eccomelt356.2 As a Substitute or Addition to Primary A356.2 to Increase Competitiveness and Reduce Carbon Footprint of Castings

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Presented by Martin Hartlieb

Requirements on structural/high tech castings

- ❑ High mechanical properties (static, dynamic, crash)
- ❑ Good corrosion resistance
- ❑ etc.
  - ➢ Therefore often primary A356.2 is prescribed by OEM

New requirements:

- ➢ Low carbon footprint
- ➢ Recycling content
- ➢ But without compromise on other requirements!

How is it possible?

What is eccmelt356.2?

- It is clean crushed wheels delivered in sacks to foundries, die casters and cast houses, is a substitute for ingot, sow, or T-bar, which was developed in response to a growing global need for ecological and economical metal sources for the aluminum foundry industry.
- It is patented in the United States, Canada, Mexico, Europe, and Japan. Over 700 million pounds (320 thousand tons) have already been sold, typically replacing A356.2 ingots (in part or completely), or as a base material for other high quality (low Fe Al-Si) alloys.
- Can it fulfill all requirements (cleanliness/excellent properties/low carbon footprint through recycling content? – We tested it at the CMQ Lab!

Performed analysis at the Quebec Metallurgy Centre

- Visual and surface contamination inspection
- Melting and analysis of dross formation / melt loss (compared to ingots)
- Chemical analysis & H measurement
- Metal cleanliness analysis (PoDFA)
- Casting test bars in permanent mold and sand molds (ASTM)
- Heat treatment of test bars
- Analysis of mechanical properties in different conditions
- Microscopic analysis

Overview of the production process at EccomeltLLC.

Aluminum wheels (A356) → Wheel shredder → Patented cleaning process → eccomelt356.2

→ Melt Sample →

→ Sample Button

Material as received at the CMQ

eccomelt356.2 was received in a “supersack”. Metal was found to be **very clean** and in broken parts small enough to give a **good compaction** for charging and high density in the furnace.

Surface quality analysis

eccomelt356.2 as received

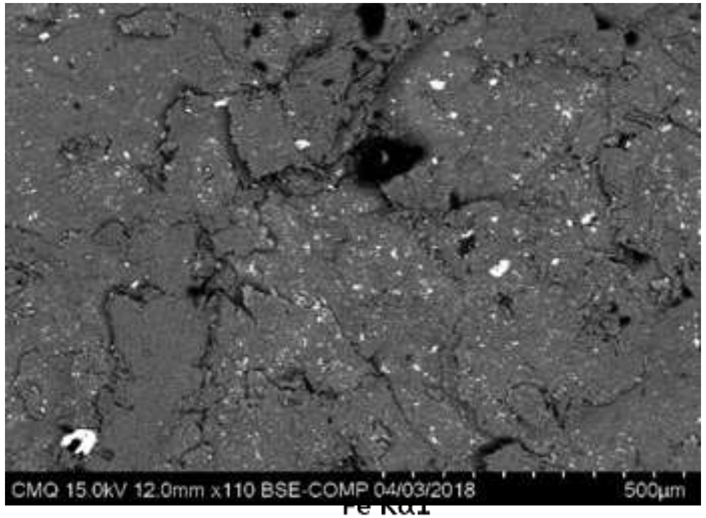
Conventionally treated scrap wheels are largely contaminated by calcium compound and iron oxide, not the eccomelt356.2.

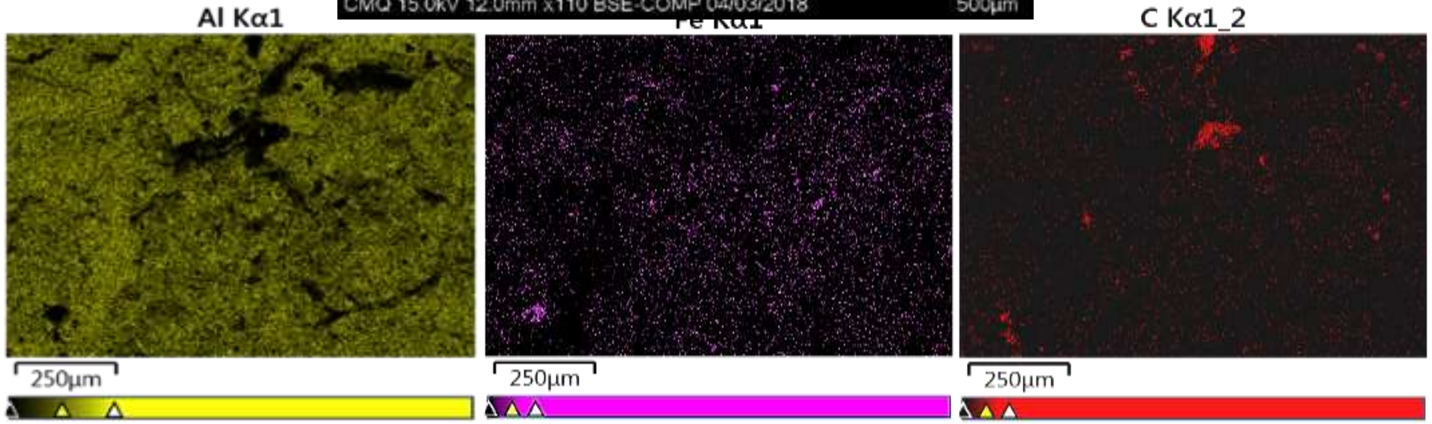
The eccomelt356.2 material is **free of the paint pigments** that are typically left on recycled aluminum when an alternative delaquering process is used.

No conventional “decoating system can remove these compounds and they usually remain on the scrap surface in the form of a white or lightly coloured friable deposit.” (Evans and Guest, “The Aluminum Decoating Handbook”).

Surface quality analysis

SEM pictures:





Surface of the **eccomelt356.2** (as received)

- Very clean aluminium with only very small iron and carbon particles
- As it is free of paints, coatings, and lubricants, eccomelt356.2 meets the definition of **"Clean Charge"** as defined in the United States National Emission Standard for Hazardous Air Pollutants for secondary aluminum production under 40 CFR 63.1503

Melting, molten metal treatment and analysis

A 275lb charge made from 100% eccomelt356.2 was prepared and melted in a Dynarad MG260 75 kW resistance furnace with a SiC crucible.

- **No fumes/smoke during melting**
- **Total skim removed was 0.66 lb or 0.5% of the charge** (very acceptable and within what is normal for most charge materials)

Once molten at 730 °C (1346 F) the quality of the untreated charge was tested by the following methods:

- Hydrogen measurement by AlSCAN
- Hydrogen measurement by Reduced Pressure test (RPT)
- Test bars cast in permanent mold per ASTM B108.

Melting, molten metal treatment and analysis

The melt was then **grain refined** with 0.05 %Ti (Al%5Ti1B). It was then **argon degassed** with a rotary degasser for 20 minutes. The degassed and treated melt was tested by the following methods:

- Hydrogen measurement by AlSCAN
- Hydrogen measurement by Reduce Pressure test (RPT)
- PoDFA for metal cleanliness (inclusions)
- Test bars cast in permanent mold per ASTM B108 (PDT samples)
- Test bars cast in Techniset® bonded resin sand mold per ASTM B26

Total skim removed after degassing was 5,97 lb or 2,17 % of the charge

Chemistry of material as received and tested

Typical chemistry of eccomelt356.2:

	Si	Fe	Cu	Mn	Mg	Cr	Ni	Zn	Ti
Max	7.500	0.140	0.020	0.030	0.400	0.030	0.008	0.018	0.150
Min	6.500				0.250				

	Ca	Li	Na	P	Pb	Sb	Sn	Sr	AL%
Max	0.005	0.0010	0.0020	0.010	0.010	0.002	0.010	0.0200	Remainder

Major elements of tested material:

	Si	Fe	Cu	Mn	Mg	Zn	Ti	others
eccomelt356.2 **As received**	**7.0**	**0.11**	**0. 004**	**0.006**	**0.334**	**0.005**	**0.12**	**0.03**

- Chemical analysis of metal as received was completely within A356.2 specification

Chemistry of material as received and tested

	Si	Fe	Cu	Mn	Mg	Zn	Ti	others
eccomelt356.2 As received	7.0	0.11	0. 004	0.006	0.334	0.005	0.12	0.03
eccomelt356.2 As melted	7.0	0.15	0. 011	0.006	0.348	0.005	0.10	0.03
eccomelt356.2 degassed melt	7.0	0.15	0,006	0.006	0.338	0.005	0.13	0.03
A356.0 ASTM B108	6,5-7.5	0,20 max	0.20 max	0,10 max	0.25-0.45	0.10 max	0,20 max	0.15 max
A356.1 ASTM B179	6.5-7,.5	0,15 max	0.20 max	0,10 max	0.30-0.45	0.10	0.20 max	0,10 max
A356.2 ASTM B179	6.5-7,.5	0,12 max	0.10 max	0,05 max	0.30-0.45	0.05	0.20 max	0,10 max

*) During melting the metal was slightly contaminated with some Fe in the crucible, but this did not have a significant impact on properties achieved.

Chemistry of material as received and tested

Minor elements and impurities:

All within ASTM B179/AA specification!

	Clean A356 shred as melted	Clean A356 shred degassed melt	A356.0	A356.1
Others	0.026	0.026	0.15 max	0.10 max
P	0.0007	0,0009	0.05 max	0.05 max
Cr	0.005	0.005	0.05 max	0.05 max
Pb	0.0015	0.0011	0.05 max	0.05 max
Li	0,0001	0.0001	0.05 max	0.05 max
Sr	0.009	0,008	0.05 max	0.05 max
Ni	0.006	0,006	0.05 max	0.05 max
V	0,01	0,010	0.05 max	0.05 max

Hydrogen content measurement

Hydrogen content was measured with AlSCAN and reduced pressure test (RPT). Results show a degassing level within normal industrial value of (0,09 to 0,15 ml/100g) after degassing.

Untreated: RPT Density 2.18, AlSCAN (0.365 ml/100g)

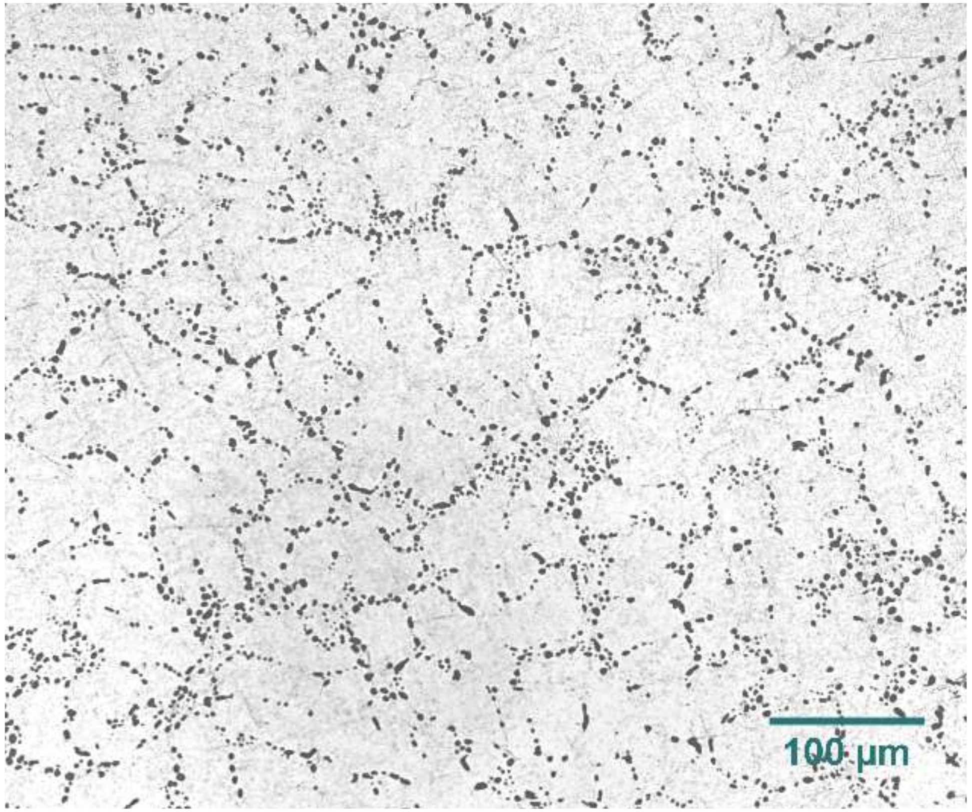
Degassed: RPT Density 2.66, AlSCAN (0.128 ml/100g)

PoDFA Analysis

- Metal cleanliness is ideally assessed with a hot PoDFA in the degassed melt. The PoDFA or Porous Disk Filtration Apparatus is a method of molten cleanliness assessment wherein the molten metal is forced under vacuum to flow through a ceramic filter. The amount of inclusion per kg filtered and inclusion type is measured by metallography and expressed in mm^2/kg.
- Our PoDFA results show an **average of 0.4 mm^2/kg, which is well within what a typical wheel foundry would see when using primary A356.2 ingots** for their melt. We have not seen any issues with metal cleanliness using eccomelt356.2 and do not expect any foundry to require any treatments beyond regular foundry practices of proper metal filtering, degassing and possibly fluxing.

Modification and grain refinement

- Sr modification was not necessary
- residual level of 88 ppm in the melt was measured before degassing and 79 ppm after degassing.
- A modification AFS Rating #5 (fully modified) was obtained.
- The melt was grain refined with 0.05 % Ti (Al%5Ti1B).



Tensile testing and results

- Tensile testing on test bars cast in PM to verify the effect of the degassing on the melt.
- The sand casting ASTM B26 gating had a filter installed at the bottom of the sprue.
- Hot isostatic pressing (HIP) done on 50 % of the PM test bars to obtain the best possible properties (with best in class foundry processes) since porosity is closed.
- Tensile testing was also performed on sand mold with the degassed treated metal, and the results were compared to ASTM B26 specifications.

As cast test bars, ASTM B26 sand mold above and B108 permanent mold below

Tensile testing and results

- All cast test bars were heat treated to T6 according to ASTM B917 and T61 with slight modification to ASTM B917 for best elongation.
- T61 for sand cast bars solution HT to 540 °C for 9h, quench in water at 25 °C then aging to 155 °C for 4 hours the day after
- T61 for PM cast bars solution HT at 540 °C for 9h, quench in water at 25 °C then aging at 162 °C for 9 hours. (50% of the samples were treated by HIP at 535 °C 15000 psi for 2 hours prior to HT).

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Mechanical properties achieved

Condition	T6 T61 Heat Treatment	YS ksi	UTS ksi	E %	Quality index MPa
Permanent mold Untreated	9 h at162 °C Standard deviation	32.8 5.7%	39.2 7.2%	4.3 39%	370
Permanent mold Degassed	9 h at162 °C Standard deviation	33.8 2.0%	44.4 2.5%	8.4 17%	446
Permanent mold Degassed + HIP	HIP + 9h at162 °C Standard deviation	33.4 1.5%	45.6 1.7%	12.1 17%	477
Permanent mold Separate test bars **Min. value ASTM B108**	6-12 h at 155 °C	**28.0**	**38.0**	**5**	**367**
Sand mold Degassed	4 h at155 °C Standard deviation	23.5 2.0%	37.4 1.6%	9.6 13%	404
Sand mold Separate test bars **Min. value ASTM B26**	2-5 h at 155 °C	**24.0**	**34.0**	**3.5**	**316**

Results of 8 tensile bars for the PM series and 4 for the sand mold series.

QI = UTS +150 log E in MPa

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ASTM min. & very good QI:

- 367MPa is minimum / 450MPa in PM is considered very good
- Best in class foundry processes can achieve a QI up to ≈470 Mpa
- 316 MPa is minimum >400 MPa in sand is an excellent result with only degassed metal.

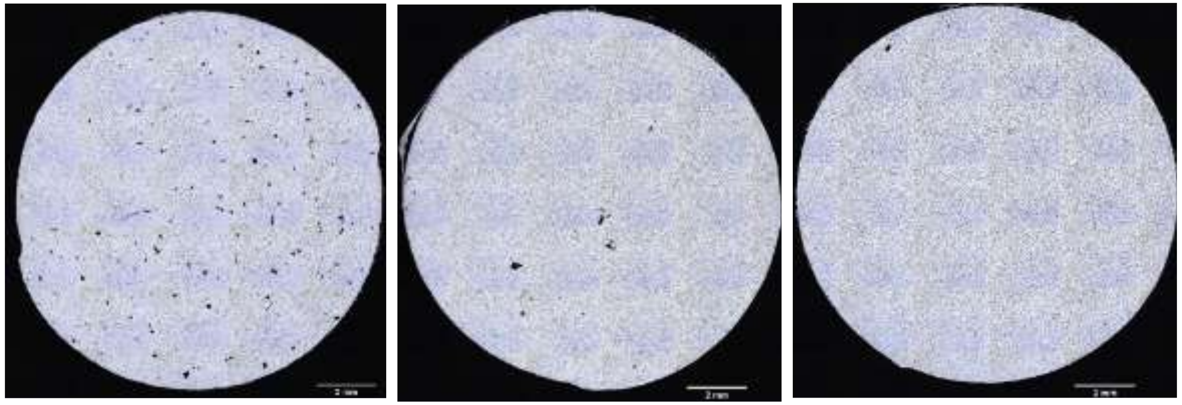
Results of 8 tensile bars for the PM series and 4 for the sand mold series.

QI = UTS +150 log E in MPa

Microscopic evaluation - Porosity

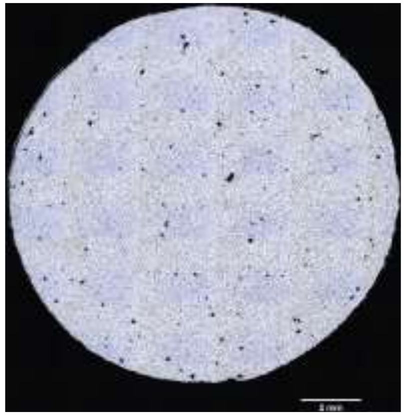
Porosity vas evaluated by image analysis of the total surface in the reduced section.

- Porosity in the PM bar was 0.67 % for the untreated, 0,36 % for the degassed melt and 0.02 % in the degassed melt after hipping.
- Hipping closed porosity (as expected)



Typical porosity in the permanent mold test bars from left to right Untreated, Degassed and Degassed+HIP sample

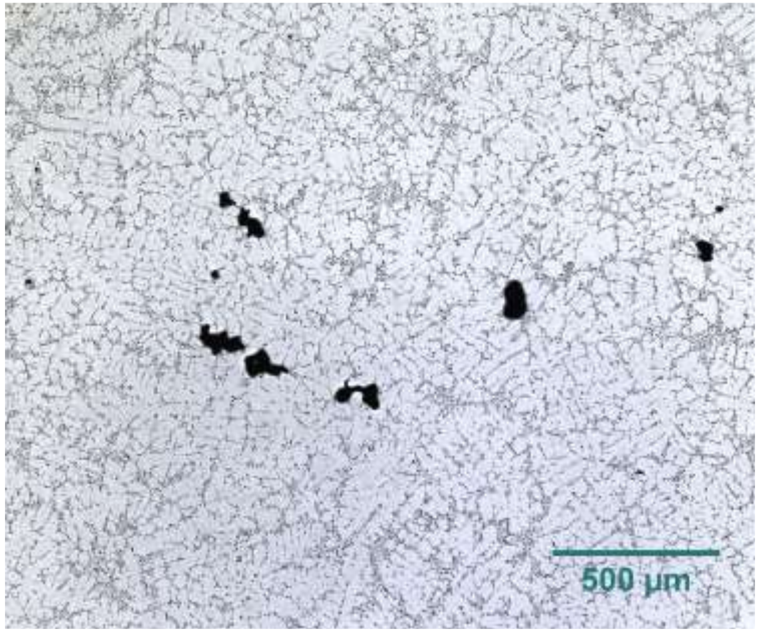
- Porosity in a sand cast test bar was found to be 0.53%. (The lower speed of solidification in the sand mold is the reason for the higher porosity content when compared to PM)
  - **The metal itself was very clean with no noticeable inclusions that contribute to porosity**

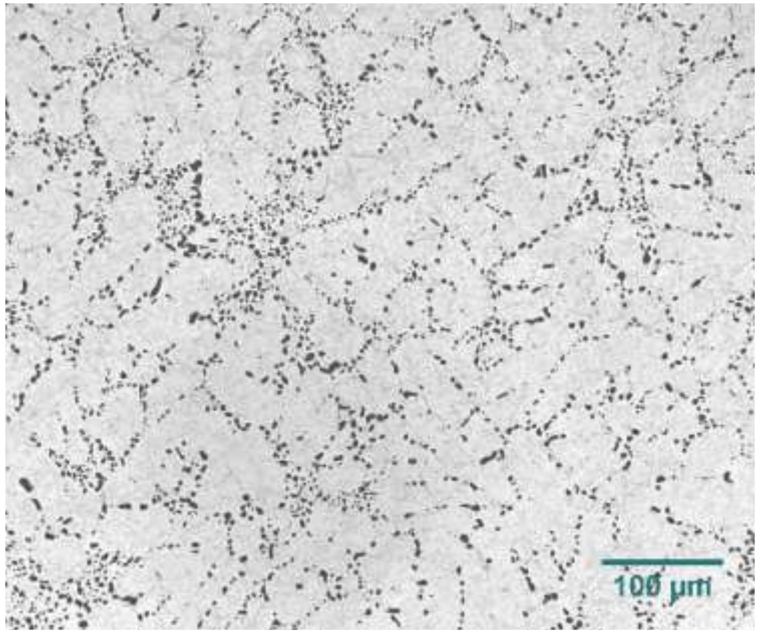


Porosity in a sand cast test bars

Dendrite arm spacing, Sr modification and structure

- The test bar cast from untreated metal shows normal/typical porosity
- A fine structure and AFS Rating #5 Fibrous silicon eutectic structure with no acicular phase ("fully modified").



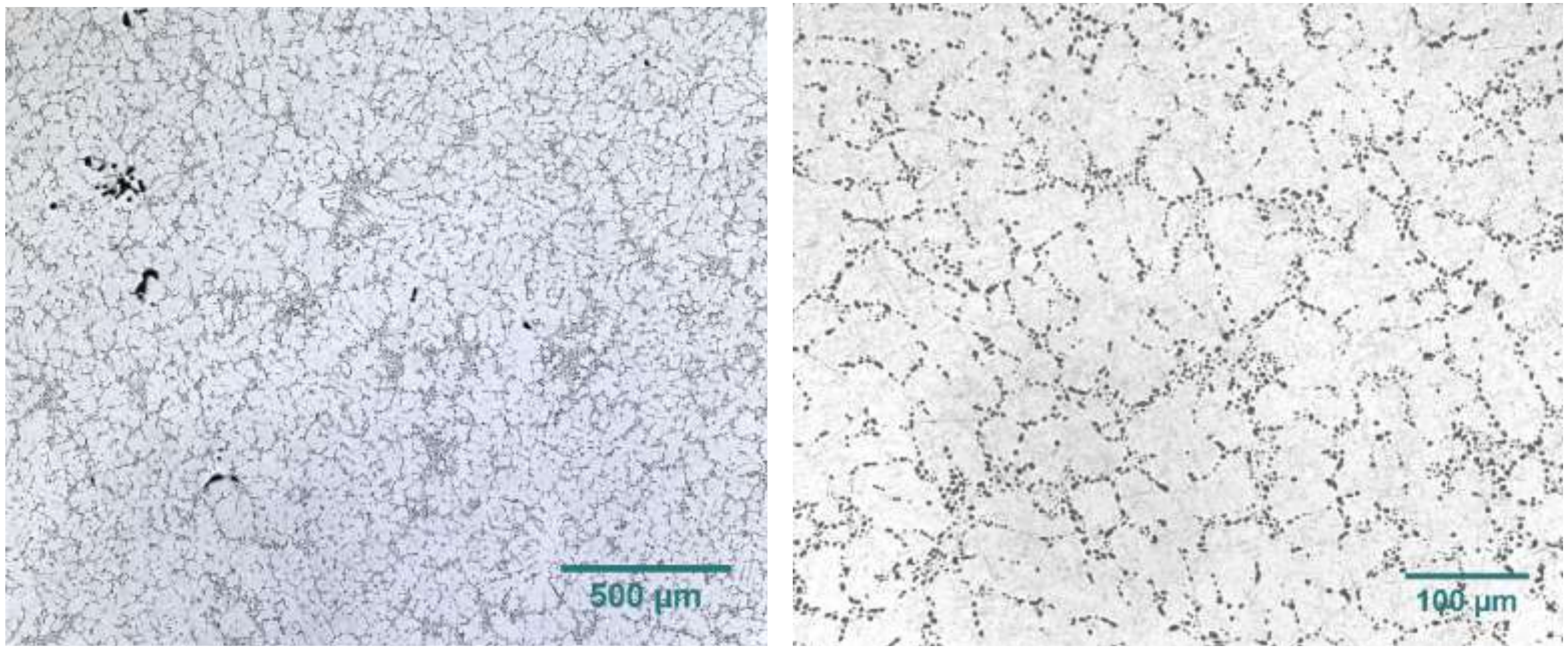


Untreated melt, permanent mold cast

- **This means that if eccomelt356.2 is melted and immediately cast at a foundry, usually no extra Sr addition is required if it is immediately cast**

Dendrite arm spacing, Sr modification and structure

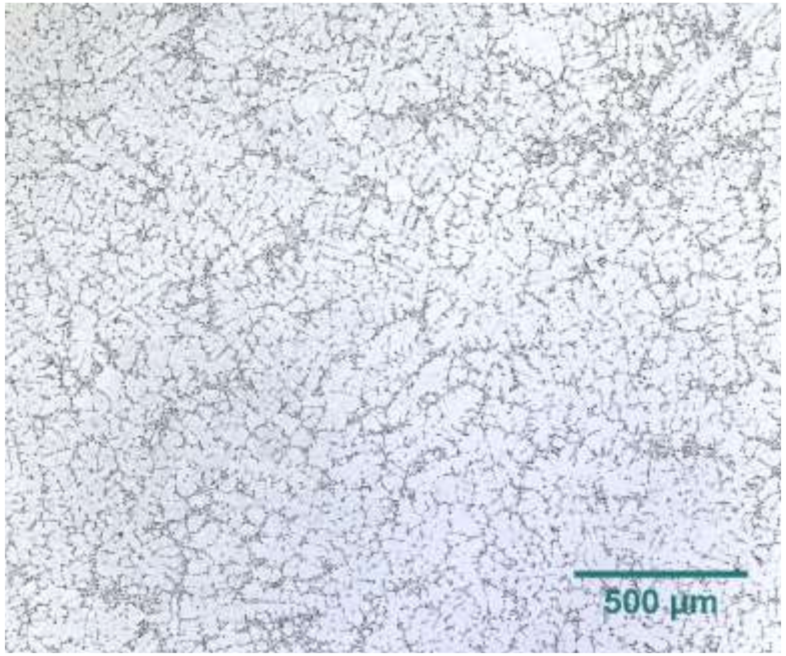
- The degassed metal shows some normal / typical porosity and a DAS equal to 30,9 µm with a standard deviation of 4,4 µm and equally a modification rating of #5.

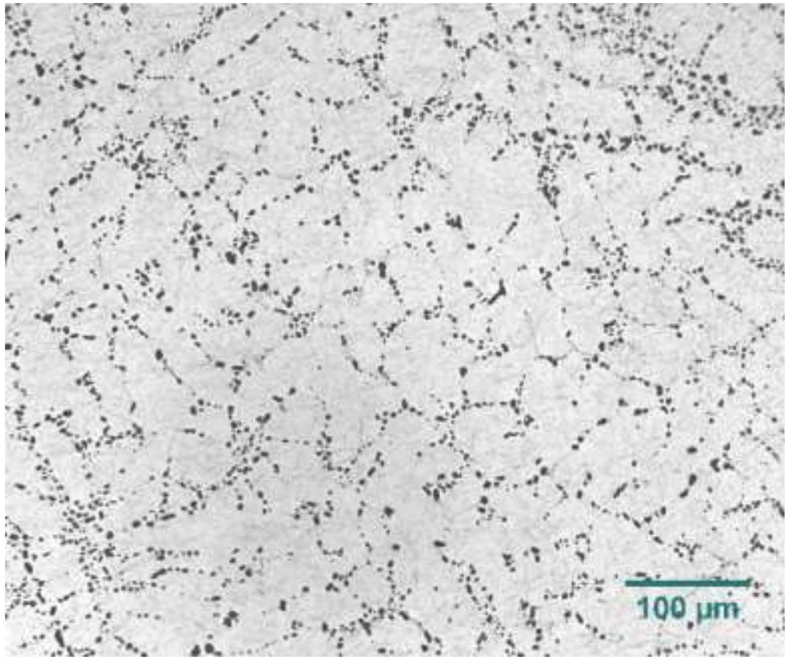


Degassed melt, permanent mold cast

Dendrite arm spacing, Sr modification and structure

- Hipping at 15000 psi and at 535 °C for 2 hours (figure 8) did not change the structure but has closed the porosity.

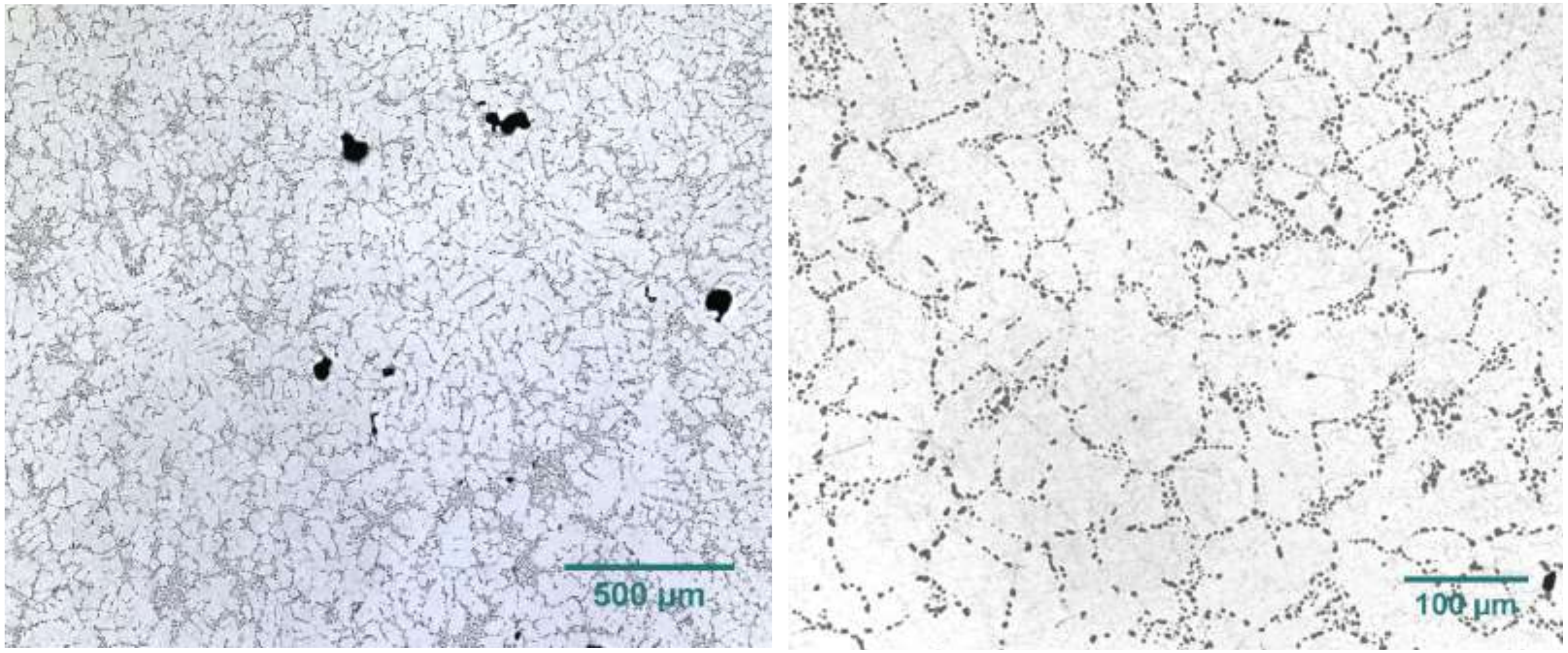




Degassed melt after hipping, permanent mold cast

Dendrite arm spacing, Sr modification and structure

- The metallographic structure in sand mold shows a dendrite arms spacing (DAS) of 39.4 µm with a standard deviation of 5.5µm.
- DAS is slightly coarser in sand mold as compared with permanent mold.



Degassed melt, sand mold

Economic and environmental aspects

- eccomelt356.2 is already being used by certain smelters for the production of A356.2 or similar high-quality aluminum alloy ingots.
- Many foundries are using this material directly, thereby **becoming more competitive** by benefiting from a lower price point, and **eliminating one melting step** with the additional logistics, handling, etc.
- This could be especially true not only for A356 castings but also for a multitude of other Al-Si alloy castings (currently made from primary aluminium)
- Charging and melting time of eccomelt356.2 will depend on the furnace type and arrangement and the way it is charged. In most cases there will be **little difference in terms of charging time** between eccomelt356.2 and small ingots, T-bars or sows if the charging is done in the appropriate way.

Economic and environmental aspects

- Melting time depends on the surface area to mass ratio which is much greater compared to ingots and especially T-bars or sows, so **generally melting is faster**, especially if the charge is immersed into molten metal.
- Increased surface area to mass creates more oxide surface and hence more dross. However, when it comes to eccomelt356.2, our CMQ testing shows that melt loss was low and quite comparable to ingots. From our test It can be assumed that using **eccomelt356.2 will likely lead to approximately 0.5-1% more dross than ingots**, which is easily offset by its lower price point and high melting rate energy savings.
- In the case of eccomelt356.2, its **surface condition is excellent and extremely clean, so it does not contribute additionally to melt loss/ dross generation**.

Conclusions

- eccomelt356.2 is a metal that can allow foundries and die casters to achieve very good quality castings.
- Additional melt loss of 0.5 – 1% can be expected, but savings on material melting costs should easily more than compensate for this.
- The metal is very clean, no fumes/smoke is generated during melting and filtering and degassing are sufficient, fluxing was not even necessary.
- For A356 very little chemical adjustment is necessary
- eccomelt356.2 can be qualified as a very viable replacement of primary A356.2 in smelters/remelters, foundries and die casters, either alone or mixed with primary ingots and/or other alloying elements.

Questions?

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