Department of Applied Science and Technology
ALTO – Metallurgy Group
ALessandria Campus & TOrino

Extremely light weight rheocast components for automotive space frame

M.Rosso[1], I.Peter[1],G.Chiarmetta[2], I.Gattelli[3]

[1]Department of Applied Science and Technology,
Politecnico di Torino

[2]Consultant – Torino, Italy

[3]ATS – Lugo Ravenna, Italy

12th International Conference on Semi-Solid Processing of Alloys and Composites
Cape Town, 8-11 October 2012

Department of Applied Science and Technology
ALTO – Metallurgy Group
ALessandria Campus & TOrino

Outline

- Quality & reliability, good opportunities *using*
- Rheocasting … go on …in collaboration with ATS Company…Aims
- Some new outcomes *after S2P 2010*
- Final remarks

12th International Conference on Semi-Solid Processing of Alloys and Composites
Cape Town, 8-11 October 2012

Department of Applied Science and Technology
ALTO – Metallurgy Group
ALessandria Campus & TOrino

Casting Defects, quality and reliability

- Alloys and their properties
- Molds/dies and their properties
- Process kind and parameters

→

- **Filling**
- **Solidification**
- **Solid State Phenomena**
- **Interactions Alloy-Mould**

↓

- ***Microstructure***
- ***Defects - Imperfections***

← NDT ←

- Final properties
- In-service behavior

12th International Conference on Semi-Solid Processing of Alloys and Composites
Cape Town, 8-11 October 2012

Department of Applied Science and Technology
ALTO – Metallurgy Group
ALessandria Campus & TOrino

ATS Company: development of an innovative *rheocasting process*

The semi-solid forming system at ATS employs a vertical press. Under the inferior level of the press a carousel with suitable containers set up at 120° turns to successive working positions:

1. After feeding, the molten alloy is cooled and stirred to slurry;
2. The slurry is injected into the die cavity and the residual biscuit is evacuated;
3. The container is lubricated and it is ready and waiting from the ladle new quantity of liquid.

12th International Conference on Semi-Solid Processing of Alloys and Composites
Cape Town, 8-11 October 2012

Department of Applied Science and Technology
ALTO – Metallurgy Group
ALessandria Campus & TOrino

Real industrial need to obtain high performance components in competitive way

Aim of the research

To optimize the new process through the investigation of the properties of the produced component:

1. Simple shape
2. More complex shape → ??? Technological transfer

12th International Conference on Semi-Solid Processing of Alloys and Composites
Cape Town, 8-11 October 2012

Department of Applied Science and Technology
ALTO – Metallurgy Group
ALessandria Campus & TOrino

A 356 alloy: ***Si 6.964; Fe 0.111; Cu 0.002; Mn 0.002; Mg 0.411; Zn 0.003; Ti 0.133; Al bal.***

T5 TT: water quenching, ageing at 165° C , 6 h;
T6 TT: 520° C, 6 h, water quenching and ageing at 165° C, 6 h.

1.-Radiography observation;

2.-Morphological and compositional analysis: OM, SEM and EDS;

3.-Evolution of the mechanical properties: Brinell hardness, three point bending test, impact test, tensile test.

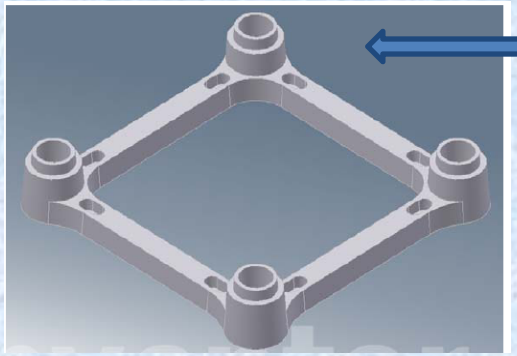
4.-Fracture surface analysis: SEM.

Department of Applied Science and Technology
ALTO – Metallurgy Group
ALessandria Campus & TOrino

Real cases study

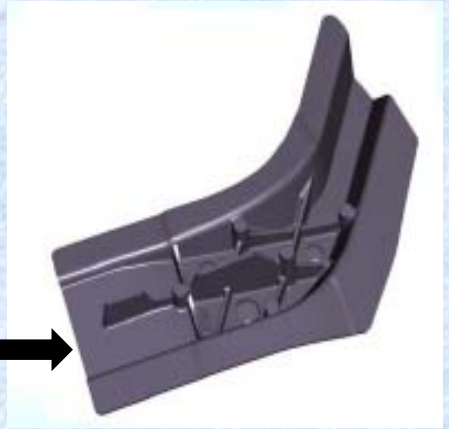
- **To produce enhanced performance *Al-based alloys components for critical areas*;**
- **To investigate some series of samples machined directly from components:**

1. *structural parts in A356 alloy*, after T5 and T6 TT;
2. *automotive components in B356.2* after T5 and T6 tempers and *B357.2* alloys after T5 TT .



Flanges for truss: relatively heterogeneous geometry, massive corner junctions, connected by slim rib arms

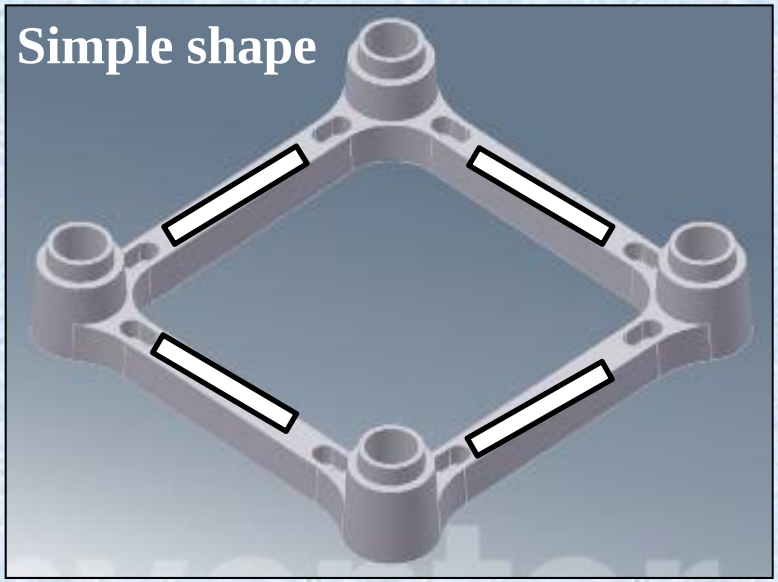
Automotive space frame Component
quite complex shape



12th International Conference on Semi-Solid Processing of Alloys and Composites
Cape Town, 8-11 October 2012

Department of Applied Science and Technology
ALTO – Metallurgy Group
ALessandria Campus & TOrino

"S2P 2010"



Morphological and mechanical characterization

The achieved results revealed superior level of mechanical strength for the components and appear very similar to those obtained by forged components.

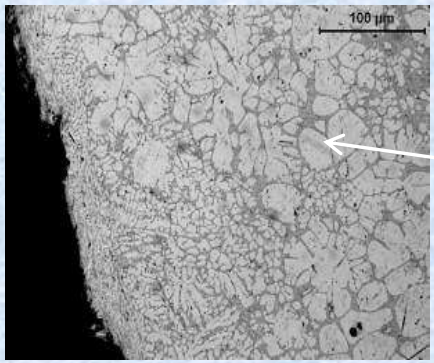
"S2P 2010 till now"

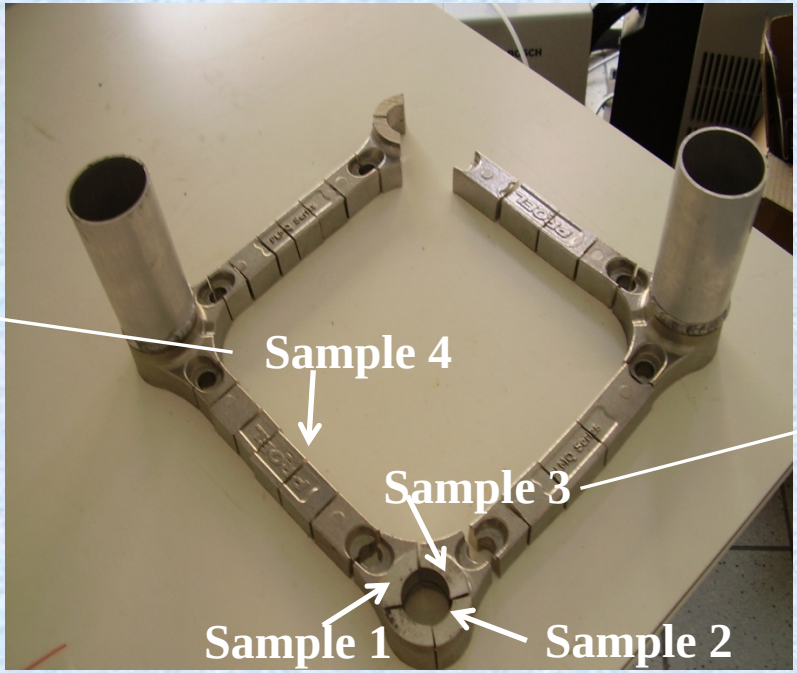
Study of *other significant areas* to get additional indication on the quality of the production process

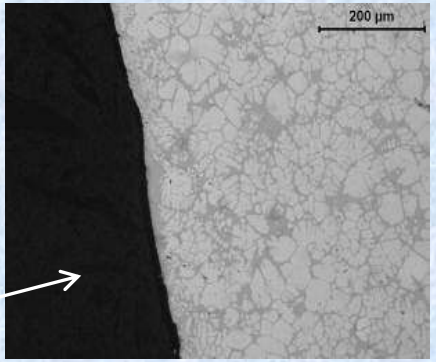
12th International Conference on Semi-Solid Processing of Alloys and Composites
Cape Town, 8-11 October 2012

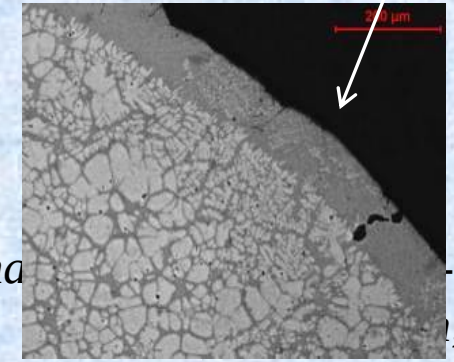
Department of Applied Science and Technology
ALTO – Metallurgy Group
ALessandria Campus & TOrino

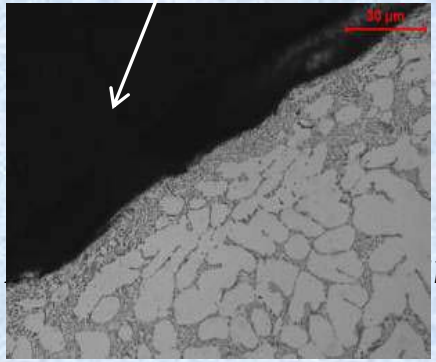
Morphological analysis











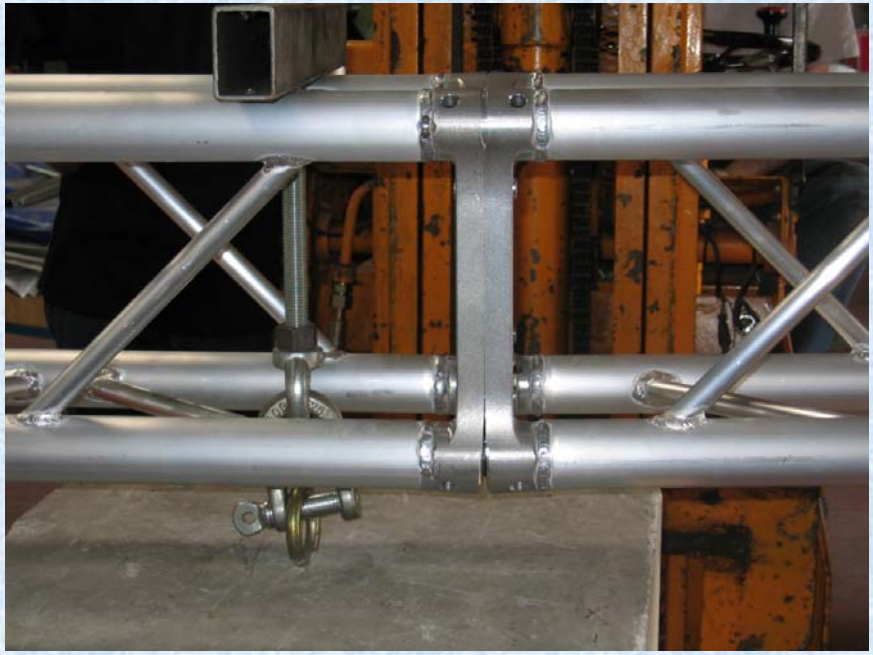
12th Internationa -Solid nd Composites
, 8-11

Department of Applied Science and Technology
ALTO – Metallurgy Group
ALessandria Campus & TOrino

Weldability

Welding procedure: TIG
Filler material: Al-based Peraluman 5083 alloy
(↓ Si and ↑ Mg content than the base Me)

The welding has been realized successfully



12th International Conference on Semi-Solid Processing of Alloys and Composites
Cape Town, 8-11 October 2012

Department of Applied Science and Technology
ALTO – Metallurgy Group
ALessandria Campus & TOrino

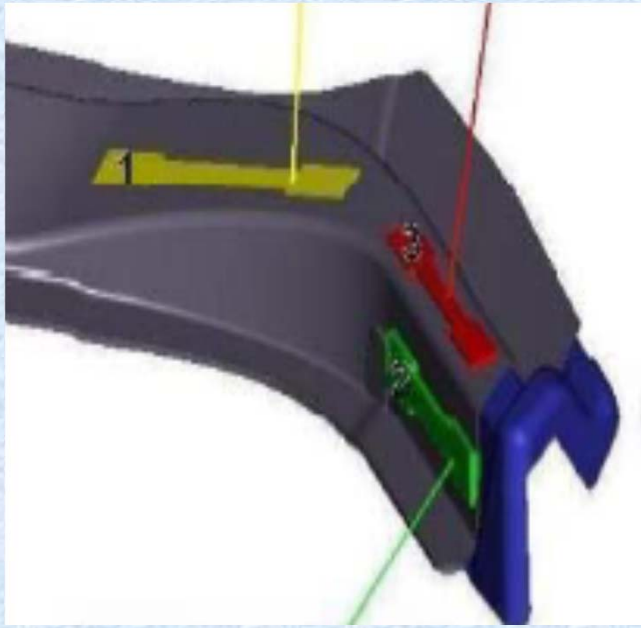
The fracture has been verified external to the welding zone

Department of Applied Science and Technology
ALTO – Metallurgy Group
ALessandria Campus & TOrino

Tensile test on space frame

B356.2 after T5 and T6 TT and *B357.2* alloys after T5 TT

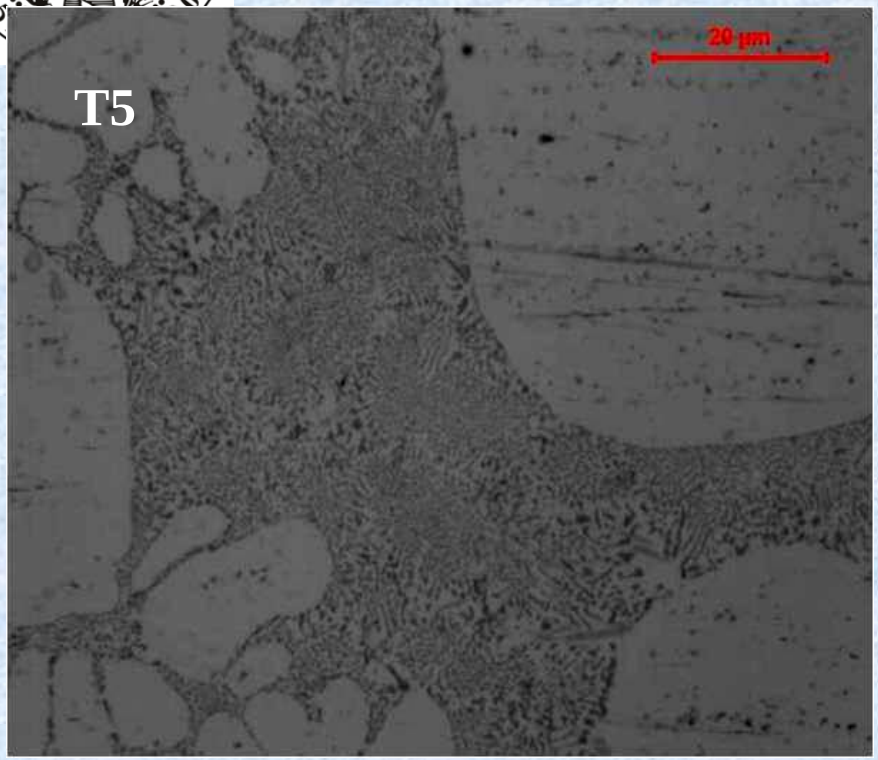
Two series of samples: *thicker ones*, obtained as a suitable appendix from the feeding zone (labelled as A) and *thinner ones*, machined from the component (labelled as T) have been considered, to evaluate possible differences.

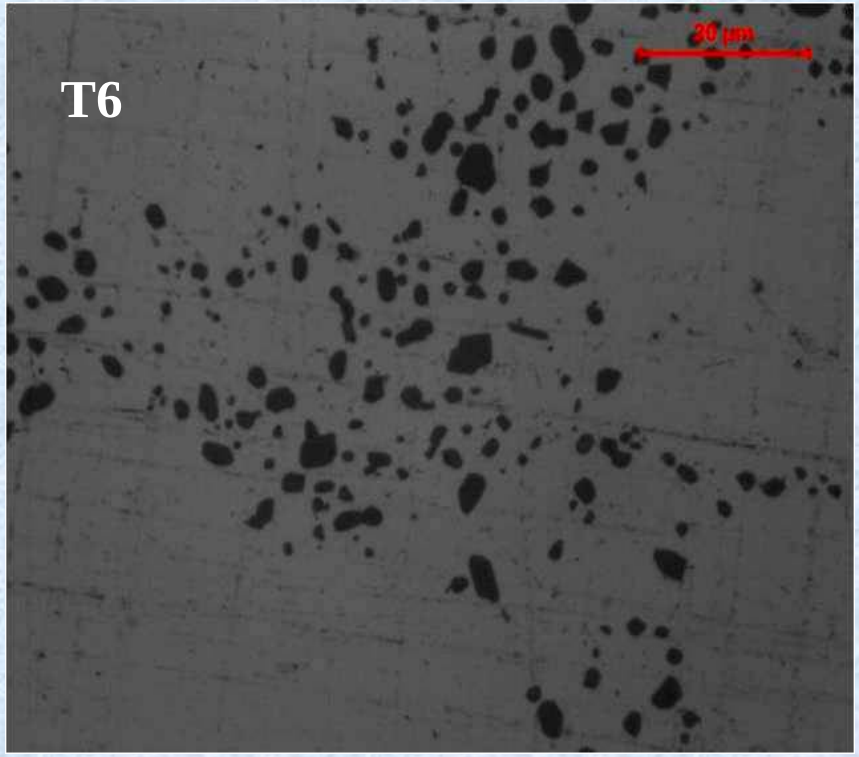


12th International Conference on Semi-Solid Processing of Alloys and Composites
Cape Town, 8-11 October 2012

Department of Applied Science and Technology
ALTO – Metallurgy Group
ALessandria Campus & TOrino

Morphological analysis





Similar microstructures, showing moderately homogeneous α phase.
T6 heat treatment consents to reach a thermodynamically more stable and globular Si particles.

12th International Conference on Semi-Solid Processing of Alloys and Composites
Cape Town, 8-11 October 2012

Department of Applied Science and Technology
ALTO – Metallurgy Group
ALessandria Campus & TOrino

Mechanical properties

Sample	Thick A: 356		Thin T: 356		A: 357	T: 357
Heat treat.	T5	T6	T5	T6	T5	T5
$\sigma_{0.2}$ [MPa]	132	190	140	200	160	165
UTS [MPa]	220	260	240	280	225	260
Elongation %	3	6	4	7	2	4

A slightly higher performances on the thin samples (T)

Brinell hardness results:

T5 condition: 68 HB

T6 condition: 90 HB - ↑ hardness due to a finer and more globular microstructure compared to T5 heat treatment condition.

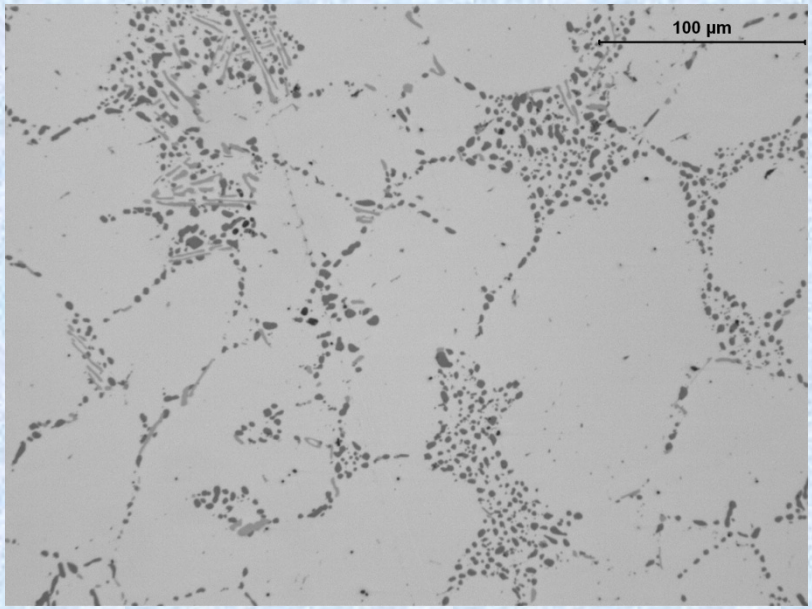
Department of Applied Science and Technology
ALTO – Metallurgy Group
ALessandria Campus & TOrino

Further case study for automotive application

Quite massive component (more than 3kg), with complex shape and highly stressed.

A357 alloy, T6 treated, zero defects detected at the radiographic control.

Morphological Analysis



OM microstructure

12th International Conference on Semi-Solid Processing of Alloys and Composites
Cape Town, 8-11 October 2012

Department of Applied Science and Technology
ALTO – Metallurgy Group
ALessandria Campus & TOrino

Mechanical properties

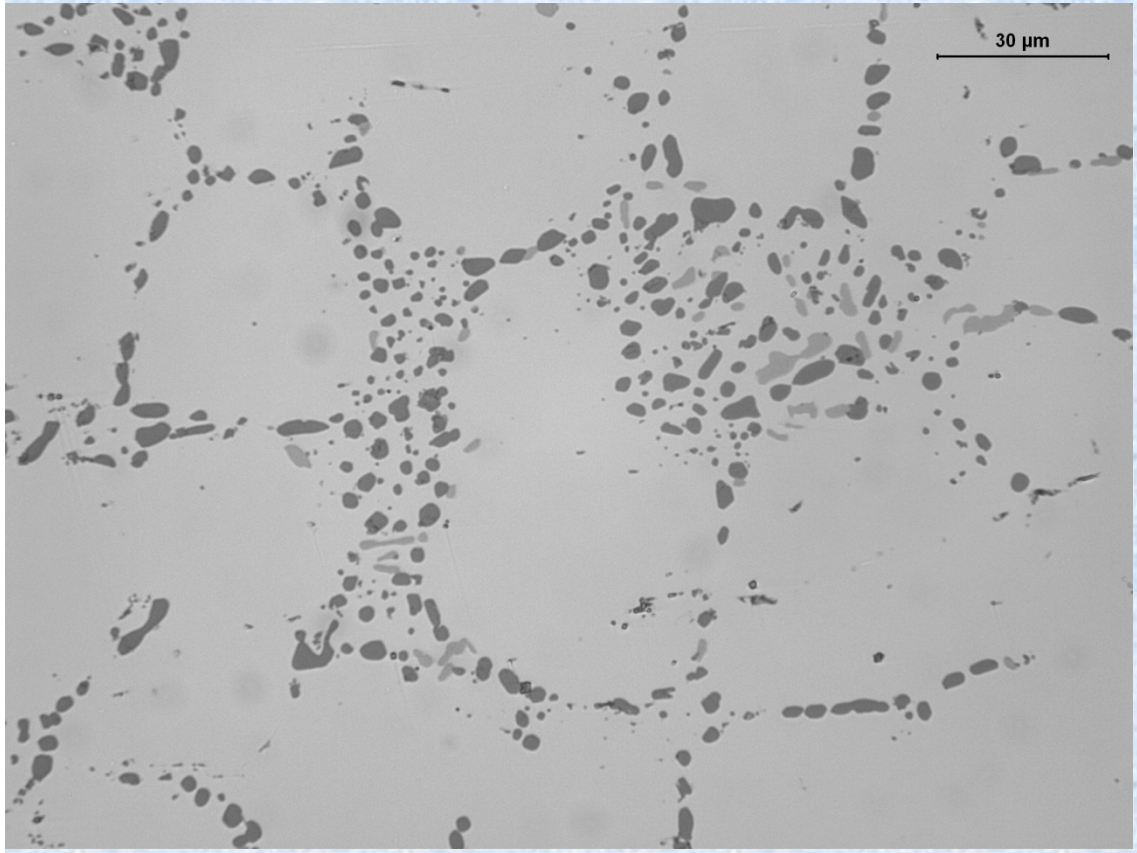
A lot of 12, at least, tensile test samples machined from the components, has produced very interesting properties.

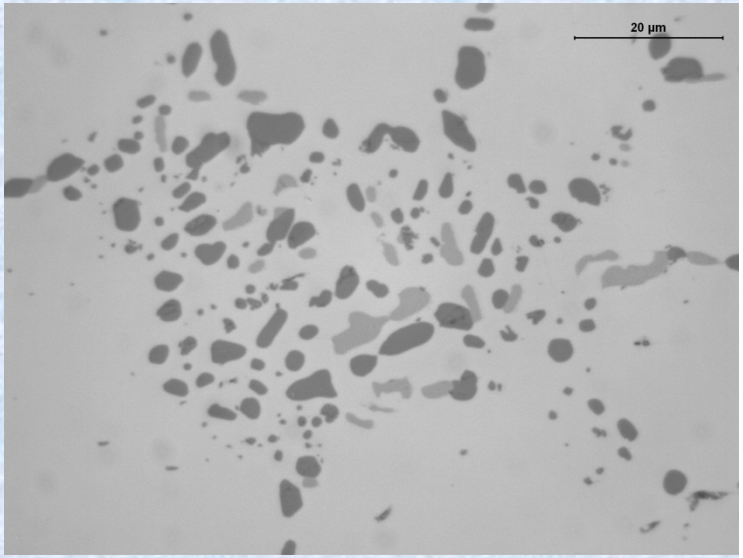
Sample	**Previous T (thin): 356**	**This case A 357**	**Die cast A 357 Expected strength values**
Heat treat.	T6	**T6**	**T6**
$\sigma_{0.2}$ [MPa]	200	**287±6**	**240-280**
UTS [MPa]	280	**342±10**	**300-350**
Elongation %	7	**5±1**	**4-6**
HB			**100-115**

Provino	Rm (N/mm^2)	Rp (N/mm^2)	A%
12A	***325.76***	***288.05***	***3.13***
12B	***333.27***	***279.51***	***3.56***
12C	***355.17***	***292.8***	***5.39***
12D	***348.18***	***286.03***	***6.04***
20A	***337.94***	***287.56***	***3.47***
20B	***328.44***	***283.51***	***2.57***
20C	***350.96***	***284.19***	***7.49***
20D	***343.83***	***278.6***	***6.25***
23A	***338.05***	***290.45***	***4.35***
23B	***339.15***	***279.41***	***4.83***
23C	***350.16***	***300.75***	***5.4***
23D	***351.44***	***286.72***	***5.03***
media	***341.9***	***286.5***	***4.8***
Dev.St	***9.60***	***6.31***	***1.44***

Department of Applied Science and Technology
ALTO – Metallurgy Group
ALessandria Campus & TOrino

Well developed & globular micorostructures

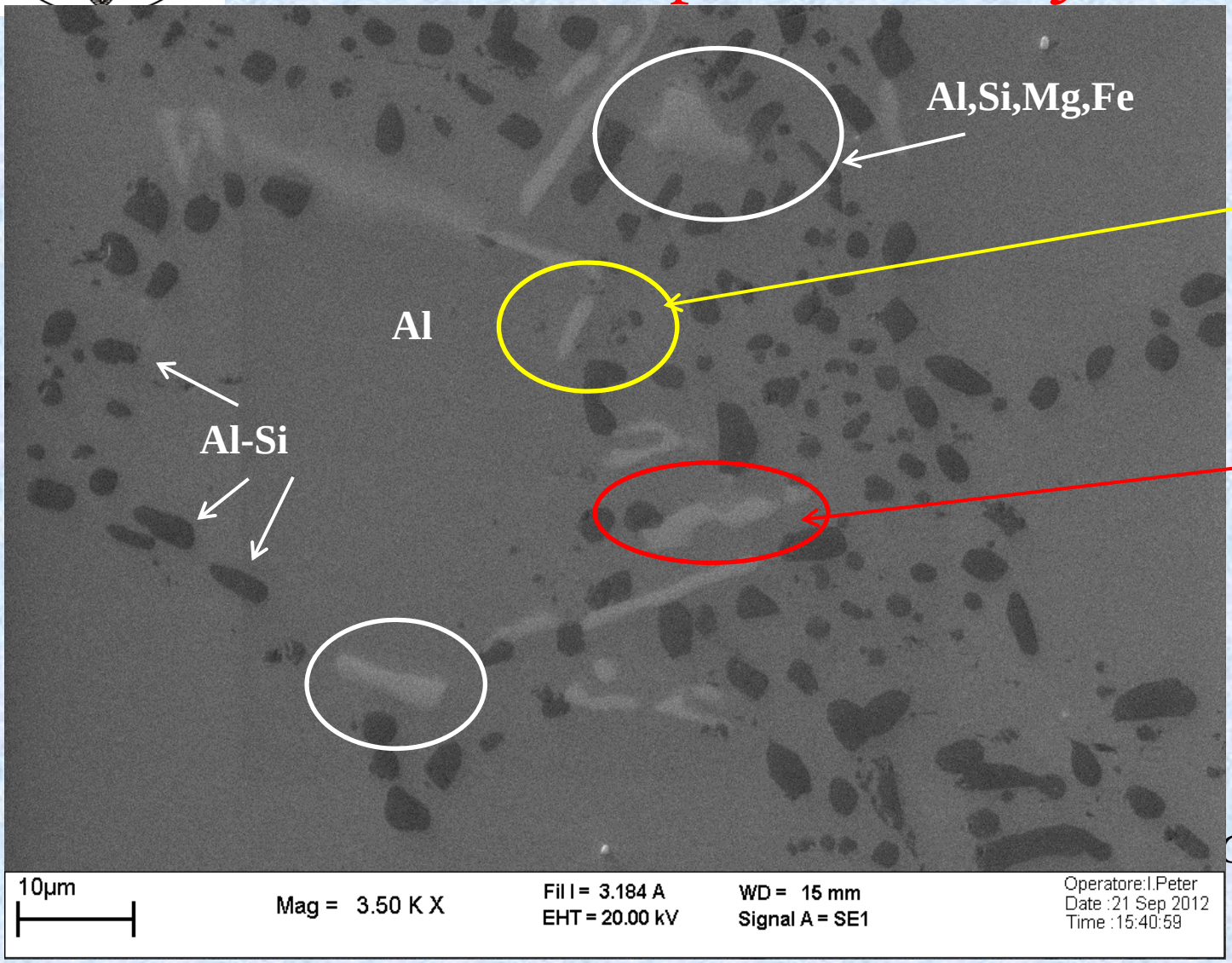




12th International Conference on Semi-Solid Processing of Alloys and Composites
Cape Town, 8-11 October 2012

Department of Applied Science and Technology
ALTO – Metallurgy Group
ALessandria Campus & TOrino

SEM and compositional analysis



Al: 52.68%
Si: 34.18%
Mg: 8.23%
Fe: 4.91%

Al: 63.25%
Si: 22.84%
Mg: 8.61%
Fe: 5.30%

Department of Applied Science and Technology
ALTO – Metallurgy Group
ALessandria Campus & TOrino

Final remarks I

- An analysis of an improved rheocasting process appropriate to produce both thin and thick high performance parts in Al-based alloys with enhanced characteristics was presented.
- Such a process leads obtaining alloys in a semisolid state directly from the liquid state, by controlled cooling of the molten alloys.
- Components for structural industrial applications, as well as advanced automotive parts have been produced and analyzed.

Department of Applied Science and Technology
ALTO – Metallurgy Group
ALessandria Campus & TOrino

Final remarks II

- The achieved results show a quite high level of mechanical strength for both series of components and appears very promising.
- As expected, the results show the well-known differences between the two considered alloys (A356 and A357) and between the T5 and T6 heat treatments.
- The attained quality is significantly high and indicates the reliability and the competitiveness of the new developed rheocasting process.
- **The process concept is very simple**

Department of Applied Science and Technology
ALTO – Metallurgy Group
ALessandria Campus & TOrino

Final remarks III

- With the safety component produced in ATS Company it had been gone over one million cycles during the fatigue test (requested max 250.000 cycles).

- It is one of the evidence that this SSM technology is excellent.

- It is important to promote this technology and to transfer to industrial scale.

Department of Applied Science and Technology
ALTO – Metallurgy Group
ALessandria Campus & TOrino

Thank you!

mario.rosso@polito.it

I.Peter, G.Chiarmetta, I.Gattelli

12th International Conference on Semi-Solid Processing of Alloys and Composites
Cape Town, 8-11 October 2012