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Document Status: With Council

EPSRC Reference: EP/D050839/1

Standard Report

Scheme: Standard Research

Programme: Engineering science: components

Award Holding Organisation

Organisation	Brunel University	Research Organisation Reference:	R25088
Division or Department	Sch of Engineering and Design		

Title of Research Project

Processing of Wrought Magnesium Alloys by a Rheoforming Approach

Project Details

Start Date	01/04/2006	Duration of Grant (months)	45
End Date	31/12/2009		
Report Due Date	31/03/2010		

Funds Awarded

Description	Value
Grant Total	£ 762,029.00

Beneficiaries

(1) The rheoforming processes represent a step change in the manufacturing technology for production of lightweight automotive and aerospace components with improved quality and reduced production cost. The new technologies circumvent existing liquid metal processing and casting technology boundaries with a simpler, lower cost process. A specific impact is the ability to produce alloys with compositions beyond those available from conventional melting technologies. This means that alloys with extended compositional ranges can be provided for the first time. Such alloys have only been made in the past by expensive and multi-step complex powder routes and/or by mechanical alloying. The rheoforming technologies can make alloys of extreme specific strength, modulus and ductility for both aerospace and other transportation applications. The potential for new alloys and applications is enormous and the technology is particularly effective for the recycling of highly impure secondary metal (low grade scrap). In addition, rheoforming processes in combination with the conventional solid deformation techniques offer a complete technological solution to the magnesium industry and provide numerous opportunities for new applications. The applications of the rheoforming technologies will greatly increase the competitiveness of the UK companies, including equipment manufacturer, materials supplier, component producer and car manufacturer. The direct benefit to the UK economy would be in millions of

pounds.

(2) The academic community will benefit from this project in terms of improved understanding on solidification behaviour under forced convection. Scientifically, solidification under intensive forced convection, the theoretical basis for the rheoforming processes, opens a new dimension for solidification research. Control of alloy solidification has been traditionally achieved by chemical means (i.e., through variation of alloy compositions). The rheoforming processes have successfully demonstrated that both nucleation and crystal growth can be effectively controlled by application of an intensive shear stress-strain field. This will allow the development of a theoretical framework for solidification under externally applied physical fields, which is anticipated to have profound implications to future solidification research and technological development. In addition, the academic community will also benefit from better understandings on the flow behaviour of semisolid slurry under shear, deformation mechanisms of fine-grained Mg alloys and kinetics of phase transformation in fine-grained Mg alloys. Perhaps more importantly, solidification under intensive forced convection is not only applicable to Mg-alloys, but also potentially applicable to other structural metals and alloys, such as Al-alloys, Cu-alloys, Ti-alloys, Ni-alloys and steels. All such theoretical understandings can be effectively used to develop processing technologies for other structural alloys. This will provide new life to a seemingly mature and conventional sector.

(3) The general public will benefit in terms of improved performance of motorcars, such as better fuel economy, reliability and durability. The general public will also benefit from an improved environment resulting from reduced CO₂ emission. Rheoforming processes, as enabling technologies, will increase the application of Mg in the automotive industries, and therefore reduce substantially the environmental burden. Indeed for every tonne of Mg used in the place of traditional heavier metals, there is a 30 tonne reduction of CO₂ emission over the life of the car (12 years on an average).

Objectives

The main objectives of the research [up to 4000 chars] at proposal time

This proposal aims to develop the rheoforming technologies for semi-finished wrought Mg-alloy products with good deformability, high productivity and low cost. The specific objectives of the proposed project are:

- (1) Development of the rheoforming equipment and processes, including DC rheocasting for billets and slabs, rheoextrusion for extruded profiles and twin-roll rheocasting for flat products;
- (2) Understanding of the solidification behaviour of wrought Mg-alloys under intensive forced convection;
- (3) Evaluation of tensile, fatigue and creep properties of rheoformed Mg-alloys under different processing conditions;
- (4) Assessment of deformation mechanism and deformability of rheoformed Mg alloys.

The main objectives of the research [up to 4000 chars] at report time

This proposal aims to develop the rheoforming technologies for semi-finished wrought Mg-alloy products with good deformability, high productivity and low cost. The specific objectives of the proposed project are:

- (1) Development of the rheoforming equipment and processes, including DC rheocasting for billets and slabs, rheoextrusion for extruded profiles and twin-roll rheocasting for flat products;
- (2) Understanding of the mechanisms for enhanced heterogeneous nucleation by intensive melt shearing;
- (3) Understanding of the solidification behaviour of wrought Mg-alloys under intensive forced convection;
- (4) Understanding the microstructural evolution during various down stream processing of the rheoformed Mg-alloys;
- (5) Evaluation of the mechanical properties of the rheoformed Mg-alloys before and after thermo-mechanical processing under different processing conditions.

Follow on Support

Awarding Organisation	Application Reference	Title of Project	Decision Made	Award Made	Start Date	End Date	Amount Sought / Awarded (£)
EPSRC [Research Council / Research Council Institute]	EP/H026177/1	Innovative Manufacturing Research Centre for Liquid Metal Engineering	Yes	Yes	01/04/2010	31/03/2015	4457826

Grant Conditions

SCHEME CONDITIONS

RGC: Research Grants
: Pre-FEC Research Grants awarded by the following Research Councils are made to Research Organisations on the basis of this single set of core terms and conditions:

Biotechnology and Biological Sciences Research Council (BBSRC)
Economic and Social Research Council (ESRC)
Engineering and Physical Sciences Research Council (EPSRC)
Medical Research Council (MRC)
Natural Environment Research Council (NERC)
Particle Physics and Astronomy Research Council (PPARC)
Arts and Humanities Research Council (AHRC)

Individual Councils may add additional conditions to the grant to reflect the particular circumstances and requirements of their organisation, or the nature of a particular grant. Acceptance of a research grant constitutes acceptance of both the core conditions and any additional conditions.

The Research Councils reserve the right to vary these terms and conditions.

Definitions

Dipstick Testing: A programme of visits and office-based tests to seek assurance that research grant funds are used for the purpose for which they are given and that grants are managed in accordance with the terms and conditions under which they are awarded.

Investigator: the generic term used to identify the individual member of staff to whom the research project is assigned. The Principal Investigator takes responsibility for the intellectual leadership of the research project and for the overall management of the research.

Large Capital: items of equipment above a threshold value set by the individual Research Council and specified in the grant. Large capital items are not paid by profiled payments; they require claims to be submitted.

Research Council: any of the bodies listed above, including the Arts and Humanities Research Board.

Research Grant: a contribution to the costs of a stated research project which has been assessed as suitable for funding through the procedures established by the relevant Research Council. Research Grants provide for the eligible direct costs of the research, plus a contribution to indirect costs.

Research Organisation: the organisation to which the research grant is awarded and which takes responsibility for the management of the research project and the accountability of funds provided.

References in these terms and conditions to statutory provisions and guidance include any subsequent amendments or re-enactments.

Data Protection Regulations

The Research Councils will use information provided on the grant proposal form for processing the proposal, the award of any consequential grant, and for the payment, maintenance and review of the grant. This may include:

Registration of proposals

Operation of grants processing and management information systems

Preparation of material for use by referees and peer review panels

Administration, investigation and review of grant applications

Statistical analysis in relation to the evaluation of research and the study of trends

Policy and strategy studies.

To meet the Research Councils' obligations for public accountability and the dissemination of information, details of grants may also be made available on the Research Councils' web sites and other publicly available databases, and in reports, documents and mailing lists.

Freedom of Information Act and Environmental Information Regulations

Attention is drawn to the provisions of the Freedom of Information Act 2000 (FOIA) and the Environmental Information Regulations (EIRs). Research Councils have issued Publication Schemes which set out the types of information publicly available on their websites or published as documents. In addition, Research Councils have an obligation to respond to specific requests and may be required to disclose information about or provided by Research Organisations. In some cases the Research Council may consult the Research Organisation before disclosure, but it is under no obligation to do so. If a Research Organisation considers that any information it provides to a Research Council would be subject to an exemption under FOIA or the EIRs it should clearly mark the information as such and provide an explanation of why it considers the exemption applies and for how long. The Research Council will consider this explanation before disclosure, but it is not obliged to accept it as binding.

Where a Research Council determines that a Research Organisation is holding information on its behalf that it requires in

order to comply with its obligations under FOIA or EIRs, the Research Organisation undertakes to provide access to such information as soon as reasonably practicable on request of the Research Council and in any event within 5 working days.

In some cases Research Organisations may be directly responsible for complying with FOIA and the EIRs; in such cases the Research Councils accept no responsibility for any failure to comply by the Research Organisations.

RG 1 Responsibilities of the Research Organisation

The Research Organisation must provide the infrastructure needed to carry out the research, together with any specific contributions identified in the application.

The Research Organisation must ensure that Investigators are made aware of their responsibilities and that they observe the terms and conditions of research grants.

The Research Organisation must ensure that the research supported by the grant complies with all relevant legislation and Government regulation, including that introduced while work is in progress. This requirement includes approval or licence from any regulatory body that may be required before the research can commence.

The Research Organisation is expected to adopt the principles, standards and good practice for the management of research staff set out in the 1996 Concordat for the Career Management of Contract Research Staff, and subsequent amendments.

The Research Organisation must notify the Research Council of any change in its status, or that of any of the investigators, that might affect the eligibility to hold a research grant.

The Research Organisation must ensure that the requirements of the Employing Organisation under the Department of Health's Research Governance Framework for Health and Social Care are met for research involving NHS patients, their organs, tissues or data, and that the necessary arrangements are in place with partner organisations. Where it also accepts the responsibilities of a Sponsor (as defined in the Governance Framework), it must also ensure that the requirements for Sponsors are met.

The Research Organisation must ensure proper financial management of research grants and accountability for the use of public funds.

RG 2 Research Governance

It is the responsibility of the Research Organisation to ensure that the research is organised and undertaken within a framework of best practice that recognises the various factors that may influence or impact on a research project. Particular requirements are to ensure that all necessary permissions are obtained before the research begins, and that there is clarity of role and responsibility among the research team and with any collaborators. The Research Councils expect research to be conducted in accordance with the highest standards of scientific integrity and research methodology.

Research Ethics

The Research Organisation is responsible for ensuring that ethical issues relating to the research project are identified and brought to the attention of the relevant approval or regulatory body. Approval to undertake the research must be granted before any work requiring approval begins. Ethical issues should be interpreted broadly and may encompass, among other things, the involvement of human participants in research, the use of animals, research that may result in damage to the environment and the use of sensitive economic, social or personal data.

Use of Animals in Research

Wherever possible, researchers must adopt procedures and techniques that avoid the use of animals. Where this is not possible, the research should be designed so that:

The least sentient species with the appropriate physiology is used;

The number of animals used is the minimum sufficient to provide adequate statistical power to answer the question posed;

The severity of procedures performed on animals is kept to a minimum. Experiments should be kept as short as possible. Appropriate anaesthesia, analgesia and humane end points should be used to minimise any pain and suffering.

The provisions of the Animals (Scientific Procedures) Act 1986, and any amendments, must be observed and all necessary licences must have been received before any work requiring approval takes place.

Medical and Health Research

The Research Organisation is responsible for managing and monitoring the conduct of medical and health research in a manner consistent with the Department of Health's Research Governance Framework for Health and Social Care. There must be effective and verifiable systems in place for managing research quality, progress and the safety and well-being of patients and other research participants. These systems must promote and maintain the relevant codes of practice and all relevant statutory review, authorisation and reporting requirements.

Health-related research within the social sciences that falls outside the Department of Health's Research Governance Framework must meet the provisions and guidelines of the ESRC's Research Ethics Framework. While this research may involve patients, NHS staff or organisations, it is defined as research that poses no clinical risk or harm to those who are the subjects of research. Research Organisations must ensure that appropriate arrangements are in place for independent ethics review of social science research that meet local research ethics committee standards.

Significant developments must be assessed as the research proceeds, especially those that affect safety and well-being, which should be reported to the appropriate authorities and to the Research Council. The Research Organisation must take appropriate and timely action when significant problems are identified. This may include temporarily suspending or terminating the research.

The Research Organisation is responsible for managing and monitoring statutory requirements for which it accepts responsibility, for example, in relation to legislation on clinical trials, use of human organs, tissues and data.

Guidance by the MRC on the conduct of medical research, and by ESRC on the conduct of social science research, provided on behalf of all Research Councils, must be observed.

Health and Safety

The Research Organisation is responsible for ensuring that a safe working environment is provided for all individuals associated with a research project. Its approach and policy on health and safety matters must meet all regulatory and legislative requirements and be consistent with best practice recommended by the Health & Safety Executive. Appropriate care must be taken where researchers are working off-site. The Research Organisation must satisfy itself that all reasonable health and safety factors are addressed. The Research Councils reserve the right to require the Research Organisation to undertake a safety risk assessment in individual cases where health and safety is an issue, and to monitor and audit the actual arrangements made.

Misconduct and Conflicts of Interest

The Research Organisation is required to have in place procedures for governing good research practice that meet the requirements of the Research Councils' guidance on good practice. The Research Organisation must ensure that there are reliable systems and processes in place for the prevention of research misconduct e.g. plagiarism, falsification of data, together with well-defined and clearly-publicised arrangements for investigating and resolving allegations of misconduct. Where an allegation of misconduct arises in respect of a researcher supported by a research grant, the Research Council must be informed immediately and notified of the outcome of any investigation.

The Research Organisation must ensure that potential conflicts of interest in research are declared and subsequently managed.

RG 3 Use of Funds

Subject to the following conditions, grant funds may be deployed to meet eligible research costs, without reference to the Research Council, in such a manner as to best carry out the research. Research grant funds are cash limited and the grant is made on the understanding that its value will not be increased, except as stated in these terms and conditions. Research grant funds are provided to sustain a specific research project. Under no circumstances may funds be used to meet costs incurred by any other project or activity.

RG 4 Starting Procedures

The start of a research grant is defined as the date on which the first member of staff paid from the grant starts work, or, if there are no staff or if staff are intended to commence later in the project, the date on which expenditure under another heading is first incurred.

Notification of this date, by submission of the starting certificate, will constitute acceptance of the grant and will activate the profiled payments. Submission of the starting certificate is required not more than 42 days after the actual start date. A separate acceptance letter may be required in certain circumstances.

The start of research may be delayed by up to 6 months (ESRC and AHRB 3 months) after the start date stated in the

award letter, the duration of the grant remaining unchanged. The grant may lapse if not started within this period.

RG 5 Changes in Research Project

The Research Council must be consulted in the event of any major change in the proposed research, including failure to gain access to research facilities and services, particularly those which make it unlikely that the objectives of the research can be achieved. If appropriate, revised proposals may be required. The Research Council reserves the right to make a new grant in place of the existing grant, or to revise, retain or terminate the existing grant.

RG 6 Transfers between Headings

The Research Organisation may increase the amounts within individual headings of expenditure by transfer from another heading, subject to the following restrictions:

Indirect costs cannot be transferred;

Funds provided for Large Capital, or savings on the purchase of such items, are not transferable without prior written approval;

If the staff heading is increased by transfer from another heading, proportional funds must also be transferred to the indirect costs heading.

RG 7 Extensions

After a research grant has started, the duration may be extended by a total of up to 6 months, subject to prior written approval. Extensions may cover breaks or delays in the appointment of staff, periods of maternity leave or paid sick leave exceeding 3 months for staff funded by the grant, or other exceptional circumstances with the agreement of the Research Council. Requests for extensions should be made as soon as the requirement is identified and confirmed when the period required is known. All requests for extensions must be made before the grant ends.

RG 8 Staff

The Research Organisation must assume full responsibility for staff funded through research grants and, in consequence, accept all duties owed to and responsibilities for these staff, including, without limitation, their terms and conditions of employment and their training and supervision, arising from the employer/employee relationship. Staff must be appointed on terms that are no less favourable than those of comparable posts in the Research Organisation.

The Research Organisation must provide research staff with a statement, at the outset of their employment, setting out the provisions for career management and development, including personal skills training.

Research staff may undertake teaching and demonstrating work for up to 6 hours a week (pro rata for part-time staff) during normal working hours provided that this work is related to the research project to which they were appointed.

RG 9 Maternity Pay and Leave

Research grant funds may be used to fund paid maternity leave if staff fulfil the qualifying conditions of the Research Organisation. Funding may be sought at the end of a grant to cover the additional costs of either a substitute appointment or an extension of the grant. The salary of any substitute appointment must not exceed that of the individual on maternity leave. Similar provisions will apply in respect of paternity leave.

Research grant funds may be used to provide paid maternity and paternity leave only to the extent that it is taken during the original period of the grant. The Research Organisation will be responsible for any liability for maternity and paternity pay for staff supported by the research grant outside the original period of the grant. If, for example, a research grant ends while a member of research staff is part-way through her maternity leave, the Research Organisation will be responsible for that part of the maternity leave which is taken after the research grant has ended.

RG 10 Sick Leave

During the period of the research grant, funds may be used to provide paid sick leave to staff supported by a research grant who fulfil the qualifying conditions of the Research Organisation. Where there is a continuous period of sick leave in excess of 3 months, the Research Organisation may apply to the Research Council to discuss the possibility of a substitute appointment to safeguard progress on the project, or an extension to the duration of the project, if the period of leave can be predicted.

For the purposes of the provisions of RG 9 and RG 10, the Research Organisation will be compensated at the end of the grant for any additional costs or time resulting from maternity leave, paternity leave or sick leave, falling within the original

period of the grant. The duration of a grant will be extended only if the period can be accommodated within the maximum period allowed for extensions.

RG 11 Procurement of Equipment

The procurement of equipment and services must comply with all relevant national and EU legislation and the Research Organisation's own financial policy. Accepted procurement best practice in the higher education sector must be observed. For all equipment costing more than 25,000, professionally qualified procurement staff must be consulted at the beginning of the procurement process and must approve the order before it is placed with a supplier.

RG 12 Ownership and Use of Equipment

Equipment is provided primarily for use on the research project for which the research grant was awarded, and belongs to the Research Organisation. In certain circumstances the Research Council may wish to retain ownership throughout the period of the grant and possibly beyond. In such cases, the grant will be subject to an additional condition.

The Research Council must be informed if, during the life of the research grant, the need for the equipment diminishes substantially or it is not used for the purpose for which it was funded. The Research Council reserves the right to determine the disposal of such equipment and to claim the proceeds of any sale.

Any proposal to transfer ownership of the equipment during the period of the grant is subject to prior approval by the Research Council. After the research has ended, the Research Organisation is free to use the equipment without reference to the Research Council, but it is nevertheless expected to maintain it for research purposes as long as is practicable.

Where there is spare capacity in the use of the equipment, the Research Council expects this to be made available to other users. Priority should be given to research supported by any of the Research Councils and to Research Council-funded students.

RG 13 Claims for Large Capital Equipment

Claims are required for major purchases of equipment at a level set by the individual Research Council and specified in the grant. In such cases, claims must be submitted in arrears. Submission of large capital claims should normally be made within a year of the start date of the grant and must be accompanied by an invoice for the relevant equipment. Reimbursement will be limited to the actual price paid, within the awarded value. Savings on the purchase cost of large capital equipment may be used elsewhere in the grant subject to prior approval.

RG 14 Transfer of a Grant

The Research Organisation must notify the Research Council if the Principal Investigator intends to transfer to another organisation. If this organisation is eligible to hold research grants, and is able to provide a suitable environment to enable the project to be successfully completed, the expectation is that the grant would be transferred with the investigator. Written agreement to this is required from both the relinquishing and receiving organisations.

The Research Council will wish to be assured that satisfactory arrangements have been agreed that will enable the project to be undertaken, or to continue, in accordance with its research objectives. If suitable arrangements cannot be agreed, the Research Council will consider withdrawing its offer of support or terminating the grant.

Where there is a basis for continuing involvement by the relinquishing organisation, agreement should be reached between both organisations on the apportionment of work and the distribution of related funding.

RG 15 Change of Principal Investigator

The Research Organisation must consult the Research Council if it is proposed to change the Principal Investigator, for example, following retirement or resignation. Where the Principal Investigator is transferring to another organisation eligible to hold a research grant, the provisions of RG 15 will apply. In other circumstances, the Research Organisation may nominate a replacement Principal Investigator. The Research Council will wish to be assured that the replacement meets the eligibility criteria for Principal Investigators and has the expertise and experience to lead the project to a successful conclusion, in accordance with its research objectives.

RG 16 Annual Statement

The Research Organisation may be required to return a statement each year showing payments made by the Research Council during the previous financial year for all the research grants it holds. Where a statement is required, the Research Organisation must certify, by signing and returning the statement, that expenditure has been incurred in accordance with the grant conditions, and those grants shown as current are continuing. No further payments will be

made until the signed annual statement has been received by the Research Council.

RG 17 Expenditure Statements

The Research Organisation must complete and return an expenditure statement within 3 months of the end date of a research grant. Once an expenditure statement has been received and the expenditure incurred has been reconciled against payments made, it will be considered as final.

Costs arising from maternity leave or sick leave should be identified in the exceptional items heading of the statement.

The Research Council reserves the right to require the Research Organisation to complete and submit a statement of expenditure at any time during the course of a research grant, or to provide supplementary information in support of an interim or final expenditure statement.

RG 18 Inspection

The Research Council reserves the right to have reasonable access to inspect the records and financial procedures associated with research grants or to appoint any other body or individual for the purpose of such inspection.

The Research Organisation must, if required by the Research Council, provide a statement of account for the grant, independently examined by an auditor who is a member of a recognised professional body, certifying that the expenditure has been incurred in accordance with the research grant terms and conditions.

Research Councils will undertake periodic reviews of Research Organisations within the Dipstick Testing programme to seek assurance that research grants are managed in accordance with the terms and conditions under which they are awarded.

RG 19 Final Report

A report on the conduct and outcome of the project must be submitted by the Research Organisation within three months of the end of the research grant, on the form provided. No further application from a Principal Investigator will be considered while a final report is overdue.

If there are exceptional reasons that will prevent submission of the final report within the period allowed, a written request may be made, before the due date passes, for the submission period to be extended.

RG 20 Sanctions

If the final report or the final expenditure statement is not received within the period allowed, the Research Council may recover 20% of expenditure incurred on the grant. All payments made by the Research Council may be recovered if the report or statement is not received within 6 months of the end of the grant.

RG 21 Public Engagement

It is the responsibility of the Research Organisation and the Investigators to actively communicate the research to the public at both local and national level, and to raise awareness of the role of science and research in any related issues of public interest. Special schemes exist in some Research Councils providing additional support for these activities, or earmarked funding may be provided in the grant for this purpose.

RG 22 Commercial Exploitation

Unless stated otherwise, the ownership of intellectual property, and responsibility for its exploitation, rests with the Research Organisation. The Research Council may, in individual cases, reserve the right to retain ownership of intellectual property and to arrange for it to be exploited for the national benefit and that of the Research Organisation involved. This right, if exercised, will be set out in an additional condition.

It is the responsibility of the Research Organisation, and all engaged in the research, to make every effort to ensure that any potentially valuable results obtained in the course of the research are exploited, and that there is a suitable return to the Research Organisation and the researchers from any such exploitation. The Research Organisation must ensure that all those associated with the research are aware of, and accept, the arrangements for exploitation.

Collaborative arrangements are expected to be put on a formal basis through an agreement covering the contributions and rights of the organisations and individuals concerning exploitation. Such agreements must be in place before the research begins. The terms of collaboration agreements must not conflict with the Research Councils' terms and conditions of research grants.

RG 23 Research Monitoring and Evaluation

While it is the responsibility of the Research Organisation and the Investigator to manage the research, the Research Council reserves the right to call for periodic information on progress or to visit the Investigator. The Investigator may also be asked to attend meetings to exchange information and ideas with others undertaking research in the same or similar fields.

The Investigator must make all reasonable efforts, if so invited, to attend events or activities organised by the Research Council concerning the research undertaken. Such events may be held after a grant has finished.

RG 24 Publication and Acknowledgement of Support

The Investigator should, subject to the procedures laid down by the Research Organisation, publish the results of the research in accordance with normal academic practice. Publications and other forms of media communication, including media appearances, press releases and conferences, must acknowledge the support received from the Research Council, quoting the grant reference number.

RG 25 Disclaimer

The Research Councils accept no liability, financial or otherwise, for expenditure or liability arising from the research funded by the research grant, except as set out in these terms and conditions, or otherwise agreed in writing.

Where studies are carried out in an NHS Trust, the Trust has a duty of care to its patients. The Research Council does not accept liability for any failure in the Trust's duty of care, or any negligence on the part of its employees.

The Research Councils reserve the right to terminate the grant at any time, subject to reasonable notice and to any payment that may be necessary to cover outstanding and unavoidable commitments.

If a grant is terminated, no liability for payment or redundancy or any other compensatory payment for the dismissal of staff funded by the grant will be accepted, but negotiations will be held with regard to other contractual commitments and concerning the disposal of assets acquired under the research grant.

RG 26 Status

These terms and conditions will be governed by the laws of England and Wales; all matters relating to the terms and conditions will be subject to the exclusive jurisdiction of the courts of England and Wales.

If any provision of these terms and conditions is found by a court or other legitimate body to be illegal, invalid or unreasonable, it will not affect the remaining terms and conditions which will continue in force.

These terms and conditions, together with any additional conditions set out in the grant, contain the whole agreement between the Research Council and the Research Organisation in relation to the stated research grant. The Research Council and the Research Organisation do not intend that any of these terms and conditions should be enforceable by any third party.

Investigators

Role	Name	Organisation	Division or Department
Principal Investigator	Professor Z Fan	Brunel University	Ctr for Advanced Solidification Tech
Co-Investigator	Dr A Das	Swansea University	School of Engineering

Revenue

Please estimate the total value raised from the Intellectual Property generated through the grant (£)

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Project Partners

Details of partners in the project and their contributions to the research.

1	Organisation Details	Contact Details
	Jaguar and Land Rover Gaydon Engineering Centre	<div></div> JLR

Lighthorne Warwick UNITED KINGDOM CV35 0RR			Banbury Road Gaydon Warwick United Kingdom CV35 0RG		
Direct contribution to project			Indirect contribution to project		
	Description	Value (£)		Description	Value (£)
Comments on partnership		JLR has been a wonderful research partner for this research project. Over the past few years, this partnership has been extended beyond the original scope for the rheoforming of magnesium alloys, to a wider research area concerning vehicle weight reduction through solidification processing of light-weight alloy components. JLR has been a partner of 2 successful TSB projects involving the Brunel rheoforming technologies. More importantly, JLR has invested heavily into the EPSRC Centre for Innovative Manufacturing in liquid Metal Engineering based at Brunel University funded recently by EPSRC (see the attached letter of support from JLR).			

2	Organisation Details		Contact Details		
Magnesium Elektron Ltd P O Box 23, Rake Lane Swinton Manchester UNITED KINGDOM M27 8DD			<div></div> PO Box 23 Rake Lane Swinton Manchester United Kingdom M27 8DD		
Direct contribution to project			Indirect contribution to project		
	Description	Value (£)		Description	Value (£)
Comments on partnership		MEL has been a long-standing research partner to our research group. MEL has made a valuable contribution to the success of this research project in terms of supplying materials, expert advice of process development and provision of equipment time for the research team. This partnership has been extended into the EPSRC Centre for Innovative			

Comments on partnership	Innoval has been a wonderful research partner for this project. A number of research engineers were seconded into Brunel to participate the research programme. They have made very useful contribution to the research project. More importantly, this partnership has extended into 4 successful TSB collaborative research programmes related to the Brunel rheoforming technologies, out of which 3 were led by Innoval.

5	Organisation Details		Contact Details		
Wagon Group 1 Kingmaker Court Warwick Technology Par Gallows Hill Warwick UNITED KINGDOM CV34 6WG			<div></div> Wagon Group 1 Kingmaker Court Warwick Technology Par Gallows Hill Warwick United Kingdom CV34 6WG		
Direct contribution to project			Indirect contribution to project		
	Description	Value (£)		Description	Value (£)
Comments on partnership		Due to the strategic change in Wagon, Wagon has ceased to be a project partner at the very start of the project (see the attached letter from Wagon).			

6	Organisation Details		Contact Details		
Rondol Technology Opal Way Business Centre Unit 6 Opal Wa Stone Business Park Stone Staffordshire UNITED KINGDOM ST15 0SS			<div></div> Unit 1/6 Opal Way Stone Business Park Stone Staffordshire United Kingdom ST15 0SS		
Direct contribution to project			Indirect contribution to project		
	Description	Value (£)		Description	Value (£)

Comments on partnership	Rondol has made very useful contribution to the equipment design and construction during the project. We are willing to continue the partnership in the future.
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Total Contribution from all Project Partners (£)	586,000.00
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Publication Summary

	Journal	Refereed Journal	Conference Proceedings	Book	Other
Total	21	21	14	0	0
Number of Reviewed (if different from above)	21	21	14	0	0
Total with Industrial Co-Author	2	2	4	0	0
Total with International Co-Author	1	1	2	0	0

Publications

Type	Title	Author(s)	Reference				Reviewed	International Co-Author	Industrial Co-Author
			Name	Year	Vol.	Page			
Journal	Grain refinement of DC cast AZ91D Mg alloy by intensive melt shearing	Dr Yubo Zuo Dr Mingxu Xia Dr Yun Wang Dr S. M. Liang Dr Geoff Scamans Professor Z. Fan	Materials Science and Technology	2010	on-line 26-Feb		Yes	No	Yes
Journal	Enhanced heterogeneous nucleation in AZ91D alloy by intensive shearing	Professor Z. Fan Dr Y. Wang Dr M Xia Dr S Arumuganathar	Acta Materialia	2009	57	4891-4901	Yes	No	No
Journal	Twin Roll Casting and Melt Conditioned Twin-roll Casting of Magnesium	Dr Z. Bian Mr I. Bayandorian Dr H. W. Zhang Professor Z. Fan	Solid State Phenomena	2008	141-143	195-200	Yes	No	No
Journal	Investigation on the microstructural refinement of an Mg-Zn alloy	Dr A. Das Dr G Liu Professor Z. Fan	Materials Science Engineering A	2006	419	349-356	Yes	No	No
Conference	Shear Enhanced Heterogeneous Nucleation during Solidification of Mg-Alloy	Professor Z. Fan Dr Y. Wang Dr M. Xia	Proc. of 8th Magnesium Int. Conference, Germany	2009		193-199	Yes	No	No

Summary

Original Summary

Magnesium (Mg) is the 8th most plentiful element in the world, comprising 2.7% of the earth's crust. Mg alloys are as light as wood, but as strong as Al-alloys. Due to the increasing environmental concerns and tightening government regulations, Mg alloys find extensive applications in the automotive industry for vehicle weight reduction to reduce fuel consumption and CO₂ emissions. We have seen a 15% annual growth rate in Mg applications in the automobile industry since 1993, and it is predicted that this growth trend will continue in the first decade of the 21st century. However, Mg as an industry is still in its infancy and very much underdeveloped, especially in the sector of wrought products. Technologies for processing wrought Mg alloys are "copied" directly from the Al industry with little modifications and have proven to be unsuitable. The current applications of Mg in the automotive industry constitute almost 100% cast components without any significant contribution from the wrought products, which hold the key to most significant weight saving. The main barrier to the penetration of the wrought Mg alloys into the motor vehicle is their poor deformability, low productivity and high cost. Therefore, it is crucial to develop alternative processing technologies to overcome such problems. The proposed project aims to develop the rheoforming technologies, which include direct chill (DC) rheocasting for billets or slabs, rheoextrusion for extruded profiles and twin-roll rheocasting for flat products. In the rheoforming processes, semi-finished wrought Mg products are shaped in the semisolid state, somewhat similar to squeezing toothpaste. In addition, the rheoformed products have a fine and uniform microstructure, and thus can be further processed by the conventional solid deformation techniques, because fine-grained Mg-alloys can deform plastically through alternative deformation mechanisms. The rheoforming technologies in combination with the conventional technologies offer the Mg industry a complete solution to the semi-finished wrought Mg products. The specific research activities include development of the rheoforming process and equipment, demonstration of the rheoforming processes at industrial scale, understanding the fluid flow and solidification behaviour during rheoforming, evaluation of the mechanical properties of the rheoformed Mg alloys and evaluation of the deformability, productivity and production cost of the rheoformed Mg-alloys. The significance of the rheoforming technologies can be understood from the following aspects. Technologically, the rheoforming processes represent a step change in the manufacturing technology for production of lightweight automotive components. Rheoforming offers a complete technological solution to the magnesium industry and provides numerous opportunities for new applications. Scientifically, solidification under intensive forced convection opens a new dimension for solidification research. Control of alloy solidification has been traditionally achieved by chemical means (i.e., through variation of alloy composition). The rheoforming processes have successfully demonstrated that both nucleation and crystal growth can be effectively controlled by application of an intensive shear stress-strain field. This will allow the development of a theoretical framework for solidification under externally applied physical fields, which is anticipated to have profound implications to future solidification research and technological development. Commercially, rheoforming offers to the UK industry competitive edge in the global market in terms of technology advantage, improved product quality and reduced cost. The potential benefit to the UK economy is expected to be huge.

Revised Summary

Magnesium (Mg) is the 8th most plentiful element in the world, comprising 2.7% of the earth's crust. Mg alloys are as light as wood, but as strong as Al-alloys. Due to the increasing environmental concerns and tightening government regulations, Mg alloys find extensive applications in the automotive industry for vehicle weight reduction to reduce fuel consumption and CO₂ emissions. We have seen a 15% annual growth rate in Mg applications in the automobile industry since 1993, and it is predicted that this growth trend will continue in the 21st century. However, Mg as an industry is still in its infancy and very much underdeveloped, especially in the sector of wrought products. Technologies for processing wrought Mg alloys are "copied" directly from the Al industry with little modifications and have proven to be unsuitable. The current applications of Mg in the automotive industry constitute almost 100% cast components without any significant contribution from the wrought products, which hold the key to most significant weight saving. The main barrier to the penetration of the wrought Mg alloys into the motor vehicle is their poor deformability, low productivity and high cost. Therefore, it is crucial to develop alternative processing technologies to overcome such problems. With the EPSRC support, we have successfully developed the rheoforming technologies, which include melt conditioned direct chill (DC) casting for billets or slabs, rheoextrusion for extruded profiles and melt conditioned twin-roll casting for flat products. In the rheoforming processes, magnesium alloy melt is intensively sheared by the patented MCAST machine at temperatures either above or below the alloy liquidus. The conditioned melt is then fed to a DC caster for billets or slabs, to an extruder for extruded profiles and to a twin roll caster for Mg-alloy strips. It has been demonstrated clearly that all the rheoformed semi-finished Mg products have a fine and uniform microstructure, uniform chemical composition and eliminated (or much reduced) cast defects. It has been confirmed that rheoformed semi-finished products can be further processed with ease by the conventional thermal mechanical processing techniques. For instance, Mg-alloy strips produced by the melt conditioned twin roll casting process can be easily hot-rolled to 1.5mm thick plates, which exhibits 3 times more elongation compared with those produced the conventional DC casting-hot rolling route. Intensive experimental investigation coupled with theoretical modelling has revealed the detailed mechanisms for microstructural refinement and microstructural evolution during the rheoforming processes. In brief, intensive melt shearing can effectively disperse the nano-sized MgO particles in the oxide films, and therefore significantly enhanced the heterogeneous nucleation by increasing the effective number of MgO particles as potent nucleation sites. The significance of the rheoforming technologies can be understood from the following aspects. Technologically, the rheoforming processes represent a step change in the manufacturing technology for production of lightweight automotive components. Rheoforming offers a complete technological solution to the magnesium industry and provides numerous opportunities for new applications. Scientifically, solidification under intensive forced convection opens a new dimension for solidification research. Control of

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Staff

Role Name	Name / Post Identifier	Duration	% FTE	
Researcher	Dr Guojun Liu	24	100	
Researcher	Dr Zan Bian	24	100	
Researcher	Dr Yun Wang	24	100	
Researcher	Dr Yubo Zuo	24	100	
Project Student	Mr Iman Bayandorian	42	100	
Researcher	Dr Huawei Zhang	12	100	

Staff Destinations

Name	Organisation details	Employment type
Dr Guojun Liu	General Research Institute for Nonferrous Metals China	PublicResearch
Dr Zan Bian	Bolton University United Kingdom	HigherEducationResearch
██████████	██████████ ██████████	██████████
Dr Yun Wang	Brunel University United Kingdom	HigherEducationResearch
Dr Yubo Zuo	Brunel University United Kingdom	HigherEducationResearch
Mr Iman Bayandorian	Brunel University United Kingdom	HigherEducationResearch
Dr Huawei Zhang	Unknow China	Not Given