Development of sustainable secondary aluminium alloys for structural castings

A Pre study within Circularity supported by Vinnova

AluCAD – Aluminium Cast Alloy Development

Scope
Development of recycled aluminium alloys for structural castings to reduce CO2 improving Circularity

Objective
With theory, calculations and tests reach properties of recycled as cast alloys comparable to hardened primary aluminium.

State of art: secondary alloys have limited availability, strength and are not ageing stable as cast. E g AlSi7MgFe0.2

The Vision *is by composition and process develop secondary cast Al alloys for crash exposed vehicle structures*

Project duration & Financing
Two consecutive pre studies in 2 years from 2022 at 1 msek each, financed 50% by Vinnova:s Circularity programme

6 Project partners, covering the complete development chain

• RISE, Luleå University of Technology	Research institutes	torsten.sjogren@ri.se, farid.Akhtar@ltu.se
• Stena Aluminium	Material supplier	Benjamin.brash@stenaaluminium.com
• Comptech AB	Casting equipment	per.Jansson@comptech.se
• CEVT/ Zeekrtech Europe	Vehicle manufacturer	christopher.Berghoff@cevt.se
• MD Material Design AB	Research Project coordination	paul.jonason1@gmail.com

Circularity - yearly CO2 reduction for as cast secondary aluminium

One OEM at 50 kg primary Al / vehicle x 1m vehicles = 50 kTon Al /yr

Remelted Aluminium replaces primary Al production

- **10 kg CO2 reduction / kg Al** x 50 kTon Al — **500 kTon** — Alloy mix AluCAD

Eliminiated specific hardening heat treatment T6,7

- Reduced energy consumption: 16 kg CO2 / Al part x 1 m vehicles — **16 kTon** — Alloy mix AluCAD

Rheocasting

- + tool life, smaller machinery, low Si alloy

Tot reduction 1 kg CO2 / kg Al x 50 kTon Al — **50 kTon p**

Total Secondary aluminium No heat treatment Rheocasting — **566 kTon**

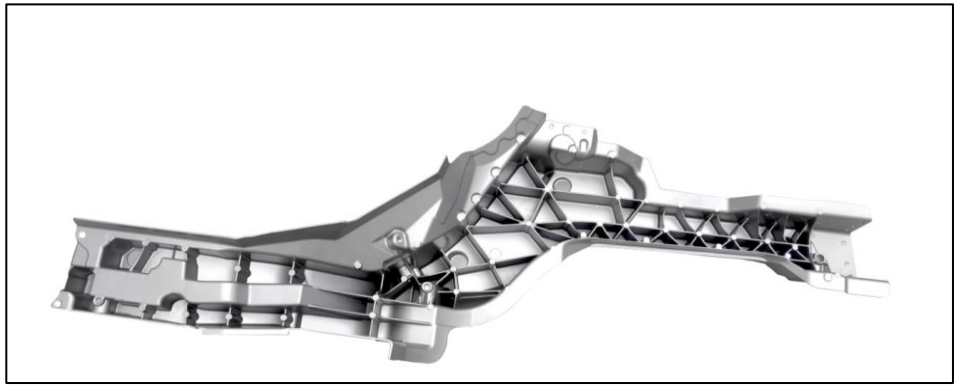
Enablers for CO2 savings with secondary alloys

- alloy elements & melt cleaning — **20 kTon p**

CO2 Min net reduction incl enablers — **500 kTon CO2 / yr**

Benchmark

Rear sidemember Passenger car, HPDC



Alloy	Std	TX	Rp	A5	Rem
AlSi10MgMn	43500	F	80	14	Ages naturally
AlSi10MgMn	43500	T7	130	12	Heat treatment T7 not applicable for structural castings
AluCAD					
AlSi4FeXX	43xxx	F	130	10	Aim AluCAD

- Existing alloys need separate hardening heat treatment for high, stable properties which requires additional process steps, create geometry issues and property scatter
- The aim of the AluCAD project is to increase the properties of secondary alloys in as cast condition

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Alloy development

Aim

- Refine the knowledge in aluminium hardening by potential elements
- Develop high strength secondary alloy without additional hardening, however not to Tx level

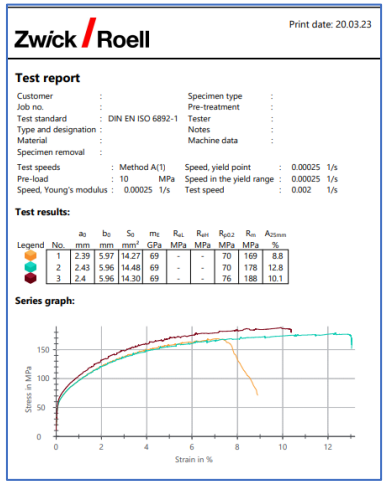
Method

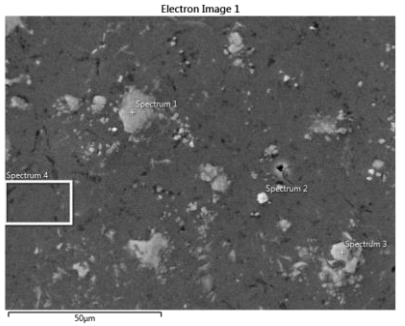
- Identify strengthening elements with calculations and trials
- Prioritize solution – rel precipitation hardening
- Minimise intermetals and their reduction of properties
- Validate melt cleaning

Experimental Procedure

- Selection of test alloys from state of art and property calculations
- Manufacturing of test alloys and samples Rheo casting & HPDC Comptech AB
- Mechanical properties validation as cast and aged Rise
- Microanalysis LTU
  - Optical
  - SEM, STEM & Xray

Alloy	Ch	%						
6 alloys +	Si	Mg	Mn	TiB	V	Zr	Mo	Fe
Loop 1a 6 alloys				Ti%				
Ref AlSi2Mg	2.18	0.4	0.03	-	-	-	-	0.76
AlSi2Mn	2.18	0.4	0.3	-	-	-	-	0.76
AlSi2 MnAlTiB	2.18	0.4	0.3	0.15	-	-	-	0.76
AlSi2 MnAlTiBV	2.18	0.4	0.3	0.15	0.1			0.76





Results Mechanical properties

Rheo casting 20 alloys validated in 3 loops

Loop / Legering	Rp	A5	Anm Rp åldrad 90C/1000h
Loop 1b			
Ref AlSi4	78	12	
AlSi4FeMnXX	98	7.9	Rp + 26 % Åldring reducerar A5
Loop 2			
Ref AlSi4	74	11.4	
AlSi4FeMnXX	84	12	Rp +14 % A5 +5 %

- Increased yield strength Rp and elongation A5 with alloying despite increased Fe content to secondary level
- Further property increase estimated possible with alloy composition and melt cleaning
- A cleaned & upgraded secondary alloy should without additional hardening reach 80 % of the strength and ~ 25% higher ductility than a *hardened* primary reference alloy
- Melt cleaning of a primary alloy has limited property impact and increases its high CO2 print

Summary

Results Rheocasting

- Secondary alloys with high Fe show properties comparable to primary alloys
- Microanalysis confirm the hardening potential of alloying elements given by calculations
- Property increasing elements identified include Mn V Zr Fe,

Conclusions

- Modified and cleaned secondary alloys can reach properties comparable to *hardened* primary alloys
- Calculation tools can be used and improved for alloy development
- Secondary alloys may replace primary alloys in structural aluminium castings
- Secondary aluminium can reduce CO2 by 500 kTon yearly for a vehicle manufacturer using structural castings

Industrialisation

Prestudy II 23m11-24m09 Diarie nr 2023-02630

- With calculations, microstudies and tests define a secondary aluminium cast alloy with properties comparable to primary material, for High Pressure Die Casting and Rheocasting

Implementation

Validation in production environment of

- An alloy defined from the prestudies in quality and joining
- Melt cleaning
- Rheo and HPDC in fluidity and component properties
- CO2 for the actual alloy incl Rheo & HPDC

CAE tool development for alloy and component properties

Continued project presentation

- Presentation time: 20 min to allow for discussion and change of speakers

Examples of suitable topics

- Current challenges
- Plans
- Results
- Remaining challenges