 2D documentation, and it will take a time until we produce proper mounting and lifting devices and modify casting lines). Cannot be just informative discussion free of charges. Client should be really and tangibly committed to such projects, and not only ask to get piece of ultrasonic equipment and place it where they like... It is much better for Client to create proper R&D lab and pilot plant (smaller size casting line) in order to test ultrasonic technology... and to be connected with certain university where Metallurgy is the main subject. From Clients' feedback we can often see that they do not care about creating such scientific, R&D and technological environment. They just select worst case scenario, which could be summarized as: give me ultrasonic toy and I will play and I expect to get perfect and fast results... NO need to go to smaller casting plants and test and learn, no need for R&D, no need for consulting and joint team work, no need to include university professors, no need to invest in technology modernization in Client's place... We need to convince clients that worst case scenario only looks like best choice and decision, but it is strategically wrong, and taking into account long term interests of a Client, it is not recommendable... Anyway, if project will be correctly financed, we could collaborate in any of mentioned conditions, but we need to insist on 100% satisfaction of here mentioned technical and technological conditions (from 1. to 5.).***

Examples:

1. **Ultrasonic liquid metal processing on relatively high temperatures**: Degassing effects will be facilitated (and grain refinement effects will be reduced). For instance, in AlSi9Cu3 alloy, good ultrasonic processing temperatures for degassing are from 700°C to 720°C. Residual vibrating life or time (of ultrasonically activated liquid metal) is reduced because cavitating effects and bubbles are not stable and have randomized behaviours and short duration, but such conditions are very much beneficial for hydrogen removal.

2. **Ultrasonic liquid metal processing on relatively low temperatures**: Grain refinement effects will be facilitated (but degassing effects will be reduced). For instance, in AlSi9Cu3 alloy, good ultrasonic processing temperatures for grain refinement are between 640°C and 680°C. The cavitation promoted during ultrasonic treatment (on lower temperatures) is more stable (than on high temperatures), and this is facilitating generation or creation of solidified nuclei. Furthermore, acoustic streams generated during the effect of cavitation will act as dispersers of created nuclei throughout the liquid mass. Here, the life of bubbles created during cavitation effects will be longer, what is important for reach grain refining.

Conclusion:

1. Such technology and equipment design, as established by MPI, is relatively new and unique. We do not have competitors or somebody else who is producing similar equipment. Conceptually, regarding ultrasonic equipment design, we are too far from anybody else, and this is still very progressive and evolving technology.

2. We did not have enough time to create very big number of references, applications and clients in order to be able to make some kind of statistics and to answer all questions related to productivity, efficiency, prices, power consumption, and maintenance and service expenses. However, we have significant success in Russia and China regarding ultrasonic processing of magnesium and aluminum, and activities in mentioned countries are still ongoing. Anyway, in the same field, nobody else is better, nobody else exist (with

equipment applicable on a practical, industrial level), and there is no real comparison between what we offer and what others are publishing.

3. Client for our technology could be somebody who is not expecting "***key-in-hands, total solution, 100% readymade factory installation***", since it is too early to offer such technological package. Price for such ambitious expectations could be few hundred millions (but this is still not available from anybody). In reality, our clients should be, very well and enthusiastically informed about benefits of ultrasonic processing of liquid metals, since in process of implementing this technology we need interactively rich collaboration with a client in order to adjust our equipment to existing technological conditions in a client's production. Practically it is preferable to have only very advanced metallurgical clients, susceptible and sensitive to logic and demands of R&D projects and scientific research. Who is only asking, "How much I will benefit next day" and similar questions, will not be a good client or partner for us. Luckily, we are still too far from others, and we already have number of technical and scientifically relevant results and answers. Anyway, there is a lot of work in front of us.