

PROJECT COMPLETION REPORT

ADVANCED MATERIALS: MATERIALS FOR EXTENDED FIRST USE
AND RE-USE

UPCYCLING OF LIGHT ALLOYS BY RHEOFORMING SCRAP

TSB Project No: TP/6/MAT/6/S/K1046J

COMMERCIAL RESTRICTED

Date: May 2011

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Part 1: Questions for the consortium as a whole

Project contact details

Actual project start date: 1st March 2007

Actual project completion date: 30th November 2010

Lead Organisation Name: Innoval Technology Limited

Project Manager's name: [REDACTED]

Organisation: Innoval Technology Limited

Address: Beaumont Close, Banbury, OX16 1TQ

Telephone number: [REDACTED]

Email address: [REDACTED]

1 The Project's Achievements.

1.1 What were the original goals of the project and to extent were these achieved? How big an impact has the project had on the issues it tried to address?

The original goal of the project was to develop and exploit a novel melt high shear conditioning technology for the direct reprocessing of aluminium and magnesium alloy scrap for technically demanding automotive and other high value added applications, so that post consumer light alloy scrap as a valuable materials resource could be reprocessed within the UK. A particular aspect was to demonstrate that alloys and components made from a reprocessed scrap base would have both enhanced mechanical performance characteristics and corrosion resistance. The intention was to make the UK less dependent on imports of expensive and energy intensive aluminium and magnesium alloys derived from primary metal sources, and to contribute significantly to a lower environmental impact by re-balancing the flow of materials through the UK economy and to reduce both landfill and carbon emissions from primary light metal production.

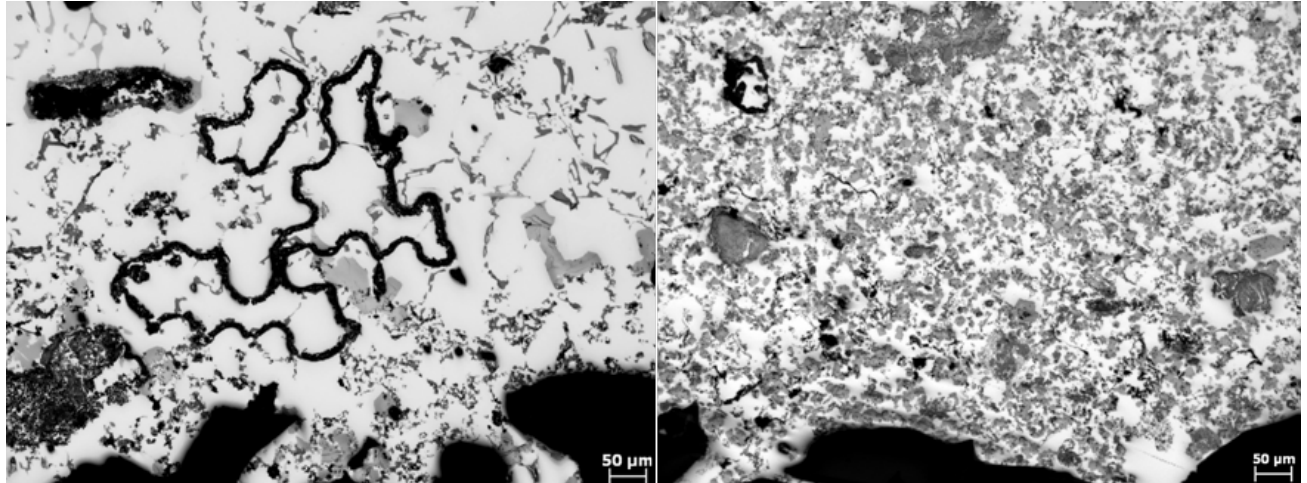
One of the main barriers to the increased use of recycled light alloy scrap (both process scrap (new) and post-consumer scrap (old)) is the existence of excessive levels of inclusions and impurity elements, which usually leads to downgrading into materials with poorer mechanical properties and reduced corrosion resistance. The main technical goal of the project was to demonstrate that increased tolerance to impurities could be achieved by melt conditioning.

The technical approach, was to melt condition light alloy scrap using a high shear twin screw melt processor and to feed this melt into a high pressure diecaster for near net shape components. For magnesium alloys the emphasis of the project was on production of high pressure diecastings, whilst for aluminium the emphasis was to be on both high performance castings and on wrought products. The main equipment expenditure was for the manufacture of a high temperature twin screw melt conditioner for aluminium alloys. The longer term aim of the project was to develop a unique UK partnership of material producers, recyclers, technology providers and product manufacturers to develop a novel process route for increasing the re-use and recycled content of light alloy materials by upcycling post consumer scrap and process scrap into higher-value products.

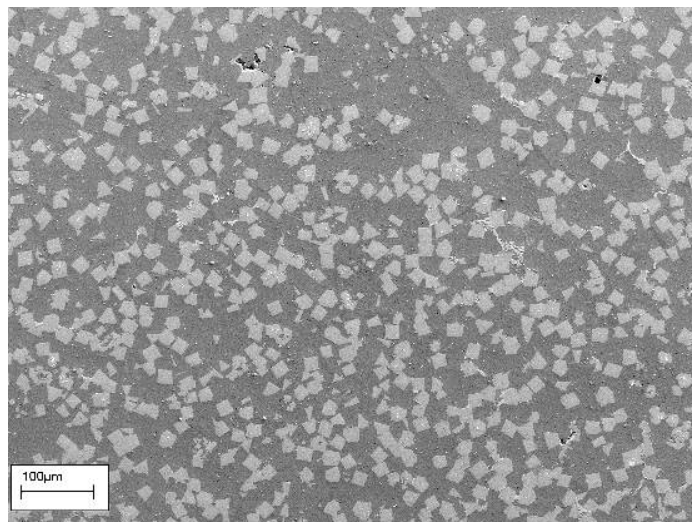
Development of novel melt conditioning technologies for the direct reprocessing of aluminium and magnesium alloy scrap.

Initial studies were carried out using twin screw melt conditioning equipment available at

Brunel University from an earlier TSB support project (Development of the Rheo-Casting Process for Lightweight Automotive Components Project No: TP No: TP/2/ET/6/I/10449). Melt conditioned scrap based melts of aluminium alloy LM24 (Al-9.4Si-2.3Cu-1Zn-0.8Fe-0.5Mg-0.2Mn) and magnesium alloy AZ91D were filtered using the Prefil pressure filtration technique and the solidified filter residue was sectioned for examination by optical and scanning electron microscopy. The images below show the results of the first filtration studies on alloy LM24 and show the comparison of the filter residue from a melt with and without high shear melt conditioning. The non-conditioned melt in the left hand image shows folded oxide films and coarse iron bearing intermetallics. The right hand image shows the filtrate from a melt subjected to high shear melt conditioning and shows that this process has a dramatic effect on both oxide films and intermetallic particle size.



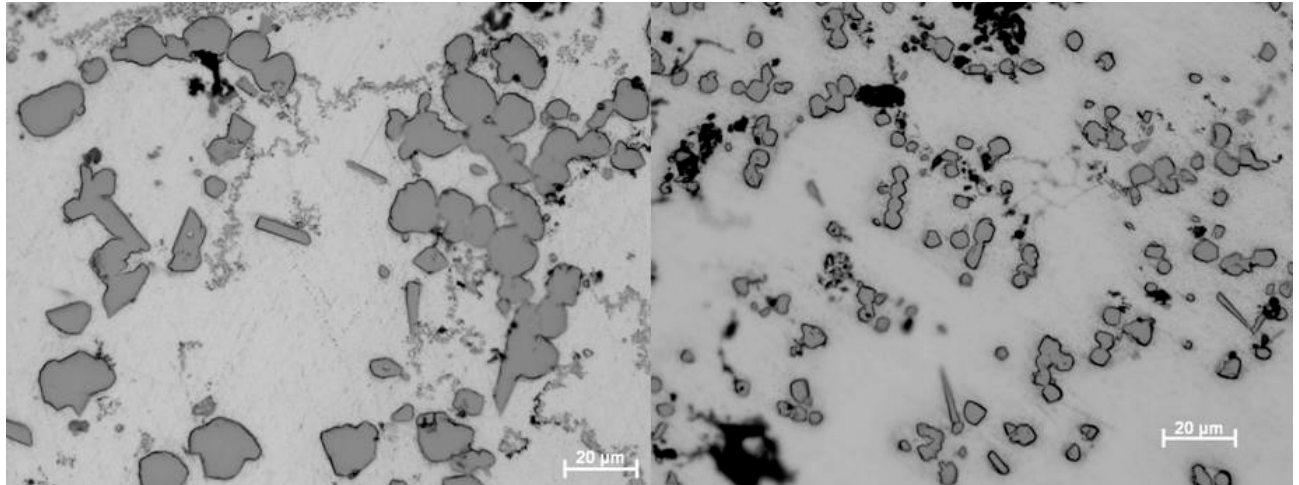
The uniformity of α -AlSiFe intermetallic size after high shear melt conditioning is shown much more clearly in the following image again for the LM24 alloy as imaged by scanning electron microscopy



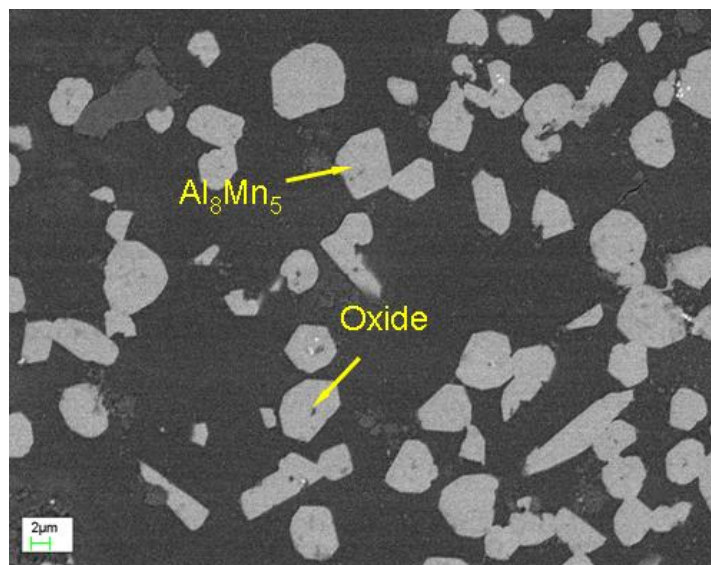
However the most profound effect was on the size and distribution of the aluminium and magnesium oxide particles after melt conditioning. This observation was the basis for the understanding that the dispersed oxide inclusions in the sheared melt were responsible for the observed microstructural refinement. This conclusion had a profound effect on all subsequent work in the project as it transformed the consideration of oxides as detrimental phases to be removed by filtration into positive alloy components that could be used to

refine cast microstructures provided that oxide films were broken up and dispersed by the melt conditioning process.

A similar melt conditioning and filtration study for the AZ91D magnesium alloy showed the same effect of oxide film dispersion by high shear melt conditioning and refinement of the cast microstructure and the intermetallic phases as shown in the next image

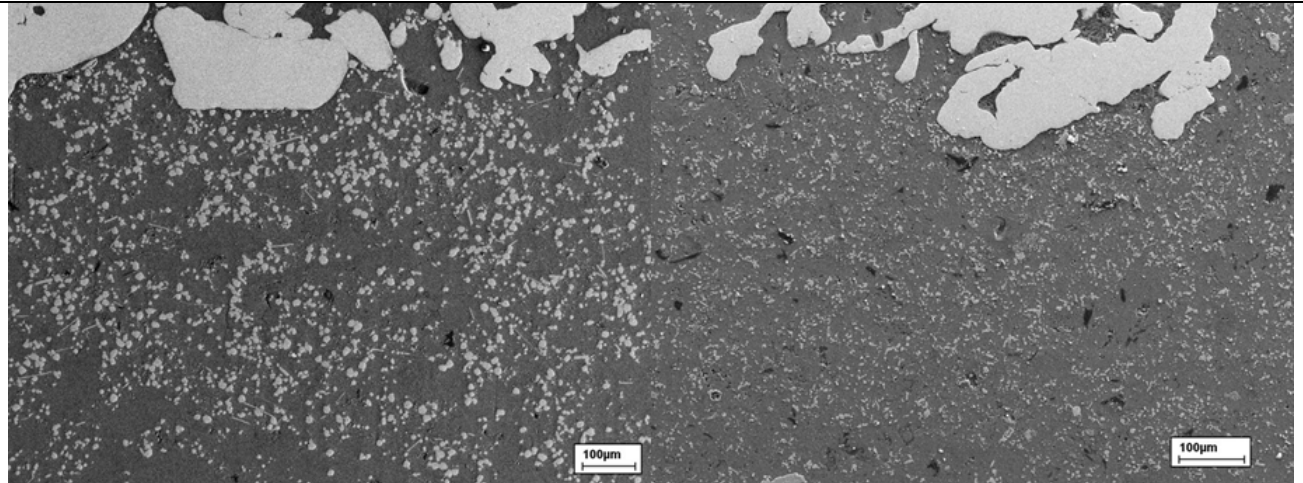


The left hand image shows the filtrate without melt conditioning showing both the oxide films and the coarser Al_8Mn_5 intermetallic compared to those in the right hand image after melt conditioning. This result confirmed the potential to utilise dispersed oxides in both aluminium based and magnesium based alloys for refinement of cast microstructure and the improved tolerance of impurities.

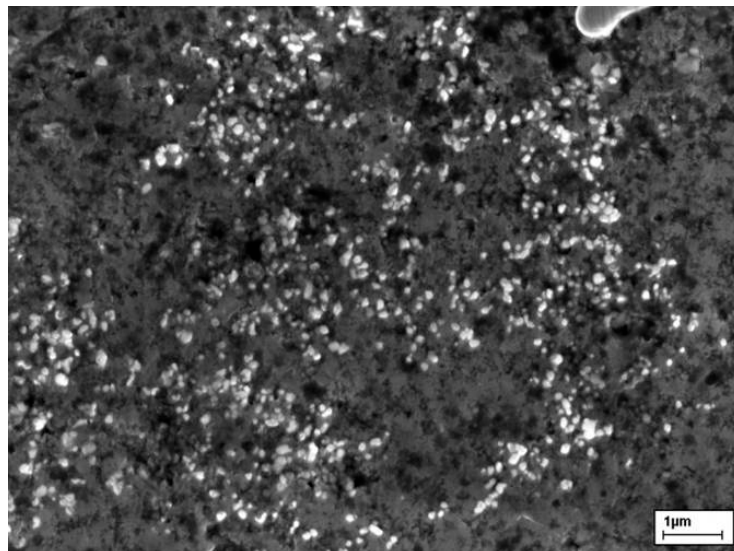


Furthermore by using high resolution low kV scanning electron microscopy with X-ray microanalysis it was possible to directly image oxide particles within the Al_8Mn_5 intermetallic phases that had acted as their nucleant.

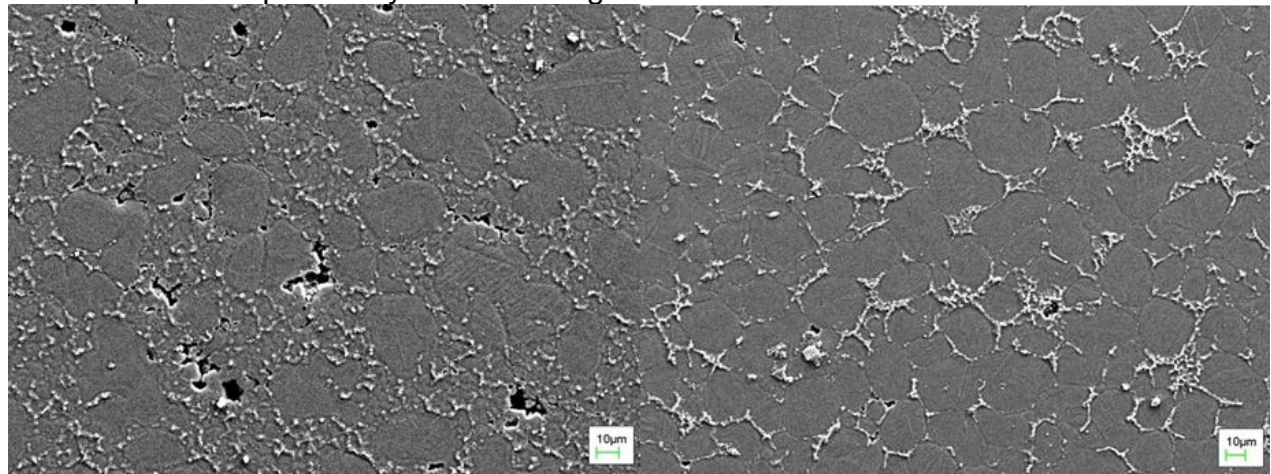
Similar results were then obtained with process scrap based magnesium alloys AM50 and AM60 showing that the results had general application for magnesium alloys. The next image shows the significant effect of high shear melt conditioning at 500rpm for 45seconds at 630°C again on the refinement of the Al_8Mn_5 intermetallic particles. The filtrate after shearing is shown in the right hand image.



High resolution scanning electron microscopy showed that high shear melt conditioning provided a relatively uniform dispersion of magnesium oxide particles of average size of 150nm.



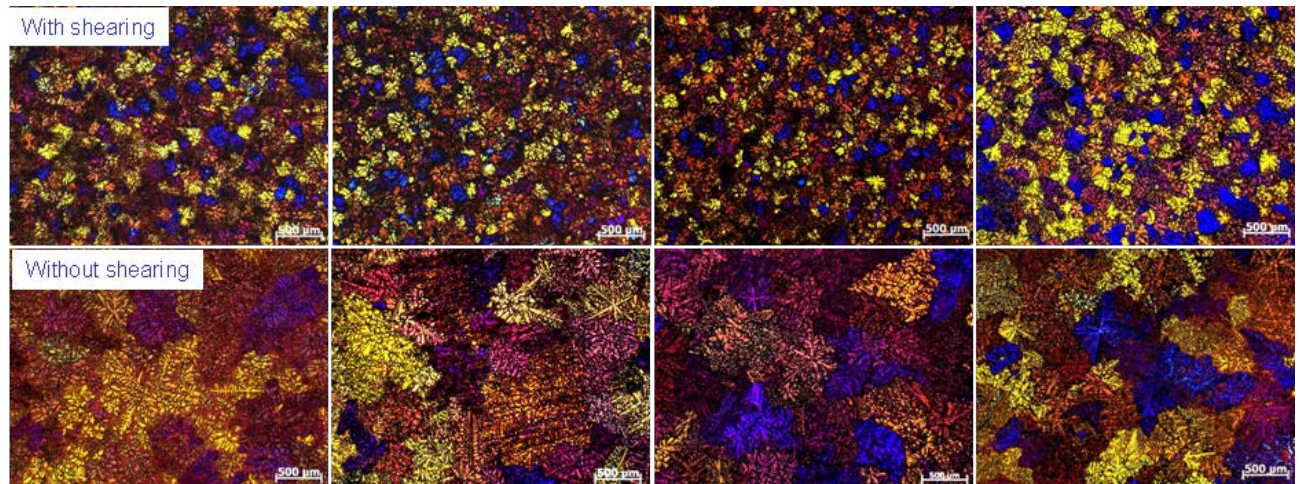
The filtration studies were supported by high pressure diecasting (HPDC) of tensile bars for mechanical property assessment. In this work two types of oxide, MgO and MgAl_2O_4 spinel were found in the AM50 and AM60 scrap based diecastings. Both types of oxide film were broken up and dispersed by melt shearing.



The melt shearing reduced the average size of the Al_8Mn_5 intermetallic particles from 7.5 µm

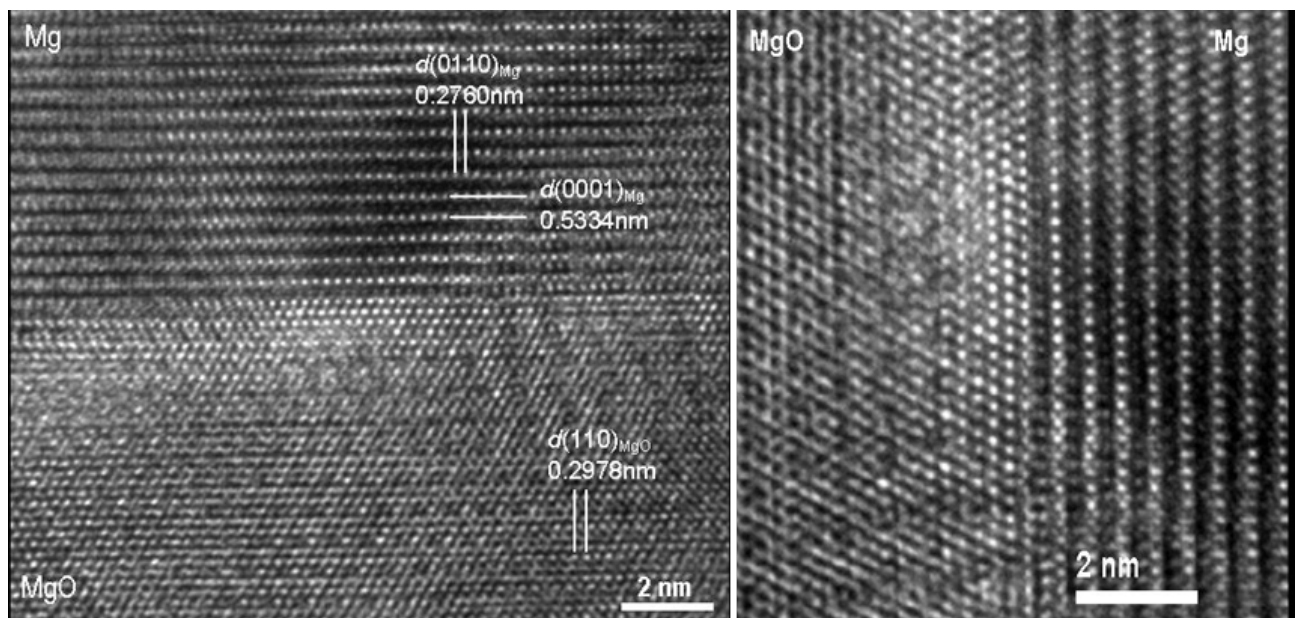
to 3.5 μm , and resulted in more uniform $\text{Mg}_{17}\text{Al}_{12}$ β -phase eutectic and significantly reduced porosity levels. However the expected increase in mechanical properties following melt conditioning was not reproducibly demonstrated.

The next significant result was the demonstration that the grain refining effect of magnesium oxide in magnesium alloys was retained over a series of remelting operations after the initial melt conditioning and casting step as shown in the images below.

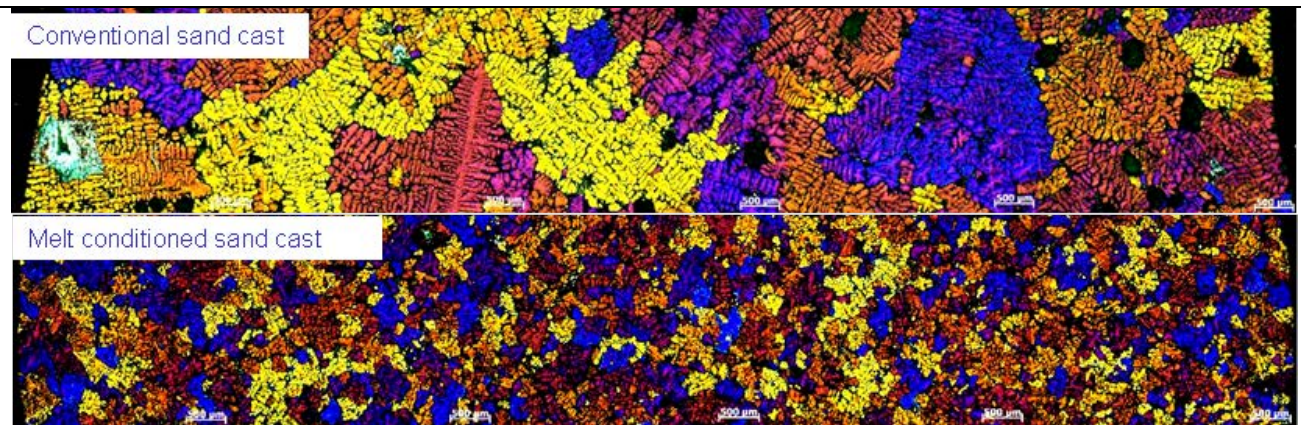


The series of optical micrographs were obtained from AZ91D castings that were melted and re-cast four times. These results helped to confirm that the effect was due to the dispersed oxide nuclei produced by high shear melt conditioning.

High resolution TEM studies confirmed that the nucleating potency of the oxide particles was strongly related to lattice matching. The image shows the lattice matching between magnesium oxide and magnesium for the AZ91D alloy



The potency of oxide nuclei over a range of solidification rates was studied using LM25 aluminium alloy sand castings as shown in the next image. This work showed that high shear melt conditioning was particularly effective at slow solidification rates that conventionally produce castings with a large as-cast grain size. However although microstructural refinement was obtained this did not result in improved mechanical properties for either sand cast tensile specimens or shape castings.

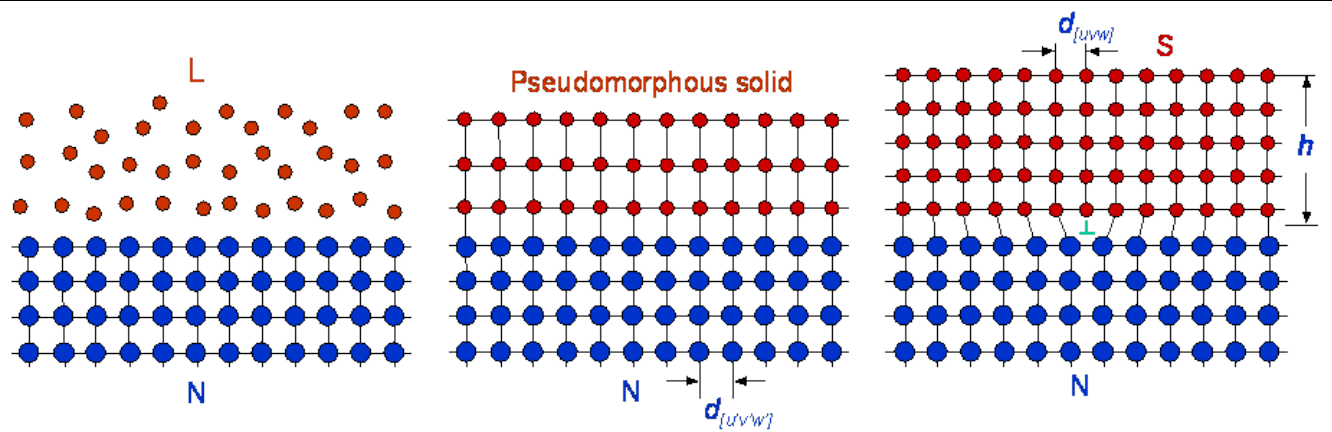


A series of experiments using a range of LM25 compositional variants with different iron and manganese levels showed that high shear melt conditioning enhanced the formation of equiaxed primary iron intermetallic particles and eliminated the formation of needle-shaped particles. Melt conditioning decreased the average particle size by 50% compared to non-sheared HPDC samples and a very narrow size distribution of iron intermetallic particles was obtained.

A further series of experiments were conducted using a stepped high pressure diecasting to simulate component production. Although microstructural refinement was obtained for both the LM24 and the AM60 castings the mechanical property results were inconsistent and did not confirm the expected benefits that should have been realised. These inconsistencies were due to a number of factors but mainly related to the inconsistent shot to shot performance of the high pressure diecasting machine at Brunel. This has subsequently been replaced by a HPDC machine with improved casting parameter control. As no samples were obtained with reliably improved mechanical performance it was not appropriate to carry out corrosion tests.

The work within the ULARS project has made a major contribution to an epitaxial nucleation model to describe the atomistic mechanisms of heterogeneous nucleation on a potent substrate. This has proposed that heterogeneous nucleation on a potent substrate takes place by epitaxial growth of a pseudomorphic layer on the surface of the substrate. The solid phase is formed for the first time by introducing misfit dislocations at the interface at a critical thickness to convert the pseudomorphic layer to the solid phase and the initially coherent interface into a semi-coherent interface. Both the critical undercooling and the critical thickness for epitaxial nucleation are closely related to the lattice misfit at the interface. Following the epitaxial nucleation model, the terms of “potency” and “efficiency” in a grain refining system have been precisely defined. Nucleating potency can be improved by: (1) selecting a substrate with minimum lattice misfit; (2) introducing solute elements which segregate at the L/N interface and reduce the misfit; (3) adding solute elements which dissolve into the substrate structure and reduce the misfit. Nucleation efficiency can be improved by optimising the number density, size, size distribution and level of dispersion of the nucleating particles, as predicted by the free growth model.

The schematic below shows the main features of the epitaxial nucleation model



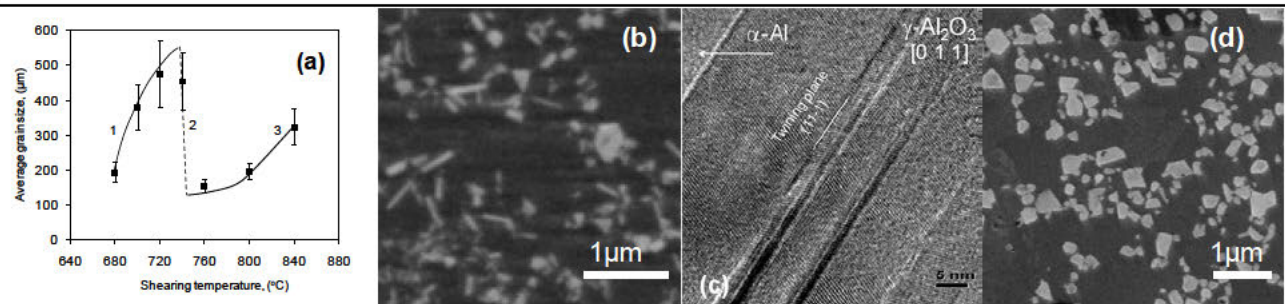
OR: $(hkl)[uvw]_S // (h'k'l')[u'v'w']_N$ Misfit strain: $f = \frac{d_{[uvw]} - d_{[u'v'w']}}{d_{[uvw]}}$

High Temperature Melt Conditioning of Aluminium Alloys

The small diameter aluminium twin screw melt conditioner at Brunel was completely rebuilt with new screws and barrel sections and high temperature heaters for higher temperature melt conditioning experiments. This work demonstrated that α -alumina was more effective than γ -alumina in the nucleation of solid aluminium from the melt. This result had a major impact on the development of the epitaxial nucleation model and in future will have major impact on the development of novel grain refiners and master alloys for aluminium alloys.

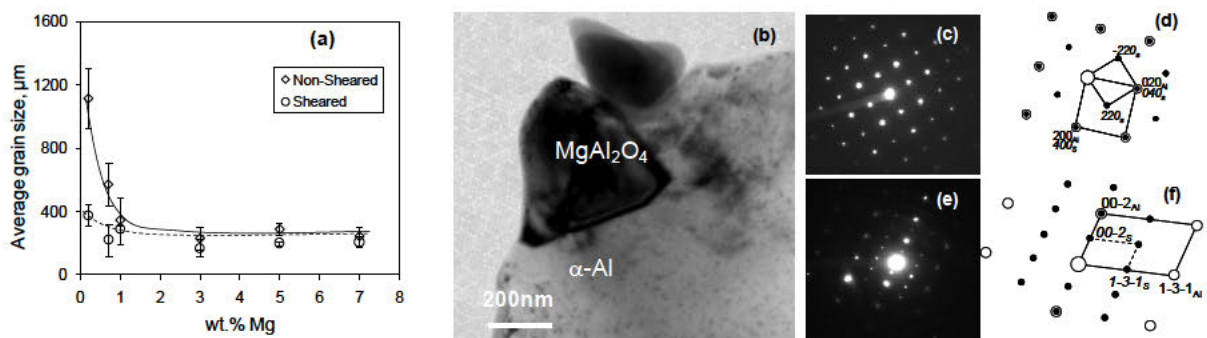
In aluminium alloys, α -Al₂O₃ and γ -Al₂O₃ are naturally occurring oxides depending on melting temperature and other conditions. The high temperature melt conditioner was used to investigate the effect of intensive melt shearing on grain refinement of commercial purity aluminium (CP Al, 99.86 Wt. %Al). Naturally occurring oxides formed at different temperatures were characterized to identify their chemical and physical characteristics. The crystallographic match between oxides and aluminium was correlated with the grain refinement by intensive melt shearing.

In aluminium alloy melts without magnesium additions, γ - Al₂O₃ and α - Al₂O₃ are the two major oxides formed at low temperatures (<750°C) and high temperatures (>750°C), respectively. High shear was used to disperse the oxides in CP Al at different temperatures and it was shown that the grain size of CP Al varies with shearing temperature in a complex manner, suggesting that the transition between γ - Al₂O₃ and α - Al₂O₃ is at 740±20°C. The image shows the dispersed γ - Al₂O₃ oxides formed in the CP Al melt sheared at 700°C. The exposed surface of γ - Al₂O₃ platelets is the {111} crystallographic plane. The α - Al₂O₃ formed at 920°C consists of individual faceted particles. The orientation relationship between the γ - Al₂O₃ and the α -Al was identified as (111)[110]Al//{(111)[110] γ - Al₂O₃. The calculated lattice misfit at 660°C is 3.38%. In the case of α - Al₂O₃, the calculated misfit at 660°C is -0.48% based on the following orientation relationship: (0001)[10-10] α - Al₂O₃//{(100)[001]Al. This suggests that α - Al₂O₃ is more potent than γ - Al₂O₃ as nucleation sites of α -Al due to the lower lattice misfit.



(a) Grain size as a function of shearing temperature in TP-1 samples of CP Al; (b) dispersed $\gamma\text{-Al}_2\text{O}_3$ in CP Al by intensive shearing; (c) a high resolution TEM image showing the interface between $\alpha\text{-Al}$ and $\gamma\text{-Al}_2\text{O}_3$ as the $\{111\}$ plane; (d) discrete $\alpha\text{-Al}_2\text{O}_3$ particles in CP Al at 920 $^{\circ}\text{C}$.

The high temperature melt conditioner was also used to examine grain refinement for a series of aluminium magnesium alloys. A set of binary Al-Mg alloys both with and without intensive melt shearing were cast into TP-1 samples under the same conditions. The quantified grain size data for all the Al-Mg alloys, both with and without melt shearing, are shown below as a function of Mg content. Without melt shearing, the grain size decreased sharply from the Al-0.2Mg to the Al-1Mg alloy, while for the Al-Mg alloys with magnesium content ranging from 1 to 7wt.%, the grain size decreased only marginally. However, if intensive melt shearing was applied to the alloy melts prior to casting, the grain size of Al-Mg alloys were consistently small, with the magnesium content only having marginal effect on the grain size. Extensive TEM examination confirmed that the MgAl_2O_4 particles are terminated with $\{111\}$ planes as their natural surface. Such MgAl_2O_4 particles can act as potent sites for nucleation of $\alpha\text{-Al}$ grains, which is evidenced by a well defined cube-on-cube orientation relationship between MgAl_2O_4 and the $\alpha\text{-Al}$ matrix $(111) [110] \text{MgAl}_2\text{O}_4 // (111) [110] \text{Al}$. Enhanced heterogeneous nucleation in Al-Mg alloys can be attributed to the high potency of MgAl_2O_4 particles with a lattice misfit of 1.4% and the increased number density of MgAl_2O_4 particles due to either natural dispersion by the increased Mg content or forced dispersion through intensive melt shearing.



(a) Grain size as a function of Mg content in Al-Mg alloys with and without shearing; (b) a bright field TEM micrograph of MgAl_2O_4 and $\alpha\text{-Al}$; (c-f) two SAD patterns with $[001]$ and with $[310]$ zone axis, showing the cube-on-cube crystallographic orientation relationship between MgAl_2O_4 and $\alpha\text{-Al}$.

1.2 What additional outcomes did the project achieve? How valuable do you feel these are? (Include any negative outcomes that you feel have value.)

The results of the research breakthroughs in the ULARS project have had a major impact on two successful EPSRC proposals that have significantly expanded the research base at Brunel University. A new EPSRC Centre for Liquid Metal Engineering (LiME) has been established as a national centre of excellence sponsored by the EPSRC, industrial collaborators and the host universities. LiME is based at Brunel University in collaboration with Oxford and Birmingham Universities and 25 industrial partners. Research activities started in September 2010 after the official launch of the Centre on 21st September.

Brunel University have invested £1.85M in the LiME centre to renovate the BCAST office and laboratory space and a further £0.5M for new equipment. LiME's academic capacity has been enlarged by the addition of 11 associate investigators and by appointing 14 new researchers. More specifically, 4 of the 6 planned platform research activities (PRAs), 5 of the 9 planned user-led research activities (ULRAs) together with a new ULRA have been launched and are progressing well. The official launch of the EPSRC Centre - LiME on 21st September 2010 attracted over 200 delegates from government, academia and industry and raised awareness of EPSRC's support for innovative manufacturing in the UK.

The LiME research programme has made excellent progress based on the work undertaken in the ULARS project. In the fundamental research area, significant further progress has been made in understanding the atomic structure at the liquid/substrate interface and on mechanisms of heterogeneous nucleation and this knowledge has been utilised to develop innovative approaches to enhance heterogeneous nucleation for grain refinement. A new high shear device for liquid metal engineering has been developed based on the requirement to disperse oxides and two types of novel grain refining master alloys have been evaluated. It has been found that this novel high shear device can (a) disperse oxide films and clusters into individual particles of nano-size; (b) improve fluidity of liquids; (c) force-wet and disperse externally added ceramic particles; (d) degas liquid metals. Three patent applications have been made. In the past year, the LiME group has secured 5 new research grants (2 EPSRC, 2 TSB, 1 EU-FP7) totalling £1.7M and has established 5 industrial research fellowships with a total industrial financial input of £1.3M.

More recently on 15th March 2011 it was announced that the Engineering EPSRC is providing £4 million for a project led by Brunel University to address fundamental research questions in developing low carbon vehicles. The TARF-LCV (Towards Advanced Recyclable Future Low Carbon Vehicles) proposal was developed in response to an EPSRC initiative with the Technology Strategy Board (TSB) through the Low Carbon Vehicle Innovation Platform Integrated Delivery Programme. The project which starts in September 2011 will cover scientific and engineering issues related to the use of recycled and recyclable materials for manufacturing vehicles, reducing their environmental footprint. TARF-LCV is a collaborative project with the University of Manchester, Imperial College, Coventry University, Exeter University, the University of Nottingham, Oxford Brookes University and the University of Strathclyde. The work programmes on aluminium and magnesium wrought and cast alloy recycling follow on directly from the research base established within the ULARS project.

1.3 What barriers to exploitation remain, and what follow on work is required? Is the consortium planning to address these? If so, how?

The industrial partners from the ULARS project (Meridian and Norton) are industrial partners in the LiME centre and are involved with the development of the new melt conditioning technique. Innoval Technology are working closely with Brunel within both the LiME centre and were closely involved with the development of the TARF-LCV proposal. Zyomax are responsible for the development of the novel dispersive mixing technology

The Brunel financial support for LiME has resulted in the purchase of a new high pressure diecasting facility at Brunel. This will be able to cast a stepped die plate to enable the completion of the work started within the ULARS project to evaluate the mechanical properties of aluminium and magnesium alloys with a high scrap content.

The exploitation barriers are the development of the new melt conditioning technique into a robust industrial melt treatment process and the demonstration of the improved mechanical properties that can be obtained by use of melt conditioning prior to high pressure diecasting or sand casting for post consumer scrap intensive melts for aluminium alloys and process scrap intensive melts for magnesium alloys.

The follow on work will be undertaken as part of the LiME consortium programme To date a rotor-stator high shear unit has been designed and successively constructed and the following results have been achieved:

- Fast and effective degassing of aluminium alloys.

- Significant grain refinement of DC cast aluminium and magnesium alloys.

- Preparation of semisolid alloy slurries with fine and uniform α phase.

- Preparation of metal matrix composites with uniformly distributed reinforcing particles and improved mechanical properties.

1.4 How will the Consortium exploit the project's results?

(If you have an exploitation plan, please attach it to the survey return)

The Consortium will exploit the results of the project through the use of the novel melt conditioning technique that is the subject of a patent application (Z. Fan, Y. Zuo, B. Jiang, UK Patent, Application No.1015498.7, filed on 16 September 2010)

Exploitation of the ULARS project results will be through participation by all the partners in the LiME centre activities.

1.5 How will the Consortium disseminate the results?

The results have been disseminated through a series of papers and presentations

Refereed Journal papers

H. Men, B. Jiang, and Z. Fan, Mechanisms of grain refinement by intensive shearing of AZ91 alloy melt, *Acta Materialia* 58 (2010) 6526

S. Tzamtzis, H. Zhang, N. Hari-Babu, and Z. Fan, Microstructural refinement of AZ91D die-cast alloy by intensive shearing, *Materials Science and Engineering A* 527 (2010)

H. Kotadia, N. Hari-Babu, H. Zhang, and Z. Fan, Microstructural refinement of Al-10.2% Si alloy by intensive shearing, *Materials Letters* 64 (2010) 671

Y. Wang, M. Xia, X. Zhou and G.E. Thompson, The effect of Al₈Mn₅ intermetallic particles on grain size of as-cast Mg-Al-Zn AZ91D alloy, *Intermetallics* 18 (2010) 1683-1689

I. Stone, Casting is considered, *Materials World* 18 (2010) 27-28

Y. Zuo, H.T. Li, M. Xia, B. Jiang, G.M. Scamans, and Z. Fan, Refining grain structure and porosity of an aluminium alloy with intensive melt shearing, *Scripta Materialia* 64 (2011) 209-212

S. Tzamtzis, H. Zhang, M. Xia, N. Hari-Babu, and Z. Fan, Recycling of high grade die casting AM series magnesium scrap with the melt conditioned high pressure die casting (MC-HPDC) process, *Materials Science and Engineering A* 528 (2011) 2664

Y.B. Zuo, H. Li, M. Xia, G.M. Scamans, and Z. Fan
Refining grain structure and porosity of an aluminium alloy with intensive melt shearing, *Scripta Materialia* 65 (2011) 209-212

Y.B. Zuo, M. Xia, S.M. Liang, Y. Wang, G.M. Scamans and Z. Fan, Grain refinement of DC cast AZ91D Mg alloy by intensive melt shearing, *Materials Science and Technology* 27 (2011) 101-107

Y.B. Zuo, B. Jiang, P. Enright, G.M. Scamans and Z. Fan, Degassing of LM24 Al-alloy by intensive melt shearing, *Journal of Cast Metals Research* (2011)

H. Men and Z. Fan, Transition of amorphous to crystalline oxide film in initial oxide overgrowth on liquid metals, *Materials Science Technology* (2011) in press

Accepted Conference papers

Z. Fan, Y. Zuo, B. Jiang, A new technology for treating liquid metals with intensive melt shearing, *Proceedings of Light Metals Technology 2011*, 19-22 July 2011, Lüneburg, Germany.

Y. Zuo, B. Jiang, Z. Fan, DC casting of aluminium alloy with intensive melt shearing, *Proceedings of Light Metals Technology 2011*, 19-22 July 2011, Lüneburg, Germany.

Z. Fan, Y. Zuo, B. Jiang, Heterogeneous nucleation and nucleation control through liquid metal engineering, *Proceedings of 3rd International Conference on Advanced Solidification Processing (ICASP-3)*, Aachen, Germany, 7-10 June 2011.

T. Qin, Z. Fan, Molecular dynamic analysis of grain refining in aluminium with Ti-5Ti-1B, *Proceedings of 3rd International Conference on Advanced Solidification Processing (ICASP-3)*, Aachen, Germany, 7-10 June 2011.

H. Men, Z. Fan, Molecular dynamic simulations of heterogeneous nucleation in liquid aluminium, *Proceedings of 3rd International Conference on Advanced Solidification Processing (ICASP-3)*, Aachen, Germany, 7-10 June 2011.

Y. Zuo, B. Jiang, Z. Fan, Microstructure of DC cast light alloys under the influence of intensive melt shearing, *Proceedings of 3rd International Conference on Advanced Solidification Processing (ICASP-3)*, Aachen, Germany, 7-10 June 2011.

H.-T. Li, Z. Fan, Enhanced heterogeneous nucleation based on oxide in Al-alloys by intensive shearing, *Proceedings of 3rd International Conference on Advanced Solidification Processing (ICASP-3)*, Aachen, Germany, 7-10 June 2011.

F. Yan, B. McKay, Z. Fan, Effect of intensive melt shearing on microstructures and mechanical properties of Al-Mg based alloys, *Proceedings of 3rd International Conference on Advanced Solidification Processing (ICASP-3)*, Aachen, Germany, 7-10 June 2011.

1.6 Did the consortium benefit from collaborating with others? If so, how? If not, why not? Will the consortium continue to work together?

Collaboration with the University of Manchester was important for the high resolution studies of oxide/metal interfaces. The consortium will continue to work together within the LiME project portfolio

Part 2: Questions to be answered individually by each consortium member about their own involvement

2 Contact data

2.1 Your company or organisation Name: **Brunel University**

2.2 Primary contact: Prof. Z. Fan

2.3 Address: BCAST, Kingston Lane, Uxbridge, UB8 3PH

2.4 Telephone number: [REDACTED]

2.5 Email address: [REDACTED]

3 The wider picture

3.1 Was your involvement in the project worthwhile? Did your organisation achieve what it set out to achieve?

Yes. It has been a very beneficial project to participate in.
It has improved our scientific understanding of recycling and further developed our MCAST technology.
It also helped us to develop more industrial links.
We are pleased that we have achieved what we set out to achieve.

3.2 What is your annual UK R&D spend in the technology area of the project?:

Approx £20m

3.3 How many researchers do you expect to have working in the UK in the technology area of the project?:

20 to 30

4 The impact of the project

4.1 Number of new or improved products or services launched;

N/A

4.2 Number of patent or other IP applications filed worldwide related to the project's technology;

2

4.3 New markets or research areas entered, or changed market share in existing markets;

Unknown

4.4 Number of new UK jobs created or existing jobs safeguarded:

None

4.5 Improved Time-to-market or changed manufacturing or service efficiency

Unknown

4.6 Sustainability benefits (e.g. reduced waste, energy consumption etc) achieved;

Unknown

4.7 Number of relevant academic papers or trade articles published:

15

4.8 New or improved workforce skills or qualifications for UK staff:

1 PhD completed

2 Research Fellows trained

4.9 Knowledge transferred, or understanding or capability gained:

This has improved our understanding in the area of knowledge transfer and collaborating with industry.

4.10 Long term collaborations or partnerships entered into:

This has strengthened our collaboration with all of the industrial partners -in particular, Norton Aluminium and Meridian - for long term collaboration.

4.11 Any other tangible or intangible benefit or change;

This project has also been beneficial to other TSB projects running at Brunel University.

- ULARS has contributed to the success of the EPSRC Centre – LiME (based at Brunel) £4.5m
- ULARS has been the starting point of another EPSRC funded project on Low Carbon Vehicle Structures. (£4.2m)

5 About the process

5.1 Did you find involvement in the Programme beneficial? What advice or comments would you give to a prospective participant?

Yes it was beneficial to us.

5.2 How do you feel about the competition process that led to the grant? How could it be improved?

The competition process was fair and smooth.
EPSRC's contribution to the project was helpful.

5.3 How do you feel about the project monitoring? How could it be improved?

The project monitor has been very helpful. He knows the subject and understands research, he has been very supportive.

5.4 How was your relationship with the Technology Strategy Board? How could it be improved?

Very good.

6 Is there anything else that you would like to raise with us?

No

Part 2: Questions to be answered individually by each consortium member about their own involvement

7 Contact data

7.1 Your company or organisation Name: **Zyomax Limited**

7.2 Primary contact:

7.3 Address:

**Brunel Science Park,
Uxbridge,
Middlesex,
UB8 3PQ**

7.4 Telephone number:

7.5 Email address:

8 The wider picture

8.1 Was your involvement in the project worthwhile? Did your organisation achieve what it set out to achieve?

Our involvement was worthwhile in terms of gaining more understanding into the development of our melt conditioning technology for high temperature applications and realisation of its recycling and particle refining capabilities. Our major role in the project was to provide and develop the melt conditioning technology and equipment to suit the experimental demands of the project specially for recycling of Al & Mg scrap. We believe we achieved our goal as set by the project.

8.2 Were you involved in the project as an academic or industrial collaborator?

(If you were involved as an Academic, please go to question 3.9)

8.3 What is your organisation's turnover in the UK (please specify which fiscal year this applies to):

Turnover for year to 31st March 2011 - £150K

What do you expect this to be in 3 years:

N/A

8.4 How many staff do you employ in the UK?:

4

8.5 What are your organisation's total annual sales in the technology area of the project ?

N/A (Because we are a university-spin-off starter company)

What additional sales do you expect in 3 years as a result the project?:

N/A

8.6 What is your average gross margin on these current sales, and how is this defined?

N/A. (All machines supplied for this project are priced on cost basis for R&D purpose)

8.7 How much of your current sales in the technology area are from export sales outside the UK?:

N/A

8.8 How many staff do you employ (excluding researchers) in the UK **in the technology area of the project?**:

4

What do you expect this to be in 3 years:

N/A

8.9 What is your annual UK R&D spend in the technology area of the project?:

N/A

8.10 How many researchers do you expect to have working in the UK **in the technology area of the project?**:

2

9 The impact of the project

9.1 Number of new or improved products or services launched;

N/A

9.2 Number of patent or other IP applications filed worldwide related to the project's technology;

None

9.3 New markets or research areas entered, or changed market share in existing markets;

Recycling of Aluminium and Magnesium alloy scrap, Investment casting and Sand casting.

9.4 Number of new UK jobs created or existing jobs safeguarded:

2

9.5 Improved Time-to-market or changed manufacturing or service efficiency

Improved machine design and manufacture for problem free and efficient operation.

9.6 Sustainability benefits (e.g. reduced waste, energy consumption etc) achieved;

None

9.7 Number of relevant academic papers or trade articles published:

1 Trade Journal Article

9.8 New or improved workforce skills or qualifications for UK staff:

Improvement of workforce in designing and manufacturing skills. Gained a better awareness of industrial practice from interactions with companies involved during the course of this project.

9.9 Knowledge transferred, or understanding or capability gained:

The role of metal oxides in grain refinement and recycling of secondary scrap.

9.10 Long term collaborations or partnerships entered into:

Collaborations with Norton Aluminium and Aeromet International Plc.

9.11 Any other tangible or intangible benefit or change;

None

10 About the process

10.1 Did you find involvement in the Programme beneficial? What advice or comments would you give to a prospective participant?

Our involvement in this project turned out to be highly beneficial due to the vast amount of knowledge and understanding gained from the R&D side of the project in terms of the demand and importance of recycling in the automotive industry.

10.2 How do you feel about the competition process that led to the grant? How could it be improved?

The process is efficient and fair.

10.3 How do you feel about the project monitoring? How could it be improved?

The project monitoring method is extensive but effective and very significant to the success of the project.

10.4 How was your relationship with the Technology Strategy Board? How could it be improved?

Our relationship with the TSB has been good on previous projects as well as this project.

11 Is there anything else that you would like to raise with us?

No

Part 2: Questions to be answered individually by each consortium member about their own involvement

12 Contact data

12.1 Your company or organisation Name: Norton Aluminium Ltd

12.2 Primary contact: [REDACTED]

12.3 Address: Norton Green Lane, Norton Canes, Cannock, Staffs WS11 9PS

12.4 Telephone number: [REDACTED]

12.5 Email address: [REDACTED]

13 The wider picture

13.1 Was your involvement in the project worthwhile? Did your organisation achieve what it set out to achieve?

Yes. The project substantially improved our understanding of solidification mechanisms and how these may be affected within our process to produce superior properties in our materials.
However processing equipment has not yet been developed to the point of industrial exploitation in terms of throughput rate or maintenance requirements. We are not therefore yet in a position to implement the technology in our production process.

13.2 Were you involved in the project as an academic or industrial collaborator? Industrial
(If you were involved as an Academic, please go to question 3.9)

13.3 What is your organisation's turnover in the UK (please specify which fiscal year this applies to):

£20 million – year to September 2010

What do you expect this to be in 3 years:

£25m

13.4 How many staff do you employ in the UK?:

65

13.5 What are your organisation's total annual sales in the technology area of the project ?

£20m – all our sales are directly relevant and could potentially apply this technology.

What additional sales do you expect in 3 years as a result the project?:

Difficult to estimate until or unless we have proven industrial scale equipment to apply, although there is and will continue to be increased sales from our improved technical understanding.

13.6 What is your average gross margin on these current sales, and how is this defined?

Approximately 24%, defined as margin over materials.

13.7 How much of your current sales in the technology area are from export sales outside the UK?:

£8m

13.8 How many staff do you employ (excluding researchers) in the UK **in the technology area of the project?**:

65

What do you expect this to be in 3 years:

70

13.9 What is your annual UK R&D spend in the technology area of the project?:

£100k

13.10 How many researchers do you expect to have working in the UK **in the technology area of the project?**:

2

14 The impact of the project

14.1 Number of new or improved products or services launched;

Continuing minor improvements across the range of products supplied

14.2 Number of patent or other IP applications filed worldwide related to the project's technology;

Nil

14.3 New markets or research areas entered, or changed market share in existing markets;

Continuing development of existing markets

14.4 Number of new UK jobs created or existing jobs safeguarded:

5 additional jobs created during project period

14.5 Improved Time-to-market or changed manufacturing or service efficiency

No effect.

14.6 Sustainability benefits (e.g. reduced waste, energy consumption etc) achieved;

Project allows equivalent mechanical properties to be obtained from lower grade feedstocks, allowing greater proportion of recycled aluminium to be used in premium alloys.

14.7 Number of relevant academic papers or trade articles published:

None

14.8 New or improved workforce skills or qualifications for UK staff:

Continuing skills and technical development of key staff. No new formal qualifications.

14.9 Knowledge transferred, or understanding or capability gained:

As above

14.10 Long term collaborations or partnerships entered into:

Actively working on a continuing basis with Brunel University, Oxford & Manchester Universities, Innoval, Jaguar Land Rover and Novelis as a direct result of this project.

14.11 Any other tangible or intangible benefit or change;

Improved technical knowledge, facilitating contact with R&D and engineering departments within prestigious OEM's and their supply base, leading to improved business opportunities.

15 About the process

15.1 Did you find involvement in the Programme beneficial? What advice or comments would you give to a prospective participant?

Yes. Need to be involved, actively participate and help direct the project activity to produce results applicable to you as the industrial collaborator.

15.2 How do you feel about the competition process that led to the grant? How could it be improved?

Appropriate way to direct limited grant funding – projects should have clear objectives with good paybacks (both financial and otherwise).

15.3 How do you feel about the project monitoring? How could it be improved?

Our Monitoring Officer was knowledgeable and helpful. These are very technical projects and it is probably difficult to find MO's with an appropriate technical background to be able to understand and contribute to the project – we were lucky that ours did.

15.4 How was your relationship with the Technology Strategy Board? How could it be improved?

We had limited contact with the TSB itself. The relationship was handled by one of the other project participants. Our relationship was mainly one of submitting reports and claims and receiving payments. In this respect the relationship was smooth from our perspective.

16 Is there anything else that you would like to raise with us?

Thank you for your assistance with this project. It is very unlikely it would have gone ahead without your support.

Part 2: Questions to be answered individually by each consortium member about their own involvement

17 Contact data

17.1 Your company or organisation Name: Meridian Lightweight Technologies

17.2 Primary contact: [REDACTED]

17.3 Address: Orchard Way, Calladine Park, Sutton in Ashfield, Nottinghamshire, NG17 1JU

17.4 Telephone number: [REDACTED]

17.5 Email address: [REDACTED]

18 The wider picture

18.1 Was your involvement in the project worthwhile? Did your organisation achieve what it set out to achieve?

We were not able to carry out the production trials as planned due to the economic conditions at the time and multiple changes in ownership and executive teams. The trials that were conducted did not demonstrate the mechanical property improvements that were expected but we intend on maintaining our links as we see value in this technology and the understanding it is creating.

18.2 Were you involved in the project as an academic or industrial collaborator? Industrial
(If you were involved as an Academic, please go to question 3.9)

18.3 What is your organisation's turnover in the UK (please specify which fiscal year this applies to):

£15m (2010)

What do you expect this to be in 3 years:

£20m

18.4 How many staff do you employ in the UK?:

100

18.5 What are your organisation's total annual sales in the technology area of the project ?

0

What additional sales do you expect in 3 years as a result the project?:

0

18.6 What is your average gross margin on these current sales, and how is this defined?

NA

18.7 How much of your current sales in the technology area are from export sales outside the UK?:

NA

18.8 How many staff do you employ (excluding researchers) in the UK **in the technology area of the project?**:

0

What do you expect this to be in 3 years:

0

18.9 What is your annual UK R&D spend in the technology area of the project?:

0

18.10 How many researchers do you expect to have working in the UK **in the technology area of the project?**:

0

19 The impact of the project

19.1 Number of new or improved products or services launched;

0

19.2 Number of patent or other IP applications filed worldwide related to the project's technology;

0

19.3 New markets or research areas entered, or changed market share in existing markets;

0

19.4 Number of new UK jobs created or existing jobs safeguarded:

0

19.5 Improved Time-to-market or changed manufacturing or service efficiency

0

19.6 Sustainability benefits (e.g. reduced waste, energy consumption etc) achieved;

0

19.7 Number of relevant academic papers or trade articles published:

0

19.8 New or improved workforce skills or qualifications for UK staff:

Improved understanding of nucleation mechanisms

19.9 Knowledge transferred, or understanding or capability gained:

Improved understanding of nucleation mechanisms

19.10 Long term collaborations or partnerships entered into:

We are an industrial partner in LiME

19.11 Any other tangible or intangible benefit or change;

Not at this time

20 About the process

20.1 Did you find involvement in the Programme beneficial? What advice or comments would you give to a prospective participant?

Yes, ensure engagement of the project with company decision makers

20.2 How do you feel about the competition process that led to the grant? How could it be improved?

I was not that involved in this process

20.3 How do you feel about the project monitoring? How could it be improved?

I was happy with this aspect of the project

20.4 How was your relationship with the Technology Strategy Board? How could it be improved?

I do not have much of a relationship to be honest

21 Is there anything else that you would like to raise with us?

No

Part 2: Questions to be answered individually by each consortium member about their own involvement

22 Contact data

22.1 Your company or organisation Name: Innoval Technology Ltd

22.2 Primary contact: [REDACTED]

22.3 Address:
Beaumont Close
Banbury
OX16 1TQ

22.4 Telephone number: [REDACTED]

22.5 Email address: [REDACTED]

23 The wider picture

23.1 Was your involvement in the project worthwhile? Did your organisation achieve what it set out to achieve?

Innoval provided project coordination and management. The original three year project was extended by nine months and this resulted in significant additional work for Innoval. Innoval have gained further experience in the leadership and management of TSB projects.

23.2 Were you involved in the project as an academic or industrial collaborator?

As an industrial collaborator

23.3 What is your organisation's turnover in the UK (please specify which fiscal year this applies to):

£2,059,013 (2009)

What do you expect this to be in 3 years:

£2,500,000

23.4 How many staff do you employ in the UK?:

26

23.5 What are your organisation's total annual sales in the technology area of the project ?

Innoval do not sell manufactured products

What additional sales do you expect in 3 years as a result the project?:

Continued income from further involvement in TSB projects up to £200k/year.

23.6 What is your average gross margin on these current sales, and how is this defined?

N/A

23.7 How much of your current sales in the technology area are from export sales outside the UK?:

N/A

23.8 How many staff do you employ (excluding researchers) in the UK **in the technology area of the project?**:

2 FTE on TSB project support

What do you expect this to be in 3 years:

2-3 FTE on TSB project support

23.9 What is your annual UK R&D spend in the technology area of the project?:

£200k

23.10 How many researchers do you expect to have working in the UK **in the technology area of the project?**:

2

24 The impact of the project

24.1 Number of new or improved products or services launched;

The project has helped to consolidate and maintain staffing levels at Innoval Technology.

24.2 Number of patent or other IP applications filed worldwide related to the project's technology;

None

24.3 New markets or research areas entered, or changed market share in existing markets;

Participation in further TSB projects and in the LiME IMRC

24.4 Number of new UK jobs created or existing jobs safeguarded:

2-3 jobs safeguarded and Innoval Technology stabilised as a major light metals UK materials research resource in the UK

24.5 Improved Time-to-market or changed manufacturing or service efficiency

N/A

24.6 Sustainability benefits (e.g. reduced waste, energy consumption etc) achieved;

This is contained in related TSB projects

24.7 Number of relevant academic papers or trade articles published:

Several trade articles and conference publications.

24.8 New or improved workforce skills or qualifications for UK staff:

Innoval Technology have developed a better understanding of melt conditioning and casting and the technical requirements for recycling aluminium and magnesium alloys

24.9 Knowledge transferred, or understanding or capability gained:

Innoval have developed their capability in cost and energy modelling of aluminium recycling

24.10 Long term collaborations or partnerships entered into:

Innoval continue to work closely with Brunel University for the promotion and exploitation of melt conditioning and recycling of aluminium and magnesium into high performance products

24.11 Any other tangible or intangible benefit or change;

Innoval have developed their expertise in recycling and upcycling of aluminium alloys and this has resulted in significant publicity and opportunities for further collaborative projects and presentations at sustainability conferences

25 About the process

25.1 Did you find involvement in the Programme beneficial? What advice or comments would you give to a prospective participant?

Our involvement with the project has been highly beneficial

25.2 How do you feel about the competition process that led to the grant? How could it be improved?

The process works well and is efficient .

25.3 How do you feel about the project monitoring? How could it be improved?

The project monitor was always helpful when difficulties arose either in administration or on technical issues. We could not have wished for better support.

25.4 How was your relationship with the Technology Strategy Board? How could it be improved?

Innoval has always had a good relationship with the TSB

26 Is there anything else that you would like to raise with us?

The outcomes of the project will have a major long term rather than a short term impact

Part 3: For completion by the Project Monitoring Officer

We would like your view of how our projects could be better run in the future, based on any lessons learned from this one. In answering, please keep your replies factual. Avoid comments on personalities and technical matters unlikely to be repeated elsewhere.

27 What lessons can be learned from this project:

- (a) In terms of the Technology Strategy Board's processes, and
- (b) In terms of the project's management and methods?

A particular feature of the PM's methods was to provide detailed yet concise minutes of QRMs shortly after the meetings. Further the agenda pack always had back-up notes showing the background to the project, the start and end dates (including those of quarters), the finance for the project and a simplified Gantt chart from the second level plan. I would consider this best-practice since it was very easy to refer to these documents when reporting to TSB.

This project was monitored under Version 3 of the old system, which had a large reporting burden. Obviously this was changed in Version 4.

A project partner, Meridian, experienced numerous take-overs and management changes during the course of the project, which caused significant difficulties in carrying out all the trials and involved significant risk mitigation. A "quick reference guide", based on TSB's considerable experience of dealing with this problem over the years, would be a useful addition to the guidance notes for the PM and MO.

Monitoring Officer Name: [REDACTED]

Monitoring Officer email: [REDACTED]