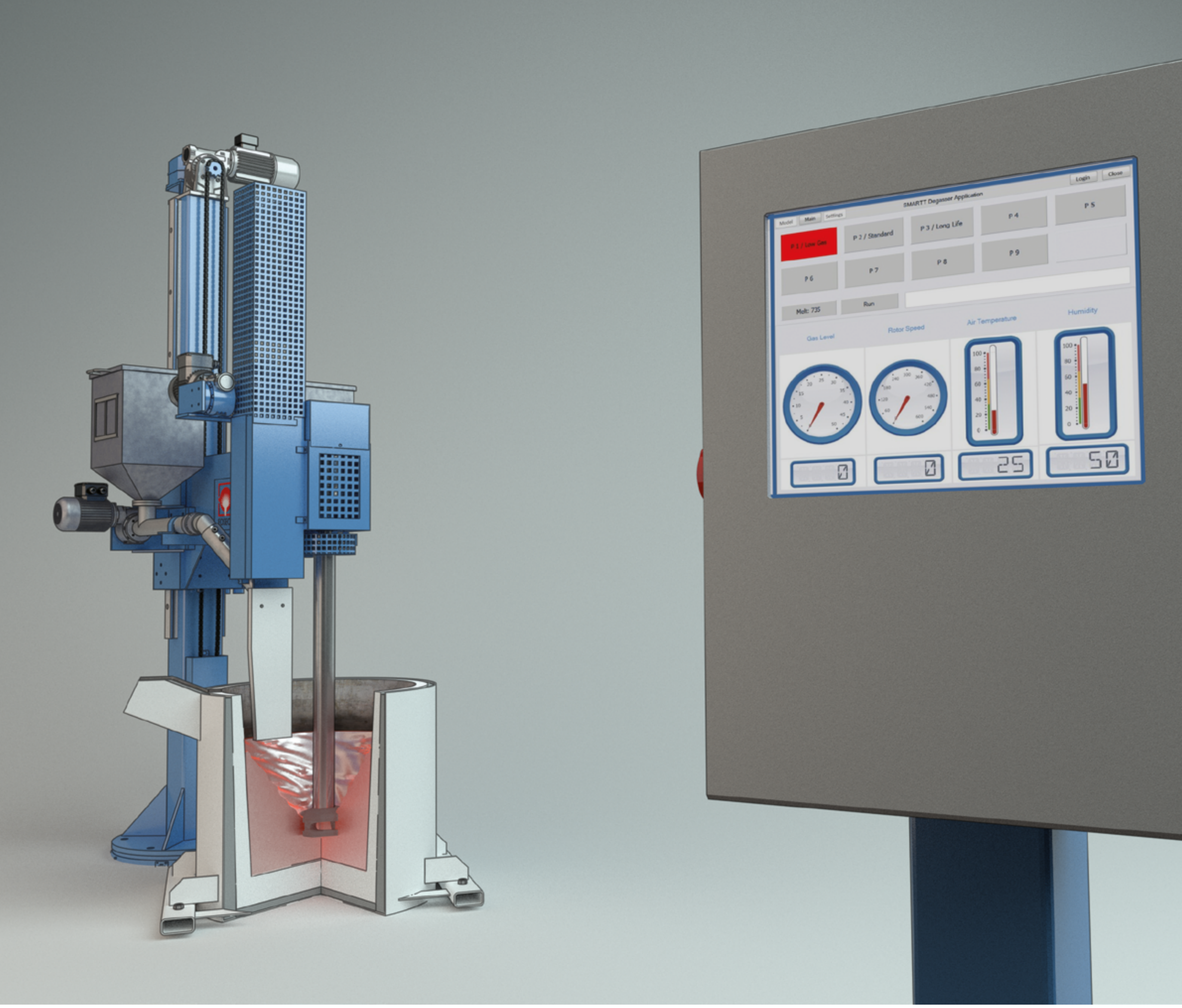


SMARTT - DEFINED HYDROGEN LEVELS AFTER ALUMINIUM ROTARY DEGASSING

Author: Ronny Simon

The production of Aluminium castings globally is dominated by the automotive industry. To ensure that the correct casting quality is achieved, a more effective and technically sound melt treatment is essential, followed by a well-designed and controlled pouring practice. Automotive industry requests process 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 with data storage capabilities becomes more attractive.

INTRODUCTION

Process control in general refers to the way in which foundries maintain a tight control over the various components and steps involved in making castings. The importance of process control is derived from the way in which a strict adherence to process control helps a foundry avert potentially costly mistakes. Considering the fact, that process control requires a complete monitoring of the various parameters, any potential problem will be spotted early, before it becomes a significant problem later.

The intelligent use of process control technologies within the manufacturing process has beneficial effects far beyond the traditional aspects of quality assurance:

- Increase throughput from existing assets
- Increase automation and reduce human intervention
- Reduce rework, concessions and scrap
- Enhance production capability and take on more work.

PARAMETERS INFLUENCING ROTARY TREATMENTS

In rotary degassing we differentiate between factors that are almost constant over longer periods of time and variable factors. Alloy composition, vessel geometry and target melt quality are often well known and do not change remarkably. Usually several programs are set in the PLC, defining treatment time, rotor speed and gas flow rate. The operator selects a program following given instructions. The number of programs is limited, the programs need to be changed manually in case of process variations, and the operator might choose the wrong program.

Other factors such as ambient conditions and melt temperatures often vary in much wider ranges. The influence on degassing is usually underestimated or operators change parameters based on their experiences. Variations in these starting conditions may cause inconsistent results.

The hydrogen concentration in the melt during degassing for various ambient conditions and melt temperatures has been calculated using the Degassing Simulation for the following widely common set of parameters (Table 1). Variations of the parameters illustrate the influence on the degassing result and the final hydrogen content in the melt after every single treatment.

AMBIENT CONDITIONS

The melt forms an equilibrium with the water in the surrounding atmosphere; a warm and humid climate results in a much higher hydrogen content in the melt than a dry and cold climate (Figure 1).

During rotary degassing the melt is in interaction with the atmosphere. The degassing simulation shows the effect of different ambient conditions (Diagram 1).

Likewise, the use of forming gas – a N_2-H_2 mixed gas - for upgassing procedures ends up with different hydrogen levels (Diagram 2).

ATL 1000 with 850 kg melt	XSR 220 rotor
AlSi7Mg	420 rpm
750 °C melt temperature	20 l/min inert gas
50 % relative humidity	20 l/min forming gas with 20 % hydrogen
25 °C outside temperature	0,30 ml H_2 / 100 g Al starting level

Table 1. Model simulation parameters

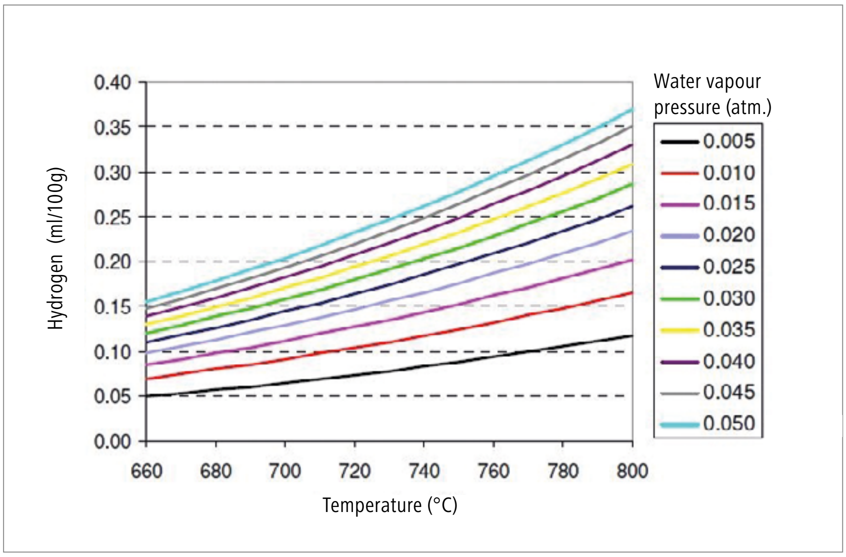


Figure 1. Influence of ambient conditions on hydrogen equilibrium
(0,005 atm = 5 °C / 50 % rH;
0,050 atm = 35 °C / 90 % rH)

Diagram 1. Degassing curves for different ambient conditions

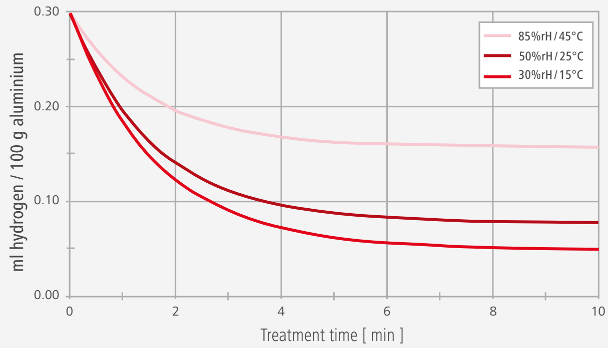


Diagram 2. Upgassing curves for different ambient conditions

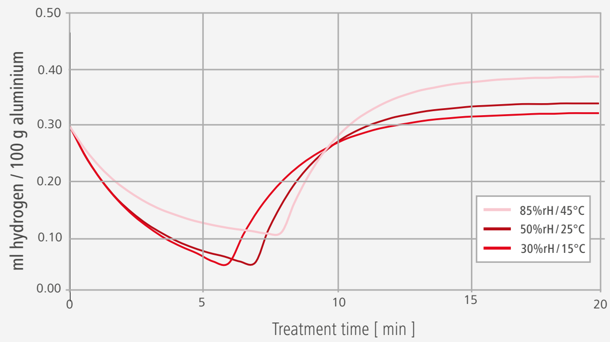


Diagram 3. Degassing curves for different melt temperatures

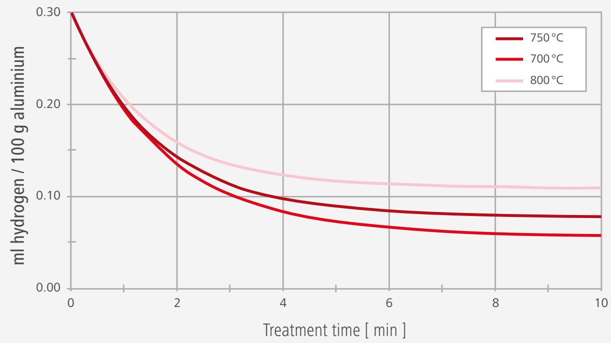
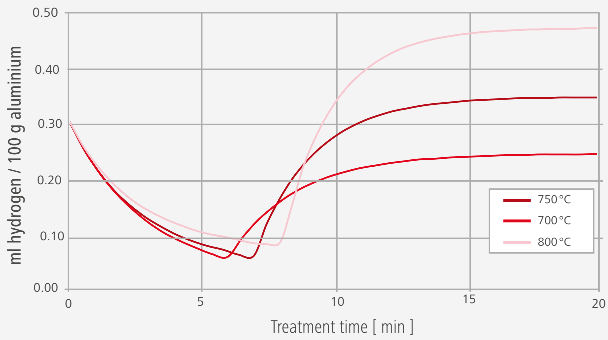


Diagram 4. Upgassing curves for different melt temperatures



MELT TEMPERATURE

The melt temperature influences the equilibrium with the atmosphere as well; melt at higher temperatures dissolves more hydrogen (Diagram 3).

The variations in final results for use of forming gas are even higher at different melt temperatures (Diagram 4).

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

SMARTT - AN INNOVATIVE PROCESS CONTROL

SMARTT is an 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 optimization 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 with a LAN connection to the SIEMENS PLC that finally controls the degassing unit.

Relative humidity and outside temperature are measured by a standard humidity meter, 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.

A full report on SMARTT is given in Foundry Practice 264 (2015).

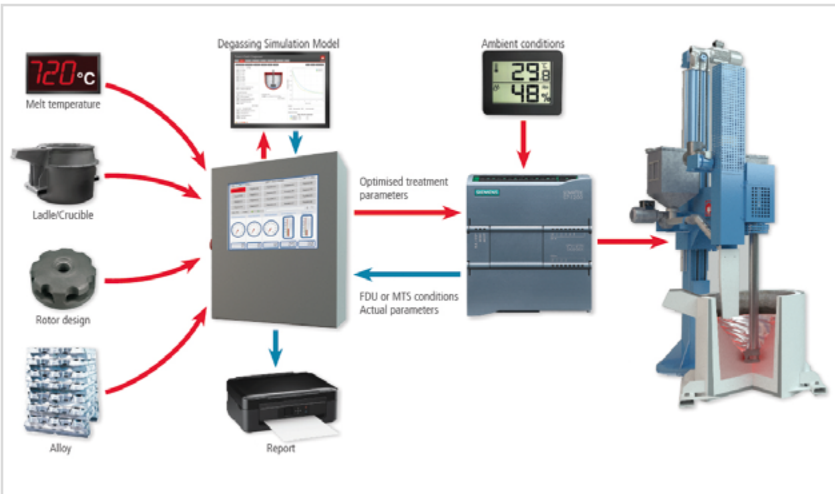


Figure 2. Schematic setting of SMARTT

BU 600 with 530 kg melt	0,06 ml H_2 / 100 g Al target
AlSi8Cu3	Standard optimization
750 °C melt temperature	240 s minimum time
XSR 190 rotor	500 s maximum time

Table 2. Process parameters for SMARTT degassing

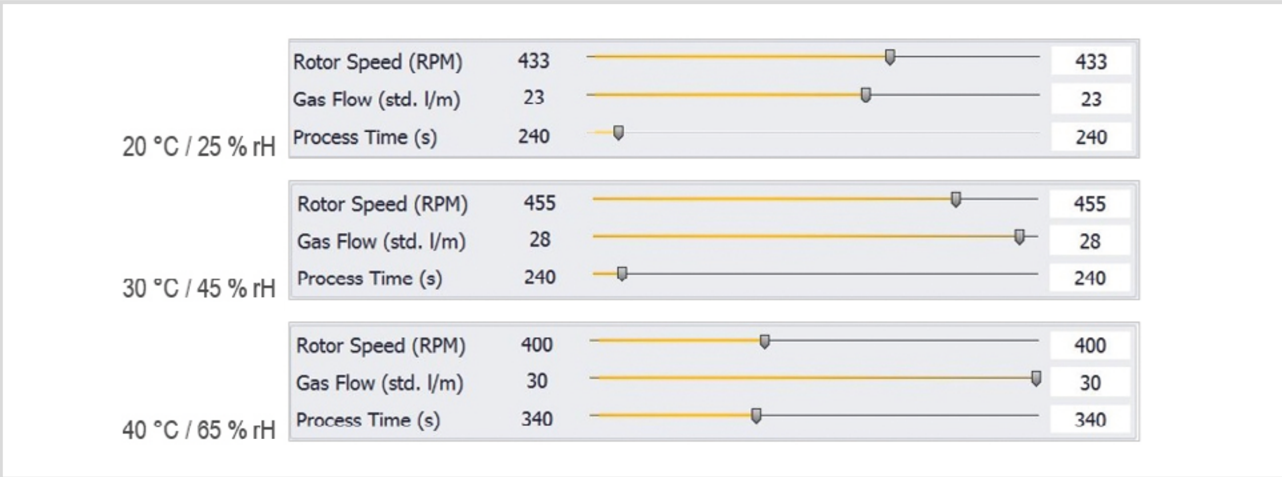


Figure 3. Treatment parameters for different ambient conditions

PRACTICE OF DEGASSING

For different ambient conditions SMARTT calculates treatment parameters to reach a target hydrogen content after each treatment. With increasing air temperature and relative humidity, the rotor speed and inert gas flow rate increases to compensate the higher moisture content in atmosphere. The optimization always starts at minimum time, a time that allows sufficient oxide and inclusion removal as well. If flow rate and rotor speed are at its specific limit, the software starts prolonging the treatment time to reach the target (Table 2, Figure3). A maximum treatment time limits temperature loss or melt shortage in the following casting step.
Variations in melt temperature before degassing are compensated by SMARTT in a similar way. Finally, every treatment is started with different rotor speed, inert gas flow rate and treatment time to achieve the same hydrogen content in the melt at the end of each treatment. Foundry trials have shown that the target was always reached regardless of starting conditions.

PRACTICE OF UPGASSING USING FORMING GAS

Some applications in foundries require a defined hydrogen content such as in the casting of wheels. It is common practice to run very short treatment times to avoid too much hydrogen removal; often oxide removal is not sufficient. The use of a N_2-H_2 mixed gas improves oxide removal due to longer treatment times but the variations in hydrogen at end of treatment are still high.

SMARTT now runs an inert gas treatment followed by a two stage upgassing. The 1st stage runs with N_2-H_2 mixed gas only; during stage 2 a mix between N_2-H_2 and inert gas provides a defined hydrogen content in treatment gas and ends in an equilibrium between treatment gas, aluminum melt and atmosphere.

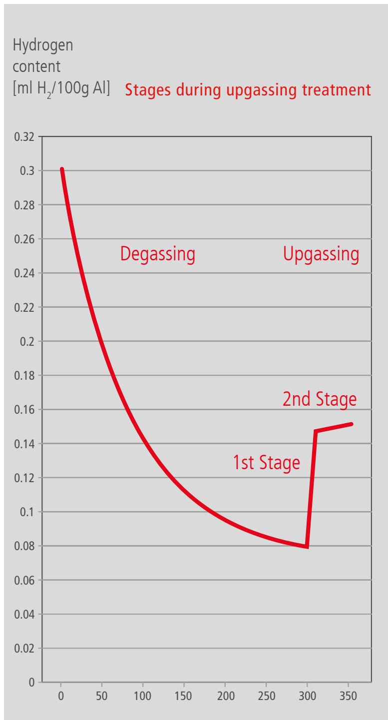


Diagram 5. Stages of an upgassing procedure

Hydrogen transfer into melt becomes easier at higher temperatures which reduces 1st stage time. In this way 2nd stage is influenced as well; the effective hydrogen level in purge gas gets lower. This value is exactly the equilibrium between degassing the melt, hydrogen pickup at melt surface and upgassing by N_2-H_2 mixed gas. Under given conditions those parameters keep the final hydrogen content in the melt at constant level; a dwell time of 30 – 45 s is sufficient to get into that equilibrium.

The mass flow controller for inert gas and N_2-H_2 mixed gas blends the correct effective hydrogen content without operator involvement. The differences in effective hydrogen in purge gas and resulted treatment times illustrate the complexity of upgassing; it is obvious that a computer based simulation only can handle all variations in starting conditions (Table 4).

ATL 1000 with 850 kg melt	0,08 ml H_2 / 100 g Al target for degassing
AlSi7Mg	0,15 ml H_2 / 100 g Al final target
50 % relative humidity	360 s minimum time
25 °C outside temperature	600 s maximum time
FDR 220 rotor	45 s dwell time (2nd stage)
Standard optimization	20 % hydrogen in N_2-H_2 mixed gas

Table 3. Process parameters for SMARTT upgassing

		Rotor [rpm]	Inert gas [l/min]	N_2-H_2 [l/min]	Time [s]	Effective H_2 [%]
720 °C	Degassing	315	16	0	360	0
	1st Stage	400	0	35	28	20
	2nd Stage	400	26	9	45	5,3
740 °C	Degassing	303	25	0	360	0
	1st Stage	400	0	35	22	20
	2nd Stage	400	28	7	45	3,8
760 °C	Degassing	309	30	0	360	0
	1st Stage	400	0	35	17	20
	2nd Stage	400	30	5	45	2,8

Table 4. Treatment parameters for different temperatures for upgassing

The latest SMARTT version communicates with either an external temperature source or a handheld thermal couple. An external source can be a temperature reading that is already available from treatment crucible or ladle and sent by ethernet or analogue signal to the SMARTT software. Alternatively, the operator uses a handheld thermal couple which is connected directly to SMARTT and measures right before every rotary degassing; the reading is used for optimization.

A report system is part of the SMARTT software package. All treatment data are stored and available in Excel file format.

SUMMARY

SMARTT - innovative degassing control - offers a comfortable interface to program all necessary treatment steps, it reads or measures the starting conditions before every rotary degassing and predicts the best treatment parameters for different schemes. An integrated report system stores all data per treatment in Excel format and enables the melt shop manager to run further analysis on the process.

The use of SMARTT for degassing processes provides a melt on a constant hydrogen level independent from inconsistent starting conditions in a foundry. SMARTT enables the foundry to always reach this in a cost-effective way, there is no need for compensating these variations in overrunning the treatment which wastes time, inert gas and graphite consumables.

In upgassing – often used in wheel foundries – even small changes in environmental conditions or melt temperature have an enormous impact on the hydrogen content after the treatment. These complex relationships can only be managed by a mathematical model. SMARTT, based on the batch degasser software, is an intelligent solution to handle data for rotary degassing.

CONTACT

RONNY SIMON
NON-FERROUS
TECHNOLOGY MANAGER

ronny.simon@vesuvius.com
+49 2861 83 504

DISCOVER MORE

Find out more about our SMARTT technology.