SMARTT – An innovative process control for rotary degassing of aluminum alloys

Introduction

The production of Aluminum castings globally is dominated by the automotive industry and the growing importance of emissions and fuel economy has resulted in a rapid increase in the use of Aluminum castings. For these demanding applications many of the attributes in terms of mechanical strength, elongation and fatigue strength can no longer be satisfied by standard alloys and so new alloys with greater potential have been, and will continue to be, developed. To exploit the potential of these alloys completely then pore-free castings of high cleanliness and fine structure must be produced. Safety critical castings now require elongation in excess of 10% from the casting itself and this is moving close to the limit for the alloy. The "window" for melt properties to fulfill these requirements becomes smaller and smaller whilst the starting conditions such as ingot quality, melting and holding furnace condition, temperature control and melt transfer can become limiting factors. To ensure that the correct casting quality is achieved then a more effective and technically sound melt treatment is essential followed by a well-designed and controlled pouring practice.

Another important attribute required by the automotive industry is reproducibility and so any melt treatment adopted must be capable of achieving consistent levels of cleanliness and hydrogen control. Many quality management systems also require a 100 % record of production data so again a sophisticated melt treatment system with data storage becomes more attractive to the automotive industry

An innovative process which can automatically achieve the same melt quality regardless of the external environmental conditions will be the key to the future production of truly high quality castings meeting the needs of this growing market segment.

Degassing simulation

Foseco's non-ferrous Marketing and Technology team have
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worked with tsc - Technology Strategy Consultants to develop a web-based batch degassing model. It has been designed as a tool to analyze quickly foundries' operations, and make suggestions for their improvement.

The mathematical model behind this software is based on the best available published information concerning the kinetics of hydrogen degassing (e.g. hydrogen solubility, diffusivity, mass transfer rates and stable bubble sizes). An extensive trial program was undertaken to provide specific information about individual rotors under different conditions.

To characterize different rotors the following trials were carried out:
Power analysis of degasser rotors

- Mixing capabilities of degasser rotors
- Gas solubility tests in water
- Foundry trials in aluminium melts

A full description of the development work is given in Foundry Practice 256 (2011).

Parameters influencing degassing results

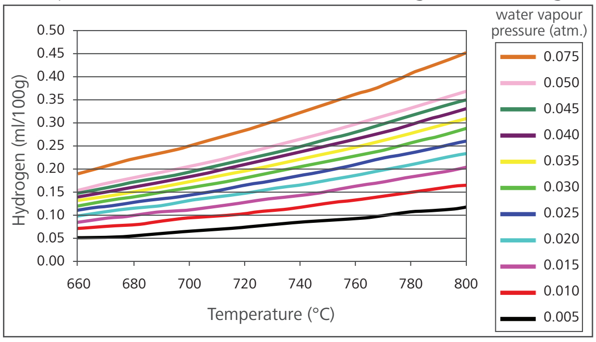
Three main groups of variables influence the degassing efficiency: ambient conditions, rotary degasser parameters, and melt properties. The hydrogen concentration in the melt has been calculated using the Degassing Simulation for the following widely common set of parameters (Table 1); and variations of the parameters illustrate the influence on the degassing result and the final hydrogen content in the melt after treatment.

ATL 1000 with 850 kg melt	XSR 220 rotor
AlSi7Mg	420 rpm
750 °C melt temperature	20 l/min inert gas
50 % relative humidity	0.30 ml H_2 / 100 g Al starting level
25 °C outside temperature	

Table 1. Model simulation parameters

1. Ambient conditions

The melt forms an equilibrium with the water in the surrounding atmosphere; a warm and humid climate gives much higher



Picture 1. Influence of ambient conditions on hydrogen equilibrium (0.005 atm = 5 °C / 50 % rH; 0.050 atm = 35 °C / 90 % rH)

hydrogen content in the melt than a dry and cold climate (picture 1).

During rotary degassing the melt is in interaction with the atmosphere and picks up hydrogen again. The degassing simulation shows the effect of different ambient conditions

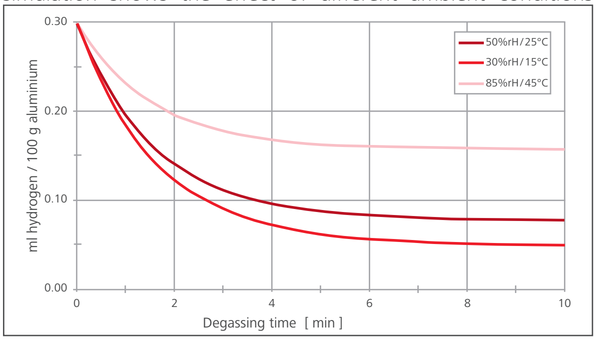


Diagram 1. Degassing curves for different ambient conditions

(diagram 1):

2. Rotary degasser parameters

The rotary degasser can run a treatment with different rotation speed and inert gas flow rates. Each rotor design has minimum and maximum values for those parameters – working conditions – for rotor speed and inert gas flow rate. It is important that both parameters are within the limits; running a treatment at very high rotation speed and extensive flow rates would create too much turbulences or in extreme cases an aeration of the rotor with a complete loss of degassing performance.

The diagrams 2 and 3 show degassing behaviour for typical

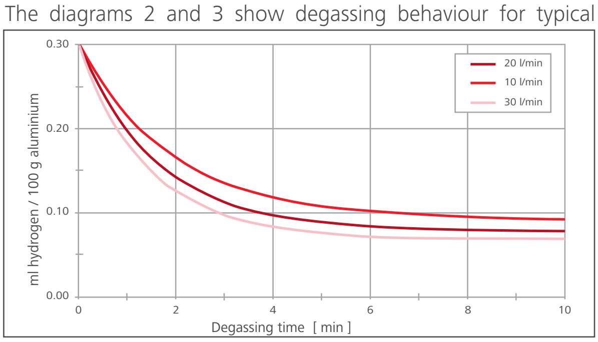


Diagram 2. Degassing curve for inert gas flow variations

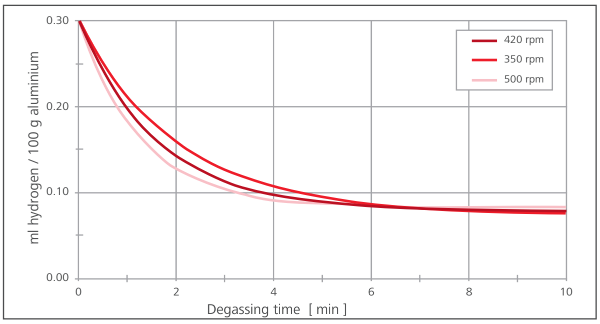


Diagram 3. Degassing curves for rotor speed variations

parameters of an XSR 220 rotor under varying conditions:

3. Melt properties before treatment

The alloys composition has a huge influence on the degassing performance. Elements like Magnesium increase hydrogen solubility whilst Silicon or Copper slightly decrease it (diagram 4). The melt temperature influences the equilibrium with the atmosphere; melt at higher temperature dissolves more hydrogen (diagram 5).

The starting hydrogen level is often unknown, but the diagram shows that variations in the initial hydrogen does not change the

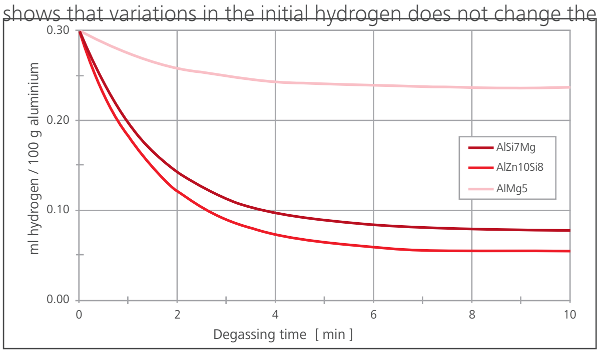


Diagram 4. Degassing curves for different alloys

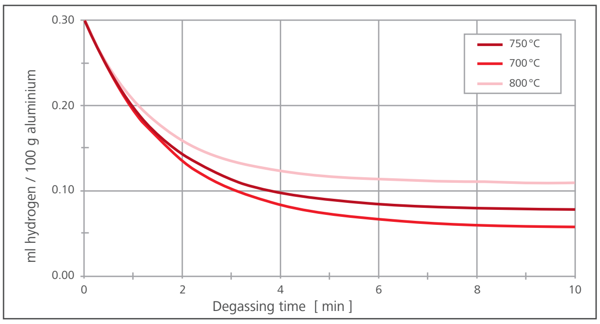


Diagram 5. Degassing curves for different melt temperatures

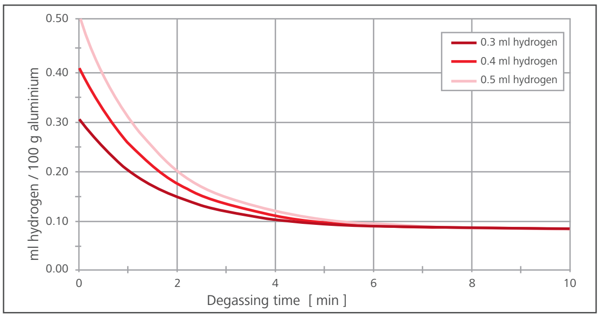


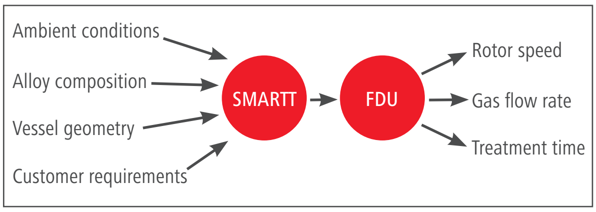
Diagram 6. Degassing curves for different initial hydrogen levels

final result (diagram 6).

SMARTT – an innovative process control

SMARTT is the acronym for self-monitoring adaptive recalculation treatment and an innovative process control that analyses all incoming parameters and calculates the treatment parameters for the rotary degassing process just before each treatment. The target for the optimisation is a constant melt quality after each treatment.

The SMARTT software is installed on a Windows PC, input and output of data is carried out on a comfortable touch screen panel. The SMARTT PC is LAN connected to the Siemens PLC that controls the degassing unit.



Picture 2. Schematic setting of SMARTT

The SQL data base system makes it to an open interface and enables the operator to define a nearly unlimited number of crucible or ladle shapes, alloy types and treatment programs

The target for all simulations is the hydrogen content in the melt and used for both degassing and upgassing procedures.

1. Ambient conditions

Relative humidity and outside temperature are measured by a standard sensor, mounted next to the control cabinet in the area where the treatment takes place. The actual readings are on-time transferred to SMARTT and recorded over time.

2. Alloy composition and vessel geometry

SMARTT comes with a number of pre-defined alloys and crucible or transfer ladle geometries. The user can easily modify, add or delete these. Alloy and treatment vessel become part of each program together with a recommended rotor type and diameter (picture 4).

3. Customer requirements

SMARTT offers four different treatment schemes to choose from. The calculation is based on a minimum and maximum gas flow rate and rotor speed depending on rotor type and diameter as well as on vessel size. The minimum degassing time is a parameter to ensure proper oxide removal.

High-speed degassing – shortest possible treatment time at highest possible rotor speed and inert gas flow rate. A minimum treatment time is observed to allow homogenisation and oxide removal.

Low gas degassing – runs the treatment for a given time at lowest gas consumption and correlative rotor speed to achieve the target.

Long life – runs at lowest possible rotation speed to reduce the shaft and rotor abrasion. The corresponding inert gas flow depends on the total treatment time.

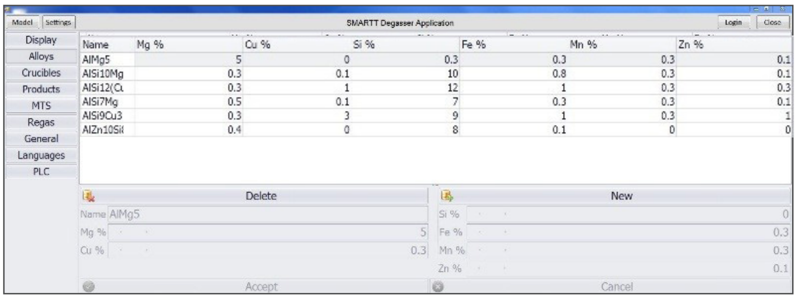
Standard degassing – the average of low gas and low speed provides a balance between the two extreme schemes.

The *high-speed* scheme is used if the degassing process is the bottleneck in the foundry and huge amounts of melt are needed for the following casting steps. The *high-speed* treatment can be used for certain time i.e. during morning shift with high melt demand or if the castings are heavy at short cycle time. The other schemes are depending on the local requirements.

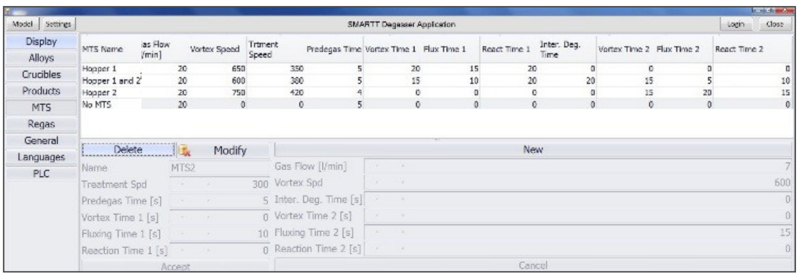
4. MTS 1500 settings

SMARTT is suitable for degassing machines with the optional MTS 1500 automated granulate addition as well. The MTS parameter setting is carried out on the touch screen in the conventional way, those parameters are not part of the optimisation. Nevertheless the different MTS programs are part of the treatment programs and combined with optimisation schemes and hydrogen targets (picture 5).

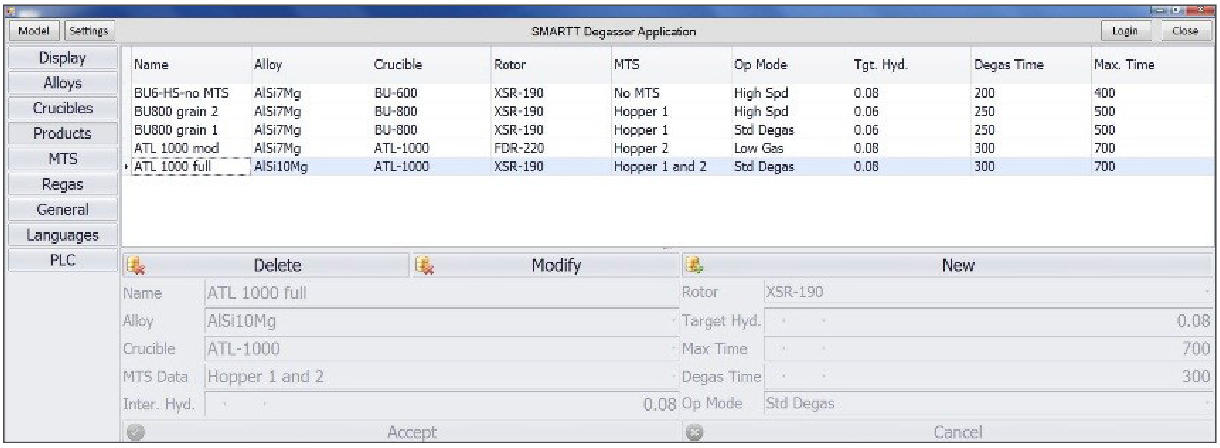
Picture 3. Touch screen interface in a FDU control cabinet door



Picture 4. Alloy screen



Picture 5. MTS parameter setting screen



Picture 6. Product screen

5. Product screen

The product menu brings all pre-defined program parameters together: treatment vessel geometry, alloy and MTS 1500. Additionally the limits for the degassing time are defined. The required hydrogen content in the melt is the target for the optimisation process (picture 6).

The different optimisation schemes enable the foundry to achieve the same degassing result in the same time using different parameter settings. The *low gas* options should be used for regions with high inert gas costs; the *long life* option reduces the erosion of shaft and rotor whilst *standard degassing* is a good balance between the two extremes. *High-speed* degassing is an option where the degassing procedure is the bottleneck in the melt shop.

A product name differentiates the different settings and makes it easy for the operator to choose the right one.

6. Operator screen

All previously described screens are accessible for the administrator only. The operator sees a specially designed interface to make an easy choice from 10 different administrator defined products. Additionally the ambient conditions and remaining treatment

Picture 7. Operator screen

Results from field trials

The SMARTT software is installed on a FDU Mark 10 mobile degassing units with a 1 hopper MTS 1500 dosing system. The trials were started with a simple degassing procedure; the target was to achieve a standard melt quality with a minimum hydrogen level of 0,08 ml hydrogen per 100 g aluminum.

The parameters in table 2 - similar to the model simulation in the beginning of this paper (table 1) - were used for the SMARTT trials:

ATL 1000 with 850 kg melt	XSR 220 rotor
AlSi7Mg	0.30 ml H_2 / 100 g Al starting level
750 °C melt temperature (*)	300 s minimum treatment time (*)
50 % relative humidity (*)	25 °C outside temperature (*)

(*) – might vary for some examples

Table 2. SMARTT simulation parameters

The following tables compare the optimised SMARTT treatment parameters to reach the target under varying conditions and parameters. Table 3 illustrates the different optimisation schemes, table 4 compares the parameters for three different ambient conditions and table 5 provides parameters for different melt temperatures before treatment.

1. Optimization schemes

The *standard degassing*, *low gas* and *long life* start their optimization procedure at given minimum treatment time and try to find a logical result to reach the target. If no result is found the treatment time is increased. The *low gas* option runs with maximum rotor speed and according inert gas flow to reach the hydrogen target in time whilst the *long life* option is following the opposite strategy with lowest possible rotor speed and inert gas at maximum limit. The *standard degassing* scheme takes a result just between the two extremes. *High speed* degassing runs the treatment close to the maximum for both rotor speed and inert gas flow and calculates the shortest possible treatment time to reach the hydrogen level after the treatment (table 3).

Optimised	Rotor Speed (RPM)	500	500
	Gas Flow (std. l/m)	29	29
Melt: 750	Process Time (s)	300	300
Low gas consumption			
Optimised	Rotor Speed (RPM)	426	426
	Gas Flow (std. l/m)	32	32
Melt: 750	Process Time (s)	300	300
Standard degassing			
Optimised	Rotor Speed (RPM)	353	353
	Gas Flow (std. l/m)	40	40
Melt: 750	Process Time (s)	300	300
Long life for consumables			
Optimised	Rotor Speed (RPM)	500	500
	Gas Flow (std. l/m)	45	45
Melt: 750	Process Time (s)	155	155
High-speed degassing			

Table 3. Results for different optimization schemes

The *low gas* option consumes 55 liters of inert gas less per treatment compared to the *long life* scheme. Foundries with 4 treatments per hour can save up to 1,500 Nm³ per year. This is an equivalent to more than 150 gas cylinders.

The reduced speed causes a reduced graphite shaft wearing. Based on customers experiences the life time of shaft and rotor increases by 25 % at 150 rpm lower speed. Depending on treatment conditions a foundry with 4 treatments an hour can save up to 15 sets of consumables – rotor and shaft – per year.

2. Ambient conditions

SMARTT takes the ambient conditions just before each treatment and starts the optimization procedure based on the product settings. At higher humidity levels in the atmosphere the rotor speed and gas flow rate increase for standard degassing and vice versus. This is an expected result due to interactions of the melt surface with the atmosphere. The SMARTT software finds results up to ambient conditions of 75 %rH and 82 °F (28 °C), for higher humidity levels the 0.08 ml hydrogen target is not achievable due to the regassing on the turbulent melt surface during the treatment.

Optimised	Rotor Speed (RPM)	404	404
	Gas Flow (std. l/m)	18	18
Melt: 750	Process Time (s)	300	300
Standard degassing - 59 °F (15 °C) outside temperature / 30 % relative humidity			
Optimised	Rotor Speed (RPM)	426	426
	Gas Flow (std. l/m)	32	32
Melt: 750	Process Time (s)	300	300
Standard degassing - 77 °F (25 °C) outside temperature / 50 % relative humidity			
Optimised	Rotor Speed (RPM)	459	459
	Gas Flow (std. l/m)	44	44
Melt: 750	Process Time (s)	300	300
Standard degassing - 82 °F (28 °C) outside temperature / 75 % relative humidity			

Table 4. Results for different ambient conditions

3. Melt temperature

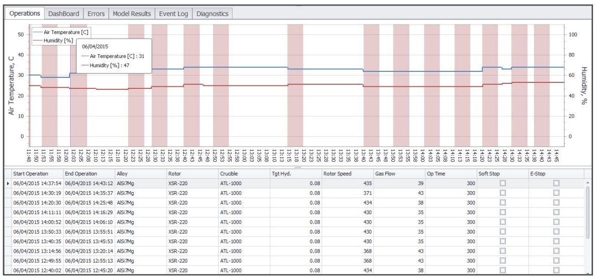
Aluminum dissolves more hydrogen at higher temperatures and takes even more hydrogen back at the melt surface from atmosphere. The treatment is carried out at faster rotor speed and higher inert gas flow rates with increasing temperature and conversely. The SMARTT found a logical solution for up to 1436 °F (780 °C), no parameter setting could be predicted for 1472 °F (800 °C) due to too high initial hydrogen content and the re-pick-up on the surface (table 5).

Optimised	Rotor Speed (RPM)	417	417
	Gas Flow (std. l/m)	23	23
Melt: 700	Process Time (s)	300	300
Standard degassing – 1292 °F (700 °C) melt temperature			
Optimised	Rotor Speed (RPM)	426	426
	Gas Flow (std. l/m)	32	32
Melt: 750	Process Time (s)	300	300
Standard degassing – 1382 °F (750 °C) melt temperature			
Optimised	Rotor Speed (RPM)	446	446
	Gas Flow (std. l/m)	44	44
Melt: 780	Process Time (s)	300	300
Standard degassing – 1436 °F (780 °C) melt temperature			

Table 5. Results for different optimization schemes

4. Data logging

The SMARTT software runs a data logging system that enables a complete parameter tracking for date time and all pre-defined and optimised degassing functions. This very comfortable function replaces complex systems that run on external computers using 3rd party data logging software. The treatment data can be exported to standard office applications for further analysis.



Picture 8. Data logging screen

Summary

- Casting requires a melt on a constant hydrogen level.
- Inconsistent starting conditions in a foundry make it impossible to always reach this in the cost effective way.
- Foundries today compensate this effect in mostly overrunning the treatment which wastes inert gas and graphite consumables.
- SMARTT offers a comfortable interface to program all necessary treatment steps.
- The innovative degassing control predicts the best treatment parameters for different schemes under given conditions.
- SMARTT saves inert gas or extends graphite consumables lifetime.
- SMARTT records all treatment parameters.
- An innovative process control is the best solution for foundries that treat high melt volumes with a number of different castings that require the same or similar quality levels.

COMMENT
Editorial policy is to highlight the latest Foseco products and technical developments.
However, because of their newness, some developments may not be immediately available in your area.
Your local Foseco company or agent will be pleased to advise.

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