



Charlemont grant report

Recipient name:	Dr Doireann O'Kiely
Discipline and subject area:	Sciences
Amount and year awarded:	€2,019 in 2022
Title of project:	Mathematical models for metal forming processes.

Summary of findings:

The goal of this project was to learn more about different metal forming processes and the models currently used to describe them, and to develop new models where they are needed. The specific aims included working on a review paper of mathematical models for metal forming, working on mathematical models for metal forming, working on mathematical modelling of the metal sheet rolling process, and learning more about microstructure modelling in metals. The Charlemont grant supported this by funding a research visit to the University of Warwick to work with Dr Ed Brambley.

The main outcomes were as follows:

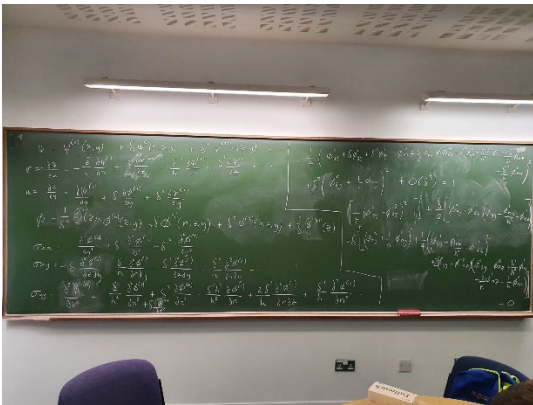
- **Learning about metal forming:** Dr Brambley kindly organised tours of Warwick Manufacturing Group (WMG) facilities with Professor Clare Davis (Steels Processing) and Dr Sumit Hazra (Advanced Manufacturing and Materials Centre), as well as a visit from Bin Xiao of Tata Steel UK. With Prof. Davis, we saw the machines used for rolling metal sheets and analysing the products. With Dr Hazra, we saw a novel failure mechanism during the Vbending process, as well as successful and unsuccessful specimens from deep-drawing processes. Dr Hazra also showed us some systems where metal products are used and where their material properties are measured. These tours helped improve my understanding of metal processing and my appreciation of its importance, and also highlighted some areas where better mathematical models would be valuable. This will all help with writing a review paper.
- **Modelling of metal sheet rolling:** we held a three-day meeting together with Mozhdeh Erfanian, who is a PhD student at the University of Warwick, and Frank Flanagan, who is a PhD student at the University of Limerick. During this time, we worked intensively on the derivation of a new mathematical model for sheet rolling. As well as the mathematical progress, this meeting provided an opportunity to discuss the alignment of the two projects and ensure that they continue to be complementary but not overlapping. This work will contribute to the theses of both Mozhdeh and Frank, and the corresponding publications.
- **Microstructure:** Dr Brambley introduced me to Dr Tom Hudson and Professor Filip Rindler. Dr Hudson is an expert in modelling of dislocations in metals and generously spent some afternoons



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teaching me about the field and some of the specifics. The four of us also discussed a potential mathematical modelling project centred around the V-bending failure observed during the WMG facilities tour.

I didn't achieve everything I hoped to on the trip, due in part to needing to continue carrying out the other obligations of my job. However, the work is continuing beyond the trip, and I found the experience as a whole very beneficial for identifying and prioritising research directions and for building future collaborations. In addition to the progress achieved in research and research planning, a key positive of the trip for me was the reinvigoration of my excitement for the research area through spending time with like-minded people.



Plans for continuing collaboration:

Dr Brambley and I continue to have regular online meetings after my visit. Some of these are one-to-one and some include our PhD students, who also continue to talk to one another separately. There is now a clear synergy between the mathematics research our respective PhD students are working on, with ongoing exchange of ideas, data and results.

Dr Brambley will use funding from his UKRI grant to support me in making a second trip to Warwick in December, when we will continue our work together and I will give a seminar for HetSys (the EPSRC Centre for Doctoral Training in Modelling of Heterogenous Systems). Furthermore, I have included Dr Brambley as an Academic Collaborator on my SFI Frontiers for the Future Project, and he will contribute to research into wrinkle occurrence during the metal spinning process as part of this.

Published work and publication plans:

Some of the work on metal sheet rolling will appear in the theses of Frank Flanagan, supervised by me, and of Mozdeh Erfanian, supervised by Dr Brambley. We plan to publish the research as co-authors. In the short-medium term, this will include a paper on insights from FEM analysis and a paper on using Airy stress functions to model the plastic zone where the metal sheet deforms.

The project also supported Dr Brambley and I in gathering material for a planned review paper on models.



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Dissemination and plans for future dissemination:

I am giving a seminar in Warwick in December.

Collaborations and planned collaborations:

When I initially discussed my application for a Charlemont grant with Dr Brambley, we had hoped to visit some metal processing labs/factories together during my time at the University of Warwick. In the end, it was not possible for us to do this due to some personal restrictions on travel. However, Dr Brambley arranged two tours of metal processing facilities in the Warwick Manufacturing Group facilities and a visit from Tata Steel UK, as well as meetings with mathematicians in the Warwick Mathematics Institute. I also carried out three separate day trips to Coventry University, the University of Oxford and the University of Manchester.

I visited Dr Paul Griffiths, Dr Liam Escott and Niall Hanevy at Coventry University, where we worked on modelling die swell. We have continued to discuss this by email.

I visited Dr Ellen Luckins at the University of Oxford, to discuss a shared interest in mathematical modelling of decontamination processes. Sarah Murphy, who is a PhD student on the SFI CRT in Foundations of Data Science, and Dr Mohit Dalwadi (UCL), who also works in this area, both visited on the same day, and we held a day of seminars and meetings with University of Oxford researchers interested in this topic. This led to some modelling improvements in Sarah's work, as well as some long-term conversations about opportunities for multiscale modelling and asymptotic homogenization in porous materials.

At the University of Manchester, I visited Dr Box, and we spent a day developing a research proposal on dynamic delamination for the EPSRC/SFI joint funding of research scheme. We have now written the bulk of the proposal and are aiming to submit before the end of 2022.

Outreach and engagement activities:

I have not carried out any public engagement activities relating to this project specifically, but this year I have worked at an open day at the University of Limerick and have continued to disseminate my research online through both social media and my own academic website.