ULTRAGASSING Report Summary

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Final Report Summary - ULTRAGASSING (DEVELOPMENT OF A DEGASSING SYSTEM FOR ALUMINIUM CASTING PROCESSING BASED ON ULTRASOUND)

Executive Summary:
The foundry sector of non-ferrous alloys in Europe is losing competitiveness against low cost countries. In the last two years about 25 % of the working places of the sector have been lost, supposing a destruction of about 30,000 employs. As long as non-EU manufacturers are able to benefit from low-cost labour and lax environmental constraints, EU manufacturers will be at a disadvantage. Therefore, to remain competitive and maintain a viable domestic industry, research and development activities are a must, in order to improve the technical performance. But the European foundry sector, composed mainly by small companies of less than 50 employees, lacks the structure and capability to promote and execute R+D projects on their own.

ULTRAGASSING is an example of R&D project that propose an important improvement for the EU foundry sector of non-ferrous alloys. The development of a new degassing system that improve the melt quality, by reducing the gas content and removing the oxides, will enhance significantly the quality of the components produced. In addition, the complete absence of harmful gas emissions will meet the present and all the future potential environmental regulations.

The ULTRAGASSING PROJECT define a methodology on the application of ultrasonic degassing treatment in the European light-alloys foundries, providing them with a safe and environmentally friendly method to improve the quality of their cast parts. Light alloys play a key role in vehicle weight reduction and in the last years the amount of aluminium parts in new vehicles has been steadily increasing. Moreover, weight is an even more critical factor in newly developed electric and hybrid vehicles, as it highly affects their autonomy. The global greenhouse savings derived from applying aluminium in vehicles is expected to double by 2025. However, the use of aluminium alloys is still limited by the quality and insufficient properties of the cast parts, which suffer from gas porosity.

The main benefits of ULTRAGASSING technology can be summarised on:

• Higher quality of the treated material: Ultrasonic treatment of molten aluminium has an important advantage over the existing methods. Not only the concentration of hydrogen is lower than by purging gas mixtures through the melt, it also reduces the oxide content, increases the density (porosity is lower) and the mechanical properties of the final material.

• Zero emissions: The technology developed will be based and use exclusively ultrasounds for the degassing treatment. It will avoid the use of gas mixtures (often containing chlorine and fluoride) that is presently the most common method for light alloys degassing. The complete absence of gas emissions will meet the present and all the future potential environment regulations.

ULTRAGASSING want to focus on market automotive, aviation and safety structural parts.

Project Context and Objectives:
During the ULTRAGASSING PROJECT the link between ultrasonic degassing parameters, melt quality and casting parameters is established, allowing the development of a versatile technology that can be finely tuned to specific casting process requirements. This new degassing technology based on ultrasound was validated and compared in performance with the currently used ones.

ULTRAGASSING main objectives:

1. To establish the link between ultrasonic degassing parameters (acoustic power, time, tool design), melt quality (gas content, oxide content), and casting parameters (temperature, melt flow rate).

2. To develop a technology that can be applied to different casting processes.

3. To demonstrate the efficiency of the developed technology as compared with the currently used one.

During the project, the following results were achieved:

- Establishment of the relationship between the parameters of degassing ultrasonic (acoustic power, time, design), quality of the molten material (gas and oxide content), and casting parameters (temperature, flow rate).

- Definition of basis for the selection and design of ultrasonic equipment (transducer and sonotrodes) and electronic required.

- Definition and implementation of a new numerical model for the design and optimization of the acoustic system (sonotrodes).

- Design and construction of two prototype for aluminium degassing based on ultrasounds, one for specific purpose (High Pressure Die Casting) and other for general purpose (Gravity Casting and Low Pressure Die Casting).

- Development of a versatile technology applicable to different casting processes.

- Demonstration of ULTRAGASSING technology efficiency compared to current degassing technologies (lab and industrial validation): mechanical properties and porosity are similar or better compared with traditional technologies, with the added value of the absence of harmful gases and less dross formation.

Project Results:

TECHNOLOGY CONCEPTUALIZATION

Main S&T results:

• Analysis of background information on the state of the art in the knowledge and technology related to the project.
• Definition of the concept of the technology and the requirements of the hardware.
• All the possible solutions to treat the molten aluminium have been analysed through describing the advantages and disadvantages of each of them. Basically, two scenarios have been drawn:
  1.- To treat a large volume of molten aluminium (with permission of technology) inside any existent part of the current process: launder, ladle or holding furnace.
  2.- To treat a small volume inside an intermediate stage, but trying to obtain an excellent degassed aluminium in order to cast high quality parts.
To reach these results the work was split in three tasks:
1. Literature review
2. Definition of the Main System Specifications
3. Technology conceptualization

RESEARCH ON ULTRASOUND EFFECT ON CAST ALLOYS

Main S&T results:
• Evaluation of the effects of ultrasound in aluminium casting alloys.
• Characterization of the system “molten aluminium/ultrasonic equipment”.
• A degassing research facility is set up.
• Hydrogen measurement methodology is developed and tested using direct and indirect hydrogen measurements.
• The mechanisms of re-gassing after the end of ultrasonic degassing are revealed and the correlations with environmental humidity, pressure and the hydrogen concentration after degassing are found.
• The microstructure of ultrasonically degassed alloys do not change as compared to the starting material. Porosity is significantly reduced as revealed by optical metallography and 3D tomography

To reach these results the work was split in three tasks:
1. Evaluation of ultrasound effects on aluminium cast alloys
2. System properties characterization
3. Test of different sonotrodes design and materials in molten aluminium

SYSTEM MODELLING

Main S&T results:
• Definition and implementation of a numerical model that provides a basis for the prototype’s design.
• Model validation in aluminum degassing system.
• Adjustment and validation of sonotrode models has been done. A successful prediction of natural frequency versus temperature has been achieved.
• The steady-state analysis and the thermo-mechanical simulations of the ultrasonic equipment coupled with experimental results present a larger understanding and control of the input parameters:
  - Geometrical shapes of each component,
  - Materials: stiffness, density, damping and thermal properties
  - Tightening conditions and pre-tensioning of the assembly
  - Thermal conditions
• The FEM model allows a more efficient ultrasonic equipment design, as it is possible to previously estimate the sonotrode’s resonance frequency, the energy losses, the sonotrode’s amplitude and the limits of use whilst analyzing the mechanical stresses inside the equipment.
• It has not been possible to obtain a model that allows to simulate the degassing process. Cavitation models implemented have not yielded results representative of reality. The main cause of this fact should be attributed to the nature of the process: the simulation of a process of rapid dynamics (an order of magnitude below microseconds) that extends for several seconds. In order to process the model in reasonable computation time, the sound wave cannot be discretized in more than six points. Possibly the accumulated errors in this temporal discretization are the cause of the malfunction of cavitation models.
• On the other hand, the simulation of the fluid dynamics without cavitation provides qualitatively correct results. These results could be used in a comparative manner to improve the shape of sonotrodes and cavities for degassing.
To reach these results the work was split in three tasks:
1. Basic research
2. Simulation procedure development
3. Model implementation and validation

RESEARCH ON ULTRASOUND EQUIPMENT

Main S&T results:
• Establishment the basis for the design of the prototype transducer and sonotrode
• Definition of the electronics required for the ultrasound equipment

To reach these results the work was split into three tasks:
1. Research on geometric and material solutions for the transducer and sonotrode construction
2. Research in temperature effect on the ultrasonic system
3. Research in the electronics of the ultrasonic system

DESIGN AND CONSTRUCTION OF THE PROTOTYPE(S)

Main S&T results:
• Definition of the electronics required for the ultrasound equipment
• To design a prototype for aluminium degassing based on ultrasounds
• To construct the prototypes required for its validation in the project
• The prototype for Gravity and HPDC have great chances of success.
• We must take special care in the LPDC prototype in the material of the flow that will be in the fusion oven to the recipient of transport.
• Installation and training of the prototypes in the Labs and Industrial facilities.
• Close collaboration with foundries to support technical problems and identify technical improvements to be implemented in DEMO project.

To reach these results the work was split into five tasks
1. General prototype definition
2. Design of the prototype
3. Construction of the ultrasounds generator.
4. Construction of the transducer and sonotrode.
5. Prototype assembly and first testing.

TEST IN AN INDUSTRIAL LABORATORY

Main S&T results:
• Evaluation of the effects of ultrasound degassing treatment on the quality of aluminium cast components
• Optimization of the process parameters for the different casting processes
• The delivered results of hydrogen content in aluminium melt from the existing technologies are depending on the collected sample.
• The melt surface is not disturbed during ultrasonic degassing, that cavitation bubbles are formed within the metal, so the bubble/melt surface is free from oxidation causing far less dross formation in comparison with the impeller degassing method, and as a result no chlorine is needed.
• The US treatment improves the mechanical properties of the alloy in comparison to the impeller treatment.
• The melt temperature has a significant effect on the efficiency of ultrasonic degassing. The degassing rate in the temperature range between 700 and 740 °C is faster than the degassing rate at lower treatment temperature.

To reach these objectives the work package was split into three tasks
1. Design of experiments and methodology
2. Cast component production with the prototypes
3. Results analysis and prototype adjustment

VALIDATION IN INDUSTRIAL CONDITIONS

Main S&T results:
• Validation of the ULTRAGASSING technology under real industrial conditions
• The comparison of the parts degassed with Prototype 1 by HPDC show similar properties to those degassed with the lance, some of them slightly better and some of them slightly worse: better hardness and yield strength, slightly lower tensile strength and elongation at brake and higher porosity.
• We had extremely hard conditions (830 °C, 550 kg melt) for the US cleaning. This will mark the worst case in an industrial foundry production.
• Nevertheless the results for porosity and fracture elongation are similar the same like in the castings after the Impeller treatment.
• With the prototype 2 (LPDC/GC) a significant hydrogen degassing was verified. In principle a degassing is feasible in the foundry industry. Above all, the rotation of the sonotrode has a positive effect on the overall degassing.
• The extreme conditions, such as high melt temperature and increased ambient temperature, respectively higher absolute humidity lead to increased hydrogen content in the melt which compensated the effect of the US degassing treatment in particular. By some small targeted optimizations of the prototype and the treatment parameters, it appears possible to achieve the same range of hydrogen content obtained with the impeller degassing method.
• Initial investigations show that the morphology of the pores by the US treatment changes. The pores become significantly smaller even with slightly higher hydrogen content, the ductility or fracture elongation of cast samples improved as a result of the lower notch effect of the pores.
• The US treatment improves the fracture elongation of the alloy in comparison to the impeller treatment.
• The melt temperature has a significant effect on the efficiency of ultrasonic degassing. The degassing rate in the temperature range between 700 and 740°C is faster that the degassing rate at lower treatment temperature. The delivered results from the existing technologies (RPT and Alspek) of hydrogen content in aluminium melts are dependent on the location of the collected samples.
• The melt surface is not disturbed during ultrasonic degassing. Cavitation bubbles are formed within the metal, so that the bubble/melt surface is free from oxidation causing far less dross formation in comparison with the impeller degassing method. Furthermore no chlorine is needed to reduce oxide inclusions in the Al-melt.
• The ultrasonic degassing rate in a large volume of melt is obviously lower than that in a small volume of melt. However, the steady-state density of RPT specimens made from ultrasonically processed melts does not change with altering the volume of the melt.

To reach this objective the work package was split into four tasks
1. Validation of the prototype in industrial conditions for Gravity Casting & HPDC
2. Validation of the prototype in industrial conditions for Low Pressure Die Casting process (LPDC)
3. Components characterization and comparison with components produced under standard industrial conditions

Potential Impact:
Potential Impac:
ULTRAGASSING is an example of R&D project that propose an important improvement for the EU foundry sector of non-ferrous alloys. The development of a new degassing system that improve the melt quality, by reducing the gas content and removing the oxides, will enhance significantly the quality of the components produced by foundries. In addition, the complete absence of harmful gas emissions will meet the present and all the future potential environmental regulations.

With the present ULTRAGASSING PROJECT the metal casting industry will benefit from a new degassing technology based in ultrasound, and the corresponding hardware, to offer to the vast market of foundries (mostly SMEs but also to larger companies) a versatile technology applicable to different casting processes.

The melt surface is not disturbed during ultrasonic degassing. Cavitation bubbles are formed within the metal, so that the bubble/melt surface is free from oxidation causing far less dross formation in comparison with the impeller degassing method. Furthermore no chlorine is needed to reduce oxide inclusions in the Al-melt.

ULTRAGASSING Main dissemination activities:

• The project Image
Since beginning of the project the graphic charter was defined and updated. This includes: ULTRAGASSING logotype, Templates for reports, Poster and leaflets for project promotion.

• The Project Web Site
The project web site is available since the beginning of ULTRAGASSING project. It is accessible at http://www.ultragassing.eu

• Partners web sites:
To increase visibility of ULTRAGASSING project, the partners implemented within their own website a link to ULTRAGASSING website insofar as it is possible.

• Professional Videos:
http://www.youtube.com/watch?v=KHz8yajAuPk
http://www.youtube.com/watch?v=xmEM2saE-XU

• Main participation in fairs/conferences:
-Euroguss International Trade Fair for Die Casting 2012: Exhibitor at the International Trade Fair for Die Casting held in Nuremberg, Germany from 17th to 19th January, 2012.

-Meeting from the European Solidification Group 2012: Presentation of the Ultragassing Project, “Degassing for low pressure die casting” to the European solidification group at the Technical University of Denmark in Copenhagen from 06th to 07th February 2012.

-Ankiros Annofer Turkcast 2012: The 11th iron-steel & foundry technology, machinery and products trade fair was held in Istanbul, from 13th to 16th September, 2012, which is the largest and most influential exhibition in the Turkey foundry industry.

-METEF International Aluminium Exhibition 2012: Showcase exhibition for the entire aluminium and non-ferrous metals manufacturing segment held in Verona, Italy from 18th to 21st of April 2012.

-Grand Foundry Technical Conference 2012: The Grand Foundry Technical Conference was held in Salzburg from 26th to 27th April 2012
METALLURGIA 2012: Held in Joinville Brazil, from 18th to 21st of September 2012, this fair has already established itself as one of the major events in the industry’s calendar. It is held in the second largest centre for casting in Brazil, where the largest foundry in Latin America is located and also one of the most advanced in the world.


Aluminium Trade Fair in Düsseldorf 2012: It was held in Düsseldorf Germany, from 9th to 11th October 2012, with 25.000 visitors from 100 nations and 950 exhibitors.

International Conference on Aluminium Alloys ICAA13: From 3rd to 6th June 2012 the International conference on aluminium alloys (ICAA13) was held in Pittsburgh, PA, USA (up to 400 participants). Presentation of “Role of solute and transition metals in grain refinement of aluminium alloys under ultrasonic melt treatment”. Also published in the conference proceedings.

European Industrial Technology Conference 2012: From 19th to 21st June 2012 the European Industrial Technology Conference was held, Aarhus, Denmark (up to 1000 participants), organized by EC, a major networking event for European Research Programme.

Annual Meeting of Minerals Metals and Materials Society TMS, 2013:The TMS Annual Meeting & Exhibition will be held in San Antonio USA, from 3rd to 7 March 2013. It is the must-attend global forum that attracts more than 4.000 materials science and engineering professionals for an outstanding exchange of technical knowledge that leads to solutions in the workplace and in society.

Grand Foundry Technical Conference 2013: The Grand Foundry Technical Conference held in Leoben Austria, from 11th to 12th April 2013, jointly organized by: Austrian Foundry Research Institute (ÖGI), Association of Austrian Foundry Specialists (VÖG), Department of Foundry Technology (LfGk) at the University of Leoben and the Association of German Foundry Specialists by the Austrian, Swiss and German foundry association (VDG).

International Light Metals Technology (LMT) Conference 2013: The article “Effect of Ultrasonic Melt Treatment on Degassing and Structure of Aluminium Alloys” was presented

Slovenia Foundry-conference 2013

- Open House events
Two Open House events were performed. One in Ascamm (Spain) – 23rd Sep - and other in ÖGI (Austria) –4th Oct. A total of 52 companies participated in both events

- Publications and Presentations
-Ultragassing-Project Publication in Annual Report 2011Publication of the Ultragassing Project by Thomas Pabel in the Annual Report of ÖGI, which is distributed to ÖGI members and customers

-Kinetics of Ultrasound Degassing of Aluminium Alloys, Written by Prof. Dmitry Eskin and Noe Alba Baena from Brunel University, it has been published at the Annual Meeting of Minerals Metals and Materials Society TMS 2013 held in San Antonio USA, from 3rd to 7th March, 2013.

- 6th International Light Metals Technology (LMT) Conference 2013, the article “Effect of Ultrasonic Melt Treatment on Degassing and Structure of Aluminium Alloys” Written by Noe Alba-Baena, Thomas Pabel, Natalia Villa-Sierra and Dmitry Eskin,
was presented by Prof. Dmitry Eskin.

- Innovative approach to structure control in light alloys, Brunel University, Prof. Dmitry Eskin.

• Press release publication in Technical Journals and Newspapers
It was published a press released in different Technical Journals and general press, such as Fundipress and Auto-Revista, and in some Newspapers, such as Diari de Sabadell, ASCAMMTECH.

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