Deliverable Report

Deliverable Title:

Report with the analysis of the different scrap groups provided by COMET

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Coordinator	Fundacion Eurecat

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RE = Restricted to a group specified by the consortium (including the Commission Services)
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Summary

The present document describes the method followed by COMET to select different fractions of scrap from their Zorba stream and the characterization conducted, as well as other sources of scrap used to conduct the experimental work of WP1 of SALEMA project.

It describes the nature of the Zorba stream and which kind of metallic material you can find in it. It is also presented the procedure followed to generate the 2 batches supplied to Eurecat and, finally, the characterization procedure followed at Eurecat to determine the type of scrap present in each batch.

As it was observed that the scrap obtained from the Zorba stream do not cover the whole necessities of WP1 tests, in both quantity and different scrap types, other sources were explored. The document also describes these alternative scrap acquired, and the characterization conducted.

Deliverable 1.2 should be a guide to consider in the development of SALEMA technology to treat the scrap and the subsequent use to produce partially recycled aluminium alloys in WP3.

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Disclaimer

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Abbreviations

Abbreviation / Acronyms	Description
HPDC	High-Pressure Die Casting
OES	Optical Emission Spectrometry
PMC	Permanent Mould Casting
XRF	X-Ray Fluorescence

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1. Introduction and Background

One of the main objectives of the Salema project is to develop new, high-performance, partially recycled aluminium alloys for electric vehicles. In other words, the feedstock of these alloys shall partially consist of secondary aluminium alloys recycled from well-identified scrap sources. WP1 sets the basis for the development of those new, high-performance alloys.

1.1. Objectives of task and deliverable

Within WP1, Task 1.2 has the objective to characterize different aluminium scraps that are commonly available, for instance in the usual material flows and stocks of COMET. The deliverable of Task 1.2 contains technical results about:

- The selection of scrap 5xxx and 6xxx series aluminium alloys by COMET from a Zorba stock, and their preliminary XRF analysis
- The further characterization of these 5xxx and 6xxx series alloys batches obtained from Zorba stock
- The characterization of alternative scrap acquired to fulfil the necessities of WP1 that could not be covered with Zorba scrap

2. Selection of scrap 5xxx and 6xxx series aluminium alloys carried out by COMET from a Zorba stock and their preliminary XRF analysis

2.1. Description of Zorba stock

In the metal recycling industry, Zorba is a jargon word for pre-treated shredding residues (e.g. from scrapped automotive vehicles, electric and electronic equipment, ...) which are composed of a mixture of non-ferromagnetic metallic alloys parts (see Figure 1). Zorba typically contains 70% of different aluminium alloys in weight and 30% of a mixture of other non-ferromagnetic metallic alloys, mainly different zinc, brass, copper alloys, bronzes and stainless steels. The aluminium fraction of Zorba contains itself scrapped cast alloys of different compositions and different scrapped wrought alloys (mainly rolled and extruded). Currently, the Zorba stocks produced in Europe are mostly sold to companies in Asia which manually sort out different metallic alloys. The Zorba stock of COMET from which 5xxx and 6xxx series aluminium alloys have been selected consists of parts the size range of which is [20 mm; 100 mm].

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Figure 1: Typical aspect of Zorba parts

2.2. Experimental methodology and equipment used

The experimental methodology used by Comet for this sub-task of Task 1.2 is as follows:

- From a Zorba stock (see Figure 2), around 560 parts have been individually, manually selected for their aluminium appearance by an operator. Then these parts have been individually numbered and partially sanded.

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Figure 2: Zorba stock at a COMET factory

- In parallel, a Zorba stock with the same parts' size range has been processed with the help of an X-ray transmission-based sorting machine, which has sorted out (assumed) aluminium parts, including wrought and cast aluminium alloys. The aluminium parts have been processed once again on the same sorting machine, and the (assumed) wrought aluminium parts have been sorted out. From the latter flow, a batch of about 790 parts has been randomly selected. These parts have also been individually numbered, and partially sanded.

- Each individual part of both aforementioned aluminium fractions has been analyzed with the help of a handheld XRF spectrometer (Bruker S1 Titan, see Figure 3). The analytical program which has been selected is "Alloys". The sanded area of an individual part has been analyzed for a duration of 25 seconds. For each fraction, an Excel file of the elemental compositions of all individual parts has been provided by the XRF software. For each part, the XRF spectrometer's software output is the nature of the analyzed alloy (more precisely the three best guesses) as characterized by its usual norm (for example: 5005, 1100, 3003, A332/333, A380 aluminium alloys) and its elemental composition.

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Figure 3: XRF spectrometer used for the individual analysis of (assumed) aluminium parts

- From the first fraction (assumed aluminium parts manually selected from a Zorba stock), the software has determined several 5xxx and 6xxx alloys parts, along with other wrought (1xxx, 2xxx, 3xxx, 7xxx) and cast aluminium alloys, and it has also identified a small but significant amount of non-aluminium parts (e.g. Mg alloys, Ti alloys, Pb, maraging steels …).
- From the second fraction (assumed wrought aluminium parts produced by a 2 steps operation on a sorting machine from a Zorba stock), only 2 parts turned out not to be aluminium alloys; as for the rest of the parts, they were mainly wrought parts with a significant minority of cast parts.
- The 5xxx aluminium alloys parts (as determined by the XRF spectrometer) sorted out from the first and second fractions respectively have been put together. From those, 11 parts have been discarded because of their (apparent) high Co-content (most of the time with a significant Ni content too), and their (apparent) zero Mg content. The remaining parts altogether have been named as "Family 5xxx" batch. This batch contains 583 parts. Figure 4 shows some of these 5xxx parts.

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Figure 4: Some parts of the "Family 5xxx" batch

- Likewise, the 6xxx aluminium alloys parts sorted out from the first fraction and sorted out from the second fraction have been put together. From those, 4 parts identified as 6253 alloy, containing between 2% and 3% Zn, were discarded. and named as the "Family 6xxx" batch. This batch contains 58 parts. Figure 5 shows some of those 6xxx parts.

Figure 5: Some parts of the "Family 6xxx" batch

- In parallel, COMET and ULIEGE have both measured with the same XRF spectrometer 7 different standard aluminum alloys, the compositions of which are known with a high precision. These alloys are respectively:
    - AlSi10Mn (certified reference material Speira 3130-1 / 4-04)
    - AlMg2 (certified reference material Speira 2300-1 / 2-03)
    - AlSi1MgMn (certified reference material Speira 2109-1 / 1-01)

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  - AlMg3 (certified reference material Speira 2301-1 / 10-09)
  - Another AlMg3 with a different composition as compared to the former one (certified reference material Speira 2302-1 / 3-03)
  - AlSi1MgMn (certified reference material 2103-1 / 10-12)
  - 6063 (Arconic spectrochemical reference material SS-6063-YZ)
- Both 5xxx and 6xxx scrap batches were shipped to EURECAT.

2.3. Preliminary, XRF characterization of 5xxx and 6xxx scrap batches

2.3.1. Average elemental concentrations

The parts of "Family 5xxx" and "Family 6xxx" batches have not been individually weighed, to avoid a too tedious and long work. The following, respective elemental concentrations of "Family 5xxx" and "Family 6xxx" batches (see Table 1 and

Si	Fe	Cu	Mn	Mg	Cr	Ni	Zn	Ti	Ag	Bi	Pb	Sn	V	Zr	Cd	Co	Al
1,22263	1,14964	0,11923	0,32877	0,80214	0,0729	0,02559	0,15681	0,24769	0	0,00061	0,02001	0,00351	0,04662	0,0042	0	0,0093	95,6142

Table 2) have been estimated under the strong but reasonable hypothesis that each part has the same weight.

Si	Fe	Cu	Mn	Mg	Cr	Ni	Zn	Ti	Ag	Bi	Pb	Sn	V	Zr	Cd	Co	Al
0,14451	0,70444	0,07045	0,24444	2,68748	0,041	0,02711	0,07236	0,12533	0,001	0,01722	0,00759	0,00666	0,0372	0,0029	0,001	0,01286	95,5664

Table 1: Estimated, average elemental concentrations of the "Family 5xxx" batch

Si	Fe	Cu	Mn	Mg	Cr	Ni	Zn	Ti	Ag	Bi	Pb	Sn	V	Zr	Cd	Co	Al
1,22263	1,14964	0,11923	0,32877	0,80214	0,0729	0,02559	0,15681	0,24769	0	0,00061	0,02001	0,00351	0,04662	0,0042	0	0,0093	95,6142

Table 2: Estimated, average elemental concentrations of the "Family 6xxx" batch

2.3.2. Alloys distribution within the "Family 5xxx" batch

The numeric (again, each part is assumed to have the same weight) distribution of aluminium alloys within the "Family 5xxx" batch is as follows:

- 5005: 29%
- 5052: 29%
- 5083/5086: 21% (remark: the XRF software library doesn't distinguish between these two alloys)
- 5356/5056: 11% (same remark)
- 5454: 10%

2.3.3. Alloys distribution within the "Family 6xxx" batch

The numeric distribution of aluminium alloys within the "Family 6xxx" batch is as follows:

- 6013: 10%
- 6022: 28%
- 6061: 33%
- 6063: 5%
- 6082: 24%

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2.3.4. Comments and remarks

The respective, estimated Fe concentrations of “Family 5xxx” and “Family 6xxx” batches are considered too high for usual aluminium alloys. It is believed that those Fe concentrations are overestimated for two reasons of different natures:

- First, an individual XRF measurement is carried out on the sanded area of a part. The sanding is done superficially, and it probably produces some particles that remains on the sanded part, for no cleaning operation is performed after the sanding. Yet the surface of Zorba parts is known to be contaminated with Fe-rich dust most probably originating from the initial shredding of Fe-containing (steel, cast iron, stainless steel) scraps. Fe might also originate from the surface of Al cast alloy parts that contain Fe-rich intermetallic particles that are known to be small and fragile. Ti might also be overestimated for similar reasons: white paint powder containing TiO_2 originating from the shredding operations may still contaminate the surface of sanded parts to some extent.
- Second, the XRF measurement itself overestimates or underestimates the concentrations of some chemical elements, and this depends on the considered element, element concentration and probably on the considered matrix. The XRF measurements carried out on the 7 aforementioned aluminium standard samples show clearly the overestimation of the Fe concentration (see Figure 6 below) in this range of Fe concentrations and for such aluminium alloy matrices. From the diagram below it can be roughly estimated that the overestimation of the Fe concentration is around 25% or 30%.

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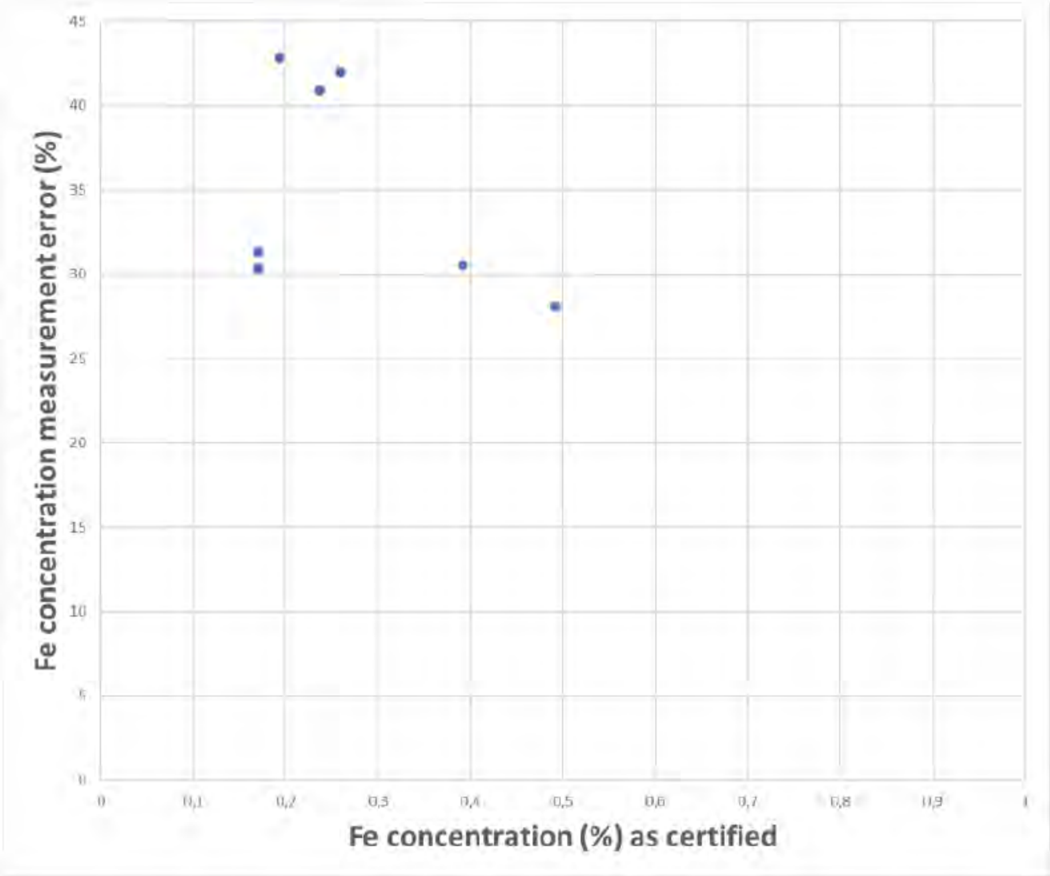

Figure 6: Fe concentrations errors in XRF measurements of standard Al alloys

The measurements of the respective chemical compositions of the “Family 5xxx” and “Family 6xxx” batches as to be molten by Eurecat will be compared with the average elemental concentrations as measured by XRF. In particular they will allow an estimation of the possible impact of Fe (and possibly Ti) superficial contamination of the individual parts on the corresponding, chemical elemental concentrations of the respective, molten batches.

3. Characterization of 5xxx and 6xxx scrap batches obtained from the Zorba stock

In order to have an exhaustive characterization of the samples of the manual sorted scrap provided that can be obained from COMET Zorba stream, Eurecat analysed carefully both batches.

3.1. Experimental methodology and equipment used

The chemical composition analysis at Eurecat have been done in an arc/spark optical emission spectrometer SPECTROMAXx F (Figure 7). The fragments of scrap, should be gridded, leaving a clean surface, by removing the dirt present. In Figure 8, are shown an image of some of the analysed pieces, where it can be seen the clean surface. The chemical composition is determined by applying the electrode over the clean sample. The equipment generates a spark that sublimes part of the material, creating a plasma. This plasma is analysed by the spectrometer, determining with high precision the chemical composition of the base material.

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Figure 7: Image of the SPECTROMAXx F used at Eurecat to analyse the chemical composition of the selected pieces

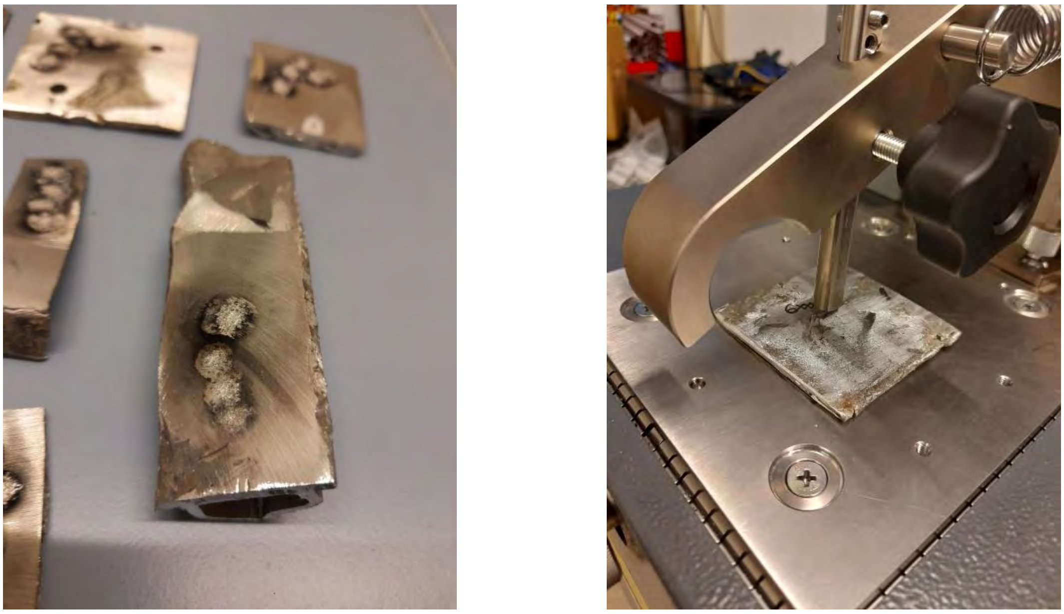

Figure 8: Image of the surface of some of the scrap pieces after being grinded, once the spark plasma analysis was already conducted (left) and picture of the analysis carried out on one of the selected scrap fragments

3.2. General overview and selection of representative pieces

Once the scrap shipped from COMET was received at Eurecat a general inspection of the 2 batches was conducted. It was observed that 5xxx series it was much larger (Figure 9). Approximately, the top 1/3 of the barrel was taken out, spread over the floor, and inspected. A total of 12 fragments, belonging to different component types, were chosen for measurement of its chemical composition by spark OES with Eurecat Spectometer.

The same process was done with the 6xxx series batch, but, in this case, being a much reduced amount, the whole batch was spread over the floor and inspected (Figure 10) and 12 representative pieces were taken for further inspection and subjecting them to spectrometry.

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Figure 9: Image of the open barrel with the whole 5xxx series batch of scrap supplied by COMET (left) and picture of the fragments belonging approximately to 1/3 of the top of the batch spread over the floor (right)

Figure 10: Image of the batch of 6xxx series scrap provided by COMET spread over the floor

3.3. Characterization of 5xxx series

The results of the chemical analysis of the 12 fragments selected from the 5xxx series scrap batch are presented in Table 3. As can be seen, the chemical composition measured in most of the fragments do not belong to a 5xxx series alloy, but to a 6xxx series.

Further analysis of the data measured by COMET and compared with the data from EURECAT chemical analysis should be done. Nevertheless, with the preliminary comparison of the data it seems that:

1. The contamination of the surface of the scrap fragments may be one of the reasons, as the chemical analysis obtained by COMET shown large amounts of Fe and other elements that in the inner section of the pieces are not present.

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2. The software used by the XRF equipment may assign a 5xxx series alloy in case of doubt. It is observed that some samples with large amounts of Si and with low Mg are considered to be a 5xxx series alloy, due to the high level of other elements.

n=5	%Si	% Fe	%Cu	%Mn	%Mg	%Cr	%Ni	%Zn	Alloy
Spec 1	0.44	0.19	<0.03	<0.03	0.39	<0.03	<0.03	<0.03	6060
Spec 2	0.39	0.19	<0.03	<0.03	0.38	<0.03	<0.03	<0.03	6060
Spec 3	0.44	0.18	<0.03	<0.03	0.40	<0.03	<0.03	<0.03	6060
Spec 4	0.82	0.15	<0.03	<0.03	0.49	<0.03	<0.03	<0.03	6005
Spec 5	0.41	0.25	<0.03	<0.03	0.66	<0.03	<0.03	<0.03	6063
Spec 6	0.45	0.19	<0.03	0.05	0.34	<0.03	<0.03	<0.03	6060
Spec 7	0.61	0.23	0.15	0.06	0.49	0.09	<0.03	<0.03	6017
Spec 8	0.42	0.22	<0.03	0.08	0.44	<0.03	<0.03	<0.03	6060
Spec 9	0.14	0.32	0.05	0.49	3.95	0.09	<0.03	<0.03	5086
Spec 10	0.09	0.30	<0.03	<0.03	0.02	<0.03	<0.03	<0.03	1050
Spec 11	0.18	0.23	<0.03	0.15	2.80	<0.03	<0.03	<0.03	5754
Spec 12	0.42	0.16	<0.03	0.07	0.47	<0.03	<0.03	<0.03	6063

Table 3: Chemical composition measured by spark OES with SPECTROMAXx equipment on the 12 fragments selected from the 5xxx series batch supplied by COMET

3.4. Characterization of 6xxx series

n=5	%Si	% Fe	%Cu	%Mn	%Mg	%Cr	%Ni	%Zn	Alloy
Spec 1	0.34	0.16	<0.03	<0.03	0.47	<0.03	<0,03	<0,03	6063
Spec 2	0.67	0.41	<0.03	0.45	0.64	<0.03	<0,03	<0,03	6081
Spec 3	0.56	0.16	0.2	0.06	0.81	0.06	<0,03	<0,03	6061
Spec 4	0.91	0.2	<0.03	0.55	0.63	<0.03	<0,03	<0,03	6082
Spec 5	0.46	0.24	<0.03	<0.03	0.48	<0.03	<0,03	<0,03	6063
Spec 6	0.44	0.17	<0.03	<0.03	0.41	<0.03	<0,03	<0,03	6060
Spec 7	0.35	0.18	<0.03	<0.03	0.33	<0.03	<0,03	<0,03	
Spec 8	0.41	0.18	<0.03	<0.03	0.41	<0.03	<0,03	<0,03	6060
Spec 9	0.93	0.16	<0.03	0.44	0.62	<0.03	<0,03	<0,03	6082
Spec 10	0.92	0.21	<0.03	0.46	0.61	0.09	<0,03	<0,03	6082
Spec 11	0.42	0.16	<0.03	<0.03	0.45	<0.03	<0,03	<0,03	6063
Spec 12	1.05	0.27	0.12	0.1	0.3	<0.03	<0,03	<0,03	6016

Table 4 shows the results obtained with the chemical analysis of the 12 fragments selected from the 6xxx series scrap. They belong to different aluminium alloys, but all of them belonging to the 6xxx family. Therefore, seems that the XRF analyser is more reliable when assigning a 6xxx series alloy, than when it links the analysed chemical composition to an alloy from the 5xxx family.

n=5	%Si	% Fe	%Cu	%Mn	%Mg	%Cr	%Ni	%Zn	Alloy
Spec 1	0.34	0.16	<0.03	<0.03	0.47	<0.03	<0,03	<0,03	6063
Spec 2	0.67	0.41	<0.03	0.45	0.64	<0.03	<0,03	<0,03	6081
Spec 3	0.56	0.16	0.2	0.06	0.81	0.06	<0,03	<0,03	6061

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Spec 4	0.91	0.2	<0.03	0.55	0.63	<0.03	<0,03	<0,03	6082
Spec 5	0.46	0.24	<0.03	<0.03	0.48	<0.03	<0,03	<0,03	6063
Spec 6	0.44	0.17	<0.03	<0.03	0.41	<0.03	<0,03	<0,03	6060
Spec 7	0.35	0.18	<0.03	<0.03	0.33	<0.03	<0,03	<0,03	
Spec 8	0.41	0.18	<0.03	<0.03	0.41	<0.03	<0,03	<0,03	6060
Spec 9	0.93	0.16	<0.03	0.44	0.62	<0.03	<0,03	<0,03	6082
Spec 10	0.92	0.21	<0.03	0.46	0.61	0.09	<0,03	<0,03	6082
Spec 11	0.42	0.16	<0.03	<0.03	0.45	<0.03	<0,03	<0,03	6063
Spec 12	1.05	0.27	0.12	0.1	0.3	<0.03	<0,03	<0,03	6016

Table 4: Chemical composition measured by spark OES with SPECTROMAXx equipment on the 12 fragments selected from the 6xxx series batch supplied by COMET

4. Characterization of other scrap sources used in SALEMA project

In order to be able to conduct the trials of WP1 with all the alloys selected for the industrial partners, 2 kinds of scrap were aquired in order to compensate the lack of primary foundry alloys and 6xxx series observed in the zorba stream from COMET.

4.1. Sprues and casting parts supplied by Raffmetal

The scrap supplied by Raffmetal was supposed to be homogeneous AlSi10MnMg scrap composed by casting sprues and defective components. Raffmetal supplied about 100 kg of this scrap in one big bag (Figure 11). However, a visual analysis, revealed some parts that seemed to have been produced by Gravity Casting and no by HPDC. An example is shown in Figure 11, where it can be observed one typical Permanent Mould Casting (PMC) sprue with its filter (left component of the right image).

Figure 11: General image of the foundry scrap provided by Raffmetal (left) and image of 3 parts selected to conduct a chemical analysis by spectrometry (right)

The 3 parts from Figure 11, as a representative selection of the different types of components and sprues, were analysed by Spark Plasma Analysis. The results of the analysed parts are presented in Table 5.

n=5	%Si	% Fe	%Cu	%Mn	%Mg	%Zn	%Ni	%Cr	%Pb	%Sn	%Ti
Spec 1	10.07	0.14	0.02	0.60	0.19	0.01	<0,01	<0,01	<0,01	<0,01	0.07
Spec 2	6.91	0.10	<0.01	0.01	0.36	<0.01	<0.01	<0.01	<0.01	<0.01	0.13
Spec 3	11.55	0.16	<0.01	0.65	0.33	<0.01	<0.01	<0.01	<0.01	<0.01	0.01

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Table 5: Chemical composition measured by spark OES with SPECTROMAXx equipment on the 3 fragments selected from the AlSi10MnMg scrap supplied by Raffmetal

The analysis confirms the presence of parts of AlSi7Mg mixed up with the rest of primary HPDC parts of AlSi10MnMg alloy. As those parts can be easily identified visually, there were excluded for the trials, using just scrap of AlSi10MnMg alloy.

4.2. Extruded profile of 6063 alloy acquired from a local aluminium recycling company

Eurecat had to acquire a large amount of scrap of 6063 aluminium extruded profile for a different project. The scrap was supplied in a large plastic container of $1m^3$ of volume (Figure 12). With a general sight it was clear that all the scrap supplied was exclusively aluminium extruded profile, but of different shapes, thicknesses, and some of them were painted or had a surface treatment. A selection of 10 representative pieces were taken from the container, in order to have a precise chemical analysis of them.


Figure 12: General overview of the 6063 extruded profile acquired from a local aluminium recycling companyl (left) and image of the 10 parts selected for a Spark Plasma chemical analysis (right)

The results of the chemical analysis of the 10 selected parts are presented in Table 6. It can be observed that the scrap is quite homogeneous and of similar composition. The compositions of all 10 pieces correspond with a 6063 alloy, just in some of them the Mg content is a little lower than the minimum content permitted for the alloy and should be considered as a 6060 alloy.

n=5	%Si	% Fe	%Cu	%Mn	%Mg	%Zn	%Ni	%Cr	%Pb	%Sn	%Ti
Spec 1	0.42	0.23	<0.01	0.05	0.36	<0.01	<0,01	<0,01	<0,01	<0,01	0.01
Spec 2	0.42	0.26	0.03	0.06	0.43	0.04	<0,01	<0,01	<0,01	<0,01	0.02
Spec 3	0.42	0.21	<0.01	0.03	0.38	<0.01	<0.01	<0.01	<0.01	<0.01	0.01
Spec 4	0.43	0.22	<0.01	0.03	0.40	<0.01	<0,01	<0,01	<0,01	<0,01	0.01
Spec 5	0.41	0.24	0.02	0.04	0.45	0.04	<0,01	<0,01	<0,01	<0,01	0.02
Spec 6	0.41	0.23	0.02	0.03	0.38	<0.01	<0.01	<0.01	<0.01	<0.01	0.01
Spec 7	0.49	0.23	0.01	0.03	0.48	0.01	<0.01	<0.01	<0.01	<0.01	0.02
Spec 8	0.53	0.19	0.02	0.08	0.44	<0.01	<0,01	<0,01	<0,01	<0,01	0.02
Spec 9	0.56	0.23	0.02	0.06	0.44	0.01	<0,01	<0,01	<0,01	<0,01	0.01
Spec 10	0.42	0.21	0.01	0.03	0.57	0.01	<0.01	<0.01	<0.01	<0.01	0.02
6063	**0.2-0.6**	**0.35**	**0.1**	**0.1**	**0.45-0.9**	**0.1**	**0.05**	**0.1**	**0.05**	**0.05**	**0.1**

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Table 6: Chemical composition measured by spark OES with SPECTROMAXx equipment on the 3 fragments selected from the 6xxx extruded profile supplied by a local aluminium recycling company

5. Conclusions and Outlook

The present document describes the method followed by COMET to select different fractions of scrap from their Zorba stream and the characterization conducted, as well as other sources of scrap used to conduct the experimental work of WP1 of SALEMA project. The main conclusions that can be inferred from the results obtained are:

- Non casting primary alloys such as AlSi10MnMg alloy were found in COMET Zorba stream, and it was required to obtain such as scrap from other sources: scrap from foundries using those kinds of alloys.
- The XRF analysis classify most of the aluminium pieces as 5xxx series and just about 10 % of the fragments as 6xxx series.
- Subsequent analysis of the inner material of the fragments, revealed that most of the pieces classified as 5xxx alloy by XRF, actually belong to an alloy from 6xxx family.
- The AlSi10MnMg scrap provided by Raffmetal was very homogeneous, but present some pieces from Gravity Casting, that Spark spectrometry reveal to belong to an AlSi7Mg alloy, typically used in this process.
- It is possible to acquire highly homogenous scrap of extruded profile, easily from a scrap dealer or aluminium recycling company.

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