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Edited by John F. Grandfield and Dmitry G. Eskin.

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ALLOYING BY INJECTION OF Mg IN AN Al–MELT

E. Myrbostad
Årdal og Sunndal Verk a.s.
ÅSV Metallurgical R & D–center
N–6601 Sunndalsoera
Norway

K. Venås
SINTEF
The Technical University of Norway
N–7034 Trondheim – NTH
Norway

Salt–coated magnesium granules produced by Norsk Hydro a.s. have been injected into 2.5 and 15 metric ton batches of liquid Aluminium at Årdal og Sunndal Verk a.s. for production of Al Mg–alloys. No problems with the injection technique have been experienced.

Preliminary experiments with 2.5 ton melts resulted in a magnesium yield of 88–100%, depending on the fraction of salt on the granules. The purity of the resultant alloy, as expressed in terms of oxide inclusions and sodium content was not affected by the injection treatment. However there was a slight increase in hydrogen concentration.

Injecting a granulate containing 5.4% salt in 15 ton melts gave a magnesium yield of 98.4% as an average over 6 days. This is 6–7% better than conventional alloying practice.

Introduction

Injecting powder into liquid iron and steel has become common practice in the last 10–15 years, and during the last 5 years Årdal and Sunndal Verk a.s. together with other aluminium producers have started to use the injection technique for alloying liquid aluminium.

The development of better powder dispensers has made this technique possible. Two of the most common dispensers in the Scandinavian region is the "SINTEF–dispenser", made by the Norwegian company Luftfiltrering a.s., and the "Lancers injection system", made by the Swedish company Scandinavian Lancers AB. The SINTEF–dispenser, being used in this experiment, is among the best equipment of its type in the world today, and is based on a massive research program at SINTEF (The Foundation of Scientific and Industrial Research at the University of Trondheim).

Alloying by injecting powder has several advantages. Some important points in aluminium casting houses are:

- High yields.
- Accurate alloying giving less need for adjustment.
- No environmental problems.
- Possibilities for automation of the whole alloying process.
- The gasfluxing gives a reduction in sodium and hydrogen content.
- The melt becomes homogeneous in a short time.

Årdal og Sunndal Verk a.s. is today injecting manganese powder daily at the Årdal plant, and low–iron silicon powder at the Sunndal plant. The next natural step is therefore to inject magnesium powder, and this time we looked closer into a product being developed at Norsk Hydro a.s. – salt–coated Mg–granules. The granules are primarly developed for use in the iron and steel industry as a desulfuring agent.

Description and operation of the system

Fig 1 shows a SINTEF–type dispenser with three separate powder containers. The desired amount of powder is transported to the dispenser silo through a rotary air lock.

The dispenser's lower section is better showed in fig. 2. The shutter knife moves backwards and forwards over the shutter plate, and the powder falls down into the fluidizing chamber. Gas enters the fluidizing chamber through a "ring" of small holes, and fluidizes the powder. In the albow under the dispenser a certain amount of gas is added to ensure that the pneumatic transport runs without problems.

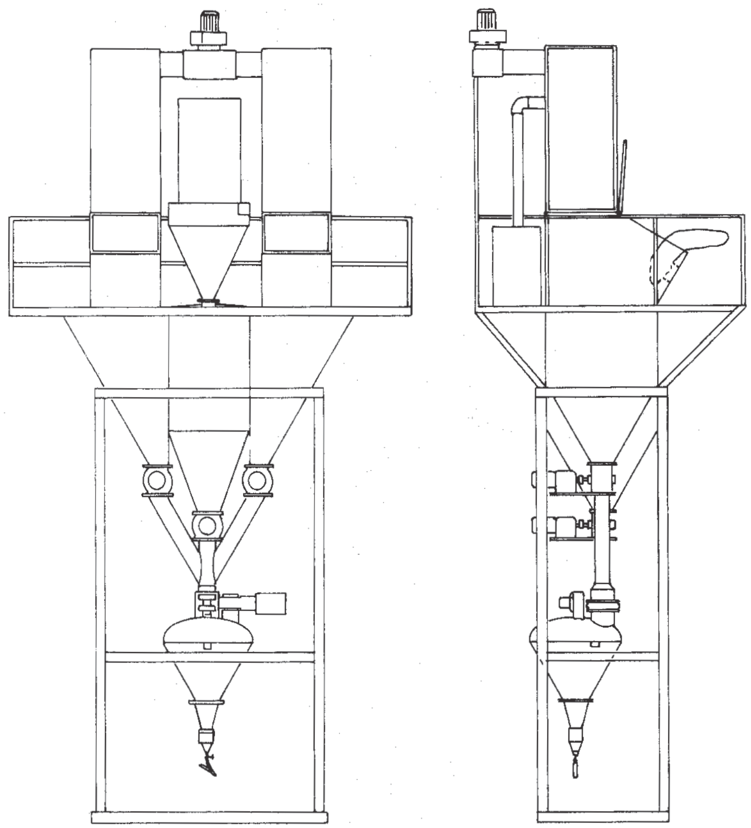

Figure 1 Example of a SINTEF–type powder dispenser /1/.

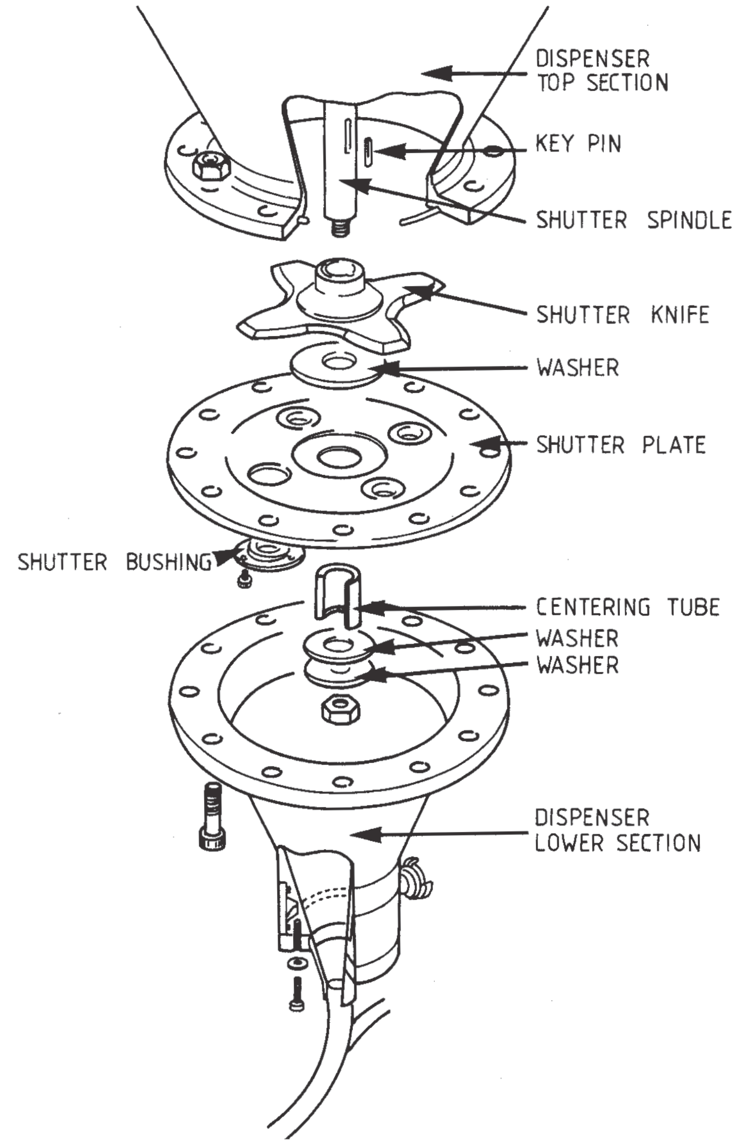

Figure 2 Lower section of the powder dispenser, exposed vieuw.

During some preliminary experiments we found that a lance/tube diameter of 1 inch seemed to give suitable transport conditions. The lance used was simply a 1—inch steel pipe, 3.5 meter long. The maximum narrowing through the couplings was 18% of the tube's inner cross section, and the total transport distance was 21 meter.

The lance was placed a little besides the center line of the furnace to give rotation to the bath, and with a angle of 30—40^{o} to the melt surface. Approximate distance to the furnace bottom was 15—20 cm, which means about 60 cm under the melt surface in our furnaces.

For the first 6 batches we used a 2.5 metric ton crucible—type furnace, and magnesium granulates with various amounts of salt, from 0 to 20%. A second set of experiments, also 6 batches, were carried out in production scale in a 20 ton vacuum furnace, using a Mg—granulate containing 5.4% salt. Both furnaces are heated by oil burners. The injection gas used was nitrogen for the first 6 experiments, and argon for the last 6.

Experience with the magnesium injection technique

The pneumatic transport and the injection of the magnesium granules ran without any kinds of problems. However, there is always a upper limit for the amount of inert gas blown into the melt, depending of the geometry and size of the furnace. In these experiments (1 inch lance) we found a upper limit of about 400 l/min for the 2.5 ton crusible—type furnace. In the vacuum furnace (20 tons) we blowed in 600 l/min gas without reaching the upper limit.

Insignificant quantities of smoke were formed during the injection, and we observed less splashing using the Mg—granules **with** salt. As usual using the injection teqnique, the melt became significantly calmer when the powder feeding started.

The dross became drier using Mg—granules **with** salt, and we also observed more dross using pure Mg—granules.

The hydrogen content, presented as mean values, is showed in table 1. The magnesium injection results in an increase in hydrogen content of about 0.04 — 0.05 ml H_2/100 g Al, giving a value of about 0.21 ml/100 g Al after injection. This is a normal value after conventional alloying, but before normal melt treatment, in our furnaces.

No significant change in any other elements was detected. For example, the content of sodium and lithium did not change during injection.

The results of a metallographic examination of the melt before and after injection are summarized in table 2, for the first 6 experiments. For the production scale tests no particles $> 20\ \mu m$ were ever recorded. 12 cm^2 divided between 4 samples were examined. We found no change in the particle content during the injection except in batch No. 2 where an increase in the particle content was observed. In that batch Mg—granules **without** salt were used.

Table 1. Hydrogen content before and after injecting Mg—granules (ml/100g Al).

	Before injection	After injection	Number of batches
Mg—granules without salt			
Mean value	0.12	0.17	2
Standard dev.	0.01	0.01	
Mg—granules with salt			
Mean value	0.18	0.22	10
Standard dev.	0.04	0.02	

Table 2 Hard particles before and after Mg—injection in the crucible—type furnace. In batch No. 1 and 2 Mg—granules without salt were used.

Particle size	Batch No	Number of particle / cm^2		Comments
		Before injection	After injection	
21 — 50 μm	1	0	0	Some particles $< 20\ \mu m$ both before and after injection in batch 2 and batch 6.
	2	0.5	1.0	
	3	0	0	
	4	0	0	
	5	0	0	
	6	0	0	
51 — 100 μm	1	0	0	
	2	0	0.5	
	3	0	0	
	4	0	0	
	5	0	0	
	6	0	0	
100 μm	1	0	0	
	2	1.0	1.5	
	3	0	0	
	4	0	0	
	5	0	0	
	6	0	0	

The magnesium yield is shown in table 3. Mg–granules without salt give low yields, and there seems to be an optimal yield using a salt addition of about 5–10%. Yields >100% occur mainly because of inaccuracies in the total metal weigh in the large scale experiments.

Table 3 The magnesium yield for each batch.

Furnace type	Batch No	% salt in the Mg-granules	Weight (kg) of Mg injected	Weight (kg) of melt	Yield (%)
Crucible furnace	1	0	36	2 045	90.6
	2	0	47.5	2 000	86.7
	3	8	40	1 740	97.7
	4	8	35.5	1 880	98.2
	5	20	50	1 895	88.5
	6	5	27.5	1 840	93.3
Vacuum furnace	7	7.6	89	13 407	100.5
	8	5.2	76	13 640	100.3
	9	5.2	83	13 886	95.5
	10	4.0	76	13 880	96.9
	11	5.2	80	13 695	97.5
	12	5.2	83.5	14 000	99.8
	Mean Value	5.4	81.3	13 751	98.4
	Standard devition	1.1	4.6	196	1.9

Tabel 4 shows some important mean values for the injection of magnesium granules. Fig. 3 showes the calculated energy loss during the injection for the two furnaces. Note that the extra cooling due to the increased stirring by injection, will also be present to some extent when Mg is alloyed in the ordinary way.

Table 4. Some importent values for the Mg–injection experiments

Mean values for		Furnace type: Crucible	Furnace type: Vacuum
Metal weigh in furnace	$\bar{M}$ (kg)	1 900 ± 100	13 750 ± 200
Injected amount of granules	$\bar{m}$ (kg)	39.4 ± 7.6	81.3 ± 4.6
Injected amount of gas	$\bar{Q}$ (Nm^3)	0.834 ± 0.120	4.15 ± 0.80
Injection time	$\bar{t}$ (min)	$2\frac{44}{60} \pm \frac{27}{60}$	$8\frac{11}{60} \pm 2\frac{1}{60}$
$\frac{\text{Normal liter gas}}{\text{kg granules}}$ =	$\frac{Q}{m}\left(\frac{l}{kg}\right)$	21	51
Rate of injection	$\frac{kg}{min}$	14	10.8
$\frac{\text{kg granules}}{\text{kg gas}} = M^{☆}$		38	12 (9–18)
Total temperature drop during the injection	(^oC)	27.2 ± 6.8	11.8 ± 2.0
Temperature drop per min	$\left(\frac{^oC}{min}\right)$	9.9 ± 1.8	1.4 ± 0.4

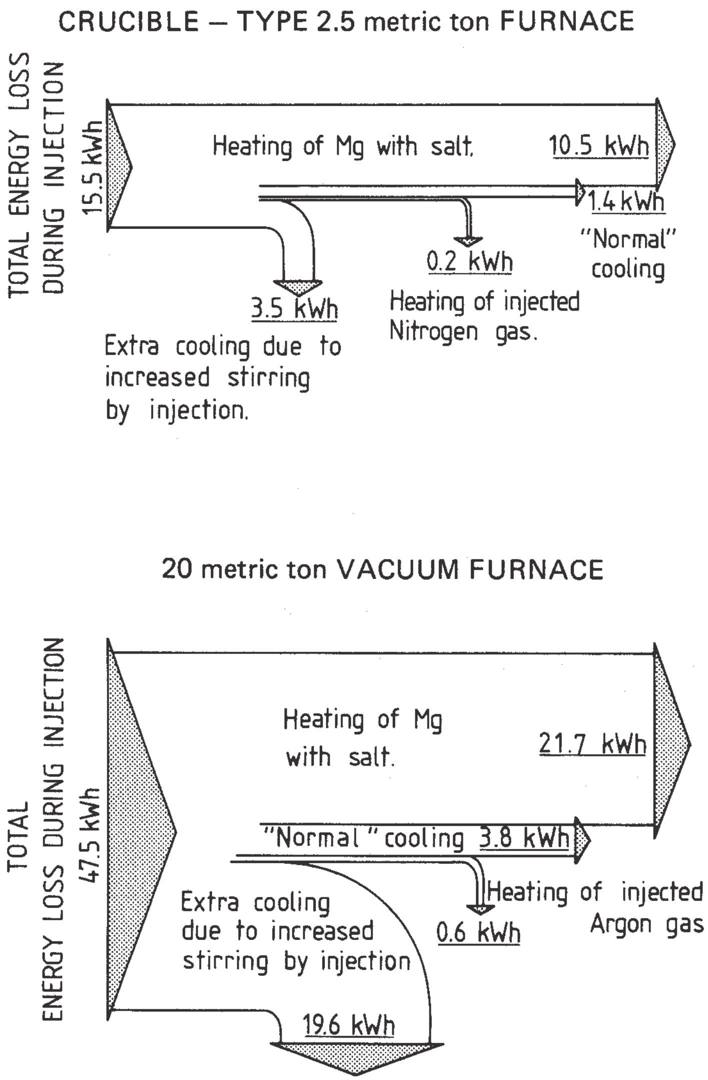

Figure 3 Graphical illustration of the energy loss during injection.

Conclusions

- Injecting salt–coated magnesium granules with 5–10% salt gives a significant improvement in the Mg–yield, compared to ordinary alloying.
- A mean yield of 98.4% is obtained in production scale under ordinary production conditions.
- Mg–granules are easy to handle and give no environmental problems.
- The salt protects the melt from oxidation.
- There is no increase in sodium, lithium or other trace elements, but a slight increase in hydrogen content.
- The stirring produced in the melt produces an extra heat loss above that found with ordinary alloying.
- The need for magnesium adjustment is less using injection resulting in a time saving.
- The profitability of the process is strongly dependent on
  1) whether the injection teqnique is used to alloy other components.
  2) the price of the magnesium granules.

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