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STUDIES ON THE FLUX TREATMENT OF SECONDARY ALUMINIUM ALLOYS OBTAINED AT LOW TEMPERATURES

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The paper presents the mechanism of microporosity formation in the secondary alloy EN AB 46100, obtained through processing of small metal chips of aluminium alloys at low temperatures when the melt is in a pasty state. The elimination of dissolved gases and oxide impurities was accomplished by means of flux treatment. The samples were solidified in air and vacuum (80 mbar), using a VAC - TEST SYSTEM equipped with a DENSITY TERMINAL installation for density determination (DI), which were processed metallographically to show both the macroscopic and microscopic structure of the alloys obtained.

Keywords: D.I. – density index, metal chips, oxidation

1. Introduction

Metal chips obtained through machining processes can be recycled by several methods such as solubilization (due to the very large outer surface), extrusion or remelting. The main problem with the reintroduction of these materials into the industrial circuit is the degree of contamination with substances which contain hydrocarbon and water used in the cutting process. In general, the humidity of these materials is around 18%. Specific processes may be down to less than 1%, with some equipment manufacturers proposing technological solutions for 0.3%.

From a metallurgical point of view, the challenges are to reduce oxidation losses and to obtain higher quality alloys by eliminating impurities and reducing porosity in the process of manufacturing secondary alloys, given the wide range of alloys and waste, classified according to SR EN 13920 or, more recently, ISRI.

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A classification of these wastes in terms of origin was made by S.N. Ab Rahim et al. [1].

Other authors have also presented studies regarding the reintroduction into the industrial circuit of small metal chips from various types of aluminium based alloys by remelting or by means of direct processing through extrusion [7], studies that also focused on the production of secondary high-quality alloys [2-6, 8-15].

2. Experimental technique

The technology for the processing of small aluminium alloy chips, with a high yield of useful metals extraction and low oxidation losses, proposed by this article is to determine the quantities of flux necessary in order to eliminate oxides and gases at low temperatures, their incorporation in the paste-like metal bath followed by increased temperature for total solubilization, homogenization and melt treatment to eliminate non-metallic and gaseous impurities.

The proposed process consists in processing the metal chips at low temperatures by gradually introducing them into the melt, after the loss of moisture and burning volatile substances by heating the batch (oils, emulsions, etc.) by the VORTEX process, as can be seen from Fig. 1.


a


b

Fig. 1. The furnace used in the experiments for the semisolid/pasty melt with the agitator (a), the furnace filled with 10 kg of molten aluminium (b),

The experiments consisted of processing metal chips in quantities starting from 3 kg, 4 kg and 5 kg melt, in which approximately 500 g damp metal chips portions were inoculated. When the crucible is filled with molten metal, and it could no longer be filled with metal chips, the melt is treated with flux in order to eliminate oxides and non-metallic impurities, but also to determine the density index.

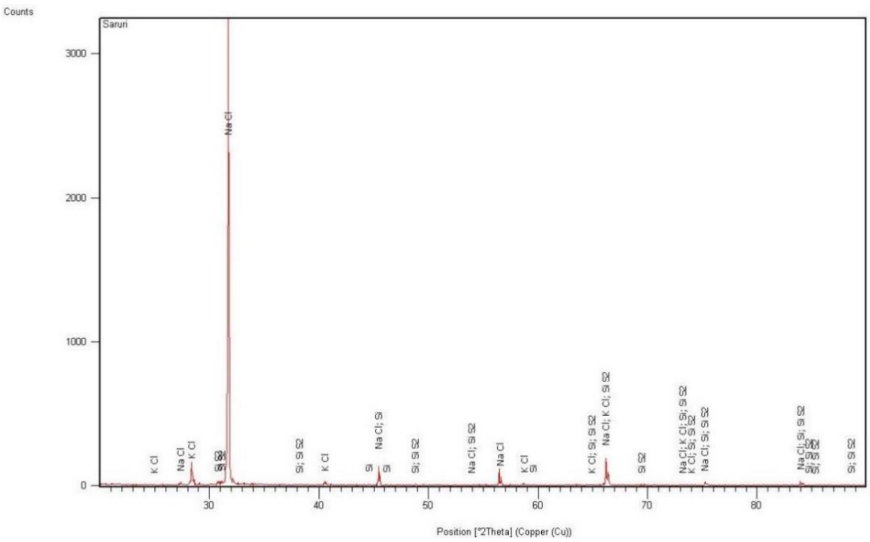
The standardized chemical composition for the EN AB 46100 alloy and the nominal chemical composition of the obtained alloy are shown in Table 1.

Table 1.

The standardized and the nominal composition of the obtained alloy

Alloy	Chemical composition [%]						
	Si	**Fe**	**Cu**	**Mn**	**Mg**	**Zn**	**Al**
EN AB 46100	10 - 12	0.45 – 1.0	1.5 – 2.5	< 0.55	< 0.30	1.0 – 1.4	ball.
Experim.	10.753	0.934	1.812	0.223	0.23	1.345	ball.
	Chemical composition [%]						
	Ni	**Pb**	**Ti**	**Sn**	**Others**		
					each	total	
EN AB 46100	< 0.45	< 0.25	< 0.20	< 0.25	< 0.05	< 0.15	
Experim.	0.108	0.06	0.054	0.038	< 0.05	< 0.15	

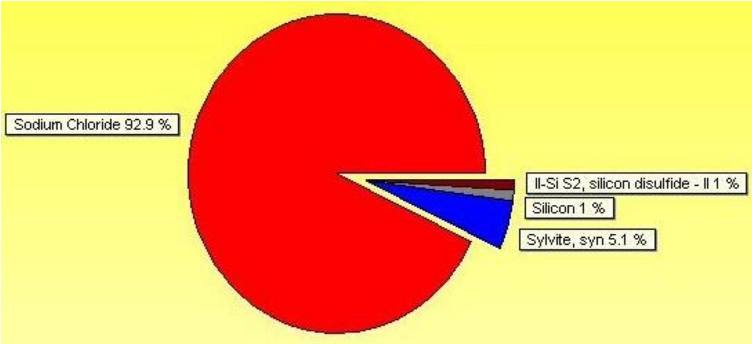
This study aims to reintroduce small metal chips with high humidity into the industrial circuit in order to obtain high-quality secondary alloys. The removal of impurities (oxides and other oxidic elements) from the melt will be done by using flux treatment to remove the oxide impurities and dissolved gases in the melt. The flux used in the experiments was analysed by using diffraction to highlight its composition.



a

No.	Visible	Ref. Code	Compound N...	Chemical Formula	Score	Scale ...	SemiQua
1	☐	01-077-2064	Sodium Chlor...	Na Cl	31	0.484	92
2	☐	01-075-0296	Sylvite, syn	K Cl	23	0.036	5
3	☐	01-089-9056	Silicon	Si	6	0.002	1
4	☐	01-072-1423	II-Si S2, silic...	Si S2	9	0.006	1

b



c

Fig. 2. XRD patent (a) for the analysed flux and (b, c) list of compounds

The experiments aim to establish a way to process small pieces of aluminium-based chips, in order to obtain the highest extraction yields of useful elements and to obtain a standard aluminium alloy composition.

The stages were:

- Heating the furnace (crucible) until it reaches the temperature of 650°C;
- Loading the crucible with 3 kg, 4 kg and 5 kg of material (non-compliant ingots brought to a small size to be inserted into the crucible) to form the metal bath where the metal chips can be assimilated without the flame interacting with it;
- Inserting the metal chips in quantities of approximately 500 g until the crucible is filled (~ 10 kg Al melt);
- Stirring the mixture for incorporating the metal chips into the molten material;
- Repeat the loading and stirring operations until the crucible is filled with melt;
- Overheating the melt (720°C) to increase fluidity and separating slag;
- Treating flux melt for degassing and removing impurities;
- Sampling to determine the density index and to determine the chemical composition of the alloy;
- Repeating the flux treatment, sampling for density index, and chemical composition;
- Casting the melt into a steel mould.

3. Experimental results and their interpretation

The final melt is heated to 720°C, then a sample is taken to determine the density index. After that, the metal bath is treated with a quantity of 50 g flux (representing ~ 0.5% of the batch weight) and then samples are again taken to establish the density index.

The operation is repeated as many times as needed with 25 g of flux, for the most advanced removal of the oxides from the melt. After sampling, the probes were weighed and placed in the Density Terminal apparatus to establish the density index. The collected samples have the physical properties shown in the following tables.

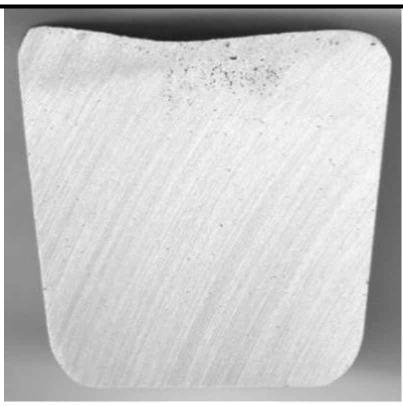
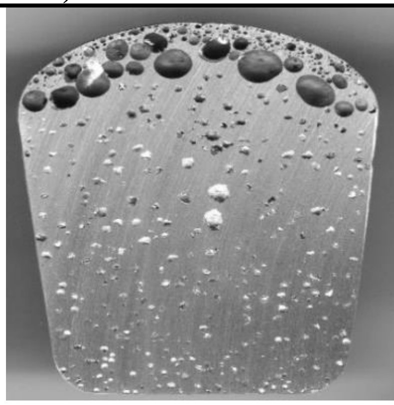
Samples were recorded as follows: A - samples solidified in the air, V - samples solidified in a vacuum. Samples were made using 3.0 kg aluminium alloy and 7.2 kg metal chips, 4.0 kg aluminium alloy + 5.3 kg metal chips, 5.0 kg aluminium alloy + 3.5 kg metal chips.

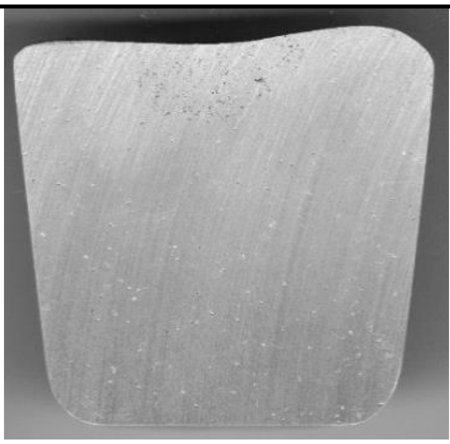
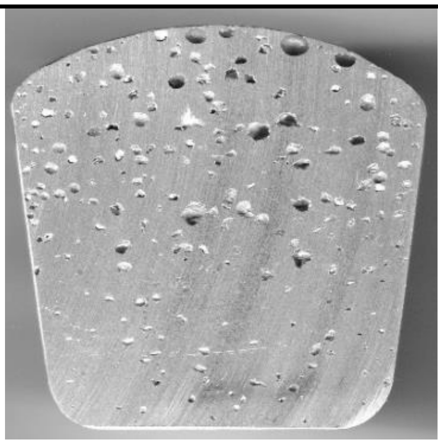
The density index was calculated using the following formula:

$$D.I. = \frac{\rho_{air} - \rho_{vac}}{\rho_{air}} \cdot 100$$

Table 3.

Optical macroscopy with resulting samples for experiment 1. The density indexes.

A03		**V03**	
Weight (g) 85.70	Density (g/cm^3) 2.603	Weight (g) 71,45	Density (g/cm^3) 1.632
DI = 37.3 (Untreated)			
 **A13**		 **V13**	
Weight (g) 71.00	Density (g/cm^3) 2.666	Weight (g) 90.35	Density (g/cm^3) 2.218
DI = 16.8 (Treated with flux 50g)			

 **A23**		 **V23**	
Weight (g) 77.30	Density (g/cm^3) 2.673	Weight (g) 81.12	Density (g/cm^3) 2.359

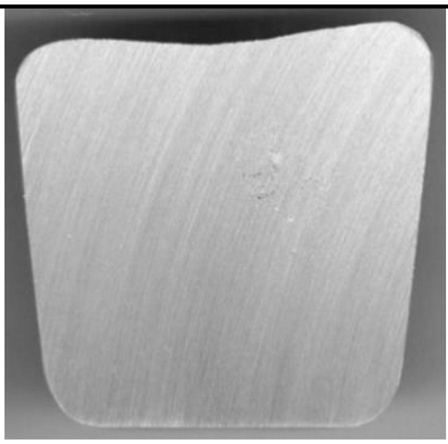
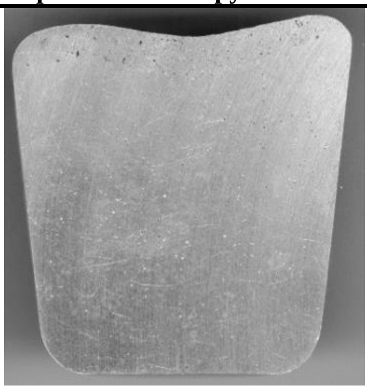
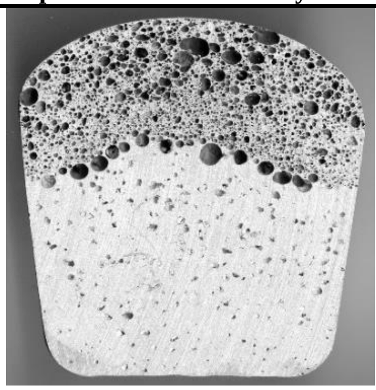
DI = 11.7 (Treated with flux 25g)			
A33		**V33**	
Weight (g) 78.19	Density (g/cm^3) 2.697	Weight (g) 64.06	Density (g/cm^3) 2.386
DI = 11.5 (Treated with flux 25g)			
 **A43**		 **V43**	
Weight (g) 78.22	Density (g/cm^3) 2.716	Weight (g) 79.52	Density (g/cm^3) 2.575
DI = 5.2 (Treated with flux 25g)			

Table 4.

Optical macroscopy with resulting samples for experiment 2. The density indexes.

 **A04**		 **V04**	
Weight (g) 85.91	Density (g/cm^3) 2,633	Weight (g) 69.91	Density (g/cm^3) 1.943
DI = 26.5 (Untreated)			
A14		**V14**	
Weight (g) 75.58	Density (g/cm^3) 2.700	Weight (g) 84.67	Density (g/cm^3) 2.472
DI = 8.4 (Treated with flux 50g)			

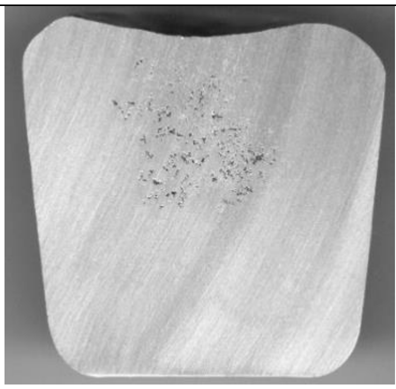
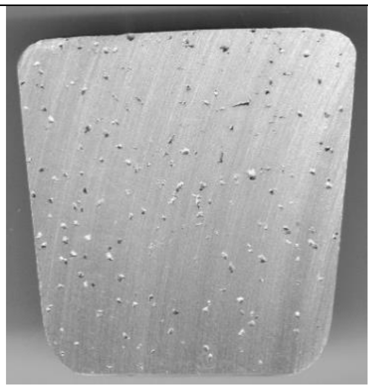
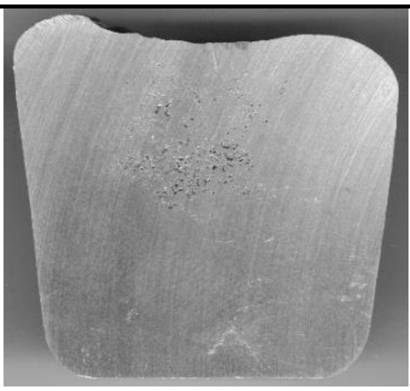
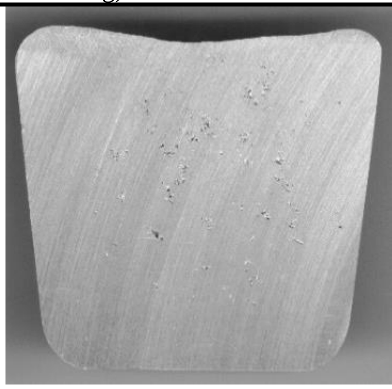
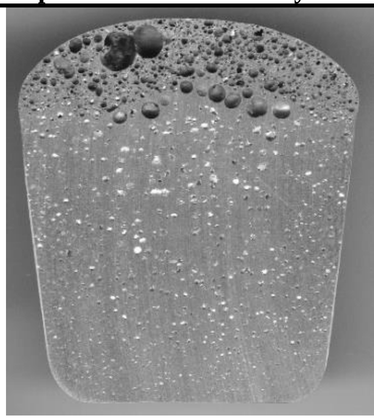
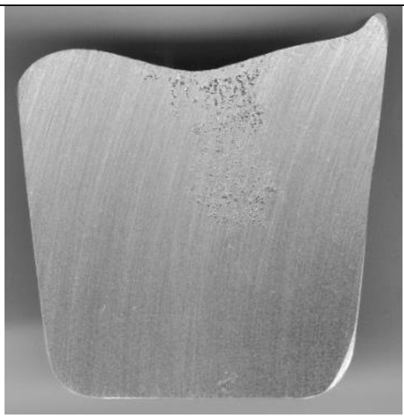
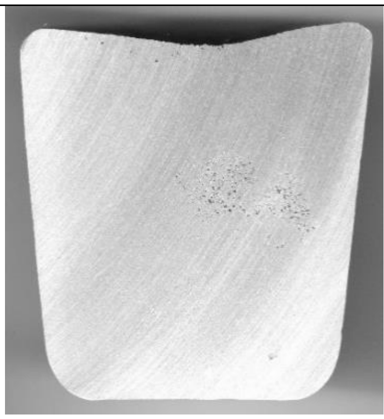
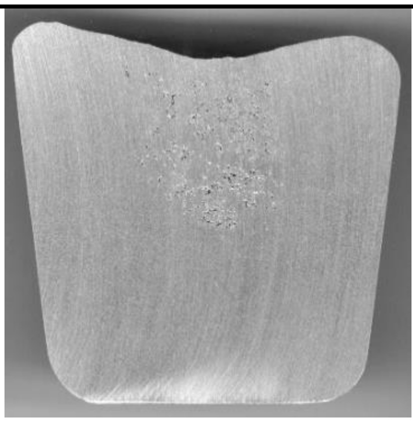
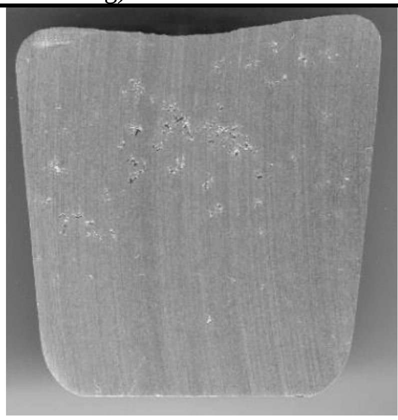
 **A24**		 **V24**	
Weight (g) 75.47	Density (g/cm^3) 2.701	Weight (g) 70.84	Density (g/cm^3) 2.592
DI = 4.0 (Treated with flux 25g)			
 **A34**		 **V34**	
Weight (g) 84.33	Density (g/cm^3) 2.706	Weight (g) 77.55	Density (g/cm^3) 2.680
DI = 1.0 (Treated with flux 25g)			

Table 5.

Optical macroscopy with resulting samples for experiment 3. The density indexes.

 **A05**		 **V05**	
Weight (g) 83.17	Density (g/cm^3) 2.631	Weight (g) 83.01	Density (g/cm^3) 2.138
DI = 18.8 (Untreated)			

 A15		 V15	
Weight (g) 81.60	Density (g/cm^3) 2.696	Weight (g) 78.55	Density (g/cm^3) 2.694
DI = 0.1 (Treated with flux 50g)			
 A34		 V34	
Weight (g) 82.12	Density (g/cm^3) 2.693	Weight (g) 74.08	Density (g/cm^3) 2.672
DI = 0.8 (Treated with flux 25g)			

Analysis by optical microscopy

The quantitative analysis of the microstructures was performed using a system composed of BX51-M - Olympus metallographic microscope, UC30 - Olympus video camera, Stream analysis software – Olympus.

The analysis of the investigated samples revealed the presence of structural defects in Fig. 6 (a, c, e) such as contraction, porosity, non-metallic inclusions, and in Fig. 6 (b, d, f) the decreased concentration of impurities and defects due to flux treatment.

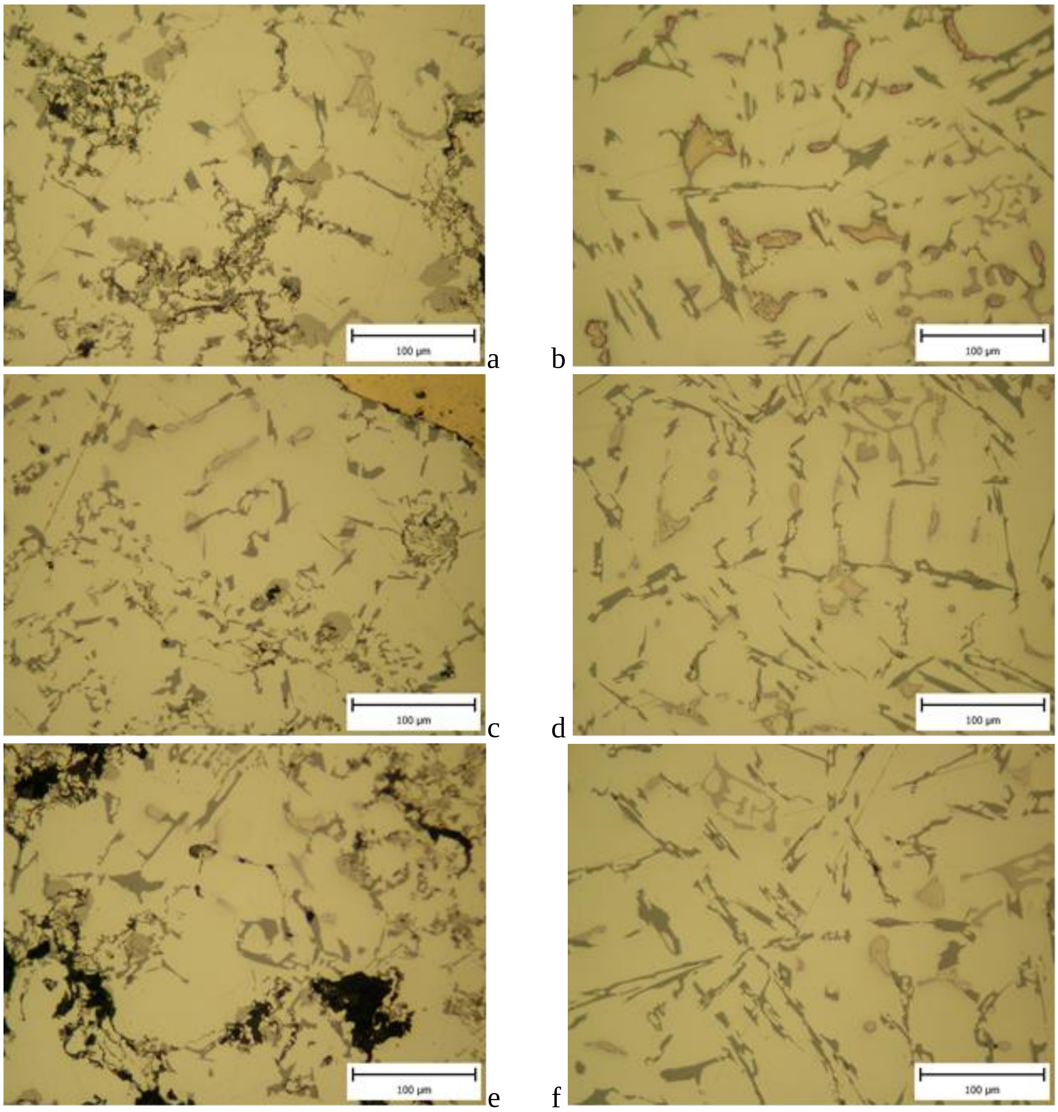


Fig. 6. Optical microstructures of the samples starting from a 3 kg (a, b), 4 kg (c, d) and 5 kg (e, f) melt, before (left) and after (right) flux treatment

4. Conclusions

Low-temperature processing reduces oxidation losses for both aluminium and other metal elements in the metal chips composition by incorporating it into the semi-solid / pasty melt. The subsequent overheating of the melt leads to advanced assimilation of the metal chips particles into the molten metal mass.

After loading each batch, the volatiles and the humidity from the metal chips evaporated after contacting the hot bath, and the remainder of the material was homogenized with the melt resulting in a viscous bath, having a temperature of about 620°C. After filling the crucible with metal, the melt is overheated, and it is treated with flux in order to remove the oxidic impurities and for degassing. Flux treatment leads to the elimination of dissolved gases and impurities, a greater amount of flux is needed as the number of metal chips used is higher.

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