GRAINGER & WORRALL

Light-weighting Gravity Cast Parts in the Automotive Industry

Jack Strong – Research Manager

TODAY'S PRESENTATION

Light-weighting Gravity Cast Parts in the Automotive Industry

COMPANY INTRODUCTION

SUPPORTING TECHNOLOGIES

AUTOMOTIVE INDUSTRY CASTINGS

NOVEL GRAIN REFINER DEVELOPMENT

CONCLUSION

GRAINGER & WORRALL CASTING FOUNDRY

Prototype business

- Concept to Pre-Series
- Focus on Low CO_2 Vehicle solutions
- Rapid technologies

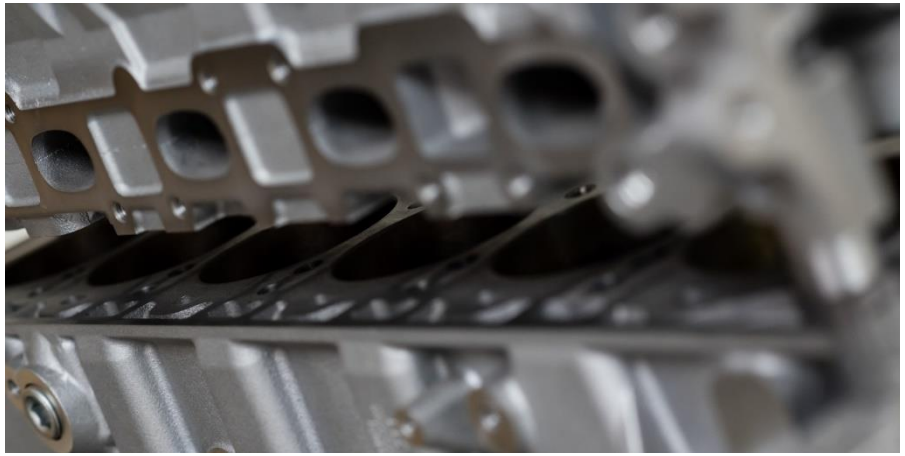
Small Series business

- High performance applications for Premium market
- Supplied Cast – Machined – Part assembled
- Gravity and Low Pressure (Cosworth process).

Motorsport business

- F1 and high end Motorsport
- Technology leading, innovative solutions.

Strategic Research Partner with BCAST Brunel University London



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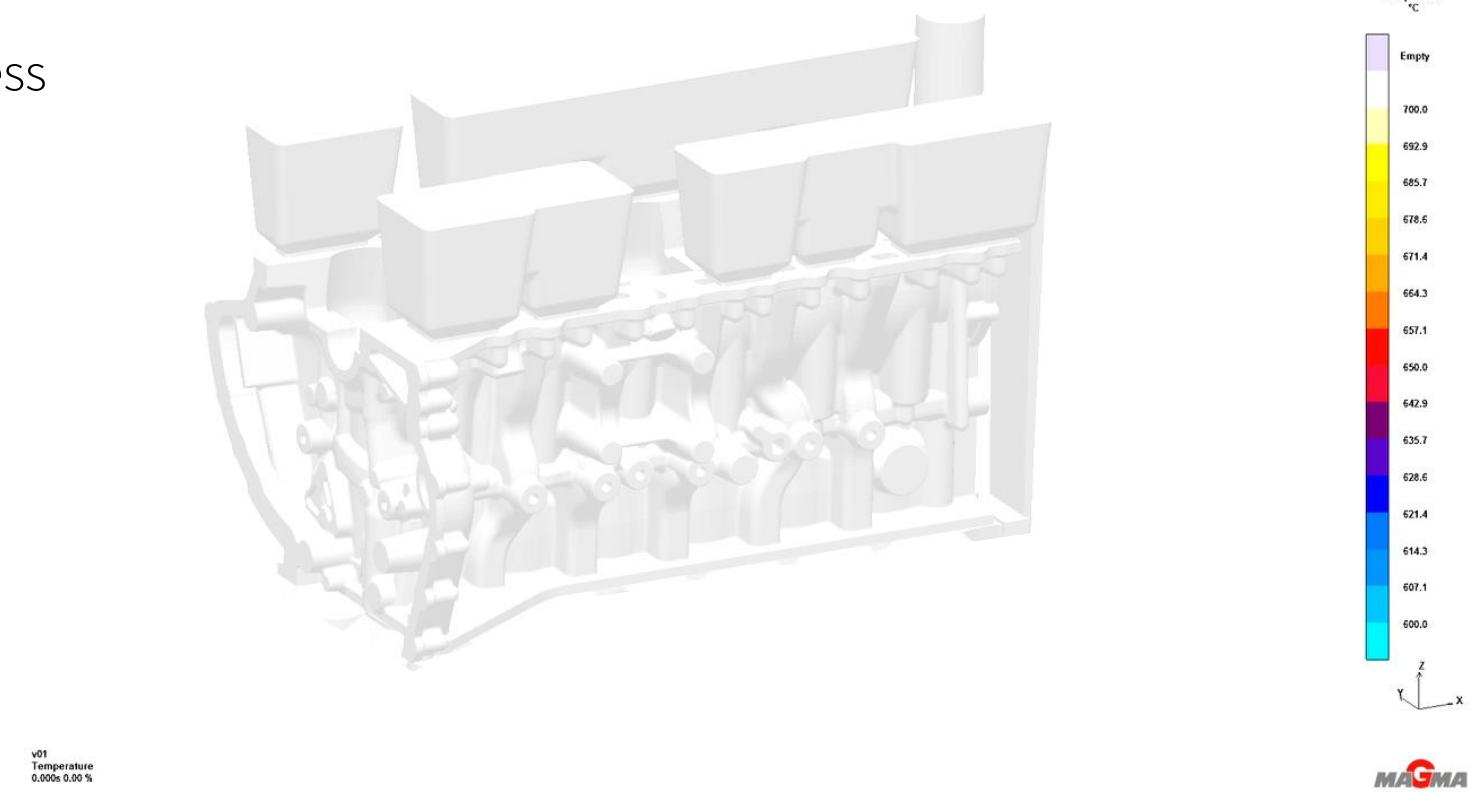
COMPUTATIONAL FLUID DYNAMICS SIMULATION (CFD) - MAGMASOFT

Magma simulation supports product development and series casting process capability, with features including:

- Cooling rate & integrity optimisation
- Heterogeneous property mapping
- Risk reduction and design optimisation
- Residual stress mapping
- Exportation to FEA (Magmalink)

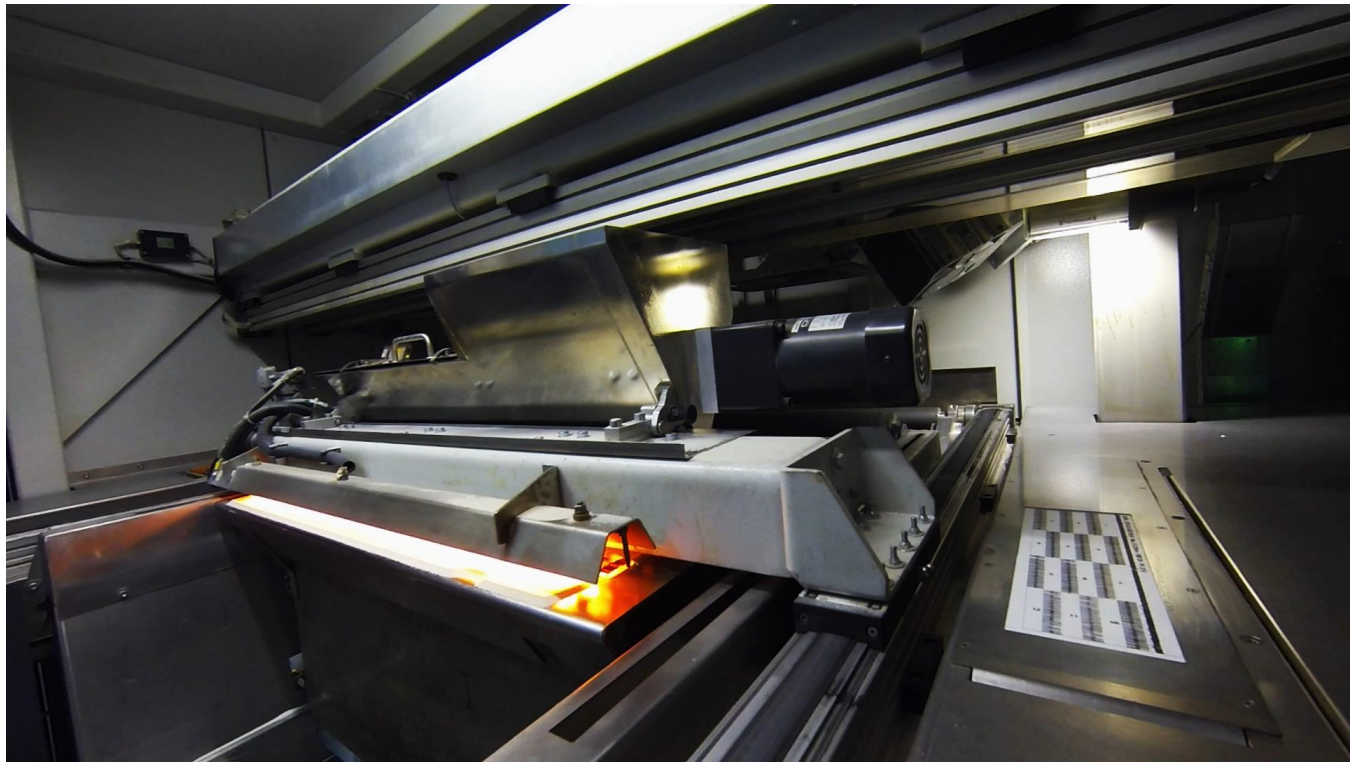


DIGITAL MANUFACTURE – SAND PRINTING

Rapid production of complex low expansion sand cores for manufacture of complex castings, e.g. Water jackets.

ExOne S-Print

ExOne S-Max



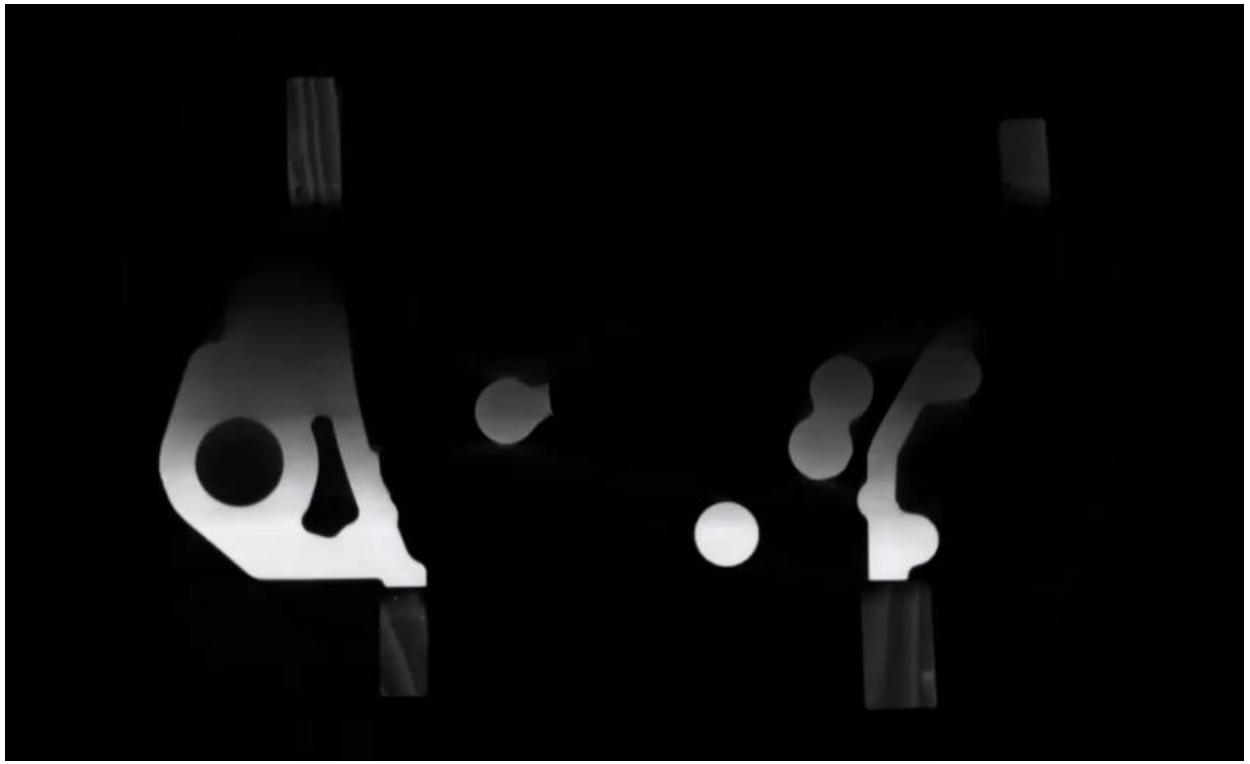
COMPUTER TOMOGRAPHY (CT) SCANNING

Utilising latest technology verification equipment for:

- Rapid product development
- Integrity inspection
- Motorsport & Series parts validation
- Reverse engineering

2x 450KV YXLON Machines

Other equipment includes;
- 225kV GE XCUBE XL Realtime X-ray
- GOM Optical Scanner
- Laser ROMER arm
- Multiple CMM Tactile



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AUTOMOTIVE ENGINE DEMANDS & REQUIREMENTS

What the automotive industry wants from aluminium castings:

- Efficiently remove waste heat from combustion process
- High material strength endurance.
  - 500,000,000 rev cycles over lifetime
- Reduced wall thickness and weight.

Current state: Localised material temperatures exceeding 240°C

Externally sourced video

CYLINDER HEAD ALUMINIUM ALLOYS

A357 AlSi7Mg0.6 β-Mg2Si

A widely used alloy for automotive structural cast components due to its good strength, moderate ductility in the T6 condition and high thermal conductivity.

Density	2.67	g/cm^3	0.2% proof stress	270 - 300	MPa
Thermal Conductivity	151	W/m-K	UTS	310 - 330	MPa
			Elongation	2 - 7	%

A354 AlSi9Cu3 Q-AlSiMgCu, β-Mg2Si

Specified for higher strength applications, especially for elevated temperature performance at compromise of thermal conductivity.

Density	2.71	g/cm^3	0.2% proof stress	290 - 310	MPa
Thermal Conductivity	126	W/m-K	UTS	340 - 360	MPa
			Elongation	2 - 4	%

Note. Alloys grain refined by TiB2 (5:1)

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NOVEL GRAIN REFINER - PLAN

Aim

- Trial current level technology and increase maturity
- Determine effectiveness of grain refiner
- Identify opportunities for future use

Objectives

- Identify suitable casting geometry
- Trial the novel grain refiner on alloys containing different silicon levels
- Evaluate the optimum potency of grain refiner by adjusting concentration
- Use non-destructive analysis to evaluate results
- Perform monotonic mechanical testing (Pending)
- Identify benefit of grain refiner over existing methodology – Yield Reduction

NOVEL GRAIN REFINER – EXPERIMENTAL

Benchmark NGR (2 types) against a control reference using current alloys:

1) A357

Control – 1)No Grain Refiner 2)TiB2 Refined 0.15 wt%

MA3 - Cast 3-off per condition; 0.05, 0.1, 0.15 wt%

MA5 - Cast 3-off per condition; 0.05, 0.1, 0.15 wt%

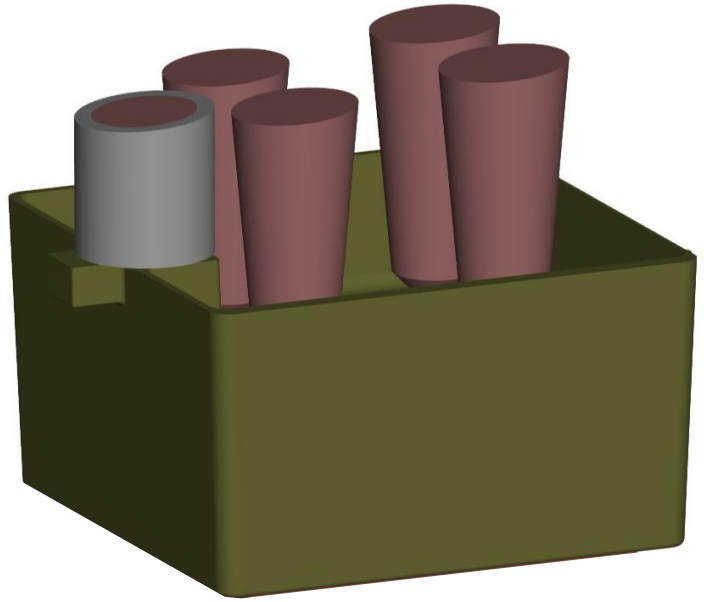
2) A354

Control – No Grain Refiner - 3-off

MA3 - Cast 3-off per condition; 0.1, 0.15, 0.2 wt%

MA5 - Cast 3-off per condition; 0.1, 0.15, 0.2 wt%

3) Pre modified A357 – Fading trials; 0.1 wt% (4 hours)

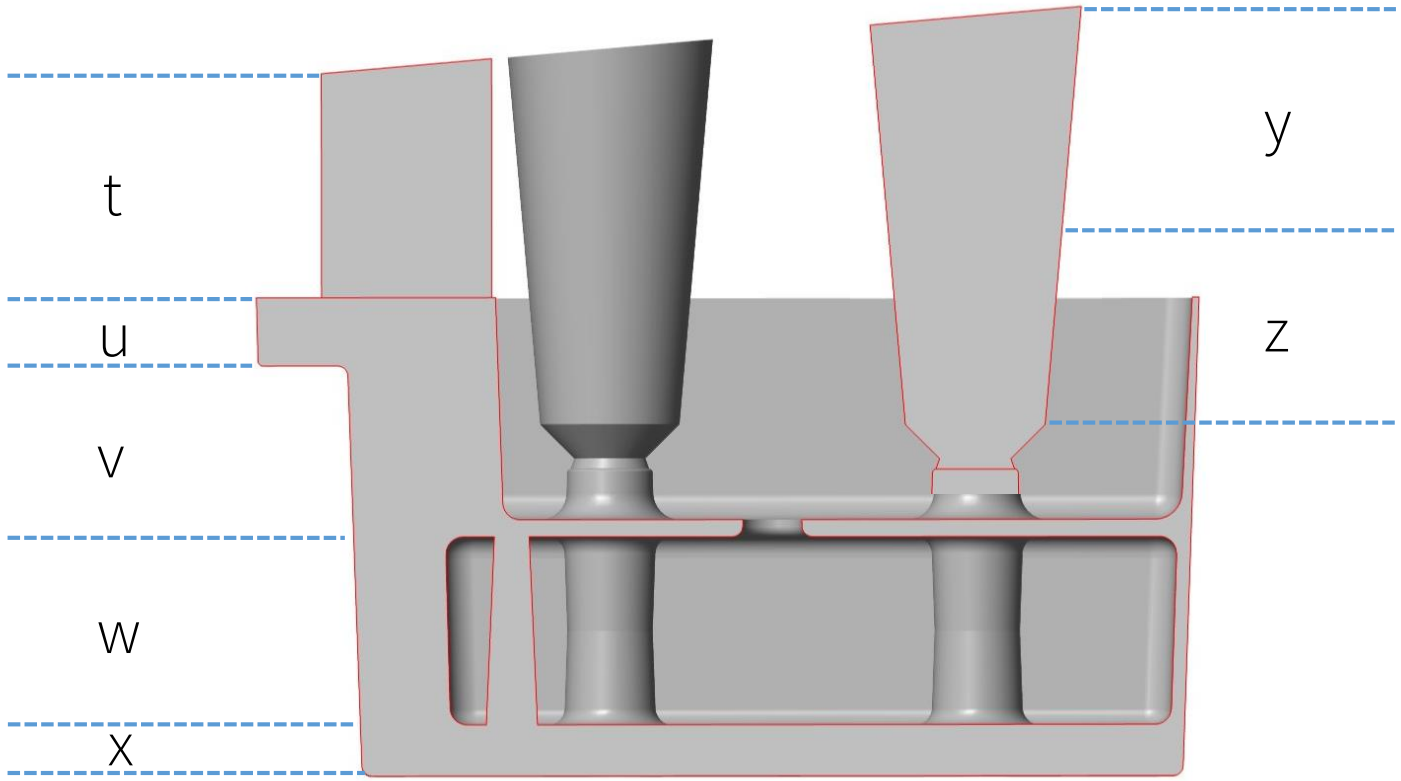


NOVEL GRAIN REFINER – EXPERIMENTAL

From CT scan images, a suitable comparative method was developed for quantifying the integrity of the casting.

Rating the level of shrinkage porosity:

1. None
2. Minor
3. Medium
4. Major
5. Severe



Zone	t	u	v	w	x	y	z
Level							

NOVEL GRAIN REFINER – RESULT'S

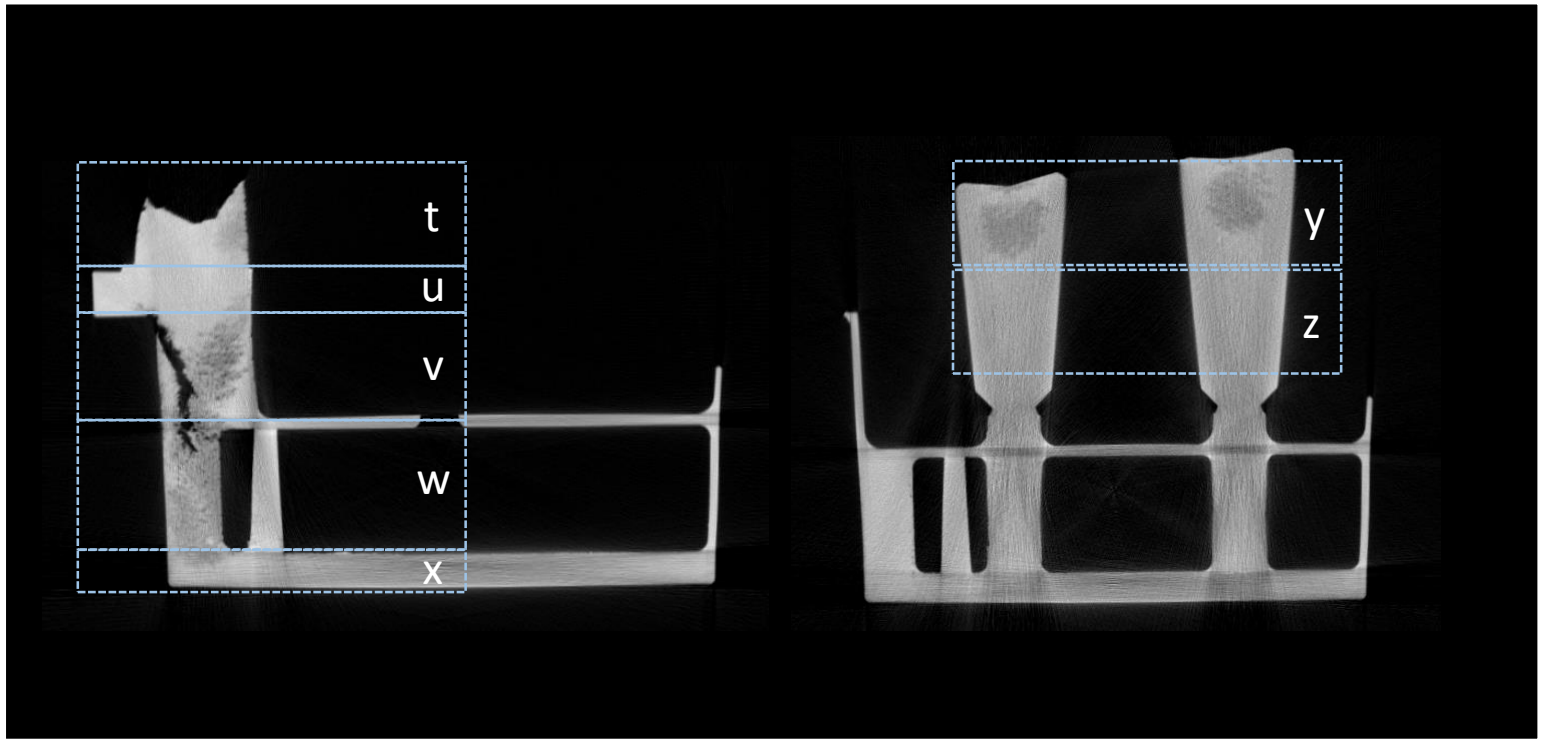
Trial: Control – No Grain Refiner

Alloy: A357

Concentration: 0.0wt%

Gas Content: 0.4

Shrinkage rating: 2.29



Zone	t	u	v	w	x	y	z
Level	1	1	5	5	1	2	1

NOVEL GRAIN REFINER – RESULT'S

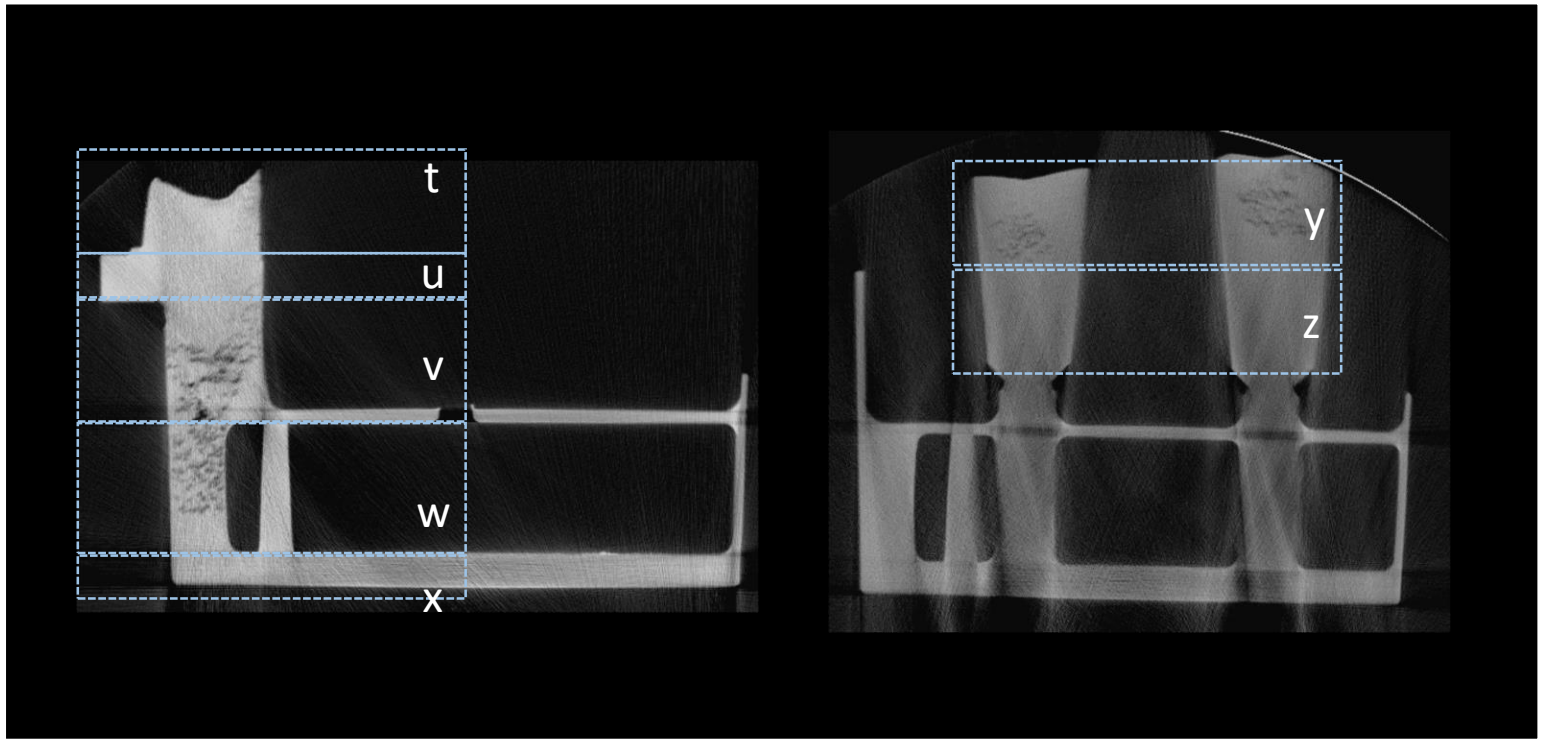
Trial: Control – Current state

Alloy: A357

Concentration: 0.15 wt% TiB_2

Gas Content: 0.4

Shrinkage rating: 1.86



Zone	t	u	v	w	x	y	z
Level	1	1	4	3	1	2	1

NOVEL GRAIN REFINER – RESULT'S

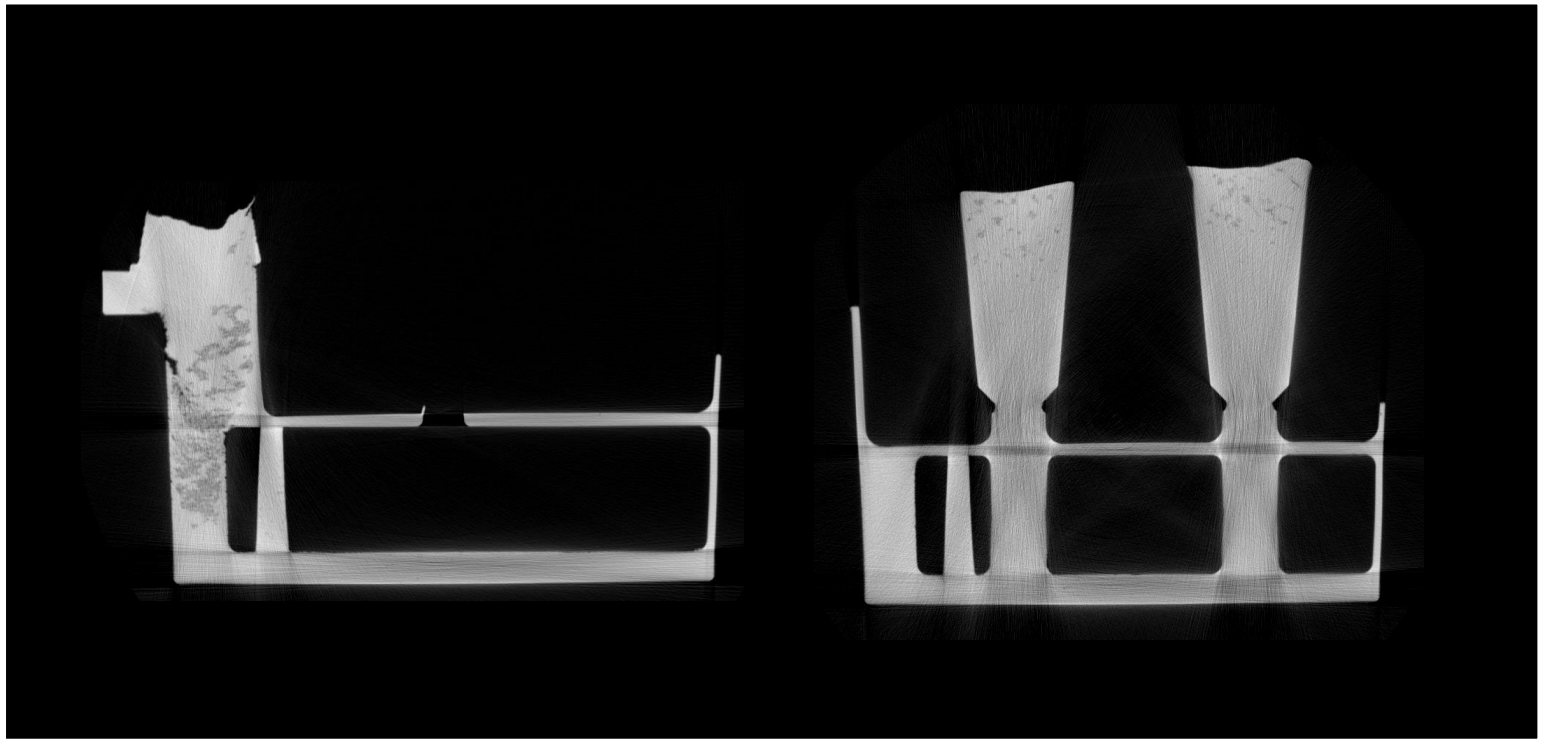
Trial: NGR MA3

Alloy: A357

NGR Concentration: 0.05 wt%

Gas Content: 0.1

Shrinkage rating: 1.86



Zone	t	u	v	w	x	y	z
Level	1	1	4	3	1	2	1

NOVEL GRAIN REFINER – RESULT'S

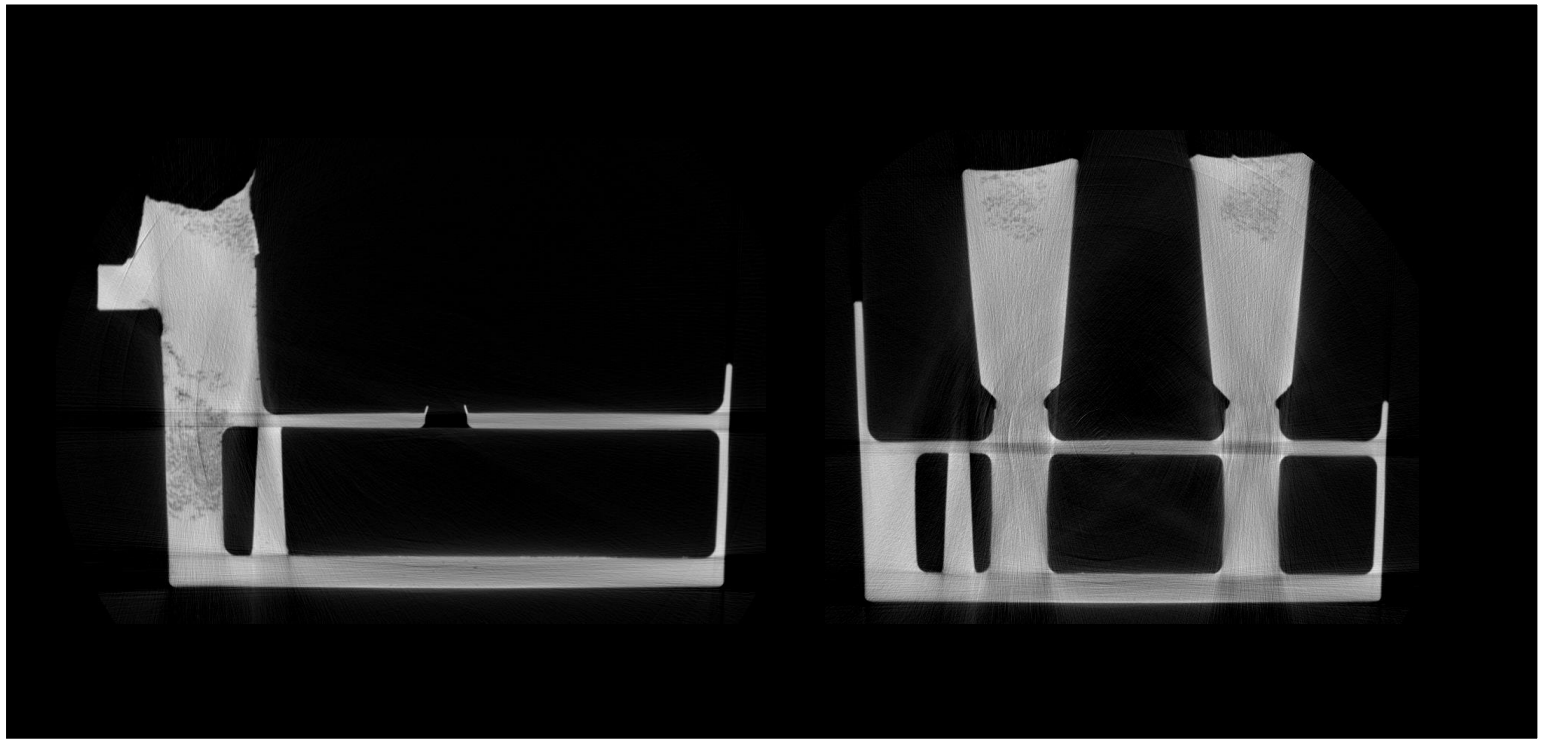
Trial: NGR MA3

Alloy: A357

NGR Concentration: 0.1 wt%

Gas Content: 0.4

Shrinkage rating: 1.71



Zone	t	u	v	w	x	y	z
Level	2	1	2	3	1	2	1

NOVEL GRAIN REFINER – RESULT'S

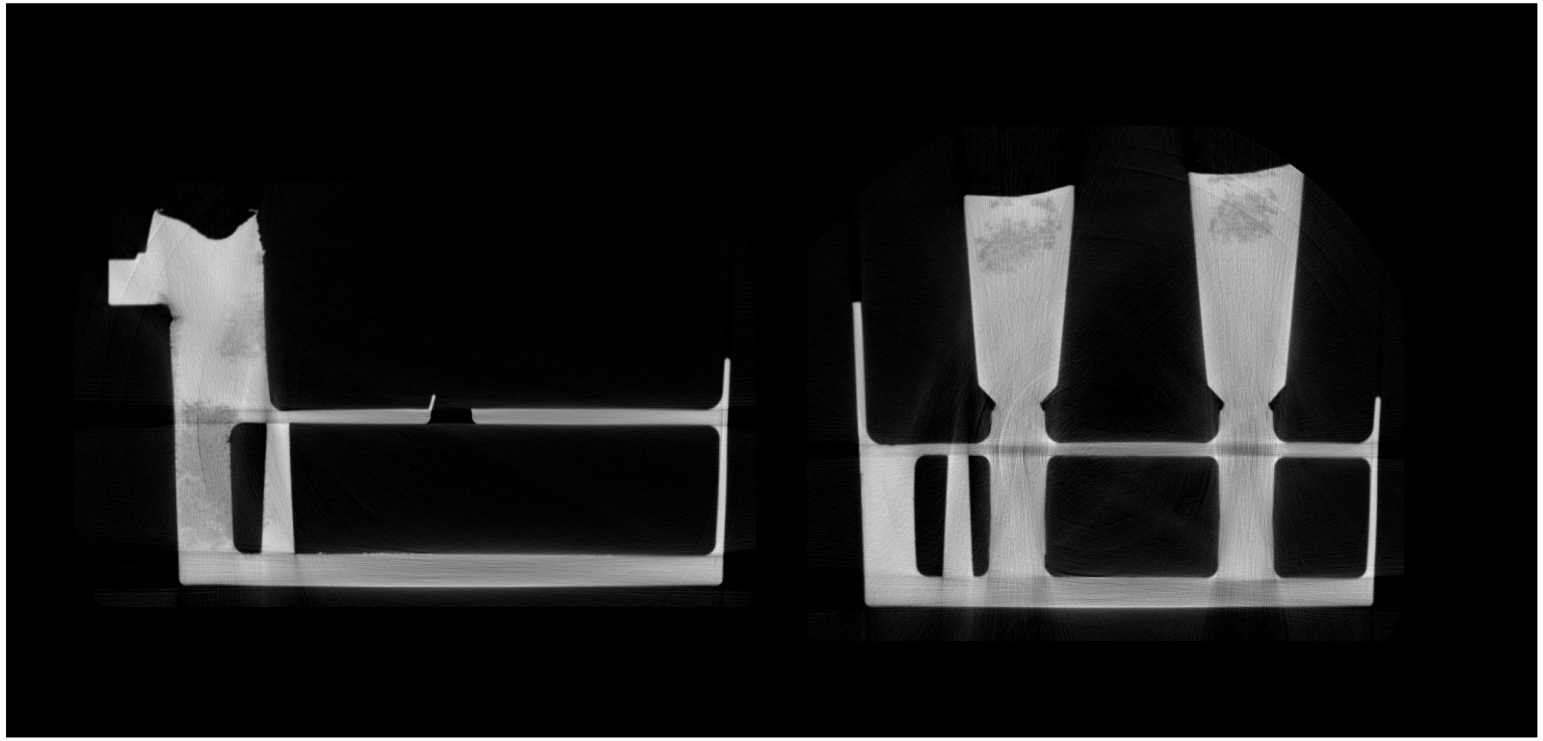
Trial: NGR MA3

Alloy: A357

NGR Concentration: 0.15 wt%

Gas Content: 0.3

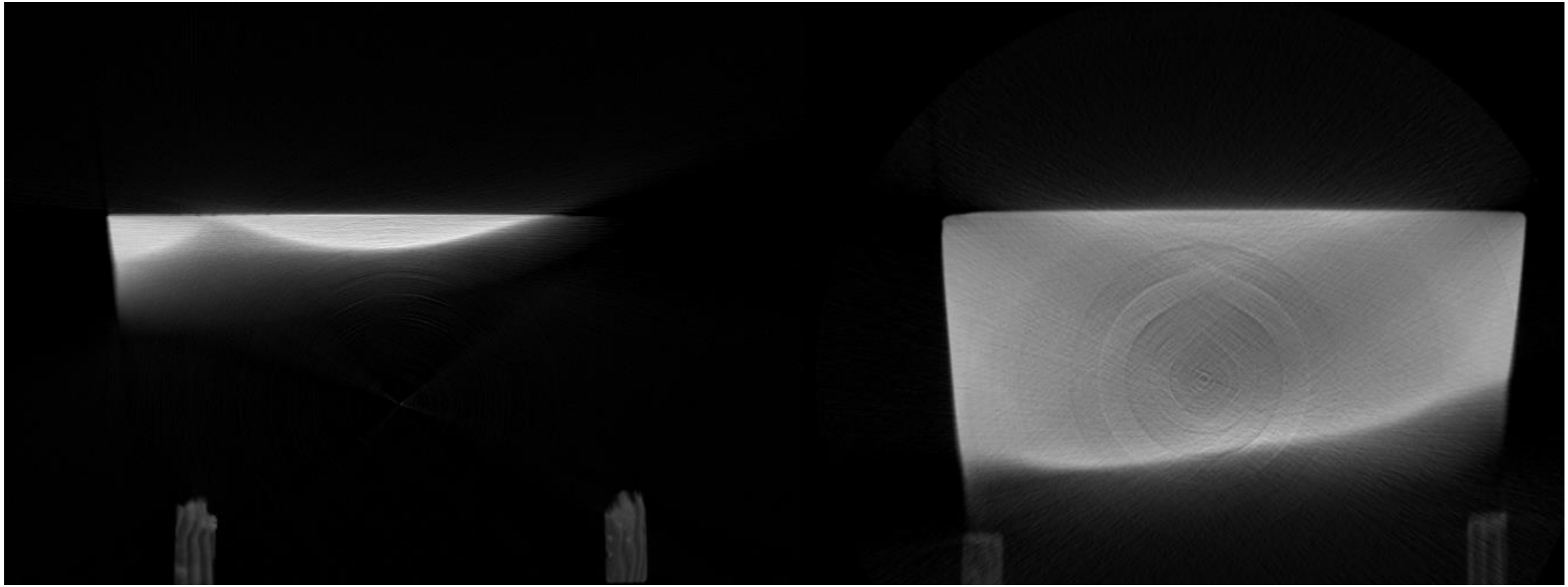
Shrinkage rating: 1.43



Zone	t	u	v	w	x	y	z
Level	1	1	2	2	1	2	1

NOVEL GRAIN REFINER – RESULT'S

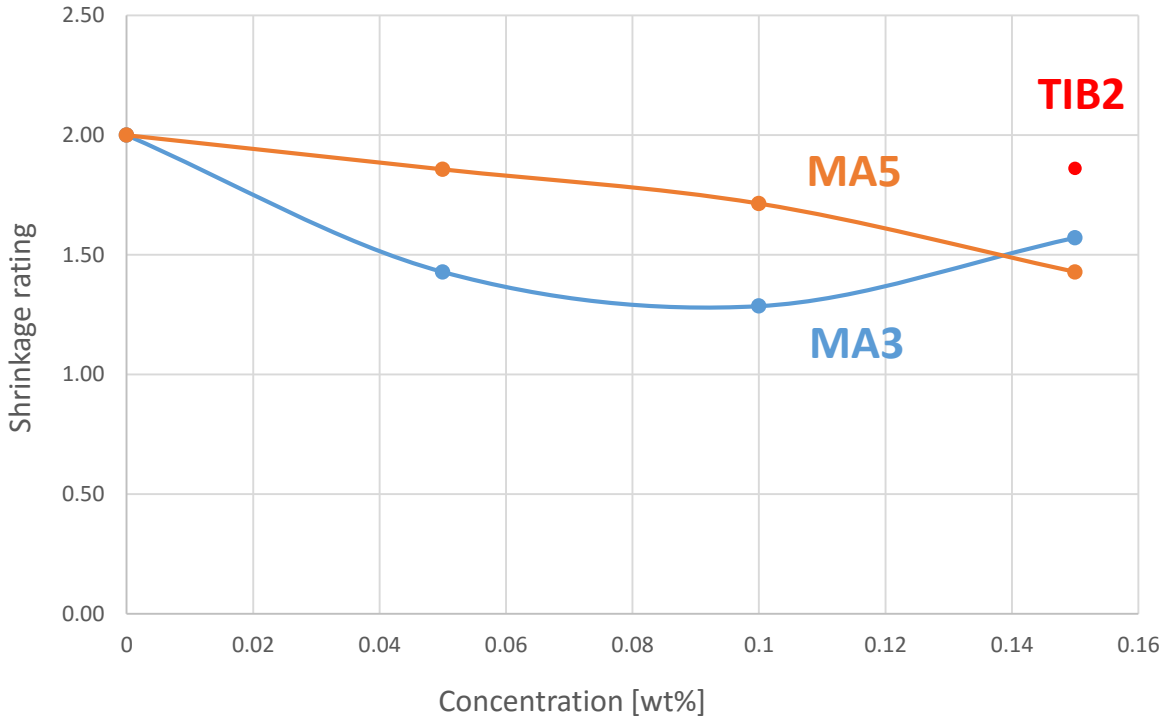
A357 Reference vs. A357 0.15 wt% MA3 NGR



NOVEL GRAIN REFINER – EVALUATION OF RESULTS

Trial: A357 (MA3 vs. MA5)

Trial	NGR	t	u	v	w	x	y	z
3	0.05	2	1	1	2	1	2	1
3.1	0.1	1	1	1	2	1	2	1
3.2	0.15	2	1	2	2	1	2	1
3.3	0	1	1	5	3	1	2	1
4.1	0.05	1	1	4	3	1	2	1
4.2	0.1	2	1	2	3	1	2	1
4.3	0.15	1	1	2	2	1	2	1



NOVEL GRAIN REFINER – RESULT'S

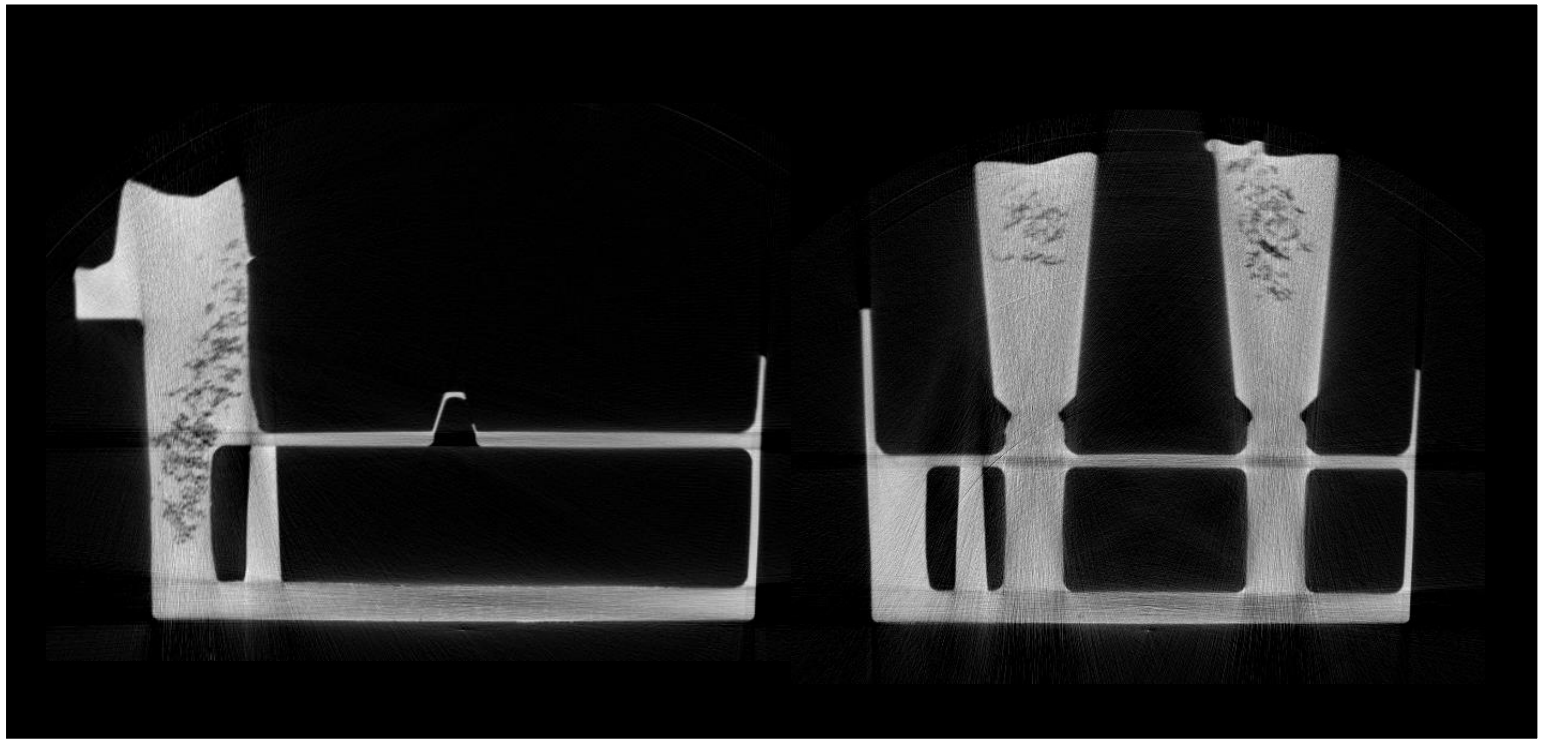
Trial: NGR MA5

Alloy: A354

NGR Concentration: 0.0 wt%

Gas Content: 0.9

Shrinkage rating: 2.57



Zone	t	u	v	w	x	y	z
Level	2	2	4	4	1	3	2

NOVEL GRAIN REFINER – RESULT'S

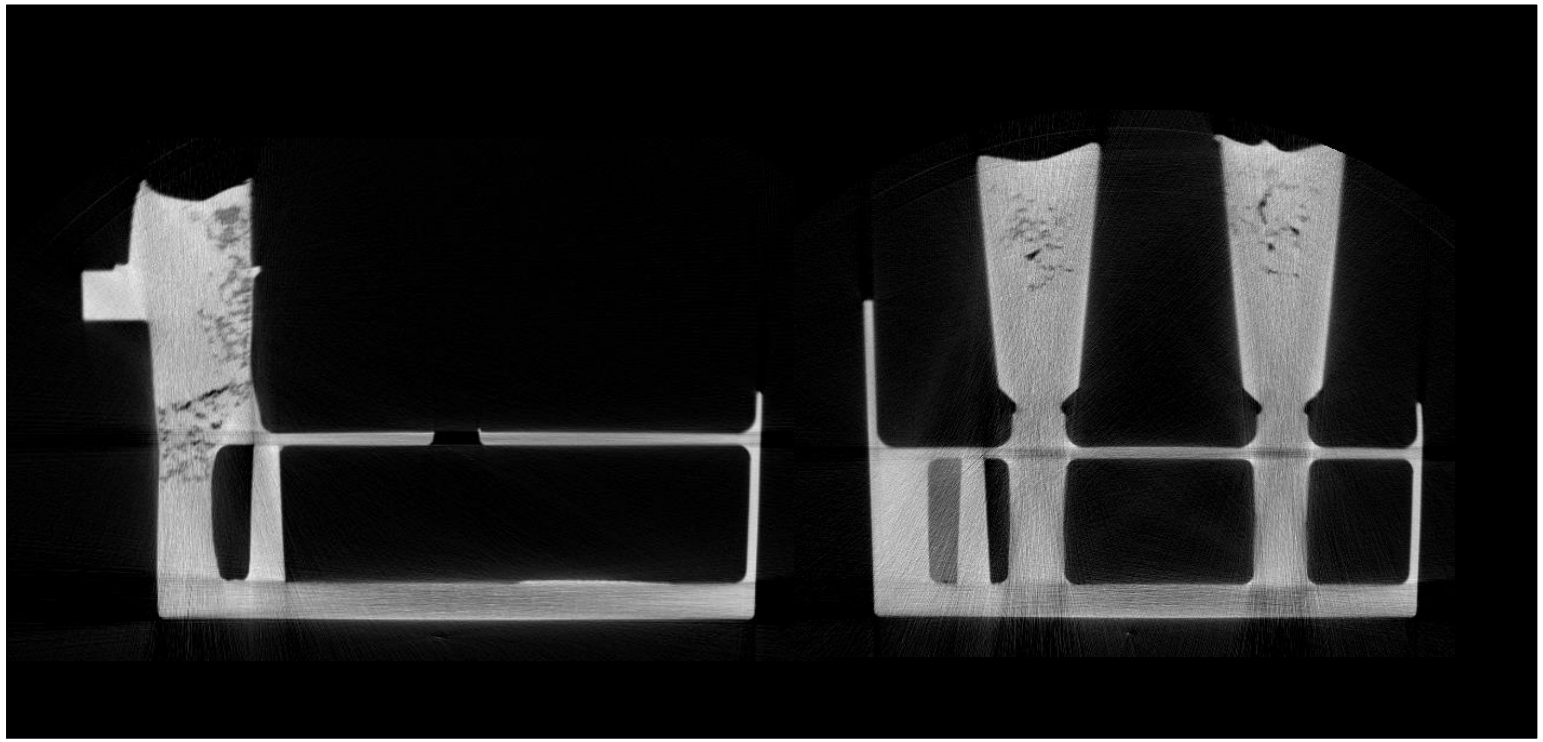
Trial: NGR MA5

Alloy: A354

NGR Concentration: 0.1 wt%

Gas Content: 0.9

Shrinkage rating: 2.43



Zone	t	u	v	w	x	y	z
Level	3	2	4	2	1	3	2

NOVEL GRAIN REFINER – RESULT'S

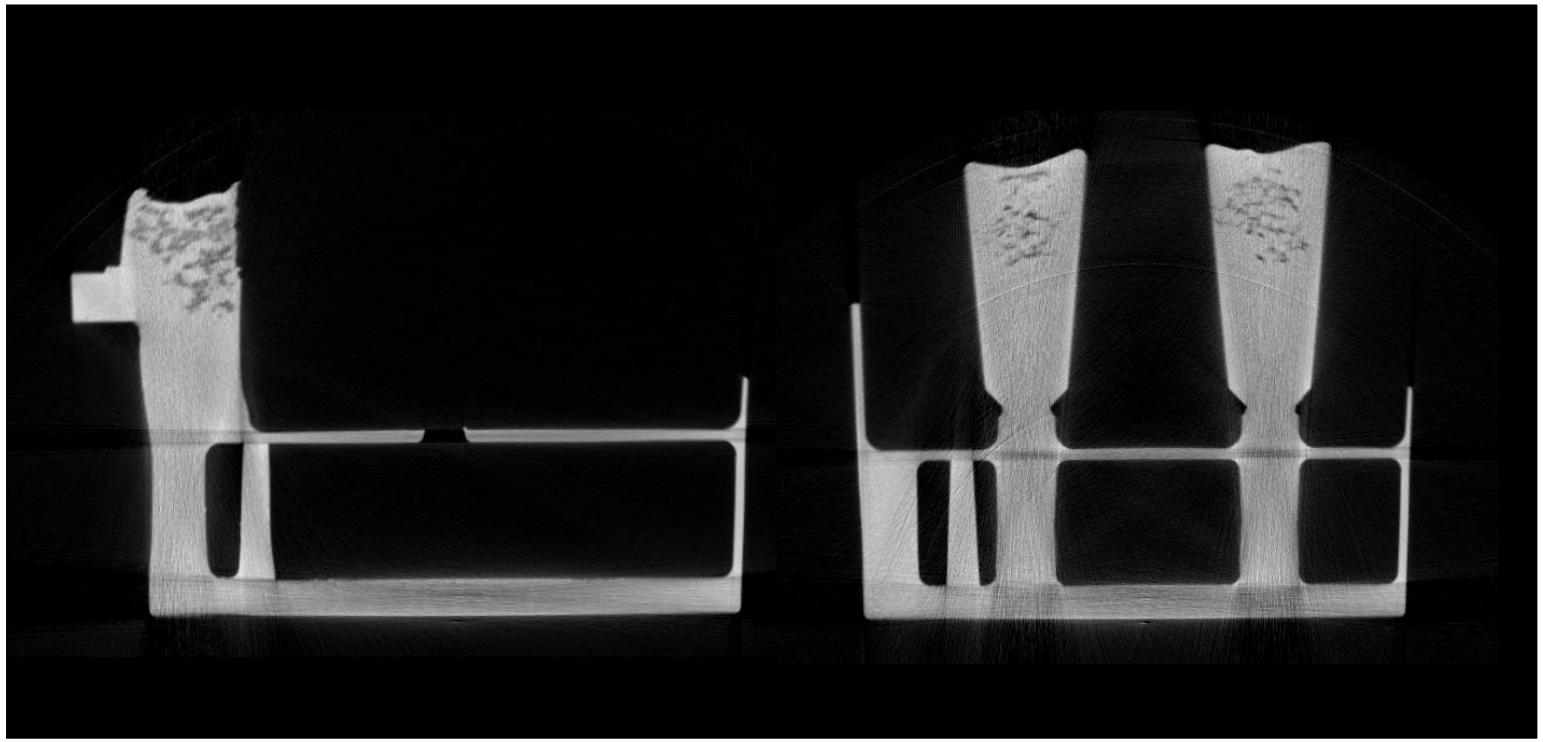
Trial: NGR MA5

Alloy: A354

NGR Concentration: 0.15 wt%

Gas Content: 0.8

Shrinkage rating: 1.71



Zone	t	u	v	w	x	y	z
Level	3	3	1	1	1	2	1

NOVEL GRAIN REFINER – RESULT'S

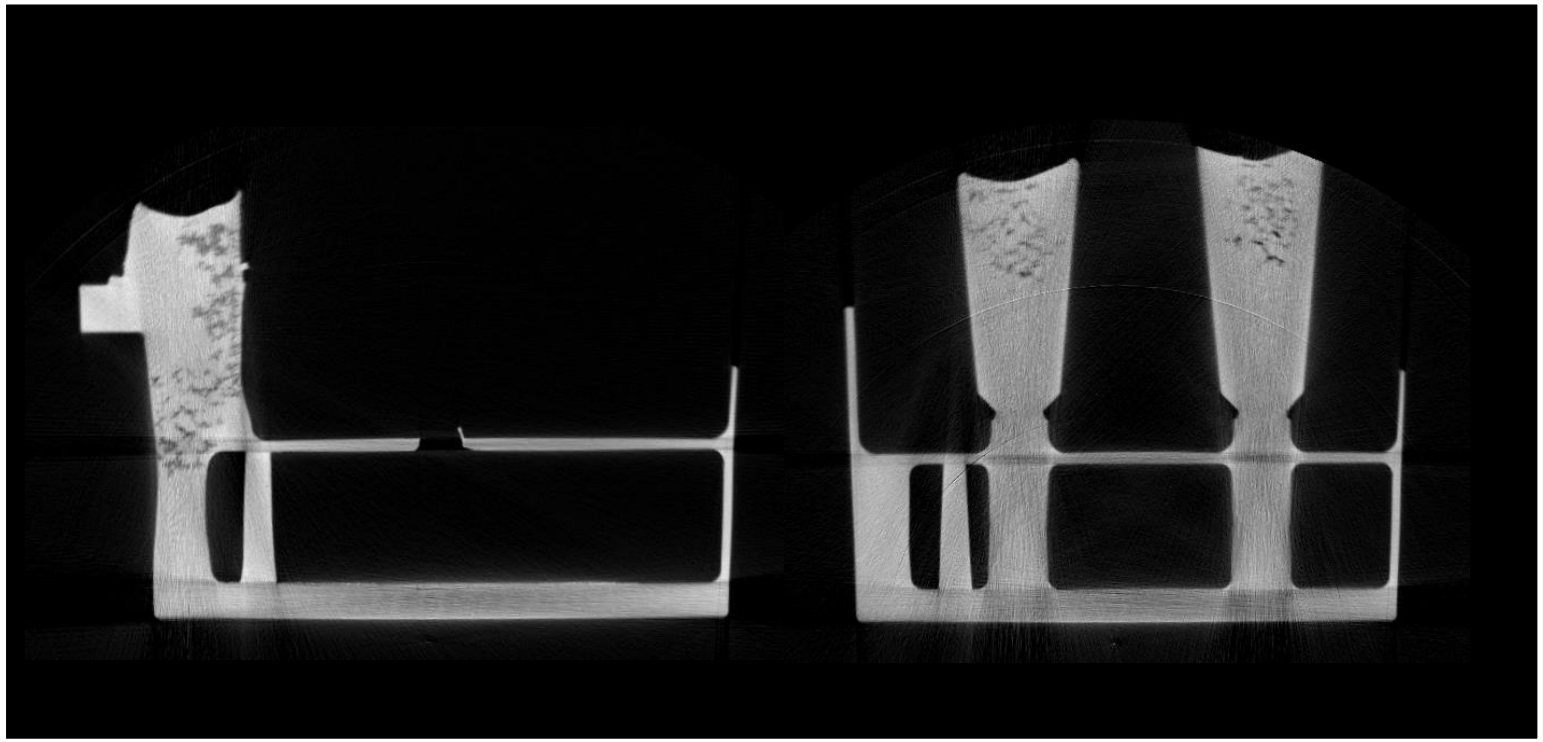
Trial: NGR MA5

Alloy: A354

NGR Concentration: 0.2 wt%

Gas Content: 0.9

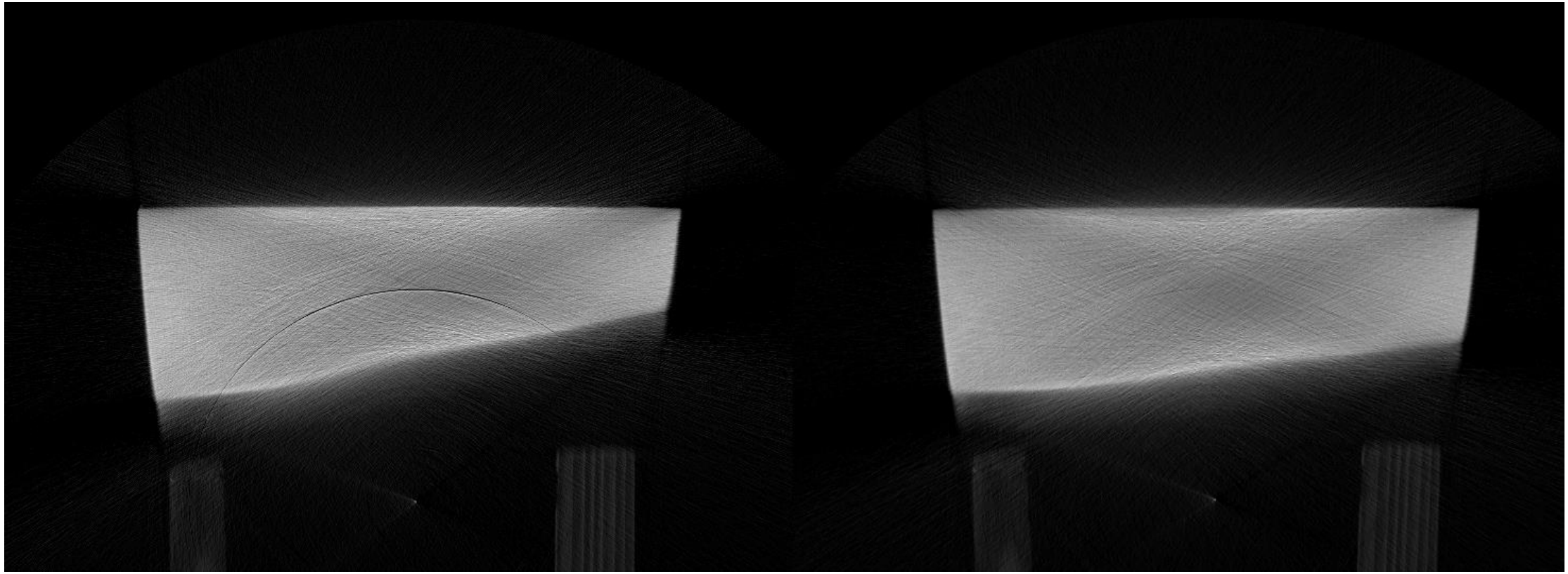
Shrinkage rating: 1.71



Zone	t	u	v	w	x	y	z
Level	2	2	3	1	1	2	1

NOVEL GRAIN REFINER – RESULT'S

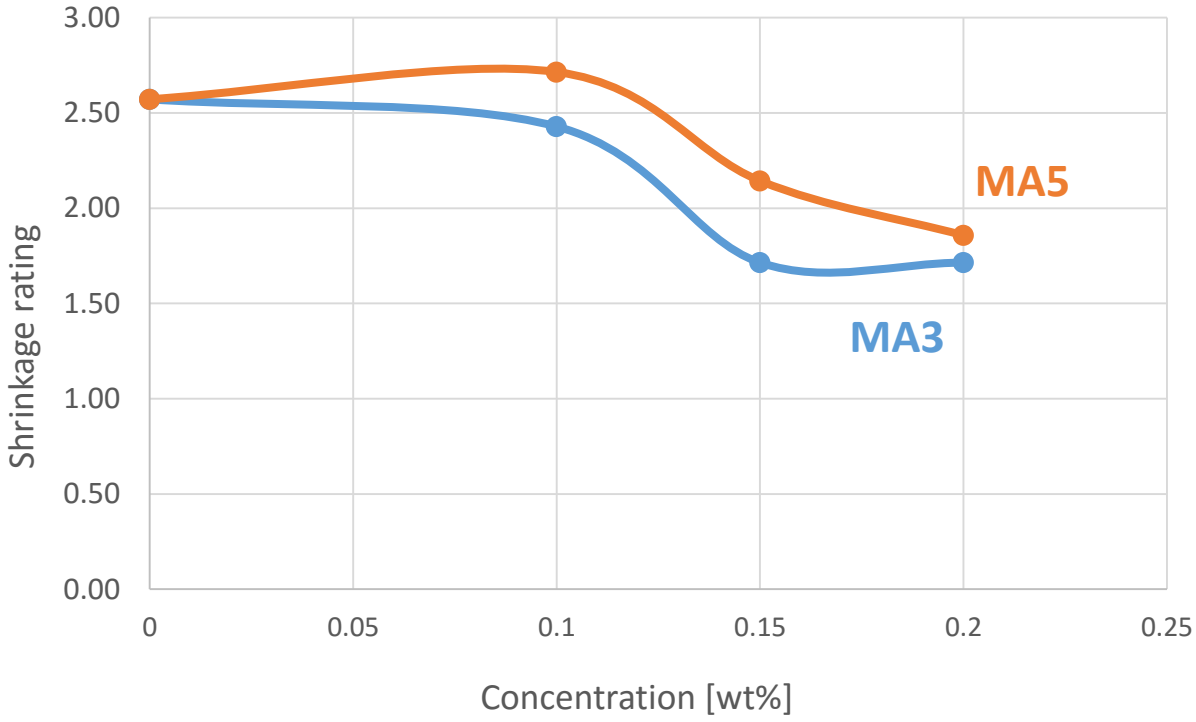
A354 Reference vs. A354 0.15 wt% MA5 NGR



NOVEL GRAIN REFINER – EVALUATION OF RESULTS

Trial: A354 (MA3 vs. MA5)

Trial	NGR	t	u	v	w	x	y	z
1	0	2	2	4	4	1	3	2
1.1	0.1	3	2	4	2	1	3	2
1.2	0.15	3	3	1	1	1	2	1
1.3	0.2	2	2	3	1	1	2	1
2.1	0.1	2	2	5	4	1	4	1
2.2	0.15	2	2	4	3	1	2	1
2.3	0.2	1	2	3	3	1	2	1



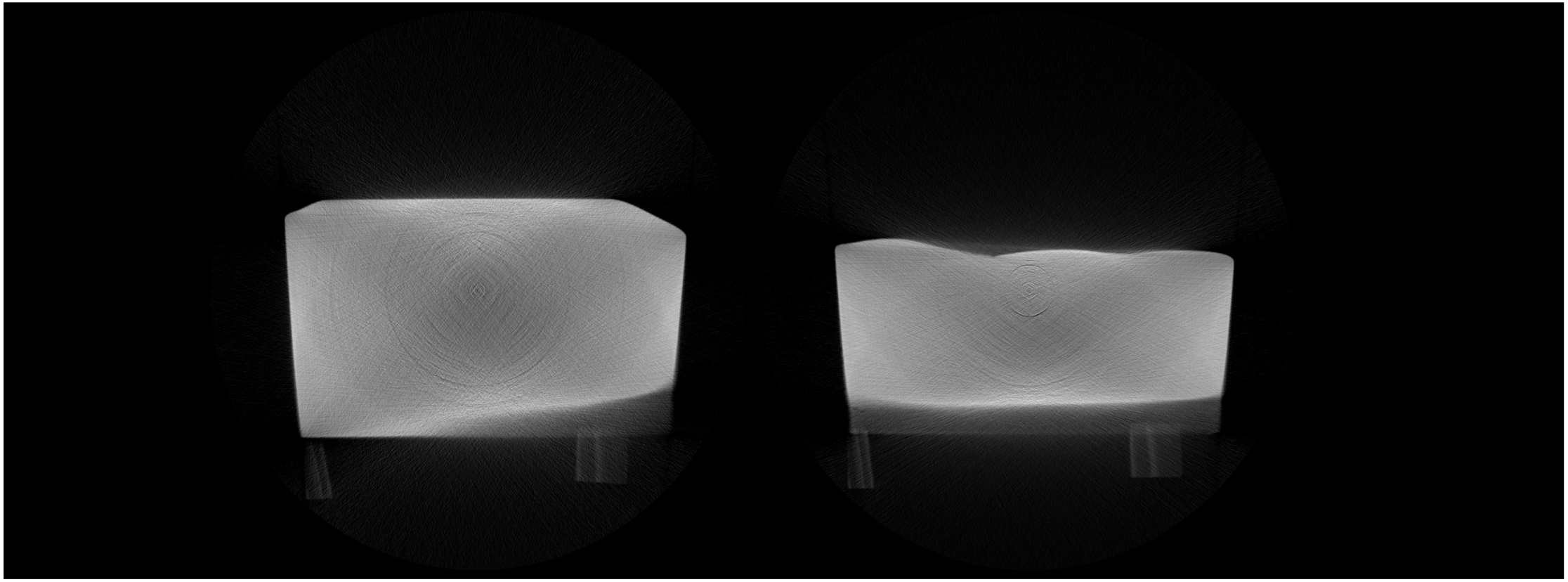
NOVEL GRAIN REFINER – EVALUATION OF RESULTS

Work has also been supported by BCAST, providing etching inspection

Grain size is reduced from ~3 mm to ~0.3mm and is similar for all three addition rates.

NOVEL GRAIN REFINER – RESULT'S

A357 – Fading trials; 0.1 wt% - 15 minutes vs 4 hours (after degas)



NOVEL GRAIN REFINER – SUMMARY

- Novel grain refiner (NGR) additions to A357 & A354 alloys refines the grain structure over TiB_2.
- Grain size is reduced, similar for all three addition rates.
- NGR addition is observed to reduce macro porosity in the casting.

Future work

- Evaluate fading and conduct further trials
- Monotonic tensile testing
- Further trial NGR on representative castings
- Heat treatment trials (T6)
- Look at effectiveness on recycled material

Thank you for listening

Any Questions